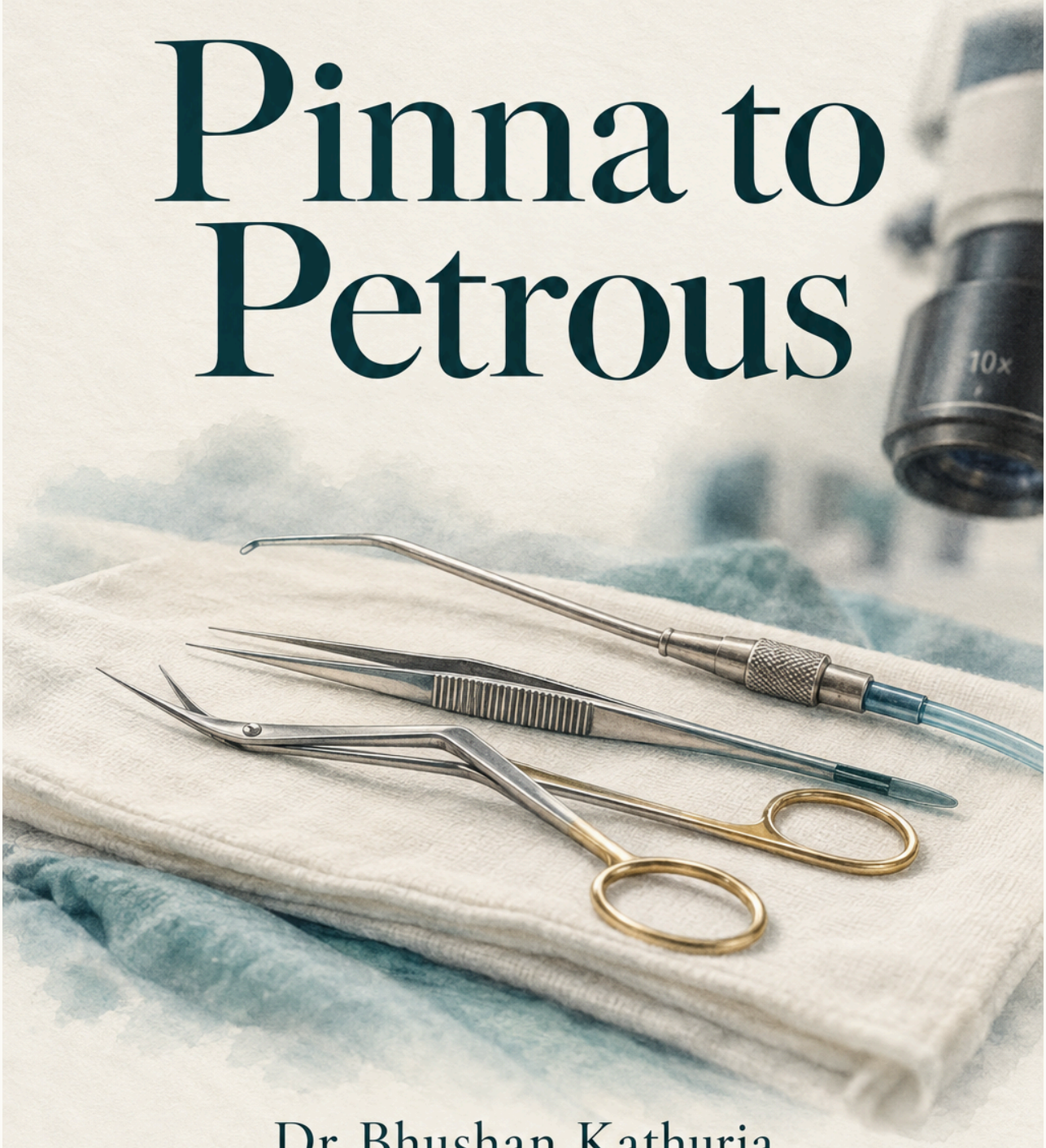
Mastering Precision in Otorhinolaryngology

SURGICAL PERSPECTIVE · BOOK 2

Pinna to Petrous



Dr Bhushan Kathuria

GeNext MedEd Foundation

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The ear, temporal bone and lateral skull base

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MASTERING PRECISION IN OTORHINOLARYNGOLOGY

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GeNext MedEd Foundation

First edition · Updated visual edition · 2026

PUBLICATION & USE

Surgical Perspective — Mastering Precision in Otorhinolaryngology
Book 2 · Pinna to Petrous

© 2026 Dr Bhushan Kathuria

Published through GeNext MedEd Foundation.
Updated visual edition: 27 October 2026.
genextmed.org · bhushankathuria.com

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DEDICATION

To my teachers,
who first showed me where to look.

To my colleagues and students,
with whom every operation became another opportunity to learn.

To my patients,
who entrusted us with something far greater than a surgical procedure.

And to every student of surgery—

who watches, questions, attempts, learns,
and returns to the same anatomy
only to see it differently again.

BEFORE WE BEGIN

यथा दृष्टि तथा सृष्टि

Yatha Drishti, Tatha Srishti

As is the vision, so is the world we perceive.

The anatomy before us may remain the same.

What changes with learning and experience
is what we are able to see within it.

Surgery begins with knowledge.

It develops through observation,
repetition, experience and reflection.

And with every return to the operating table,
we may discover something
that had always been there—

but that we had not yet learned to see.

ABOUT THIS EDITION

Learning through observation and judgement

This complete visual edition brings together all thirty-two chapters, the concluding reflections and the subject index.

The interior retains the source pagination so that existing contents and index references remain usable. Clinical text and original illustrations have been preserved; the changes concern presentation and navigation.

The cover and interior use a consistent ivory, teal and copper palette. Chapter bookmarks support direct navigation in compatible PDF readers.

Author: Dr Bhushan Kathuria
Publication medium: GeNext MedEd Foundation

Preface

I did not begin writing this book because surgery needed another description of how an operation is performed.

Excellent textbooks, atlases, operative videos and scientific literature already describe surgical procedures in remarkable detail.

The question that continued to interest me was different:

What happens between knowing the steps of an operation and actually becoming capable of performing it?

As students, we begin with anatomy. We read. We listen to our teachers. We observe operations. We remember steps. Eventually, an instrument is placed in our hand and we attempt to reproduce what we have learned.

But surgery soon teaches us that an operation does not always unfold as it appeared in the book.

The exposure may be inadequate.

The expected plane may not exist.

Previous surgery or radiation may have altered the anatomy.

Bleeding may obscure the field.

A tumour may extend farther than anticipated.

A nerve may not lie where we expected it.

A reconstruction may need to change.

Sometimes the correct decision is to proceed.

Sometimes it is to change the approach.

And sometimes it is to stop.

That space—between **what is described and what is encountered**—is where much of surgical learning occurs.

FROM SEEING TO UNDERSTANDING

Early in training, we often watch the surgeon's hands.

With experience, we begin watching something else.

The direction of traction.

The tissue under tension.

The sequence in which landmarks appear.

The relationship between structures.

The change in colour or consistency of tissue.

The point at which a surgeon slows down.

The moment an approach is modified.

The operation has not changed.

What we are capable of observing has.

This idea has influenced the way this book has been conceived.

It is not intended to replace conventional surgical knowledge. On the contrary, anatomy, pathology, patient selection, investigations, operative planning, technique, reconstruction, complications, postoperative care, outcomes and evidence remain its foundation.

But alongside them, I have tried to include another layer:

the reasoning that accompanies the operation.

Why this approach?

Why this plane?

What am I trying to expose?

What should appear next?

What if it does not?

Where is the danger?

What alternatives are available?

What would make me change the plan?

What would make me stop?

These questions are often more useful in the operating room than memorising another sequence of steps.

BASIC AND ADVANCED

We frequently divide surgery into basic, advanced and complex procedures.

These categories are useful for training, but experience repeatedly reminds us that surgery does not always respect them.

A supposedly simple operation can become extraordinarily demanding.

An operation considered advanced can become systematic once its anatomy, exposure and principles are understood.

For this reason, this book attempts to connect procedures rather than place artificial walls between them.

The principles learned during a routine operation may later become essential during a complex one.

Exposure remains exposure.

A plane remains a plane.

Traction and counter-traction remain forces.

A vessel still requires anticipation and control.

A nerve still requires identification, respect and understanding of its course.

The scale changes.

The consequences may change.

But many of the principles travel with us.

EXPERIENCE

Some lessons in these pages come from successful operations.

Others come from operations that were difficult.

Some come from changing an approach halfway through.

Some from complications.

Some from watching teachers and colleagues.

And some from realising, after performing the same procedure many times, that what I had always done one way could be done better another way.

Experience should not be presented as evidence when it is not evidence.

Throughout this book, established scientific knowledge and published evidence must remain distinguishable from personal operative preference and experience.

But experience has value of another kind.

It tells us what questions to ask.

FAILURE

Surgical writing naturally gravitates toward successful technique.

Yet surgical education would be incomplete if it discussed only what worked.

A complication forces us to examine our assumptions.

A failed exposure makes us reconsider planning.

A reconstruction that does not behave as expected teaches us about tissue.

An operation that must be abandoned can teach judgment.

Failure should never be romanticised; the patient bears its consequences.

But neither should it be hidden from surgical education.

The purpose is not to celebrate failure.

It is to **learn honestly from it**.

FOR THE READER

This book is written for the student beginning to look at surgery, the resident learning to perform it, the young surgeon beginning independent practice, and the experienced surgeon who continues to question familiar operations.

It does not ask the reader to operate exactly as I do.

That would contradict its purpose.

Instead, I hope these pages encourage the reader to understand the anatomy, study the evidence, observe carefully, learn from teachers, practise deliberately, respect complications and gradually develop independent surgical judgment.

There are many ways to reach an anatomical space.

There may be several ways to reconstruct a defect.

Different surgeons may reasonably choose different approaches.

The important question is not whether an operation resembles somebody else's operation.

The important questions are:

Do you understand what you are doing?

Do you understand why you are doing it?

Can you recognise when the situation has changed?

And above everything else:

Is what you are doing right for the patient in front of you?

Surgery will continue to change.

Technology will change.

Instruments will change.

Approaches will evolve.

What should remain is the willingness to learn.

To observe.

To question.

To respect what we do not yet understand.

And after years of operating—

to remain capable of seeing again.

Dr Bhushan Kathuria

How to use this book

This book has been designed to be read in two ways.

It may be studied sequentially—from surgical foundations through progressively more demanding procedures—or opened directly before an operation to review a particular anatomy, approach, technique or complication.

To make both possible, each surgical chapter combines **established knowledge, operative technique, decision-making and experience** in a recurring framework.

1. SURGICAL ANATOMY

Anatomy is presented from the operative perspective.

Rather than describing structures in isolation, illustrations and text emphasise:

- surgical landmarks
- three-dimensional relationships
- operative corridors
- danger areas
- structures at risk
- anatomical variations
- relationships visible from different surgical approaches

Where appropriate, anatomy is correlated with CT, MRI and the endoscopic and operative views.

2. BEFORE THE OPERATION

The reader is taken through the decisions that precede the incision:

Patient Selection → Clinical Evaluation → Imaging → Planning → Preparation → Positioning → Approach

The purpose is not merely to answer *how to perform the operation*, but also:

Why this operation?
Why this approach?
Why in this patient?

3. OPERATIVE TECHNIQUE

Procedures are described in reproducible stages.

Each major operation follows the actual progression of surgery:

Position → Exposure → Identification → Dissection → Resection / Correction → Reconstruction → Haemostasis → Closure

Important steps are supported by illustrations and anatomical orientation wherever these improve understanding.

4. THE OPERATIVE VIEW

Selected figures reproduce what the surgeon actually encounters.

Orientation will be clearly identified so that the reader understands:

Where am I?
What am I looking at?
What should appear next?
What lies beyond what I can currently see?

This feature is particularly important in endoscopic, microscopic and skull base surgery.

5. DECISION POINT

Not every operation follows a fixed sequence.

At important moments, **Decision Point** boxes pause the procedure and examine the available choices.

Examples may include:

Preserve or sacrifice?
Continue or change the corridor?
Primary closure or reconstruction?
Endoscopic or open?
Proceed, stage or stop?

The objective is to make operative reasoning visible alongside operative technique.

6. SURGICAL PERSPECTIVE

These short sections contain observations that may not fit naturally into conventional step-by-step descriptions.

They may address:

- exposure
- tissue handling
- traction and counter-traction
- maintaining orientation
- anticipating the next landmark
- ergonomics
- instrument selection
- operative efficiency
- avoiding unnecessary dissection

These represent practical perspectives and should be interpreted alongside established surgical principles and evidence.

7. FROM EXPERIENCE

Selected chapters include situations encountered during actual surgical practice.

These are not presented as proof that one technique is superior to another.

Instead, they illustrate how anatomy, disease or circumstances can force the surgeon to reconsider a plan.

Each experience is examined through:

What was expected?
What was encountered?
What was done?
What could have been done differently?
What was learned?

8. WHEN THE PLAN CHANGES

Surgery sometimes departs from the expected pathway.

These sections address situations such as:

- absent or distorted planes
- unexpected disease extension
- difficult exposure
- major bleeding
- nerve involvement

- previous surgery
- post-radiation anatomy
- inadequate margins
- reconstructive difficulty
- equipment limitations

Where possible, alternatives and bailout strategies are discussed.

9. COMPLICATIONS

Complications are integrated with the relevant procedure rather than treated only as lists at the end of chapters.

They are approached through:

Anticipate → Prevent → Recognise → Control → Recover → Learn

Major complications receive dedicated algorithms or decision pathways where appropriate.

10. EVIDENCE & PERSPECTIVE

Published evidence, accepted standards and guideline-based recommendations are distinguished from individual operative preferences.

Where more than one accepted technique exists, alternatives are presented rather than implying that a single method is universally correct.

11. TAKE IT TO THE OT

Major operative chapters conclude with a concise review designed for rapid reading before surgery.

It may include:

Know the anatomy
Review the imaging
Prepare the equipment
Identify the critical landmarks
Anticipate the difficult step
Know the structures at risk
Have an alternative plan
Know when to stop

This is not intended to replace complete study or supervised surgical training.

It is a final orientation before entering the operating room.

THE VISUAL LANGUAGE

Throughout the book, recurring visual symbols will allow the reader to identify information quickly:

ANATOMY — structures and relationships
LANDMARK — reliable operative orientation
DECISION — a point requiring judgment
CAUTION — structure or manoeuvre carrying significant risk
PEARL — practical operative observation
ALTERNATIVE — another accepted technique or approach
BAILOUT — strategy when the planned pathway cannot safely continue
EXPERIENCE — lesson derived from operative experience
EVIDENCE — literature-supported recommendation

The intention is simple:

Read the science.
See the anatomy.
Understand the operation.
Think through the decision.

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Control First ● Preserve Function ● Reconstruct ● Then Complete

Ear & Temporal Bone Surgery

From Pinna to Petrous

The ear brings several forms of surgery into a remarkably small anatomical region.

Skin · Cartilage · Bone · Mucosa · Ossicles · Labyrinth · Facial nerve · Major vessels · Dura · Brain

Within a few centimetres, surgery may move from reconstruction of the external ear to microscopic middle-ear work, drilling of the temporal bone, hearing restoration, cochlear implantation and lateral skull-base surgery.

The scale becomes smaller.

The consequences do not.

THE SHAPE OF THIS BOOK

External Ear
Pinna → External Auditory Canal → Congenital & Acquired Disorders → Reconstruction → External Auditory Canal Malignancy

Middle Ear & Mastoid
Tympanic Membrane → Middle Ear → Ossicular Chain → Mastoid → Cholesteatoma → Revision Surgery

Hearing Restoration
Tympanoplasty → Ossiculoplasty → Stapes Surgery → Implantable Hearing Devices → Cochlear Implantation

Facial Nerve
Identification → Decompression → Injury → Repair → Rehabilitation

Lateral Skull Base
Temporal Bone → Petrous Bone → Jugular Foramen → Internal Auditory Canal → Major Vessels & Cranial Nerves → Skull Base Resection → Reconstruction

BEFORE ENTERING THIS BOOK

For every temporal bone operation, repeatedly ask:

Where am I?

What landmark have I established?

What structure should appear next?

What lies medial to my current depth?

Where is the facial nerve?

Where is the labyrinth?

Where are the dura and major venous structures?

What does the preoperative CT show in this particular patient?

In temporal bone surgery, a few millimetres can move the operation from one anatomical system into another.

The surgeon should therefore progress:

FROM KNOWN LANDMARK

TO KNOWN LANDMARK

until the target is reached.

VISUAL LANGUAGE FOR THIS BOOK

The regional chapters will repeatedly correlate four views:

1. ANATOMICAL VIEW

Three-dimensional relationships.

2. CT VIEW

The patient's individual temporal bone anatomy.

3. SURGICAL VIEW

What is actually seen through the microscope or endoscope.

4. DRILLING MAP

What bone is removed, in which direction, and what lies beyond it.

SECTION PRINCIPLE

The temporal bone should not be learned as a collection of cavities.

It should be understood as a three-dimensional relationship between hearing, balance, facial function, major vessels, dura and brain.

CHAPTER 01

Surgical Anatomy of the External Ear

Pinna • External Auditory Canal • Surgical Relationships

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- identify the major anatomical landmarks and subunits of the pinna
- understand the relationship between skin, perichondrium and auricular cartilage
- describe the vascular and sensory supply relevant to surgery
- recognise surgically important posterior auricular relationships
- understand the cartilaginous and bony external auditory canal
- identify areas where skin is particularly vulnerable during canal surgery
- plan incisions and reconstruction according to auricular subunits
- correlate external-ear anatomy with common operative approaches

1.1 THE PINNA IS A THREE-DIMENSIONAL FRAMEWORK

The pinna appears superficial.

Its surgery is not necessarily simple.

Its characteristic form is created by a thin framework of elastic cartilage covered by skin.

Small changes in:

- contour
- projection
- cartilage support

- skin coverage
- symmetry

may produce obvious functional or cosmetic consequences.

The surgeon should therefore understand the pinna not simply as an external structure, but as a series of **three-dimensional anatomical subunits**.

1.2 SURFACE LANDMARKS

The principal landmarks include:

HELIX

The outer curved rim of the auricle.

ANTIHELIX

A prominent inner ridge that divides superiorly into the crura of the antihelix.

SCAPHA

The depression between helix and antihelix.

TRIANGULAR FOSSA

The depression between the superior and inferior crura of the antihelix.

CONCHA

The deep central depression leading toward the external auditory canal.

The crus of the helix divides it into:

cymba conchae (above the crus)

and

cavum conchae (below the crus, leading into the canal).

TRAGUS

Cartilaginous projection overlapping the external auditory canal from in front.

ANTITRAGUS

Projection opposite the tragus, posteroinferiorly, at the lower end of the antihelix.

INTERTRAGIC NOTCH

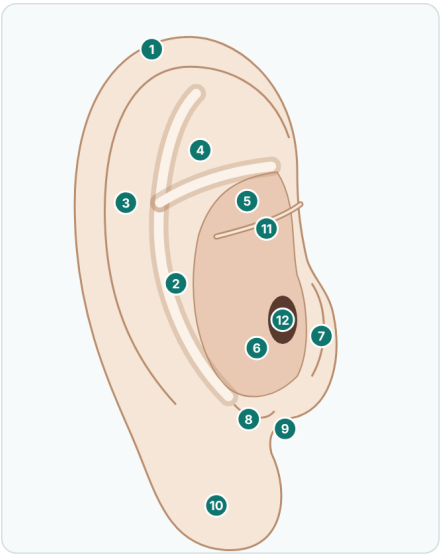
Depression between tragus and antitragus.

LOBULE

Inferior portion of fibrofatty tissue covered by skin; unlike the remainder of the auricle, it contains no cartilage.

Figure 1.1 · Lateral surface of the auricle: surface landmarks

Schematic, not to scale — right ear, lateral view, anterior (face) to the viewer's right



KEY

1. Helix
2. Antihelix → divides superiorly into the superior and inferior crura
3. Scapha
4. Triangular fossa → between the two crura
5. Cymba conchae
6. Cavum conchae
7. Tragus
8. Antitragus
9. Intertragic notch
10. Lobule → no cartilage
11. Crus of helix → divides the concha
12. External acoustic meatus

Every contour above the lobule is shaped by cartilage.

1.3 THINK IN AURICULAR SUBUNITS

For reconstruction, the pinna can be conceptualised as multiple aesthetic and structural subunits.

These include:

- helical rim
- antihelix
- concha
- tragus
- antitragus
- lobule

The importance of this concept is practical.

A defect crossing the helical rim behaves differently from an equally sized defect confined to the conchal bowl.

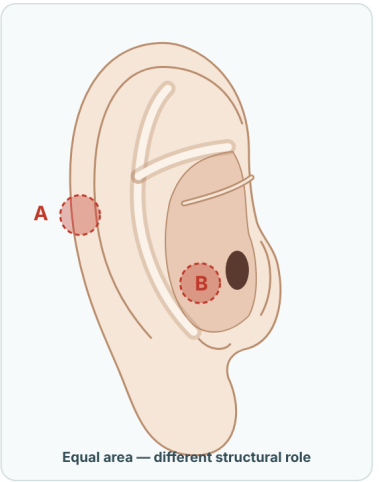
Therefore:

> **DEFECT SIZE ALONE DOES NOT DETERMINE RECONSTRUCTION.**

Location and structural role matter.

Figure 1.2 · Auricular subunits: the same defect size, different consequences

Schematic — right ear, lateral view; two defects of equal area in different subunits



A · HELICAL RIM

- Visible border of the ear
- Loss of contour and outline
- Rim notch or cupping if closed carelessly
- Often needs advancement, cartilage support or a composite repair

B · CONCHAL BOWL

- Hidden in a hollow
- Surrounding framework intact
- Contour largely preserved
- Often heals well with a graft or local flap on viable perichondrium

Subunits: helical rim · antihelix · concha · tragus · antitragus · lobule

Size alone does not determine reconstruction.

1.4 SKIN

Auricular skin varies considerably across the pinna.

On the lateral (anterior) surface, particularly over the helix, antihelix and concha, skin is thin and closely adherent to the underlying perichondrium, with little subcutaneous tissue.

On the medial (posterior) surface, the skin is thicker and more mobile over a looser subcutaneous layer.

This affects:

- flap elevation
- reconstruction
- haematoma formation

- cartilage exposure
- wound healing

SURGICAL PRINCIPLE

The same skin thickness and dissection plane should not be assumed across the entire pinna.

1.5 CARTILAGE

The auricular framework consists primarily of elastic cartilage.

It provides:

- contour
- projection
- structural support

Cartilage itself is avascular and depends upon the overlying perichondrium for nourishment, largely by diffusion.

Therefore extensive separation of cartilage from viable soft-tissue coverage can compromise healing.

This becomes important in:

- trauma
- otoplasty
- tumour resection
- cartilage grafting
- reconstructive surgery

1.6 PERICHONDRIUM

The perichondrium contributes to cartilage nutrition and healing.

During surgery, preservation of viable perichondrial coverage where appropriate can improve cartilage survival.

Loss of skin and perichondrium may leave cartilage vulnerable to:

- infection

- necrosis
- deformity

> **PRINCIPLE**
>
> **Exposed cartilage is not merely an uncovered surface.**

It is a structure whose biological support has been reduced.

1.7 AURICULAR HAEMATOMA — AN ANATOMICAL LESSON

Shearing trauma can separate the perichondrium from the cartilage and allow blood to accumulate in the subperichondrial space, most often on the lateral surface.

Persistent separation deprives the cartilage of its nutrition and may produce necrosis, fibrosis, new cartilage formation and deformity (the "cauliflower ear").

The clinical problem demonstrates a broader surgical principle:

TISSUE CONTACT MATTERS.

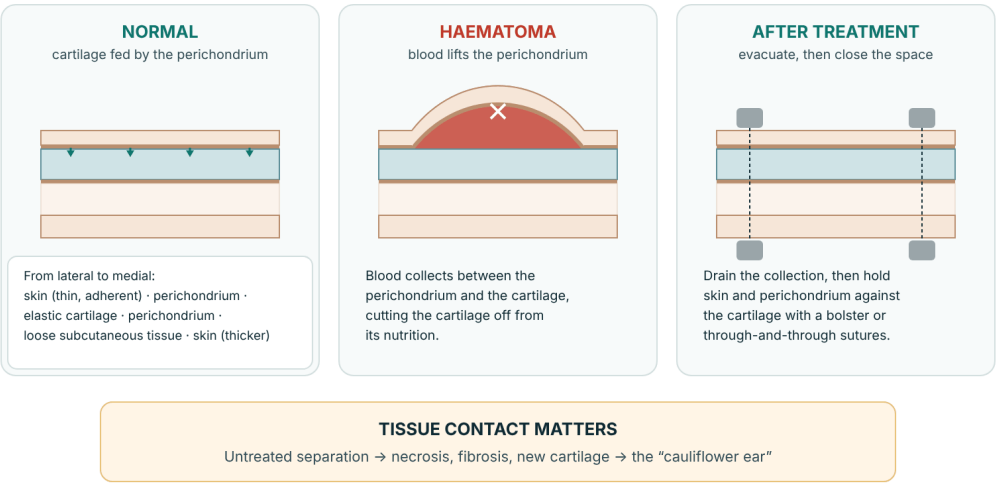
After appropriate treatment, elimination of the potential space is important to reduce reaccumulation.

The anatomy explains the complication.

Management of auricular haematoma is described in Chapter 2, Congenital & Acquired External Ear Surgery.

Figure 1.3 · Layers of the auricle and the subperichondrial space

Schematic section through the auricular cartilage — lateral surface above, medial surface below



TISSUE CONTACT MATTERS

Untreated separation → necrosis, fibrosis, new cartilage → the "cauliflower ear"

1.8 VASCULAR SUPPLY

The pinna receives its blood supply primarily from branches of the external carotid artery:

- the superficial temporal artery (anterior auricular branches, chiefly to the lateral surface)
- the posterior auricular artery (chiefly to the medial surface, with perforating branches through the cartilage to the lateral surface)
- with a smaller contribution from the occipital artery

Anastomotic networks contribute to auricular perfusion.

This vascularity permits multiple local flap designs, but flap planning should still respect:

- pedicle orientation
- tissue width
- previous scars
- radiation
- trauma

RECONSTRUCTIVE PRINCIPLE

Do not design a flap only according to what skin will move.

Design it according to what skin will remain alive after it moves.

1.9 POSTERIOR AURICULAR REGION

The postauricular region is surgically important because it provides:

- access for otologic procedures
- potential local reconstructive tissue
- relationship to mastoid cortex
- access to cartilage graft harvest in selected settings

Important considerations include:

- postauricular sulcus
- mastoid periosteum
- posterior auricular soft tissue
- vascular supply
- proximity of the great auricular nerve and other sensory branches

The incision should be planned according to the intended deeper operation.

1.10 SENSORY INNERVATION

Auricular sensation is supplied through contributions from several nerves:

- great auricular nerve (C2, C3): most of the medial surface and the lower lateral surface, including the lobule
- auriculotemporal nerve (V3): the tragus, anterior helix and anterosuperior canal
- lesser occipital nerve (C2): the upper medial surface
- auricular branch of the vagus (Arnold's nerve): the concha and posterior canal wall
- sensory fibres of the facial nerve: a variable contribution to the concha and posterior canal

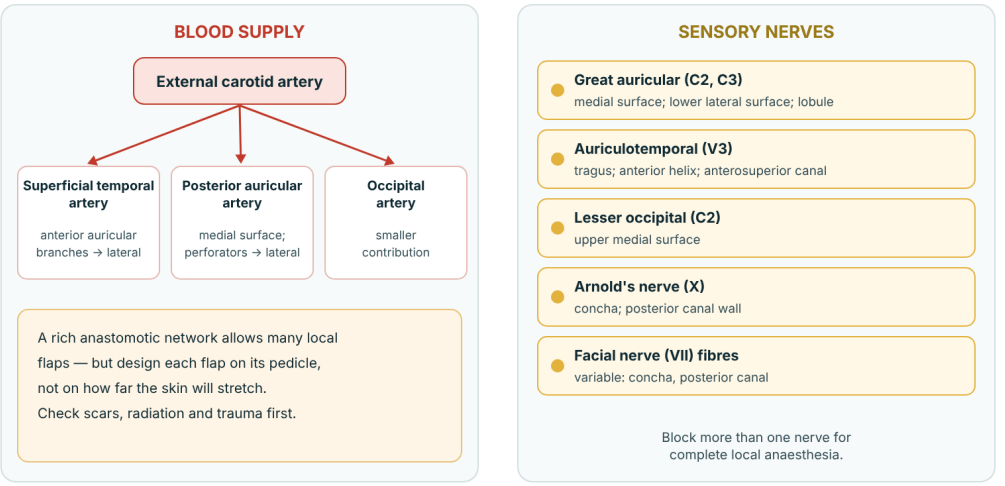
The distribution overlaps.

This helps explain why local anaesthesia and postoperative sensory change may not follow one perfectly isolated territory.

Detailed nerve distributions should be interpreted with awareness of anatomical variability.

Figure 1.4 · Blood supply and sensory innervation of the auricle

Schematic summary — territories overlap and vary between individuals



Plan flaps on blood supply · expect sensory change to cross territories

1.11 GREAT AURICULAR NERVE

The great auricular nerve emerges at the posterior border of the sternocleidomastoid and ascends across the muscle toward the parotid and auricular regions.

It is relevant during:

- postauricular surgery
- parotid surgery
- neck dissection
- local flap elevation

Preservation of appropriate branches may reduce postoperative sensory deficit where compatible with the surgical objective.

1.12 THE TRAGUS

The tragus provides:

- anterior boundary of the external canal
- cartilage for selected grafting procedures
- an important external landmark

When harvesting tragal cartilage, preserve appropriate contour and support.

A graft donor site should not create an unnecessary visible deformity.

1.13 CONCHAL CARTILAGE

Conchal cartilage may be used in selected reconstructive procedures.

Its curvature and relative accessibility can be advantageous.

Harvest planning should consider:

- amount required
- preservation of auricular framework
- skin and perichondrial integrity
- donor-site contour

The donor ear should remain an ear after it has donated tissue.

1.14 THE EXTERNAL AUDITORY CANAL

The external auditory canal extends from the conchal region to the tympanic membrane, a length of about 2.5 cm in the adult.

It consists of:

LATERAL CARTILAGINOUS PORTION (about one-third)

and

MEDIAL BONY PORTION (about two-thirds).

These two segments behave differently surgically.

1.15 CARTILAGINOUS CANAL

The lateral canal contains:

- skin
- subcutaneous tissue
- cartilage
- hair follicles

- sebaceous and ceruminous glands

The skin is relatively thicker and more mobile than in the medial bony canal.

This difference becomes important during:

- canal incisions
- flap elevation
- meatoplasty
- reconstruction

1.16 BONY CANAL

In the bony canal, skin becomes extremely thin and closely adherent to periosteum.

There is little soft tissue between:

SKIN
and

BONE.
Therefore traumatic elevation may:

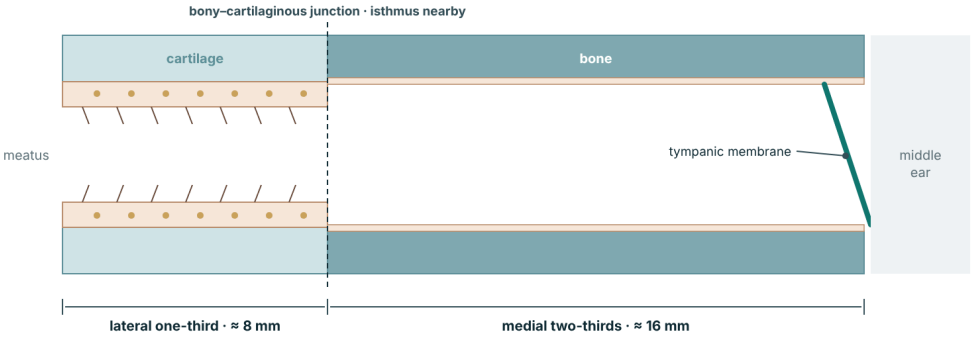
- tear canal skin
- create exposed bone
- compromise healing
- contribute to stenosis

SURGICAL PRINCIPLE

As the canal becomes more medial, tissue handling must become progressively finer.

Figure 1.5 · The two parts of the external auditory canal

Straightened schematic, not to scale — the real canal is gently S-shaped (adult values approximate)



CARTILAGINOUS CANAL
thicker, mobile skin
hair follicles · sebaceous and ceruminous glands
fissures of Santorini in the cartilage

BONY CANAL
very thin skin bound to periosteum
no hair or glands
little tissue between skin and bone
tears and exposed bone heal poorly

1.17 CANAL ORIENTATION

The external auditory canal is not a simple straight tube.

It follows a gentle S-shaped course, and its orientation changes from lateral to medial; the narrowest point, the isthmus, lies near the junction of the cartilaginous and bony parts.

In the adult, drawing the pinna upward and backward straightens the cartilaginous segment.

During examination and surgery, manipulation of the pinna or canal can alter the visual pathway.

Understanding canal geometry is important for:

- otoscopy
- microscopic surgery
- endoscopic ear surgery
- canalplasty
- tympanoplasty

1.18 THE TYMPANIC RING

Medially, the bony canal ends at the tympanic annulus, which sits in the tympanic sulcus; the sulcus is deficient superiorly at the notch of Rivinus, where the pars flaccida attaches directly to bone.

This region forms the transition from external canal surgery to middle-ear surgery.

The surgeon should understand:

- annular attachment
- canal-wall geometry
- tympanomeatal flap relationship
- nearby middle-ear structures

These relationships are developed in Chapter 6, Surgical Anatomy of the Temporal Bone.

1.19 ANTERIOR CANAL WALL

The anterior bony canal has an important relationship with the temporomandibular joint and, inferiorly, the parotid gland.

A prominent anterior canal wall can hide the anterior part of the tympanic membrane.

Pathways for spread of infection and tumour exist here: the fissures of Santorini in the cartilaginous canal and, when present, a persistent foramen of Huschke in the anteroinferior bony canal.

This matters during:

- canalplasty
- tumour resection
- trauma
- anterior canal-wall defects

Over-aggressive bone removal can enter an unintended anatomical compartment.

> **PRINCIPLE**
>
> **Every canal wall has something on the other side.**

Know what it is before drilling.

1.20 POSTERIOR CANAL WALL

The posterior canal wall separates the external auditory canal from the mastoid air cells; medially, the mastoid segment of the facial nerve runs deep to it.

Its preservation or removal becomes a major decision in selected mastoid procedures.

The wall should therefore be understood not merely as a boundary but as a structure influencing:

- canal anatomy
- mastoid access
- postoperative cavity
- disease control

Detailed canal-wall decisions are discussed in Chapter 12, Canal Wall Up Mastoid Surgery, and Chapter 13, Canal Wall Down Mastoid Surgery.

1.21 SUPERIOR CANAL RELATIONSHIPS

Above the bony canal lie the epitympanum medially and the tegmen and middle cranial fossa dura.

The exact operative risk depends upon:

- canal position
- tegmen anatomy
- pneumatisation
- previous disease or surgery

Preoperative CT becomes particularly valuable when bone removal is planned.

1.22 INFERIOR CANAL RELATIONSHIPS

Inferior canal surgery should be performed with awareness of the parotid gland and, medially, the jugular bulb, which may be high or dehiscent.

Anatomical variation may alter the proximity of major structures.

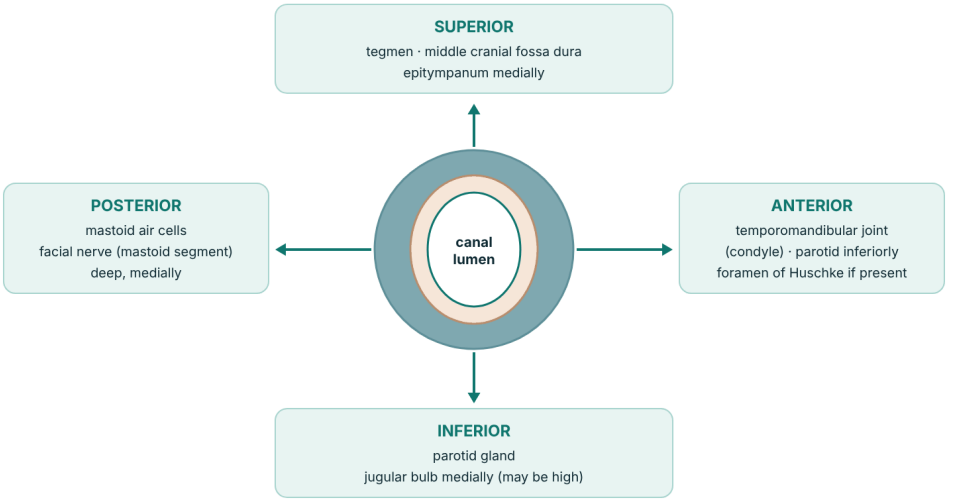
Again:

CT IS THE PATIENT'S ANATOMY.

Do not rely exclusively upon the idealised diagram.

Figure 1.6 · Every canal wall has something on the other side

Schematic — right ear, looking medially down the canal; superior up, anterior to the viewer's right



Know what lies beyond the wall before drilling it — the CT is the patient's anatomy.

1.23 CANAL SKIN AS RECONSTRUCTIVE TISSUE

Canal skin is functionally important.

Preservation helps:

- epithelialisation
- canal patency
- healing
- avoidance of exposed bone

During canal surgery, consider whether skin can be:

- preserved
- elevated as a flap
- repositioned
- grafted

rather than unnecessarily removed.

1.24 STENOSIS

Canal stenosis may result from:

- trauma
- inflammation
- surgery
- circumferential scarring
- inadequate epithelial coverage

The anatomical lesson is important:

> **A CIRCULAR WOUND CAN CONTRACT CIRCULARLY.**

Therefore reconstruction should aim to:

- maintain lumen
- provide epithelial coverage
- minimise opposing raw surfaces
- support healing

The management of canal stenosis is described in Chapter 4, External Auditory Canal Surgery.

1.25 SURGICAL APPROACHES AROUND THE EXTERNAL EAR

Common access routes may include:

ENDAURAL

Through the incisura terminalis, the cartilage-free gap between the tragus and the crus of the helix, extending into the canal.

POSTAURICULAR

Behind the pinna.

TRANS-CANAL

Through the external auditory canal.

ENDOSCOPIC TRANS-CANAL

Using the canal as a natural optical and working corridor.

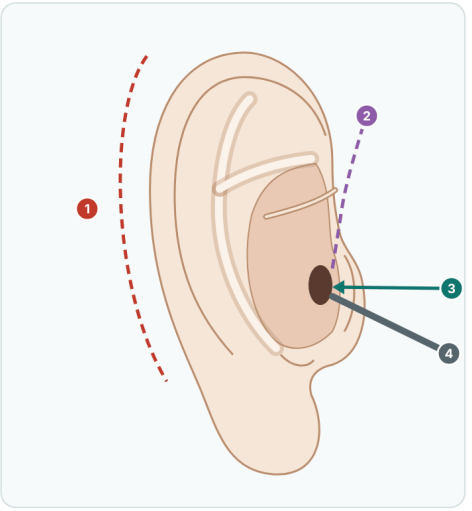
The appropriate approach depends upon:

- target
- canal anatomy
- disease
- required exposure
- surgeon technique

No approach is universally superior.

Figure 1.7 · Access routes around the external ear

Schematic — right ear, lateral view, anterior to the viewer's right



1 POSTAURICULAR
in or just behind the postauricular sulcus
wide access to mastoid; temporalis fascia; concha

2 ENDAURAL
through the incisura terminalis,
between tragus and crus of helix

3 TRANSCANAL (MICROSCOPE)
through the canal, with a speculum
limited by the narrowest canal segment

4 ENDOSCOPIC TRANSCANAL
the canal as optical and working corridor
one-handed; angled views around corners

Choose by target, canal anatomy, disease and required exposure.
The incision must allow the whole operation — including its extension.

1.26 INCISION PLANNING

Before incision, ask:

What is the target?

How much exposure is required?

Will cartilage need to be harvested?

Could the operation extend?

Will reconstruction be required?

Where will the final scar lie?

The incision should support the entire operation, not merely the first step.

1.27 EXTERNAL-EAR DEFECT ANALYSIS

When reconstructing an auricular defect, assess:

SKIN ONLY?

SKIN + CARTILAGE?

FULL THICKNESS?

HELICAL RIM INVOLVED?

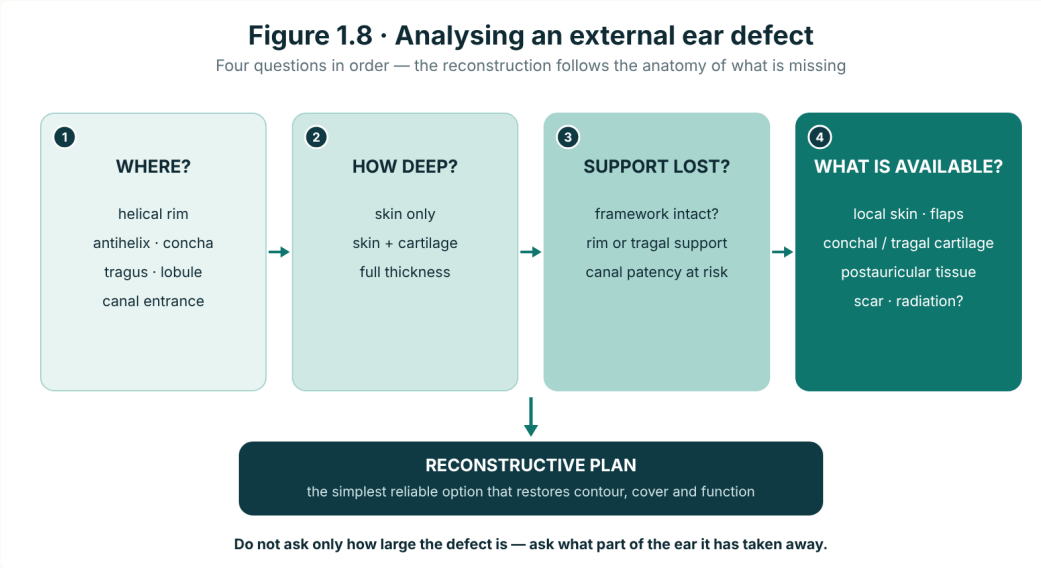
CONCHA INVOLVED?

CANAL INVOLVED?

SUPPORT LOST?

LOCAL TISSUE AVAILABLE?

The reconstructive method should follow the defect's anatomy; options are discussed in Chapter 3, Otoplasty & Reconstruction of Auricular Defects.



DECISION POINT

PRESERVE, RESECT OR RECONSTRUCT CARTILAGE?

Ask:

Is the cartilage healthy?

Is it involved by tumour or infection?

Does it provide essential structural support?

Will removing it distort the auricle?

Can the defect be reconstructed reliably?

Do not preserve diseased cartilage merely for shape.

Do not remove uninvolved structural cartilage without understanding the deformity that will follow.

SURGICAL PERSPECTIVE

The pinna teaches an early lesson in reconstructive surgery.

A defect of only a few centimetres may appear small.

But if those centimetres remove the helical rim, tragal support or canal entrance, the functional and cosmetic consequence can be disproportionately large.

Therefore:

> **THE IMPORTANCE OF A DEFECT IS NOT MEASURED ONLY BY ITS SIZE.**

It is measured by what anatomical function that tissue was performing.

TAKE IT TO THE OT

Before external-ear surgery, identify:

SUBUNIT
Which part of the auricle is involved?

SKIN
Can it be preserved?

CARTILAGE
Does it need to remain?

VASCULARITY
What supplies the planned flap?

CANAL
Will patency be affected?

DONOR TISSUE
Is cartilage or skin graft required?

INCISION
Does it provide adequate access and future extension?

RECONSTRUCTION
How will contour and function be restored?

CHAPTER SUMMARY

The external ear is a thin, three-dimensional cartilaginous framework covered by tissue of varying thickness and mobility.

Understand the pinna in structural subunits.

Respect perichondrial and soft-tissue vascularity.

Plan flaps according to blood supply, not movement alone.

Recognise the transition from thicker lateral canal skin to extremely delicate medial canal skin.

Remember the structures lying beyond each canal wall.

Preserve epithelial coverage where possible.

And when planning reconstruction:

> **Do not ask only how large the defect is.**

> **Ask what part of the ear the defect has taken away.**

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CHAPTER 02

Congenital & Acquired External Ear Surgery

Preserve Structure • Eliminate Disease • Restore Form

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- evaluate common congenital and acquired external-ear abnormalities from a surgical perspective
- understand the operative principles of preauricular sinus surgery
- approach accessory auricular tissue and selected congenital deformities
- understand the anatomical basis of prominent-ear correction
- manage auricular haematoma with attention to prevention of recurrence
- understand surgical principles in perichondrial and cartilaginous infection
- assess traumatic auricular defects
- recognise when specialised auricular reconstruction is required

2.1 THE EXTERNAL EAR HAS LITTLE ROOM FOR ERROR

The pinna is visible.

Its skin is thin.

Its cartilage defines contour.

Small changes can therefore produce obvious deformity.

External-ear surgery should aim to balance three objectives:

DISEASE CONTROL

STRUCTURAL PRESERVATION

APPEARANCE

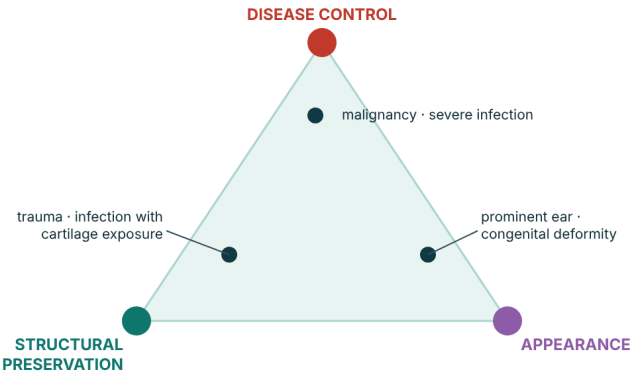
The priority among these changes according to the condition.

In malignancy or severe infection, disease control dominates.

In reconstructive and congenital surgery, contour and symmetry become increasingly important.

Figure 2.1 · Three objectives whose priority changes with the condition

External-ear surgery balances disease control, structural preservation and appearance



All three always matter — the condition decides which leads.

Dots: where the emphasis usually lies

2.2 PREAURICULAR SINUS

A preauricular sinus is a congenital epithelial-lined tract, thought to arise from incomplete fusion of the auricular hillocks.

The opening lies most often at the anterior margin of the ascending limb of the helix, and the condition may be bilateral.

Patients may remain asymptomatic or develop:

- recurrent discharge
- infection
- abscess
- scarring from previous drainage

Surgery is generally considered for recurrent or persistent symptomatic disease after appropriate management of acute infection.

The surgical problem is not the visible opening.

It is the tract beneath it.

2.3 THE OPENING IS NOT THE DISEASE

The external punctum may be only the entrance to:

- a branching tract
- scarred tissue
- chronically infected epithelium

The tract and its branches usually lie lateral to the temporalis fascia and are frequently adherent to the perichondrium of the helical root.

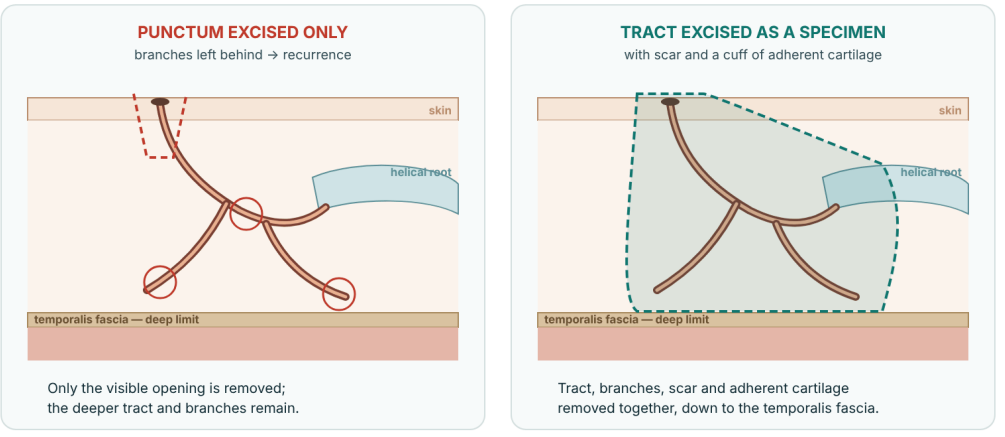
Therefore simply excising the skin opening risks leaving residual tract behind.

PRINCIPLE

Follow the disease beyond what is visible on the surface.

Figure 2.2 · Preauricular sinus: the opening is not the disease

Schematic section, not to scale — branching tract beneath a small punctum



2.4 OPERATIVE PLANNING FOR PREAURICULAR SINUS

Assess:

- site of opening
- previous infections
- previous drainage scars
- previous surgery
- active inflammation
- relationship to auricular cartilage and surrounding tissues

Where acute infection is present, definitive excision may be more difficult because inflammation obscures tissue planes.

Timing should therefore be individualised.

2.5 TRACT IDENTIFICATION

Methods described for tract identification include combinations of:

- magnification
- gentle probing
- dye techniques
- careful dissection of surrounding tissue

Each method has limitations.

Forceful probing can create a false passage.

Dye can stain surrounding tissue if extravasated.

The central principle remains:

> **IDENTIFY THE TRACT WITH ITS SURROUNDING SCARRED TISSUE AND REMOVE IT COMPLETELY WITHOUT CREATING ARTIFICIAL PATHWAYS.**

2.6 DISSECT THE TRACT AS A SPECIMEN

Repeatedly opening the sinus tract during dissection can make orientation more difficult.

Where feasible, maintain the tract and associated scar as a coherent specimen.

If the tract is closely related to the helical root cartilage, a small cuff of the adherent cartilage is commonly removed with it.

Extending the exposure superiorly above the auricle (a supra-auricular approach) and taking the dissection down to the temporalis fascia as the deep limit helps ensure that branches are not left behind.

The objective is complete disease removal with preservation of uninvolved anatomy.

2.7 RECURRENT PREAURICULAR SINUS

Recurrence may follow:

- incomplete tract removal
- branching anatomy
- surgery during significant inflammation
- poor identification of scarred extensions

Revision surgery should account for:

- previous scar
- distorted tract
- altered planes

Do not assume recurrence follows the original tract exactly.

2.8 ACCESSORY AURICLE

Accessory auricular tissue may contain:

- skin
- subcutaneous tissue
- cartilage

Before excision, determine:

Is cartilage present?

How deeply does it extend?

What contour will remain after removal?

Simple superficial removal without addressing an underlying cartilaginous stalk may leave a palpable or visible prominence.

2.9 CONGENITAL AURICULAR DEFORMITY

Congenital auricular abnormalities exist across a broad spectrum.

They may involve:

- size
- projection
- folding
- cartilage deficiency
- canal abnormalities
- complete or partial absence of the auricle

Assessment should consider:

HEARING

EXTERNAL AUDITORY CANAL

MIDDLE-EAR DEVELOPMENT

CONTRALATERAL EAR

FACIAL SYMMETRY

ASSOCIATED CRANIOFACIAL ABNORMALITIES

Auricular appearance should not be evaluated in isolation from auditory function.

2.10 PROMINENT EAR

Prominent ear commonly results from one or more anatomical characteristics such as:

- underdeveloped antihelical fold
- increased conchal depth or projection
- altered concha–mastoid relationship
- lobular prominence

The operative plan should identify the actual anatomical contributor.

PRINCIPLE

Do not perform a standard cartilage manoeuvre on every prominent ear.

Correct the anatomical reason for prominence.

Analysis and techniques are described in Chapter 3, Otoplasty & Reconstruction of Auricular Defects.

2.11 OTOPLASTY — THE OBJECTIVE

The objective is not simply to move the ear closer to the head.

A satisfactory correction should aim for:

- natural antihelical contour
- appropriate conchal relationship
- smooth helical line
- reasonable symmetry
- avoidance of overcorrection
- preservation of natural auricular appearance

An ear that is flat against the scalp is not necessarily a well-corrected ear.

2.12 CARTILAGE-SHAPING PRINCIPLES

Techniques may broadly involve:

CARTILAGE-SUTURING

Reshaping without major cartilage removal.

CARTILAGE-SCORING / WEAKENING

Altering cartilage memory.

CARTILAGE-RESECTION

Removing selected tissue where appropriate.

Different cartilage behaves differently according to:

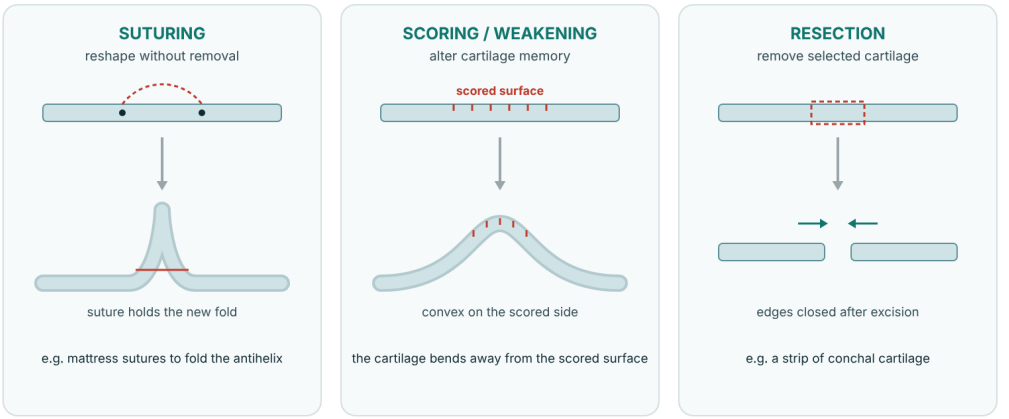
- thickness
- elasticity

- age
- deformity

No single technique is universally required.

Figure 2.3 · Three ways to change cartilage shape

Schematic sections of auricular cartilage — before (above) and after (below)



Choose by the anatomical cause, the cartilage's thickness, elasticity and age — not by habit.

2.13 SYMMETRY

Perfect bilateral symmetry is rarely achievable because normal ears are not perfectly identical.

The objective should be:

BALANCE
rather than mathematical duplication.

Assess the patient from:

- front
- side
- posterior view

A correction that looks appropriate from one direction may appear unnatural from another.

2.14 AURICULAR HAEMATOMA

Auricular haematoma develops when blood accumulates between the perichondrium and the cartilage, separating the cartilage from its nutrition (see Chapter 1, Surgical Anatomy of the External Ear).

If persistent, this may lead to:

- cartilage necrosis
- fibrosis and new cartilage formation
- contour deformity ("cauliflower ear")

The operative principles are:

EVACUATE THE COLLECTION

CONTROL BLEEDING

> **ELIMINATE THE POTENTIAL SPACE**

PREVENT REACCUMULATION

2.15 DRAINAGE ALONE MAY NOT BE ENOUGH

If the tissue layers remain separated, the space can refill.

Methods to maintain tissue apposition may include, according to the clinical situation:

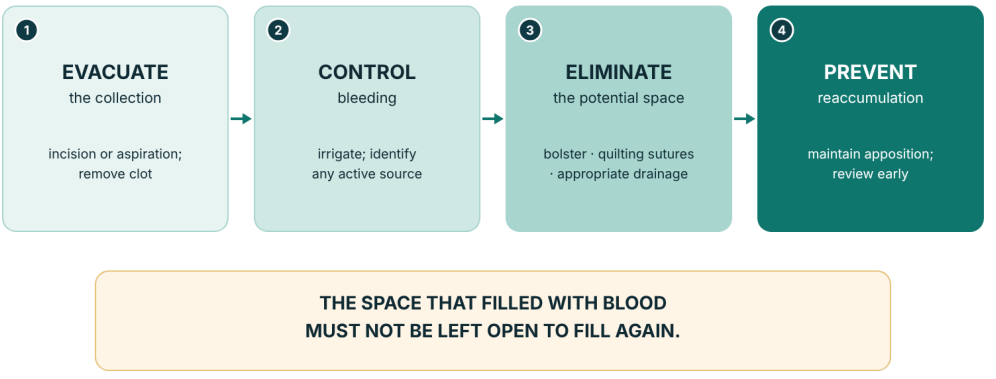
- compression
- bolster techniques
- quilting-type sutures
- appropriate drainage

The specific method is less important than the principle:

> **THE SPACE THAT FILLED WITH BLOOD MUST NOT BE LEFT OPEN TO FILL AGAIN.**

Figure 2.4 · Auricular haematoma: four steps, one principle

Drainage alone may not be enough — the space must be closed



The specific method matters less than restoring contact between perichondrium and cartilage.

2.16 PERICHONDRITIS & CARTILAGE INFECTION

Infection involving the perichondrial/cartilaginous framework can threaten auricular contour.

Pseudomonas aeruginosa is the most common organism, particularly after high cartilage piercing, trauma or surgery.

Because the lobule contains no cartilage, sparing of the lobule helps distinguish perichondritis from simple cellulitis.

Management may require:

- appropriate antimicrobial therapy, with anti-pseudomonal cover
- drainage of collection
- debridement of non-viable tissue
- preservation of viable cartilage and skin where possible

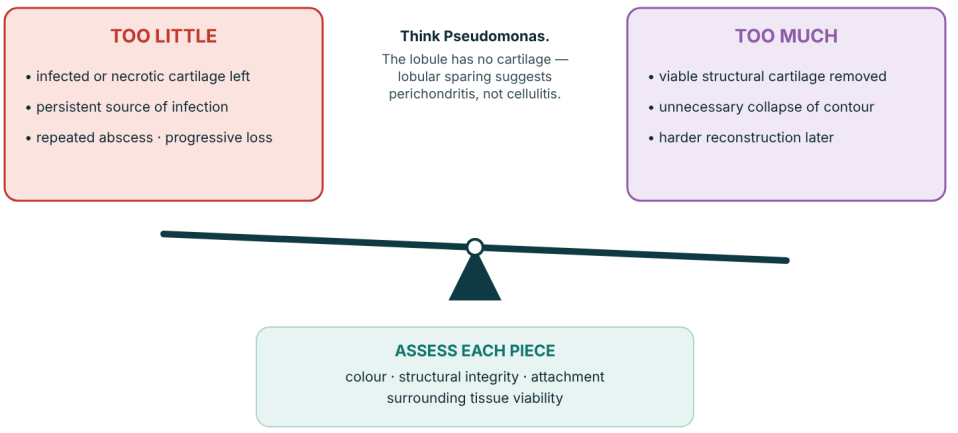
The balance is important.

Overly conservative treatment may leave infected or necrotic tissue.

Overly aggressive debridement may produce unnecessary deformity.

Figure 2.5 · Infected cartilage: the debridement balance

Remove what is non-viable; keep what still holds the shape



2.17 CARTILAGE NECROSIS

Non-viable cartilage may act as a persistent source of infection.

Assess:

- colour
- structural integrity
- attachment
- surrounding tissue viability

Debride tissue that is clearly non-viable while preserving viable structural cartilage where clinically appropriate.

Reconstruction may need to be delayed until infection is controlled.

2.18 TRAUMATIC AURICULAR INJURY

Trauma may produce:

- laceration
- cartilage exposure
- cartilage fracture
- partial avulsion

- complete avulsion
- tissue loss

Initial assessment should determine:

SKIN VIABILITY

CARTILAGE VIABILITY

PEDICLE / ATTACHMENT

CONTAMINATION

TISSUE LOSS

EXTERNAL CANAL INVOLVEMENT

2.19 LACERATION REPAIR

The objective is restoration of:

- cartilage framework
- skin coverage
- contour

Where cartilage is disrupted, alignment should be restored without excessive suturing or crush.

Skin should cover cartilage wherever possible.

PRINCIPLE

Repair the framework before expecting the skin to create the shape.

2.20 PARTIAL AVULSION

A partially attached auricle may retain valuable blood supply through a tissue pedicle.

Avoid unnecessary division of viable attachments.

Assess:

- perfusion
- pedicle width
- tissue viability

- contamination

Preservation of viable tissue may significantly simplify later reconstruction.

2.21 COMPLETE AVULSION

Complete auricular avulsion is a specialised reconstructive problem.

Potential management strategies depend upon:

- injury mechanism
- tissue condition
- ischaemia time
- microsurgical resources
- patient factors

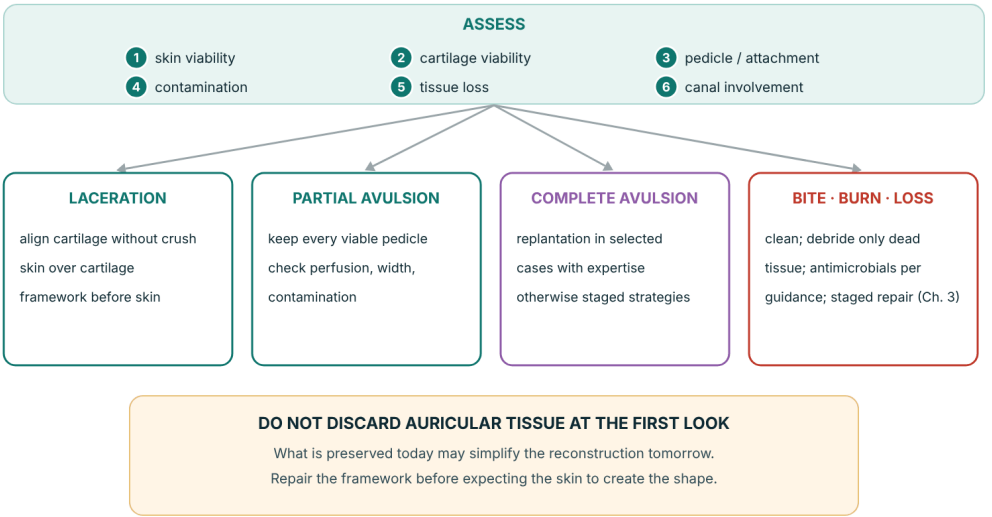
Microsurgical replantation may be considered in selected circumstances where expertise is available.

Other reconstructive strategies may be required when replantation is not feasible.

These cases should be managed according to available reconstructive expertise rather than a universal algorithm.

Figure 2.6 · Auricular trauma: assess, then match the repair to the injury

Six checks before any decision; preserve viable tissue at the first operation



2.22 BITE INJURIES

Human or animal bites require attention to:

- contamination
- devitalised tissue
- infection risk
- cartilage exposure
- tissue loss

Management should integrate:

- wound cleaning
- appropriate antimicrobial cover, tetanus prophylaxis and, for animal bites, rabies post-exposure prophylaxis according to current guidance
- conservative debridement of clearly non-viable tissue
- reconstructive planning

Auricular tissue should not be unnecessarily discarded during initial assessment.

2.23 BURNS

Thermal injury may compromise:

- skin
- perichondrium
- cartilage

The pinna is vulnerable because cartilage lies close beneath thin skin.

Management depends upon:

- burn depth
- tissue viability
- infection
- cartilage exposure

Pressure on injured auricular tissue should be minimised where clinically appropriate.

2.24 KELOID & HYPERTROPHIC SCARRING

The auricle is a common site for problematic scarring, particularly after piercing or trauma.

Management may involve combinations of:

- excision
- intralesional therapy (usually corticosteroid)
- pressure therapy
- other adjunctive treatments

Recurrence can be significant.

The treatment plan should therefore extend beyond simple excision where appropriate.

2.25 PIERCING-RELATED COMPLICATIONS

Cartilage piercing may be associated with:

- infection
- perichondritis
- abscess
- cartilage necrosis
- keloid formation

The consequence can be disproportionate to the small entry wound.

This again reflects the vulnerability of the auricular cartilage–perichondrial relationship.

2.26 MICROTIA

Microtia represents a spectrum of auricular underdevelopment.

Assessment should include:

- degree of auricular deficiency
- external canal status
- hearing

- middle-ear anatomy
- contralateral hearing
- associated craniofacial abnormalities

Reconstruction may involve:

- autologous framework reconstruction
- prosthetic reconstruction
- selected implant-based approaches
- staged strategies

When canal atresia is present, candidacy for atresia repair is usually judged on high-resolution CT (for example, with the Jahrsdoerfer grading system); bone-conduction and other implantable devices are an alternative route to hearing (see Chapter 18, Implantable Hearing Devices).

Detailed total auricular reconstruction requires specialised expertise and deserves treatment beyond a brief generic operative recipe.

2.27 HEARING BEFORE APPEARANCE

In congenital external-ear abnormality, do not allow visible deformity to distract from auditory assessment.

Particularly in children:

HEARING STATUS
can influence:

- speech development
- educational development
- timing of intervention
- hearing rehabilitation

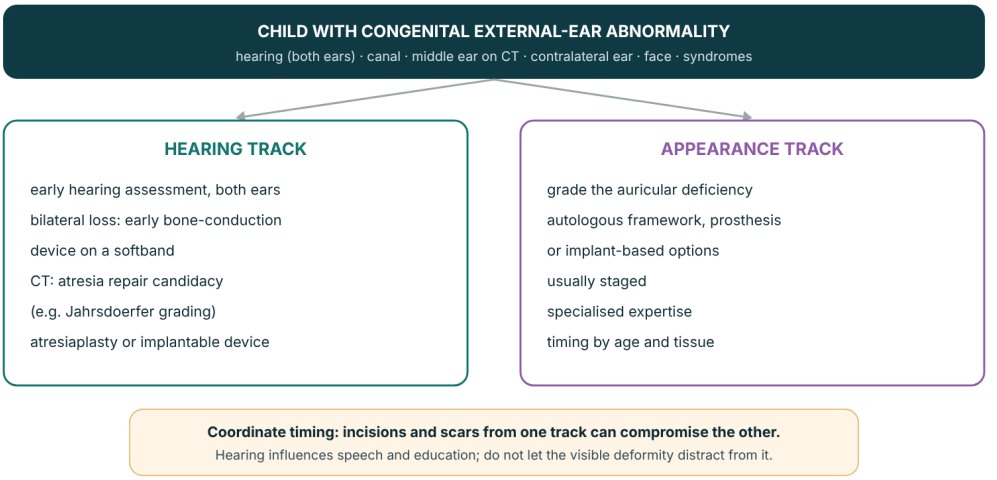
In bilateral conductive loss, early amplification, usually a bone-conduction device worn on a softband, should not wait for any reconstructive decision.

Cosmetic reconstruction and hearing rehabilitation should be planned as related but distinct objectives.

The timing of canal surgery and implantable devices should be coordinated with auricular reconstruction, because incisions and scars from one can compromise the other.

Figure 2.7 · Hearing before appearance: two coordinated tracks

Microtia and canal atresia — related but distinct objectives



DECISION POINT

EXCISE NOW OR CONTROL THE FIELD FIRST?

When infection or inflammation is active, ask:

Can disease be safely and completely removed now?

Are tissue planes identifiable?

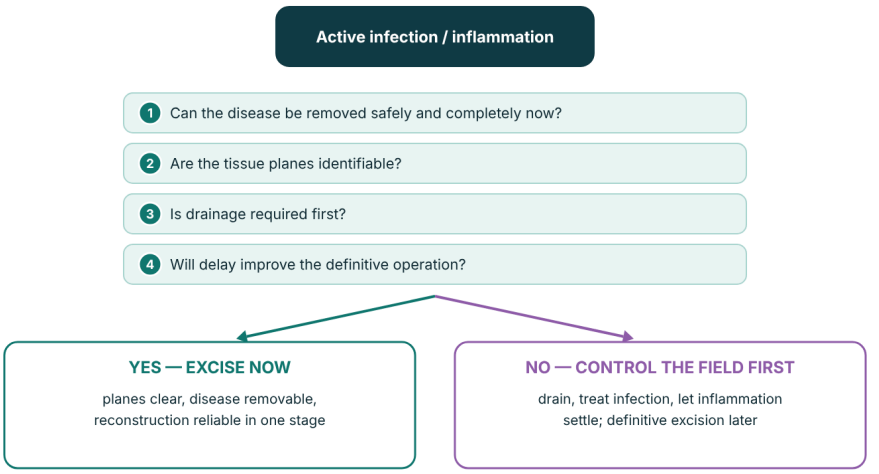
Is drainage required first?

Will delay improve definitive reconstruction?

Urgent control of infection and definitive reconstructive surgery are not always the same operation.

Figure 2.8 · Excise now or control the field first?

Active infection or inflammation — urgent control and definitive surgery are not always the same operation



FROM EXPERIENCE

External-ear surgery reminds us that the apparent size of an operation can be misleading.

A small incision can affect a structure whose contour is visible every day.

A small haematoma can permanently alter cartilage.

A tiny congenital opening can lead to a branching recurrent tract.

A few millimetres of tissue loss along the helical rim can become a significant reconstructive problem.

The operation may be small.

The anatomical consequence may not be.

TAKE IT TO THE OT

Before external-ear surgery, define:

DISEASE
Congenital, inflammatory, traumatic or reconstructive?

SKIN
Is it viable?

CARTILAGE
Healthy, infected, fractured or absent?

SPACE
Is there a collection requiring elimination?

VASCULARITY
Which tissue must remain attached?

CANAL
Is hearing or canal patency affected?

CONTOUR
What structural change will surgery create?

RECONSTRUCTION
Immediate or staged?

CHAPTER SUMMARY

External-ear surgery requires respect for thin skin, vulnerable cartilage and visible three-dimensional contour.

For preauricular sinus, treat the tract—not merely the opening.

For prominent ear, correct the anatomical cause rather than applying a standard manoeuvre.

For auricular haematoma, evacuate the collection and eliminate the potential space.

Preserve viable cartilage and tissue during infection and trauma.

Assess hearing in congenital abnormalities.

And remember:

> **A small operation on the pinna can produce a large anatomical consequence.**

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CHAPTER 03

Otoplasty & Reconstruction of Auricular Defects

Reconstruct the Shape, Not Merely the Wound

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- analyse prominent-ear deformity according to its anatomical components
- understand the major principles of cartilage-sparing and cartilage-modifying otoplasty
- analyse auricular defects by location, size, depth and structural loss
- recognise when cartilage support must be reconstructed
- select local tissue according to auricular subunit and vascularity
- understand the principles of helical, conchal, lobular and full-thickness reconstruction
- recognise when staged or specialised reconstruction is preferable
- avoid common causes of unnatural contour and secondary deformity

3.1 THE EAR IS SHAPE

A wound can heal completely and still leave an unsatisfactory ear.

Why?

Because auricular success is not determined by skin closure alone.

The pinna depends upon:

CONTOUR

PROJECTION

CARTILAGE SUPPORT

SKIN COVERAGE

SUBUNIT RELATIONSHIPS

Therefore reconstruction should aim not simply to close the defect but to restore the three-dimensional framework.

3.2 BEGIN WITH THE NORMAL EAR

Before altering an auricle, examine:

- helix
- antihelix
- concha
- lobule
- projection
- height
- width
- cranioauricular relationship
- contralateral ear

Photographic documentation from standardised views is useful.

FRONT

SIDE

OBLIQUE

POSTERIOR

The surgeon should know what anatomical feature is being changed before changing it.

PART I — OTOPLASTY

3.3 PROMINENT EAR IS NOT ONE DEFORMITY

Prominence may result from one or more factors:

POORLY DEFINED ANTIHELIX

DEEP / PROMINENT CONCHA

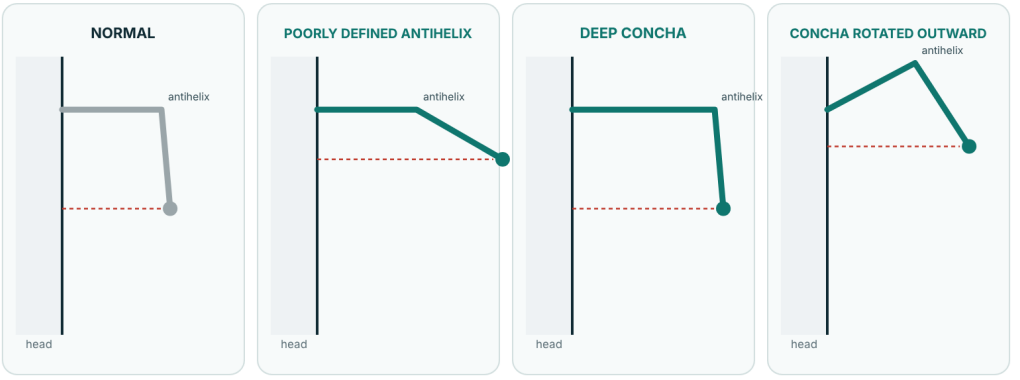
INCREASED CONCHOMASTOID ANGLE

LOBULAR PROMINENCE

COMBINATION

Figure 3.1 · Four anatomical patterns producing auricular prominence

Schematic horizontal sections of the auricle seen from above (head on the left, posterior downward) — not to scale



The operation should match the deformity.

3.4 ANALYSE BEFORE CORRECTING

Ask:

Is the antihelical fold deficient?

Is the concha excessively deep?

Is the entire auricle rotated outward?

Is the lobule independently prominent?

Is there asymmetry?

A single standardised manoeuvre applied to all prominent ears risks creating an unnatural result.

3.5 THE OBJECTIVE OF OTOPLASTY

A satisfactory otoplasty should aim for:

- natural antihelical definition
- appropriate conchal relationship
- smooth helical contour
- balanced projection
- reasonable bilateral symmetry
- preservation of the postauricular sulcus
- absence of obvious surgical distortion

> **PRINCIPLE**
>
> **The goal is not an ear that looks operated upon.**

It is an ear that no longer attracts attention because of its prominence.

3.6 CARTILAGE-SPARING APPROACHES

Cartilage-sparing techniques primarily reshape cartilage through sutures rather than extensive scoring or resection.

Potential advantages include:

- smoother contour
- reduced risk of sharp cartilage edges
- reversibility or adjustability during surgery

Limitations may include:

- recurrence
- suture-related complications

- inadequate correction in stiff cartilage

Technique should be selected according to cartilage characteristics and deformity.

3.7 ANTIHELIX CREATION

When the antihelical fold is underdeveloped, mattress-type cartilage suturing techniques (conchoscaphal sutures, as described by Mustardé) can be used to recreate the fold.

The important concepts are:

MARK THE DESIRED FOLD

PLACE SUTURES SYMMETRICALLY

CONTROL TENSION

ASSESS THE EAR FROM THE FRONT

Excessive tightening may create:

- sharp fold
- buried helix
- unnatural contour

The fold should look formed—not folded by force.

3.8 CONCHAL SETBACK

When conchal prominence contributes significantly, the concha may be repositioned towards the mastoid region, typically with conchomastoid sutures (as described by Furnas) and, where the concha is excessively deep, excision of a crescent of conchal cartilage.

Before fixation, consider:

- conchal depth
- cartilage stiffness
- external auditory canal
- postauricular soft tissue
- desired projection

Overcorrection can narrow the postauricular sulcus or distort the canal.

If the mastoid bites of conchomastoid sutures are placed too far anteriorly, the concha is rotated forward and the meatus can be narrowed; place them posteriorly on the mastoid periosteum.

3.9 CARTILAGE-MODIFYING TECHNIQUES

Cartilage may be:

- scored
- weakened
- partially excised
- reshaped

when appropriate.

These techniques can be useful in:

- stiff cartilage
- significant conchal excess
- selected deformities

But cartilage injury can produce:

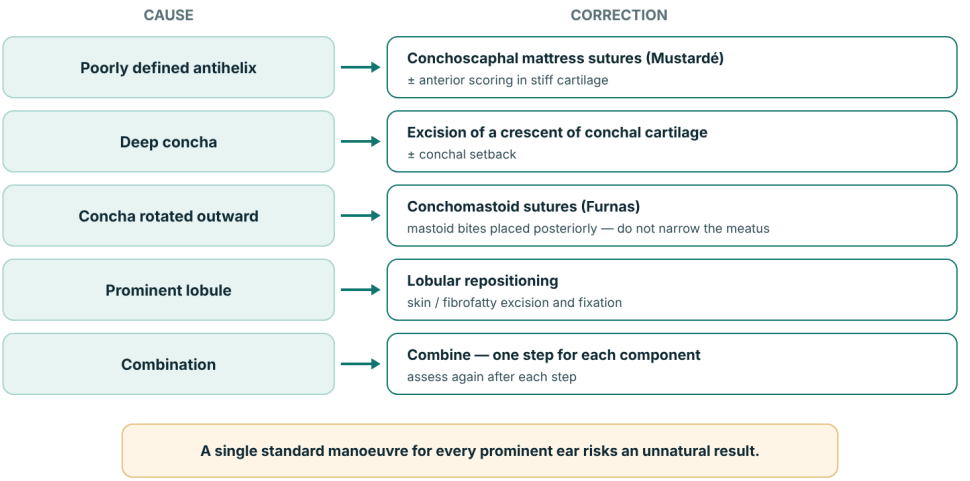
- irregularity
- sharp contour
- asymmetry

Scoring the anterior surface of the cartilage causes it to bend away from the scored side, towards the posterior surface; this is the basis of anterior scoring techniques for the antihelix.

Use the minimum modification required to achieve the intended shape.

Figure 3.2 · Match the technique to the cause of prominence

Identify which component is abnormal; correct that component with the least cartilage injury



3.10 CHECK THE EAR BEFORE CLOSURE

Before completing closure:

SIT BACK.

Look at the ear from:

- front
- side
- posteriorly
- above where useful

Compare with the opposite side.

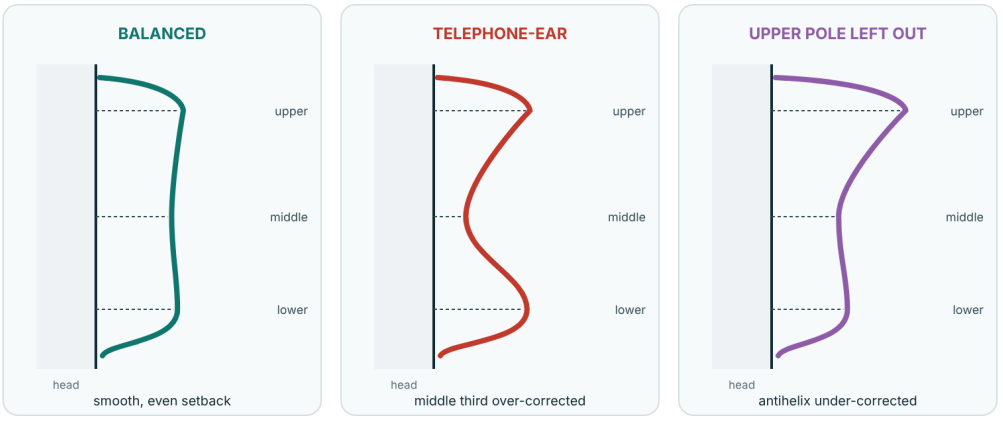
A technically perfect posterior suture line may still create an unsatisfactory anterior appearance.

RECONSTRUCTIVE PRINCIPLE

The final shape is judged from outside the wound—not from inside it.

Figure 3.3 · Judging the result: the three thirds of the ear

Schematic posterior view of the right ear — distance of the helical rim from the head at each third



Look from the front, the side and behind before closing — compare with the other ear.

The final shape is judged from outside the wound, not from inside it.

PART II — AURICULAR DEFECTS

3.11 FOUR QUESTIONS DEFINE THE DEFECT

Every auricular defect should initially be described by:

1. LOCATION

Which subunit?

2. SIZE

How much tissue is missing?

3. DEPTH

Skin only or full thickness?

4. SUPPORT

Is cartilage missing?

This creates:

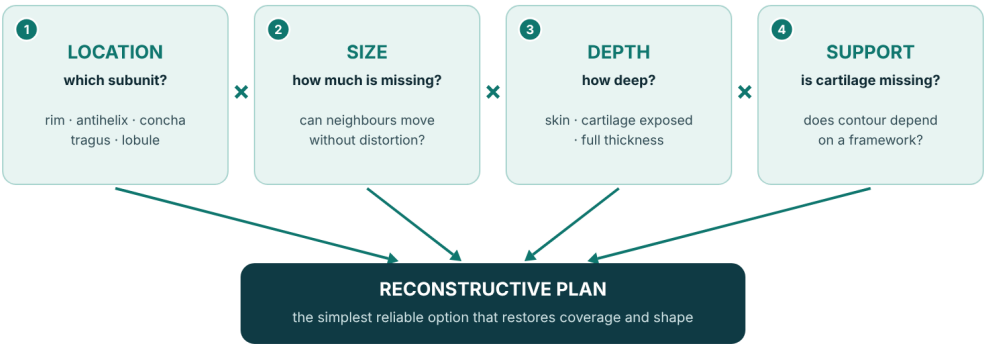
> **LOCATION × SIZE × DEPTH × SUPPORT**

↓

RECONSTRUCTIVE PLAN

Figure 3.4 · Auricular reconstruction decision framework

Four descriptors of the defect combine into one reconstructive plan



Location often matters more than area: a 1-cm rim defect is not a 1-cm conchal defect.

3.12 LOCATION MATTERS MORE THAN AREA ALONE

A 1-cm defect in the conchal bowl is not equivalent to a 1-cm defect of the helical rim.

Why?

Because the helical rim defines the outer silhouette.

Small changes become visible immediately.

The concha, in contrast, may tolerate selected contour changes more easily.

Therefore reconstructive difficulty depends upon the **structural importance of the missing tissue**.

3.13 SKIN-ONLY DEFECTS

When cartilage remains intact and viable, options may include:

- secondary healing in selected sites
- primary closure
- skin graft
- local flap

Selection depends upon:

- size
- location
- vascularity
- cartilage exposure
- expected contraction
- cosmetic consequence

3.14 EXPOSED CARTILAGE

A skin graft requires an adequately vascularised recipient bed.

Bare cartilage without suitable vascularised covering may provide a less reliable surface.

Possible strategies may include:

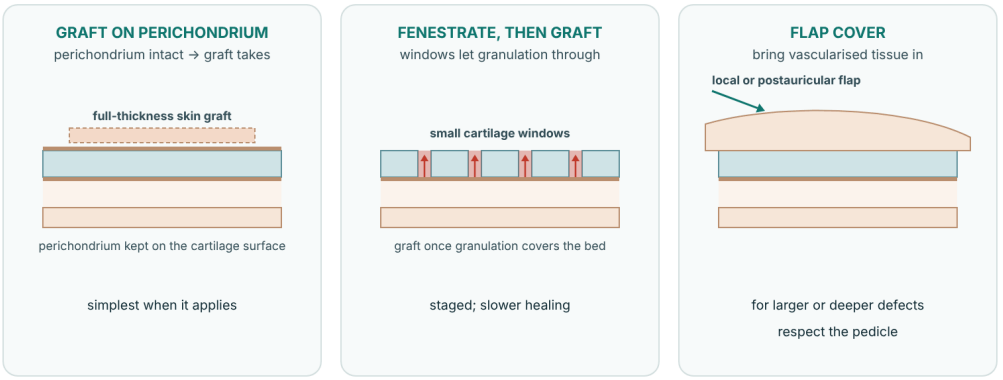
- preservation of perichondrium
- local flap coverage
- creation of an appropriate vascular bed
- fenestration of the cartilage (removing small windows) so that granulation tissue can grow through from the posterior surface before grafting
- excision of a small area of exposed cartilage where this does not compromise contour

A full-thickness skin graft generally survives well on intact perichondrium; on bare cartilage it is unreliable.

The specific method depends upon the defect.

Figure 3.5 · Exposed cartilage: three ways to provide a vascular bed

Schematic sections — a skin graft needs a vascularised bed; bare cartilage is unreliable



Exposed cartilage is not merely uncovered — its biological support has been reduced.

3.15 PRIMARY CLOSURE

Small defects may sometimes be closed directly.

But ask:

What will direct closure do to the ear?

It may:

- shorten the rim
- distort the helix
- narrow the concha
- pull the lobule
- alter projection

PRINCIPLE

If closing the wound deforms the ear, the wound is not truly closable primarily.

3.16 HELICAL RIM DEFECTS

The helical rim creates the external silhouette.

Reconstruction should aim to preserve:

- continuity
- curvature
- height
- projection

Depending upon defect size and location, options may include:

- primary approximation
- wedge-type excision and closure
- advancement techniques
- local flaps
- cartilage-supported reconstruction
- staged reconstruction

The exact technique should follow defect geometry.

3.17 WEDGE EXCISION

For selected small full-thickness rim defects, conversion to a controlled wedge and primary approximation may provide effective reconstruction.

Modifying the wedge into a star shape, or excising small accessory triangles of cartilage (Burow's triangles), helps prevent cupping and buckling of the remaining auricle.

However, excessive wedge removal can:

- reduce auricular height
- distort contour
- create asymmetry

The surgeon should not enlarge a defect unnecessarily simply to fit a familiar reconstructive technique.

3.18 HELICAL ADVANCEMENT

Local helical tissue can sometimes be mobilised towards a defect, for example as chondrocutaneous helical advancement flaps (as described by Antia and Buch), based on the posterior auricular skin.

The principle is:

RELEASE ENOUGH TO MOVE
but

PRESERVE ENOUGH TO LIVE.
Advancement should avoid:

- excessive tension
- vascular compromise
- unnatural flattening
- distortion of adjacent subunits

3.19 CONCHAL DEFECTS

The concha has:

- concave geometry
- cartilage support
- relatively hidden position compared with the rim

Selected superficial defects may heal well by:

- secondary intention
- grafting
- local flap

depending upon perichondrial integrity and defect characteristics.

Larger full-thickness defects may require structural consideration.

3.20 TRAGAL DEFECTS

The tragus contributes to:

- external canal contour
- anterior auricular appearance

Reconstruction should avoid:

- canal distortion
- loss of support
- excessive bulk

Because the tragus is small, even modest tissue loss can become visible.

3.21 LOBULAR DEFECTS

The lobule contains no cartilage.

Reconstruction therefore focuses on:

- soft-tissue volume
- inferior contour
- symmetry
- scar placement

Defects may arise from:

- trauma
- piercing
- tumour excision
- split lobule

The absence of cartilage makes the mechanics different from upper auricular reconstruction.

3.22 POSTAURICULAR TISSUE

Postauricular skin is valuable because it is:

- close to the defect
- relatively well matched
- capable of movement through several local flap designs

It can be particularly useful for selected:

- helical
- posterior
- conchal
- full-thickness defects

For conchal defects, a postauricular island flap can be passed through a window in the cartilage to resurface the concha (the "revolving door" or flip-flop flap).

Flap design should respect vascularity and avoid excessive tension.

3.23 CARTILAGE SUPPORT

When structural cartilage is missing, ask:

Does this defect require a framework?

Not every defect does.

Cartilage support becomes particularly important when loss threatens:

- helical continuity
- projection
- contour
- canal patency

Potential donor cartilage may come from:

- remaining auricular cartilage
- contralateral auricle in selected cases
- septal cartilage
- costal cartilage

depending upon reconstructive requirement.

3.24 SKIN + CARTILAGE = TWO PROBLEMS

A full-thickness defect often requires separate consideration of:

FRAMEWORK
and

COVER.
Trying to solve both with one manoeuvre may compromise one component.

Think:

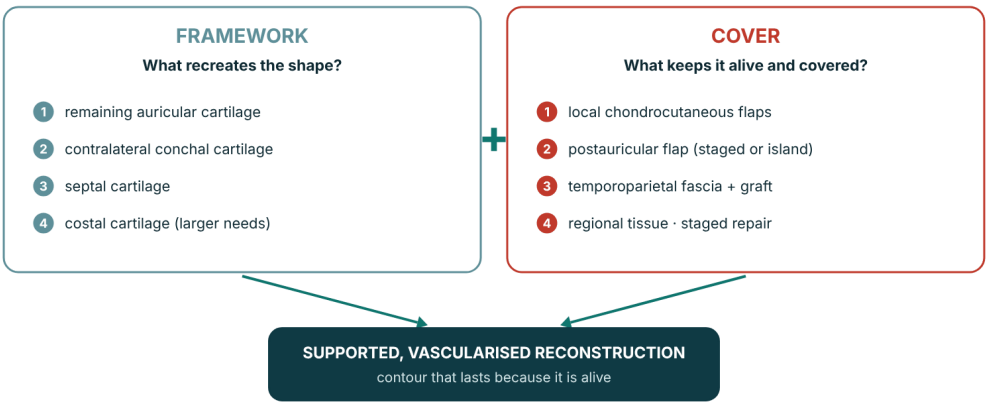
What recreates the shape?

then:

What keeps that reconstruction alive and covered?

Figure 3.6 · A full-thickness defect is two problems: framework and cover

Solve each on its own terms — one manoeuvre for both often compromises one



A framework without reliable cover will be exposed; cover without framework will collapse.

3.25 LARGE DEFECTS

As defect size increases, forcing local tissue into the defect can distort the remaining ear.

At some point, reconstruction may require:

- larger regional tissue
- staged reconstruction
- cartilage framework
- prosthetic options
- specialised auricular reconstruction

PRINCIPLE

Know when a local defect has become a total-ear reconstructive problem.

3.26 ONCOLOGICAL DEFECTS

When reconstructing after tumour removal:

ONCOLOGICAL CLEARANCE COMES FIRST.

Do not reduce the required resection simply to make reconstruction easier.

After adequate resection:

- orient the defect
- confirm margins as appropriate
- assess structural loss
- reconstruct accordingly

The reconstruction should adapt to the oncological defect.

Not the reverse.

3.27 TRAUMATIC DEFECTS

Traumatic wounds may contain tissue that initially appears unreliable.

Assess:

- perfusion
- contamination
- cartilage viability
- pedicle
- tissue loss

Preserve viable auricular tissue where possible.

Every millimetre retained may reduce later reconstructive complexity.

3.28 SCAR CONTRACTURE

Scar contraction can alter:

- helical contour
- canal entrance
- lobular position
- projection

When planning reconstruction, consider not only the immediate result but also:

WHAT WILL THIS SCAR DO AS IT MATURES?

This is particularly important around circumferential or narrow openings.

3.29 RECONSTRUCTIVE ALGORITHM

STEP 1 — WHERE?

Helix / antihelix / concha / tragus / lobule / combined.

↓

STEP 2 — HOW DEEP?

Skin only / cartilage exposed / full thickness.

↓

STEP 3 — HOW LARGE?

Can surrounding tissue move without distortion?

↓

STEP 4 — IS SUPPORT LOST?

Yes / No.

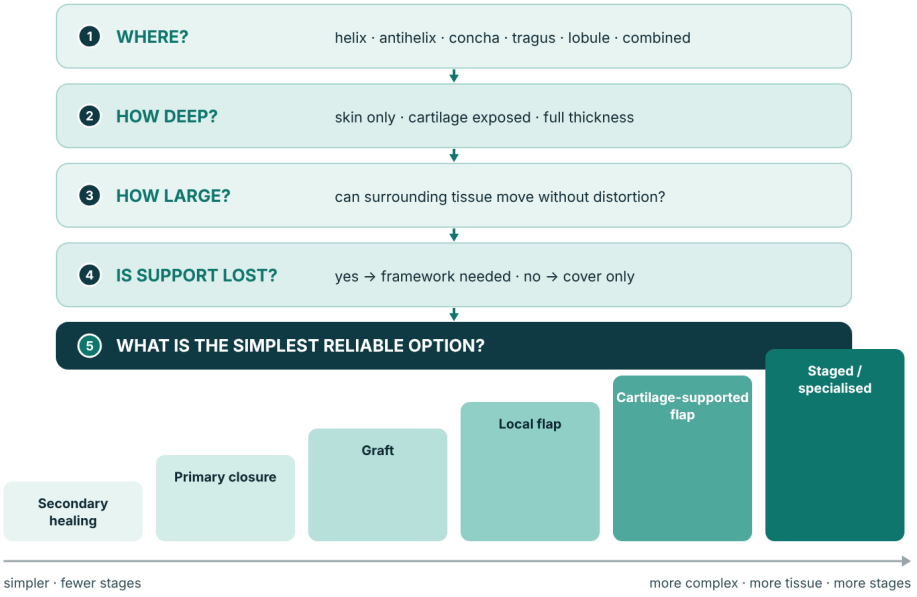
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STEP 5 — WHAT IS THE SIMPLEST RELIABLE OPTION?

Secondary healing
Primary closure
Graft
Local flap
Cartilage-supported flap
Staged / specialised reconstruction

Figure 3.7 · Auricular defect reconstruction algorithm

Answer the questions in order; then choose the simplest reliable option



Escalate only when the simpler option would distort the ear or fail.

3.30 WHAT MAKES AN EAR LOOK OPERATED?

Common causes include:

- overcorrection
- sharp unnatural antihelical fold
- "telephone-ear" deformity, when the middle third is set back more than the upper pole and lobule
- excessive flattening
- notching of the helix
- loss of auricular height
- poor lobular alignment
- contour irregularity
- visible scar
- asymmetry

The goal is not simply absence of the original deformity.

It is restoration of a believable ear.

DECISION POINT

CAN I CLOSE THIS DEFECT PRIMARILY?

Before saying yes, ask:

Will the wound close?

and separately:

What will the ear look like after it closes?

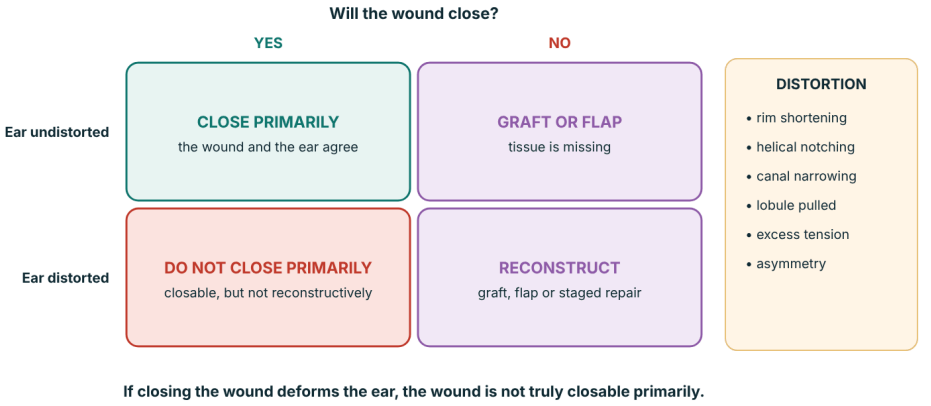
If primary closure produces:

- rim shortening
- canal distortion
- excessive tension
- major asymmetry

then technically possible closure may not be reconstructively appropriate.

Figure 3.8 · Can I close this defect primarily?

Two separate questions — the wound closing and the ear looking right



FROM EXPERIENCE

The easiest way to close a defect is not always the easiest way to reconstruct an ear.

The pinna exposes this difference clearly.

Pull two edges together and the wound may disappear.

But the helix may shorten.

The lobule may rotate.

The canal may narrow.

The ear may flatten.

Reconstruction therefore requires us to look beyond the wound.

> **The defect is what is missing.**

> **The reconstruction is what must be restored.**

TAKE IT TO THE OT

Before auricular reconstruction, define:

LOCATION

SIZE

DEPTH

CARTILAGE LOSS

SKIN AVAILABILITY

VASCULARITY

EXPECTED DISTORTION WITH PRIMARY CLOSURE

NEED FOR FRAMEWORK

DONOR TISSUE

FINAL CONTOUR

Then choose the least complex technique that restores both:

COVERAGE AND SHAPE.

CHAPTER SUMMARY

Otoplasty begins by identifying the anatomical cause of prominence.

Correct the deformity rather than applying a standard operation to every ear.

For auricular defects, analyse location, size, depth and structural loss.

Do not equate wound closure with reconstruction.

Preserve vascularity.

Restore cartilage support when contour depends upon it.

Use local tissue without distorting the remaining ear.

Escalate to staged or specialised reconstruction when the defect exceeds local options.

And remember:

> **The wound is two-dimensional.**

> **The ear you are reconstructing is three-dimensional.**

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CHAPTER 04

External Auditory Canal Surgery

Canalplasty • Meatoplasty • Stenosis • Bony Lesions

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the surgical anatomy of the cartilaginous and bony external auditory canal
- evaluate canal narrowing according to its level, cause and extent
- understand the principles of canalplasty and meatoplasty
- preserve viable canal skin during bone work
- distinguish common surgical considerations in exostosis and osteoma
- recognise structures at risk beyond the anterior, posterior, superior and inferior canal walls
- understand the role of epithelial coverage in preventing restenosis
- plan postoperative canal care to maintain long-term patency

4.1 THE CANAL IS NOT A TUBE

The external auditory canal is a curved, skin-lined corridor extending from the concha to the tympanic membrane.

Its surgery must preserve three things:

LUMEN

The canal must remain adequately open.

LINING

Bone should ideally remain covered by viable epithelium.

DIRECTION

The reconstructed canal should provide a functional pathway toward the tympanic membrane.

A technically wider canal that heals with exposed bone and circumferential scar may ultimately become narrower than it was before surgery.

4.2 CARTILAGINOUS AND BONY CANAL

The lateral cartilaginous canal has relatively thicker skin and subcutaneous tissue.

The medial bony canal has:

- very thin skin
- close adherence to periosteum
- little intervening soft tissue

This transition changes tissue handling.

LATERAL

More forgiving.

MEDIAL

Increasingly delicate.

PRINCIPLE

As the surgeon moves medially, force should decrease and precision should increase.

4.3 BEFORE OPERATING, DEFINE THE LEVEL OF THE PROBLEM

Canal obstruction may involve:

MEATUS

CARTILAGINOUS CANAL

BONY CANAL

TYMPANIC RING

COMBINATION

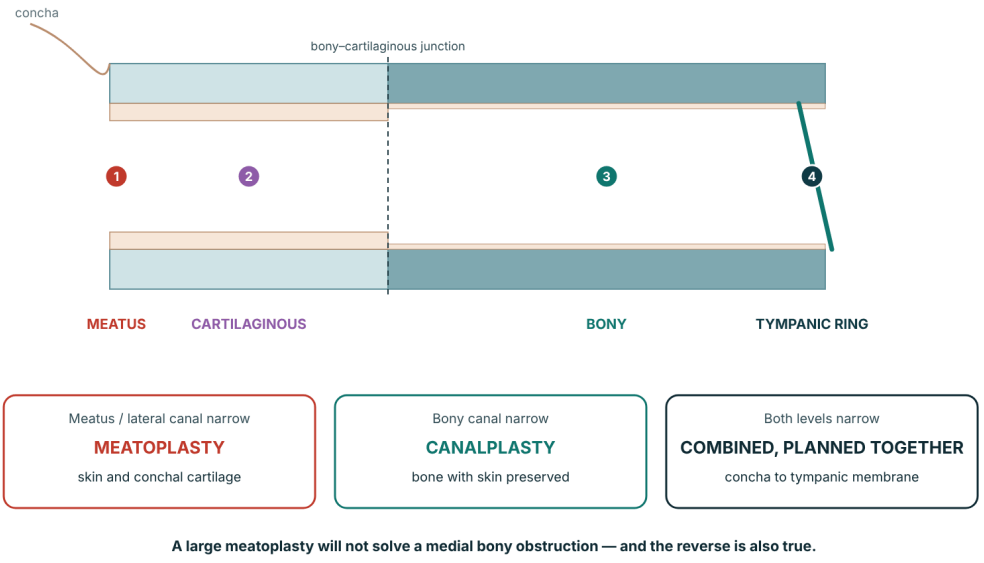
The surgical solution depends upon where the narrowing exists.

A large meatoplasty will not solve a medial bony obstruction.

A perfect canalplasty will not solve an inadequately opened meatus.

Figure 4.1 · The level of the narrowing decides the operation

Straightened schematic of the canal from concha to tympanic membrane — not to scale



A large meatoplasty will not solve a medial bony obstruction — and the reverse is also true.

4.4 CAUSES OF CANAL NARROWING

Narrowing may result from:

- congenital stenosis or atresia (see Chapter 2, Congenital & Acquired External Ear Surgery)
- inflammatory disease
- trauma
- previous surgery

- circumferential scar
- exostoses
- osteoma
- tumour (see Chapter 5, Malignancy of the External Auditory Canal)
- post-radiation change

The cause influences:

- tissue quality
- recurrence risk
- skin availability
- bone work
- reconstructive need

Do not treat all narrow canals as the same operation.

4.5 PREOPERATIVE ASSESSMENT

Evaluate:

- otoscopic / microscopic findings
- canal level and diameter
- tympanic membrane visibility
- hearing
- middle-ear status
- active infection
- skin quality
- previous surgery

CT is particularly useful when:

- significant bony narrowing exists
- congenital abnormality is suspected
- deeper anatomy is not visible
- revision surgery is planned
- disease extent is uncertain

Imaging is discussed in Chapter 7, Temporal Bone Imaging for the Surgeon.

4.6 READ THE CT AS A DRILLING MAP

Before canal drilling, review:

ANTERIORLY

Temporomandibular joint; in the cartilaginous canal, the parotid gland.

POSTERIORLY

Mastoid air cells; medially, the mastoid segment of the facial nerve, which at the level of the annulus lies only a few millimetres behind the posteroinferior canal wall.

SUPERIORLY

Tegmen and middle cranial fossa dura; medially, the epitympanum.

INFERIORLY

Jugular bulb, which may be high or dehiscent, and the tympanic bone.

MEDIALLY

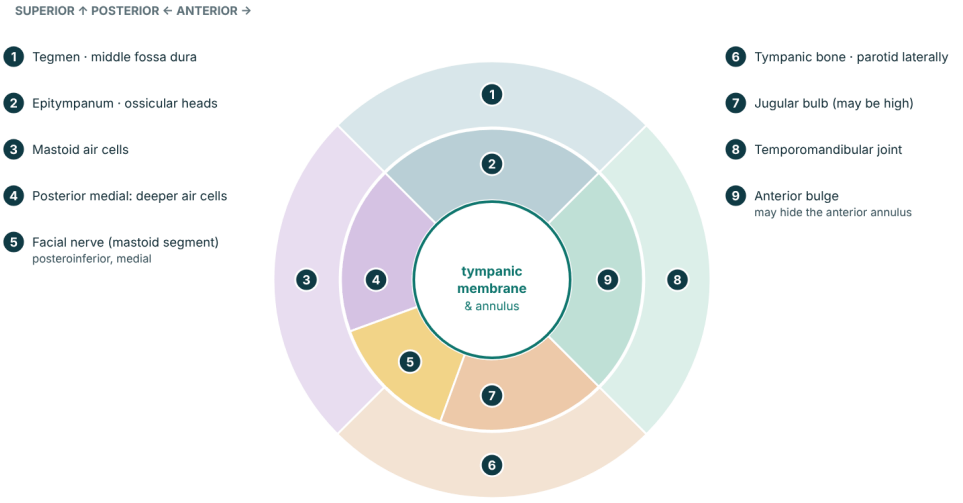
Tympanic membrane, annulus and middle ear.

SURGICAL PRINCIPLE

Every wall of the canal is also the wall of something else.

Figure 4.2 · A drilling map of the right canal: what lies beyond each wall

Schematic — right ear, looking medially down the canal; superior up, anterior to the viewer's right; inner ring = medial canal



Lateral: exposure. Medial: precision. The patient's CT outranks the average anatomy in your memory.

4.7 CANALPLASTY

Canalplasty enlarges or reshapes the bony external auditory canal.

Possible objectives include:

- improving access
- removing obstructing bone
- correcting stenosis
- improving visualisation of the tympanic membrane, particularly when an anterior canal wall bulge hides the anterior annulus
- supporting another otologic procedure

The objective is not maximum bone removal.

It is:

> **adequate lumen with preserved surrounding anatomy and viable epithelial coverage.**

4.8 DEFINE THE TARGET DIAMETER BY FUNCTION, NOT BY APPEARANCE

An excessively enlarged canal may:

- expose unnecessary bone
- sacrifice skin
- create healing problems
- alter canal geometry

An inadequately enlarged canal may:

- limit access
- retain disease
- restenose

Therefore enlargement should be proportional to the surgical objective.

4.9 PRESERVE CANAL SKIN

Canal skin is valuable reconstructive tissue.

Before drilling:

- plan skin incisions
- elevate flaps deliberately
- maintain orientation
- protect the skin from the burr
- keep tissue moist
- avoid unnecessary trauma

PRINCIPLE

Bone can be removed in seconds. Canal skin may take weeks to replace—and may never return normally if lost circumferentially.

4.10 SKIN FLAPS

Canal skin may be elevated and preserved as:

- anterior
- posterior
- superior
- inferior
- circumferentially designed flaps

depending upon the procedure.

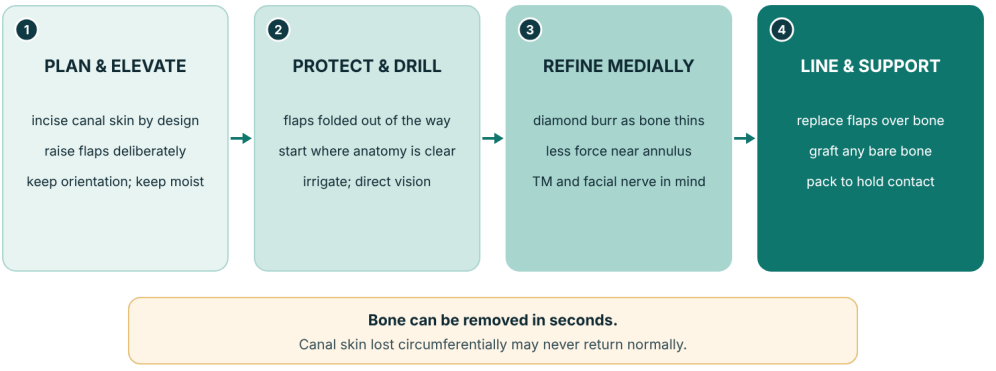
The exact design should provide:

- exposure
- protection during drilling
- adequate final epithelial coverage

Do not create a flap whose blood supply or final position has not been considered.

Figure 4.3 · Canalplasty in four steps

Protect the skin before the bone is touched — details vary with the lesion and approach



4.11 DRILLING THE CANAL

General principles include:

START WHERE ANATOMY IS CLEAR

USE A BURR APPROPRIATE TO THE AVAILABLE SPACE

MAINTAIN IRRIGATION

DRILL UNDER DIRECT VISION

REDUCE FORCE AS THE TYMPANIC MEMBRANE AND CRITICAL STRUCTURES APPROACH

KNOW THE SAFE DIRECTION OF BURR MOVEMENT

The canal is narrow.

A small uncontrolled movement may involve another anatomical compartment.

4.12 THE ANTERIOR WALL

The temporomandibular joint lies beyond the anterior canal wall.

During anterior canalplasty:

- review CT

- understand wall thickness
- avoid unnecessary deep drilling
- recognise dehiscence if encountered
- use a diamond burr as the bone thins

Violation may create communication with the joint region and complicate healing.

PRINCIPLE

Do not remove the final millimetre of bone unless that millimetre needs to be removed.

4.13 THE POSTERIOR WALL

The posterior canal wall is an important boundary in otologic surgery.

Excessive removal may:

- enter the mastoid air cells
- endanger the mastoid segment of the facial nerve, particularly in the medial, posteroinferior canal
- alter canal-wall integrity
- change later mastoid surgical options

In combined procedures, posterior wall management should be coordinated with the overall mastoid strategy (see Chapter 12, Canal Wall Up Mastoid Surgery, and Chapter 13, Canal Wall Down Mastoid Surgery).

4.14 THE SUPERIOR WALL

Superior drilling requires awareness of the tegmen and middle cranial fossa dura above, and of the epitympanum and ossicular heads medially.

Anatomical variation and previous disease can reduce expected bony protection.

CT should be reviewed before significant superior bone work.

4.15 THE INFERIOR WALL

Inferior canal drilling should be performed with awareness of the jugular bulb and individual temporal-bone variation.

A high jugular bulb or other variation may alter the expected safety margin in deeper surgery.

> **PRINCIPLE**
>
> **The patient's CT outranks the average anatomy in your memory.**

4.16 MEDIAL CANAL WORK

As the surgeon approaches:

- annulus
- tympanic membrane
- middle ear

the tissue becomes less tolerant of rough manipulation.

The objective shifts from broad enlargement to precise preservation.

LATERAL CANAL
Exposure.

MEDIAL CANAL
Precision.

4.17 EXOSTOSES

External auditory canal exostoses are usually multiple, bilateral, broad-based bony prominences in the medial bony canal, arising from the tympanic bone.

They are associated with repeated exposure of the canal to cold water ("surfer's ear").

Histologically they consist of dense lamellar bone.

Surgery may be considered when clinically indicated because of:

- significant obstruction
- recurrent infection

- debris trapping
- conductive hearing problems
- inability to access deeper disease

The surgical objective is removal sufficient to restore a functional canal while preserving skin and avoiding deeper injury.

4.18 DO NOT CHASE EVERY MILLIMETRE OF EXOSTOSIS

If the canal is functionally adequate and further drilling places:

- skin
- tympanic membrane
- joint
- deeper structures

at disproportionate risk, complete geometric normalisation may not be necessary.

> **PRINCIPLE**
>
> **Treat the functional obstruction—not the CT image for its own sake.**

The medial posterior exostosis deserves particular respect: the facial nerve lies close behind it, and the tympanic membrane and annulus lie just medial to it.

4.19 OSTEOMA

Canal osteoma is usually a solitary, unilateral, pedunculated lesion arising more laterally, often along the tympanosquamous or tympanomastoid suture near the bony–cartilaginous junction, whereas exostoses are multiple, bilateral and broad-based; clinical and imaging assessment should define the lesion.

Histologically, an osteoma contains cancellous bone with fibrovascular channels.

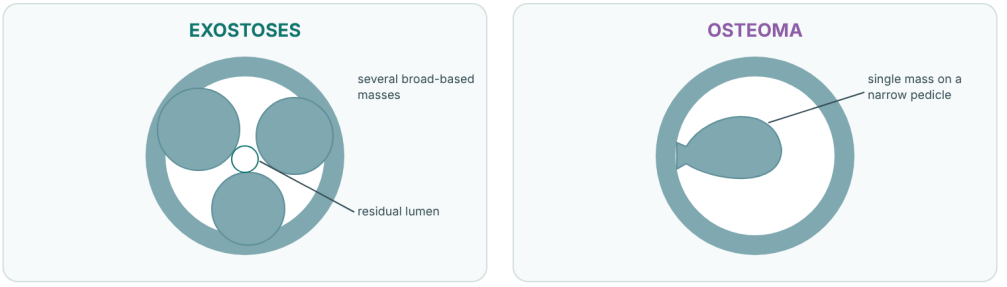
Surgical planning considers:

- site of attachment
- canal obstruction
- symptoms
- skin coverage
- relationship to tympanic membrane

A focal lesion may require a different strategy from circumferential or multiple exostoses; a pedunculated osteoma can often be removed at its narrow base.

Figure 4.4 · Exostoses and osteoma compared

Schematic cross-sections of the bony canal, looking medially — typical features, not rules



	EXOSTOSES	OSTEOMA
Number	usually multiple	usually single
Side	usually bilateral	usually unilateral
Base	broad, sessile	pedunculated
Site	medial bony canal	more lateral, near the junction
Bone	dense lamellar	cancellous, fibrovascular
Association	cold-water exposure	—

Treat the functional obstruction — not the CT image for its own sake.

4.20 MEATOPLASTY

Meatoplasty enlarges or reshapes the lateral external auditory canal opening.

It may be used:

- for lateral stenosis
- as part of canal wall down mastoid surgery (see Chapter 13, Canal Wall Down Mastoid Surgery), usually with excision of conchal cartilage
- to improve ventilation and access
- to facilitate postoperative cavity care

The objective is a meatus that is:

ADEQUATELY OPEN

but

NOT UNNECESSARILY DEFORMED.

4.21 A WIDE DEEP CANAL WITH A NARROW MEATUS IS STILL A NARROW EAR

Canal reconstruction should be considered from:

CONCHA
to

TYMPANIC MEMBRANE.
Failure to address one level may compromise the entire result.

Similarly, an excessively enlarged meatus does not compensate for untreated medial stenosis.

4.22 STENOSIS

Canal stenosis may contain:

- skin scar
- fibrous tissue
- bony narrowing
- mixed disease

Before surgery define:

Where does normal canal begin?

How long is the stenotic segment?

Is the tympanic membrane intact?

Is middle-ear disease present?

How much viable canal skin remains?

4.23 CIRCUMFERENTIAL RAW SURFACE IS THE ENEMY

If canal surgery leaves circumferential bare bone or opposing raw surfaces, contraction may lead to restenosis.

Therefore reconstruction should aim to:

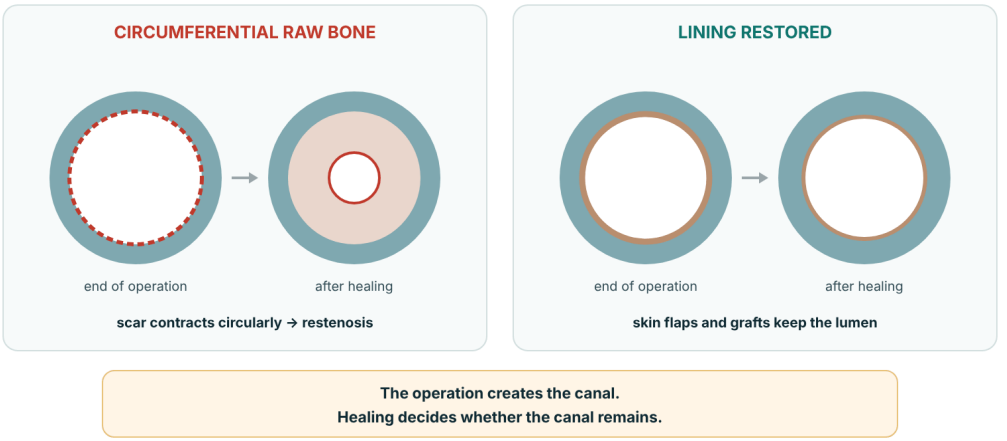
- preserve native skin
- reposition skin flaps
- provide graft coverage where necessary
- prevent opposing scar surfaces
- maintain lumen during healing

RECONSTRUCTIVE PRINCIPLE

The operation creates the canal. Healing decides whether the canal remains.

Figure 4.5 · Circumferential raw surface is the enemy

Schematic cross-sections of the canal after surgery and after healing



4.24 SKIN GRAFTING

When native skin is insufficient, selected canal defects may require grafting.

Success depends upon:

- viable recipient bed
- stable graft contact
- absence of infection
- appropriate postoperative support

The graft should be positioned to provide epithelial coverage without obstructing the lumen.

4.25 PACKING AND STENTING

Postoperative support may help:

- maintain graft contact
- protect flaps
- preserve canal diameter
- reduce haematoma or displacement

But packing can also:

- exert excessive pressure
- cause pain
- injure tissue
- obscure early complications

The material and duration should match the reconstructive objective.

4.26 POSTOPERATIVE CARE

Long-term outcome depends upon:

- epithelialisation
- infection control
- canal cleaning where required
- monitoring for granulation
- early recognition of restenosis
- management of graft or flap problems

Canal surgery does not end when the pack is placed.

Follow-up is part of the reconstruction.

4.27 GRANULATION

Granulation may reflect:

- exposed bone
- infection
- trauma

- retained debris
- poor epithelialisation

Treat the cause rather than repeatedly treating only the visible granulation tissue.

4.28 REVISION CANAL SURGERY

Revision surgery may involve:

- scar
- absent skin
- altered canal geometry
- previous drilling
- tympanic membrane changes
- chronic infection

The first objective is to understand why the original canal failed.

WAS IT:

insufficient enlargement?

poor skin coverage?

circumferential scar?

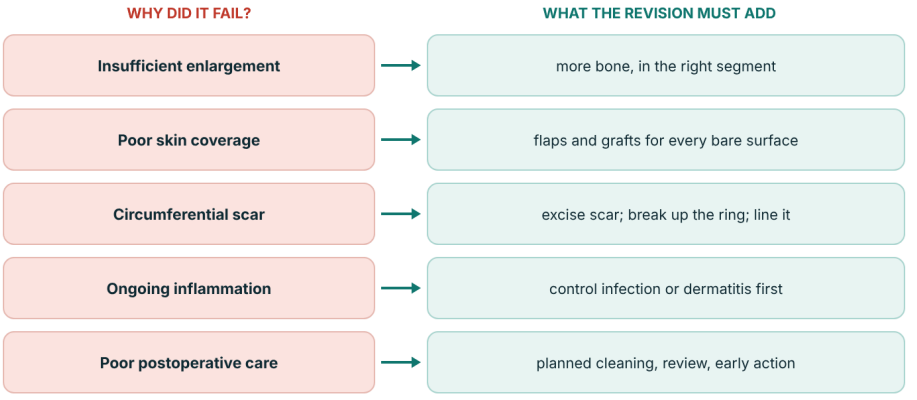
ongoing inflammation?

poor postoperative care?

Without answering this, revision risks reproducing the same failure.

Figure 4.6 · Revision canal surgery: name the failure first

Each cause of failure has a different remedy — do not simply repeat the operation



Without an answer, revision risks reproducing the same failure.

DECISION POINT

MORE BONE OR MORE SKIN?

When the canal remains narrow, determine whether the limiting structure is:

BONE

or

SOFT TISSUE / SCAR.

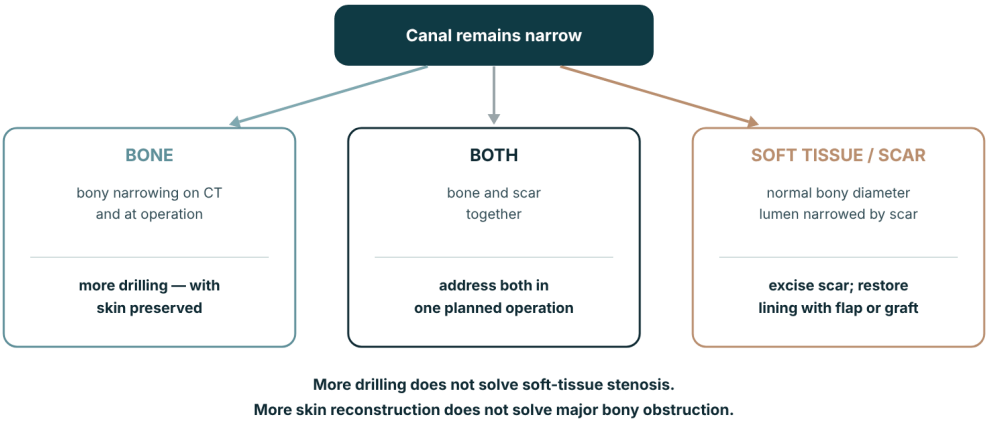
More drilling does not solve soft-tissue stenosis.

More skin reconstruction does not solve major bony obstruction.

Often both must be addressed.

Figure 4.7 · More bone or more skin?

When the canal is still narrow, find the structure that limits the lumen



More drilling does not solve soft-tissue stenosis.
More skin reconstruction does not solve major bony obstruction.

FROM EXPERIENCE

Canal surgery can tempt the surgeon to focus on the burr.

But the long-term result often depends just as much on the skin.

A beautifully drilled canal covered by damaged or insufficient epithelium can restenose.

A well-preserved skin flap over inadequate bony enlargement can remain narrow.

The operation therefore has two equal components:

CREATE THE SPACE.

PRESERVE OR RESTORE THE LINING.

TAKE IT TO THE OT

Before external auditory canal surgery, define:

LEVEL
Meatus / cartilaginous / bony / medial / combined.

CAUSE
Bone / scar / congenital / tumour / previous surgery.

CT
What lies beyond each wall?

SKIN
How much can be preserved?

BONE
What actually needs removal?

TM
Where is the tympanic membrane?

LINING
How will bare bone be covered?

MEATUS
Is lateral opening adequate?

HEALING
How will restenosis be prevented?

CHAPTER SUMMARY

External auditory canal surgery requires both bony and soft-tissue planning.

Define the level and cause of narrowing before operating.

Read CT as a map of what lies beyond each canal wall.

Preserve canal skin wherever possible.

Remove only the bone necessary to create a functional corridor.

Respect the temporomandibular joint, tympanic membrane and deeper temporal-bone relationships.

Avoid circumferential raw surfaces.

Restore epithelial coverage.

And remember:

Canalplasty creates the lumen.

Skin preservation keeps it open.

FURTHER READING & REFERENCES

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CHAPTER 05

Malignancy of the External Auditory Canal

From Canal Disease to Temporal Bone Resection

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- recognise clinical features that should raise suspicion of external auditory canal malignancy
- understand the importance of biopsy planning and histological diagnosis
- evaluate local disease extent using clinical examination and imaging
- understand the anatomical pathways through which EAC malignancy can spread
- distinguish conceptually between limited canal resection and temporal bone resection
- assess involvement of parotid, facial nerve, temporomandibular joint, dura and skull base
- understand the principles of nodal evaluation
- plan resection and reconstruction together
- recognise when disease extent requires multidisciplinary skull base management

5.1 THE DANGER OF A FAMILIAR PRESENTATION

External auditory canal malignancy is uncommon.

Its symptoms may initially resemble more common ear disease.

Patients may present with:

- otalgia

- otorrhoea
- bleeding
- hearing loss
- canal granulation
- visible mass
- facial weakness
- persistent "infection"

The important clinical question is:

> **When does an ear that looks infected stop behaving like an infection?**

Persistent, recurrent, atypical or destructive canal disease deserves reconsideration.

5.2 DO NOT TREAT GRANULATION AS A DIAGNOSIS

Granulation tissue is an appearance.

It is not a diagnosis.

Possible causes include:

- infection
- chronic inflammation
- trauma
- postoperative change
- cholesteatoma
- malignancy

Suspicious features may include:

- persistent pain, particularly pain out of proportion to the findings
- bleeding
- progressive mass
- bone destruction
- cranial nerve deficit
- failure to respond to appropriate treatment

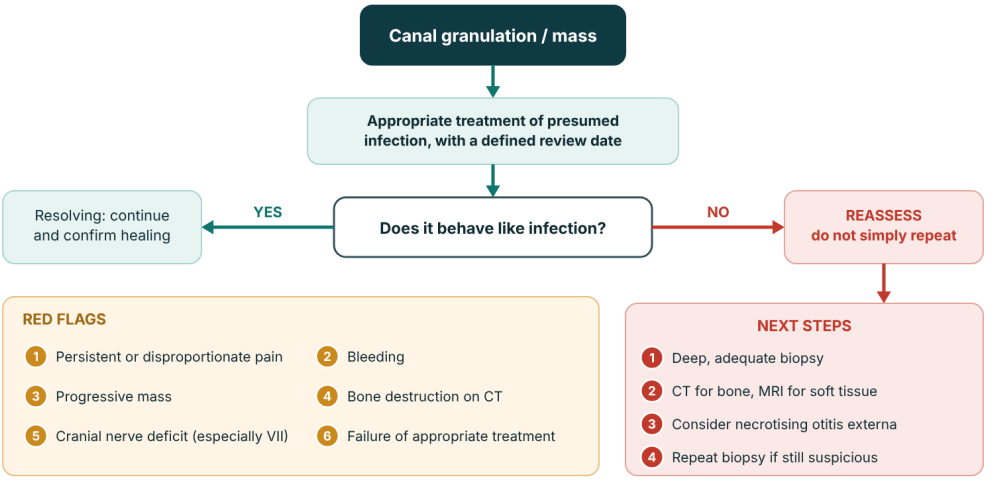
In an elderly, diabetic or immunocompromised patient, necrotising otitis externa must also be considered; it can mimic malignancy and the two can coexist.

When the behaviour of the disease does not fit the presumed diagnosis:

REASSESS.

Figure 5.1 · When granulation stops behaving like infection

Granulation is an appearance, not a diagnosis



5.3 BIOPSY

Histological diagnosis should be established before definitive oncological treatment whenever feasible.

Biopsy planning should consider:

- adequate tissue
- avoidance of unnecessary fragmentation
- haemostasis
- anatomical location
- relationship to deeper structures

A superficial sample of necrotic or inflamed tissue may not answer the clinical question.

A negative biopsy from a lesion that still behaves suspiciously should be repeated, deeper, before it is accepted.

PRINCIPLE

Biopsy the disease — not merely the reaction around it.

5.4 HISTOLOGY MATTERS

Squamous cell carcinoma is the commonest malignant tumour of the external auditory canal, but other histologies occur, including basal cell carcinoma, ceruminous gland adenocarcinoma, adenoid cystic carcinoma and melanoma.

Tumour type influences:

- biological behaviour
- spread
- treatment
- prognosis
- role of surgery and adjuvant treatment

Therefore the operative plan should not be finalised from imaging alone.

Anatomy tells us where the tumour is.

Histology helps tell us how it behaves.

5.5 THE CANAL IS SURROUNDED BY IMPORTANT ANATOMY

The EAC lies within a compact region bordered by structures that can rapidly convert a localised canal tumour into a skull base problem.

Potential directions of spread include:

MEDIAL

Toward the tympanic membrane, middle ear and beyond.

ANTERIOR

Toward the temporomandibular joint and adjacent soft tissue.

INFERIOR

Toward the parotid and the infratemporal / upper-neck region.

The fissures of Santorini in the cartilaginous canal and a persistent foramen of Huschke in the anteroinferior bony canal are natural pathways toward the parotid and

glenoid fossa.

POSTERIOR

Toward the mastoid and posterior temporal bone.

SUPERIOR

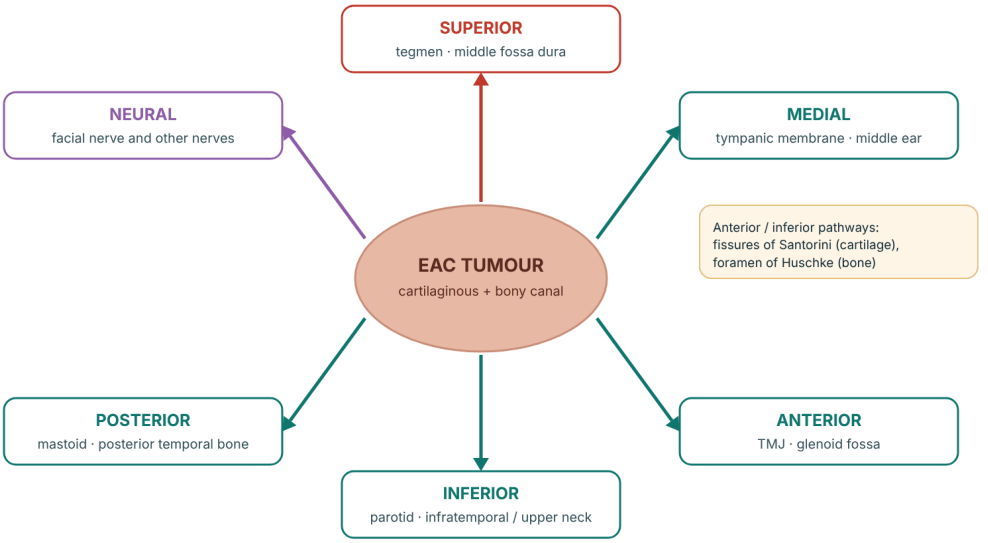
Toward the tegmen and intracranial boundaries.

NEURAL

Along facial or other neural pathways, depending upon the disease.

Figure 5.2 · Six directions of spread from the external auditory canal

Conceptual map, not to scale — each arrow crosses a boundary that changes the operation



5.6 EXAMINE MORE THAN THE CANAL

Clinical examination should include:

- pinna
- EAC
- tympanic membrane where visible
- parotid region
- temporomandibular joint symptoms, including trismus
- facial nerve function
- other relevant cranial nerves

- neck nodes

The visible canal lesion may represent only the accessible portion of the disease.

5.7 FACIAL NERVE FUNCTION

Document facial function before treatment.

Facial weakness may indicate:

- advanced local disease
- neural involvement
- inflammatory effects
- previous treatment-related injury

Its presence changes:

- staging considerations
- operative planning
- counselling
- reconstructive planning

A normal facial nerve does not exclude proximity or microscopic involvement.

5.8 IMAGING

Imaging should define:

Bone

CT is particularly valuable for assessing:

- canal erosion
- middle-ear extension
- mastoid involvement
- temporomandibular relationship
- temporal bone destruction
- skull base anatomy

Soft Tissue

MRI is particularly useful for:

- soft-tissue extent
- parotid relationship
- dural / intracranial relationship
- neural involvement
- marrow and deeper skull base assessment

CT and MRI are complementary; inflammatory soft tissue and tumour can look alike on CT alone.

Appropriate systemic staging should be performed according to tumour type and stage.

5.9 READ THE SCAN AS A RESECTION MAP

Do not ask only:

How large is the tumour?

Ask:

Where is the medial limit?

Is the middle ear involved?

Is the mastoid involved?

Is the facial nerve involved?

Is the TMJ involved?

Is the parotid involved?

Is the dura involved?

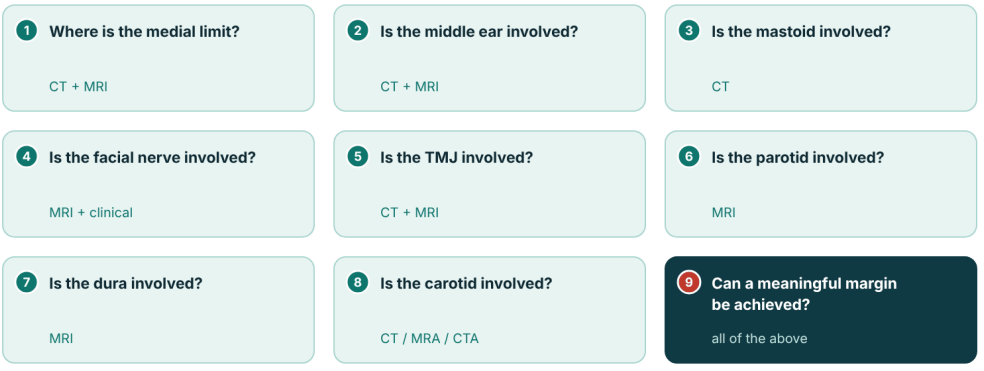
Is the carotid involved?

Can a meaningful margin be achieved?

The operation follows these relationships.

Figure 5.3 · Read the scan as a resection map

Not "how large?" but "which boundaries?" — the questions that decide the operation



Each "yes" moves the medial boundary of resection — and the reconstruction — one step further.

CT shows bone; MRI separates tumour from inflammation and shows dura, parotid and nerve.

5.10 STAGING

Several staging approaches have been used for EAC and temporal bone malignancy. The University of Pittsburgh system, in its modified form (in which facial nerve paralysis places a tumour in T4), is the most widely used for squamous cell carcinoma.

The purpose of staging is not simply classification.

It helps communicate:

- local extent
- prognosis
- treatment strategy

Because staging definitions and evidence evolve, the reader should consult current disease-specific guidelines and literature when applying a staging system clinically.

Figure 5.4 · Modified Pittsburgh staging for squamous cell carcinoma of the EAC

Arriaga et al. 1990, modified by Moody et al. 2000 — summary; consult the source and current guidance

T1	Limited to the EAC; no bone erosion and no soft-tissue extension
T2	Limited (not full-thickness) bony EAC erosion, or soft-tissue involvement < 0.5 cm
T3	Full-thickness bony EAC erosion with soft-tissue involvement < 0.5 cm, or tumour in the middle ear and/or mastoid
T4	Erosion of cochlea, petrous apex, medial middle-ear wall, carotid canal, jugular foramen or dura; soft-tissue extension > 0.5 cm (e.g. TMJ, styloid); or facial paralysis

NODES AND STAGE GROUPING

Stage I	Stage II	Stage III	Stage IV
T1 N0	T2 N0	T3 N0 or T1 N1	T4 N0 · T2–T4 N1 · any M1

Nodal involvement (N1) is a poor prognostic sign and upstages the tumour.

Facial nerve paralysis places the tumour in T4 (Moody modification).

5.11 THE SURGICAL SPECTRUM

Depending upon tumour extent and histology, surgical treatment may range conceptually from:

LIMITED CANAL / SLEEVE-TYPE RESECTION

↓

LATERAL TEMPORAL BONE RESECTION

↓

SUBTOTAL TEMPORAL BONE RESECTION

↓

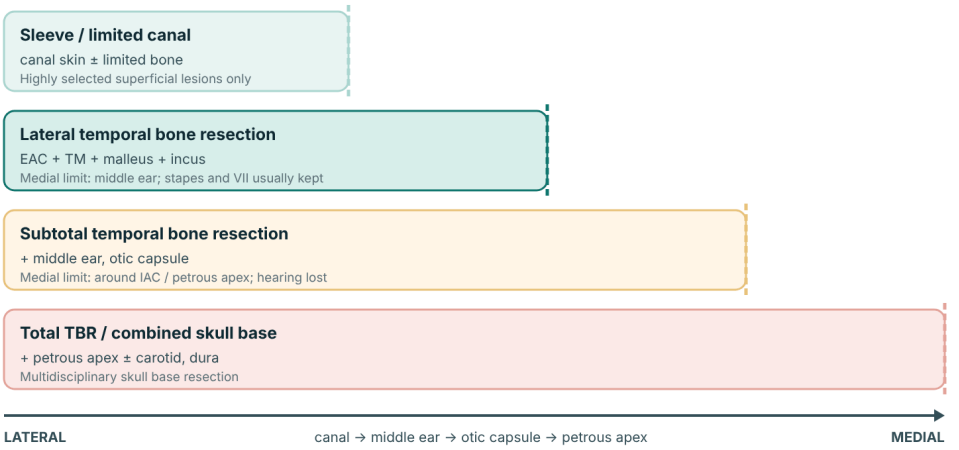
TOTAL TEMPORAL BONE / COMBINED SKULL BASE RESECTION

These are not simply progressively "bigger operations".

Each represents a different anatomical boundary of resection.

Figure 5.5 · The surgical spectrum: each operation is a different boundary

Conceptual — the medial limit of the specimen defines the operation, not its size



Parotidectomy, condylectomy and neck dissection are added according to extent — not by name.

5.12 LIMITED CANAL RESECTION

Highly selected superficial lesions confined to an appropriate region of the external canal may be amenable to limited resection.

The central requirement is:

> **ONCOLOGICALLY ADEQUATE MARGINS.**

A smaller operation is appropriate only when disease biology and extent allow it.

Do not select limited surgery merely to avoid temporal bone resection.

For squamous cell carcinoma involving the bony canal, lateral temporal bone resection is generally regarded as the minimum oncological operation.

5.13 LATERAL TEMPORAL BONE RESECTION

Conceptually, lateral temporal bone resection removes the external auditory canal with the tympanic membrane, malleus and incus as one oncological specimen. The medial limit is the middle ear; the stapes and the facial nerve are normally preserved unless disease requires otherwise.

The operation requires understanding of:

- mastoid
- middle ear
- facial nerve
- temporomandibular joint
- parotid relationship
- skull base
- vascular structures

Detailed operative technique is described in Chapter 30, Temporal Bone Resection for Malignancy.

Here the important principle is:

> **THE RESECTION IS DESIGNED AROUND DISEASE EXTENT, NOT A PROCEDURE NAME.**

5.14 EN BLOC THINKING

Where anatomically and oncologically appropriate, resection should aim to avoid unnecessary violation of the tumour.

This requires planning the operation from the boundaries inward.

DEFINE THE MARGINS

↓

OBTAIN EXPOSURE

↓

CONTROL CRITICAL STRUCTURES

↓

> **COMPLETE BONE CUTS / DISSECTION**

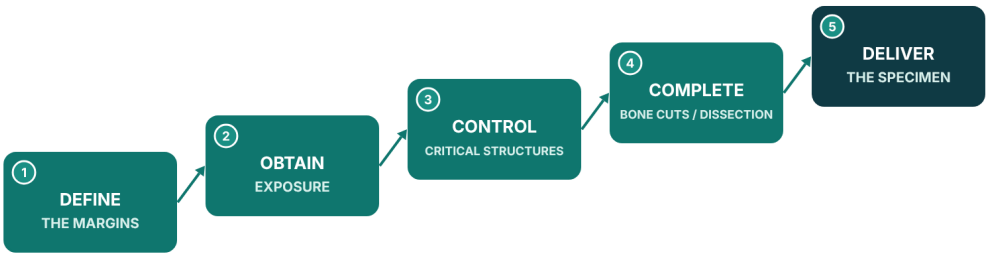
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DELIVER THE SPECIMEN

The tumour should not dictate the dissection plane simply because it is visible.

Figure 5.6 · Plan from the boundaries inward

En bloc thinking — the tumour should not choose the plane just because it is visible



Piecemeal removal may be unavoidable deep in the temporal bone — then margin mapping and specimen orientation matter even more.

5.15 THE TEMPOROMANDIBULAR JOINT

Anterior canal-wall disease may approach or involve the TMJ.

Assess:

- bony erosion
- soft-tissue extension
- joint involvement
- mandibular condyle relationship

The surgical plan may require extension beyond the temporal bone in selected cases, including condylectomy.

This should be anticipated before surgery.

5.16 PAROTID RELATIONSHIP

The external canal has important relationships with the parotid region.

Depending upon disease extent and biological risk, parotid management may become part of the oncological plan.

Questions include:

Is the parotid directly involved?

Has disease spread through the pathways between canal and parotid — the fissures of Santorini or a foramen of Huschke?

Is parotid surgery required for margin or nodal considerations?

The parotid is both a direct-extension site and a first-echelon nodal basin for the canal.

The answer should be individualised according to stage, histology and contemporary evidence.

5.17 FACIAL NERVE

The facial nerve may be:

- uninvolved
- adjacent
- displaced
- encased
- invaded

The decision to preserve or sacrifice depends upon:

- preoperative function
- imaging
- intraoperative involvement
- ability to achieve adequate clearance
- reconstructive options

ONCOLOGICAL PRINCIPLE

Do not sacrifice an uninvolved functioning nerve merely because the operation is large.

And:

Do not preserve an invaded nerve at the cost of inadequate oncological treatment when sacrifice is required for meaningful clearance.

5.18 IF THE FACIAL NERVE MUST BE SACRIFICED

Plan before division.

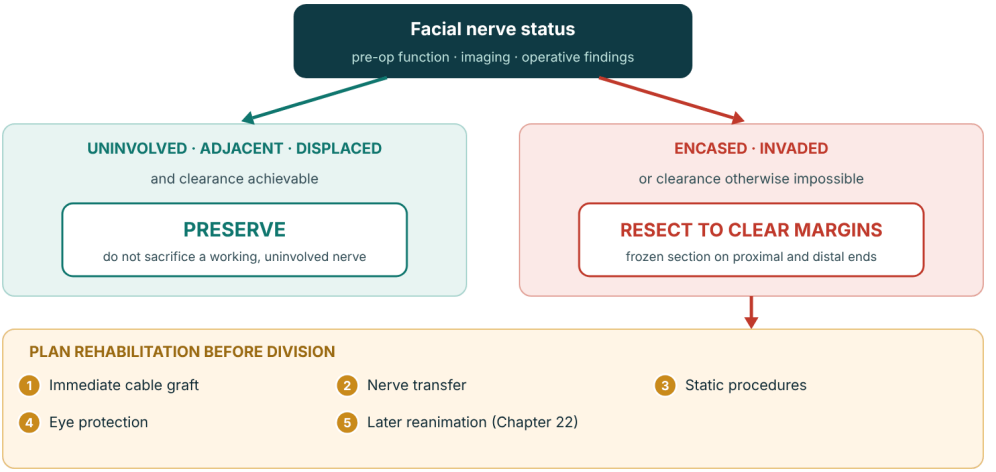
Consider:

- proximal and distal nerve availability
- frozen-section assessment of the nerve margins
- immediate grafting
- nerve transfer
- static procedures
- eye protection
- later facial rehabilitation

The oncological operation and facial rehabilitation should be planned together whenever sacrifice is anticipated (see Chapter 22, Facial Reanimation & Functional Rehabilitation).

Figure 5.7 · Facial nerve: preserve or sacrifice

Decide on involvement and clearance — not on the size of the operation



5.19 MIDDLE-EAR EXTENSION

Once disease extends medially beyond the canal, the resection strategy changes.

Assess:

- tympanic membrane
- ossicles
- middle-ear mucosa
- hypotympanum
- epitympanum

- mastoid
- facial nerve
- deeper temporal bone relationships

A lesion that appears small externally may have substantially greater medial disease.

5.20 DURA & INTRACRANIAL RELATIONSHIP

Superior or advanced disease may approach:

- tegmen
- dura
- intracranial contents

Define:

BONE INVOLVEMENT?

DURAL CONTACT?

DURAL INVASION?

INTRADURAL EXTENSION?

These are different anatomical situations.

When dura or intracranial structures are involved, multidisciplinary skull base planning may be required.

5.21 MAJOR VESSELS

Advanced temporal bone disease may approach:

- internal carotid artery
- jugular bulb
- sigmoid sinus
- other major vascular structures

If significant vascular involvement is suspected, planning may require:

- dedicated vascular imaging
- assessment of resectability
- proximal/distal control strategy

- vascular, neurosurgical and interventional support

A tumour is not surgically resectable simply because the surgeon can reach it.

5.22 NECK NODES

Regional nodal assessment should form part of staging.

The role and extent of elective or therapeutic neck treatment depend upon:

- histology
- tumour stage
- nodal status
- parotid involvement
- contemporary evidence

This should be decided within multidisciplinary oncological planning.

5.23 RESECTION AND RECONSTRUCTION

Temporal bone oncological resection may leave defects involving:

- skin
- EAC
- temporal bone
- parotid region
- TMJ region
- dura
- skull base
- facial soft tissue

Reconstruction may need to:

COVER

FILL DEAD SPACE

SEPARATE COMPARTMENTS

PROTECT MAJOR VESSELS / DURA

RESTORE CONTOUR

Possible options range from local and regional tissue to free tissue transfer, depending upon defect magnitude (see Chapter 31, Skull Base Reconstruction after Temporal Bone Resection).

5.24 OBLITERATION VERSUS CAVITY

After major temporal bone resection, the reconstructive objective may differ fundamentally from chronic-ear surgery.

The priority may become:

- durable soft-tissue coverage
- separation from intracranial structures
- elimination of dead space
- protection of vessels
- wound healing

Hearing preservation may no longer be the dominant objective in an oncologically ablative procedure.

Postoperative radiotherapy is common after resection of advanced disease; the reconstruction must be robust enough to tolerate it.

5.25 PREVIOUS RADIOTHERAPY

Salvage surgery after radiotherapy may involve:

- fibrosis
- impaired vascularity
- difficult planes
- wound-healing risk
- exposed or vulnerable vessels
- reconstructive challenges

Vascularised tissue may become particularly important.

The operation should be planned as salvage surgery — not simply primary surgery performed later.

5.26 MARGIN ASSESSMENT

Potential critical margins may include:

- canal soft tissue
- middle ear
- parotid / anterior soft tissue
- mastoid
- bone
- neural margin
- dura
- deep skull base margin

Specimen orientation is essential.

The pathologist should understand the three-dimensional geometry of the resection.

The general principles of margins are discussed in Book 1, Chapter 15, Surgical Margins & Oncological Principles.

DECISION POINT

HOW MUCH TEMPORAL BONE SHOULD BE REMOVED?

Do not begin with:

Sleeve? Lateral? Subtotal?

Begin with:

WHERE IS THE DISEASE?

↓

WHAT MARGIN IS REQUIRED?

↓

WHICH ANATOMICAL BOUNDARIES MUST BE CROSSED TO ACHIEVE IT?

↓

WHAT FUNCTION WILL BE LOST?

↓

CAN THE DEFECT BE RECONSTRUCTED?

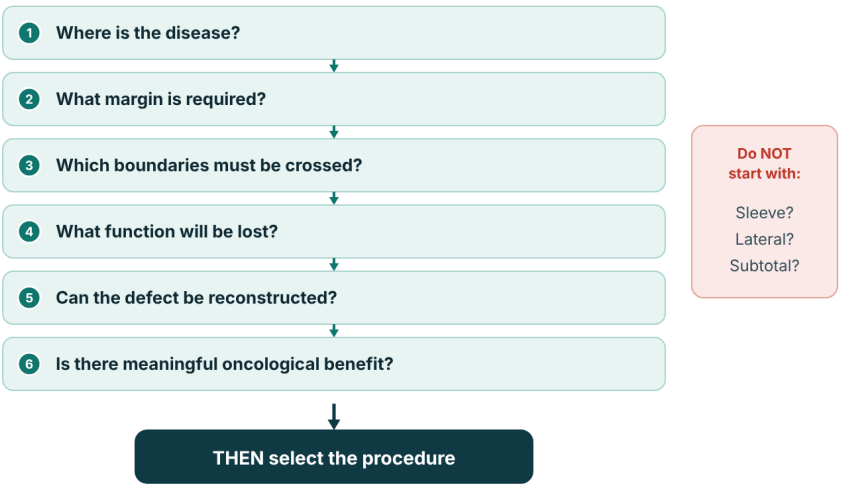
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DOES THIS OPERATION OFFER MEANINGFUL ONCOLOGICAL BENEFIT?

Then select the procedure.

Figure 5.8 · How much temporal bone should be removed?

Start from the disease and the margin; the procedure name comes last



FROM EXPERIENCE

External auditory canal malignancy demonstrates how misleading surgical labels can become.

The lesion may begin in a space only a few millimetres wide.

But immediately beyond that canal lie:

the parotid,

the facial nerve,

the middle ear,

the mastoid,

the temporomandibular joint,

the dura,

and major vascular structures.

The operation therefore changes rapidly as the disease crosses anatomical boundaries.

The important question is not:

How advanced is the operation?

It is:

> **Which boundary has the disease crossed?**

TAKE IT TO THE OT

Before EAC malignancy surgery, define:

HISTOLOGY

LOCAL EXTENT

BONE INVOLVEMENT

MIDDLE-EAR INVOLVEMENT

FACIAL NERVE FUNCTION & RELATIONSHIP

PAROTID RELATIONSHIP

TMJ RELATIONSHIP

DURA / INTRACRANIAL RELATIONSHIP

MAJOR VESSELS

NECK NODES

PLANNED MARGINS

RECONSTRUCTION

MULTIDISCIPLINARY SUPPORT

CHAPTER SUMMARY

Persistent or atypical canal disease should not be assumed to be infection.

Obtain appropriate histological diagnosis.

Use CT and MRI to define the anatomical boundaries crossed by disease.

Plan surgery from the required margin rather than from a preferred procedure name.

Assess the facial nerve, parotid, TMJ, middle ear, dura and major vessels deliberately.

Orient the specimen.

Plan reconstruction before resection.

And remember:

> **External auditory canal cancer begins in a small space.**

> **Its surgery is determined by the boundaries it crosses.**

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CHAPTER 06

Surgical Anatomy of the Temporal Bone

From Surface Landmarks to the Petrous Apex

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- orient the temporal bone as a three-dimensional surgical structure
- identify major surface landmarks used for otological access
- understand the relationships of the mastoid, middle ear and petrous temporal bone
- identify the facial nerve throughout its intratemporal course
- understand the surgical relationships of the labyrinth, cochlea and internal auditory canal
- identify the sigmoid sinus, jugular bulb and internal carotid artery on imaging and during surgery
- understand the relationship of tegmen, dura and middle cranial fossa
- use multiple landmarks rather than a single structure for operative orientation
- correlate axial and coronal CT with the microscopic and endoscopic operative field

6.1 THE TEMPORAL BONE IS A THREE-DIMENSIONAL CROSSROAD

Within a remarkably small volume lie structures responsible for:

HEARING

BALANCE

FACIAL MOVEMENT

MAJOR VASCULAR FLOW

CRANIAL NERVE FUNCTION

SEPARATION OF EAR FROM BRAIN

The temporal bone contains:

- external auditory canal
- middle ear
- ossicular chain
- mastoid
- facial nerve
- cochlea
- vestibular labyrinth
- internal auditory canal
- carotid artery
- jugular bulb
- sigmoid sinus
- dura

Temporal bone surgery therefore depends upon understanding **relationships**, not memorising isolated structures.

6.2 THINK FROM OUTSIDE TO INSIDE

A useful surgical journey is:

SKIN

↓

MASTOID CORTEX / EXTERNAL AUDITORY CANAL

↓

AIR-CELL SYSTEM

↓

ANTRUM

↓

MIDDLE EAR

↓

FACIAL NERVE

↓

LABYRINTH

↓

INTERNAL AUDITORY CANAL

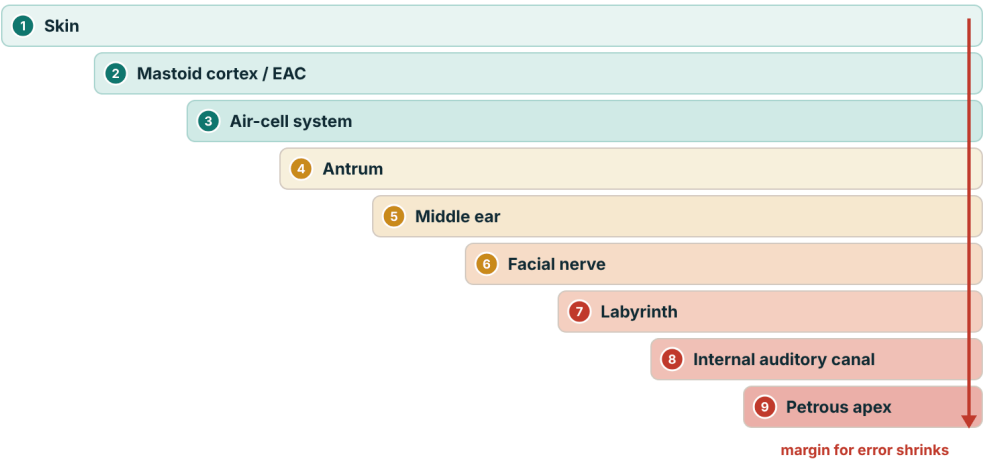
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PETROUS APEX

At every stage, deeper anatomy becomes progressively less forgiving.

Figure 6.1 · From outside to inside

Each step deeper is less forgiving — establish one level before entering the next



Order shown for a transmastoid route; the middle-ear and middle-fossa routes reach the same structures from other directions.

6.3 THE TEMPORAL BONE ON CT

Before temporal bone surgery, review thin-section CT in multiple planes.

Axial

Useful for following:

- mastoid
- middle ear
- labyrinth
- internal auditory canal
- petrous carotid relationships

Coronal

Useful for:

- tegmen
- facial nerve relationships
- jugular bulb
- labyrinth
- middle-ear vertical anatomy

Sagittal / Reformatted Views

May assist in understanding selected trajectories and structures, such as the mastoid segment of the facial nerve along its length.

> **PRINCIPLE**
>
> **Do not learn temporal bone CT as a radiology exercise.**

Read it as the operation you are about to perform.

CT reading for the surgeon is developed in Chapter 7, Temporal Bone Imaging for the Surgeon.

6.4 SURFACE LANDMARKS

Important external landmarks include:

- external auditory canal
- suprameatal (Macewen's) triangle and spine of Henle
- mastoid tip
- temporal line
- zygomatic root
- postauricular sulcus

The suprameatal triangle overlies the mastoid antrum, which lies roughly 12–15 mm deep to it in the adult.

These help orient the initial exposure.

But surface landmarks predict deeper anatomy only approximately.

Individual CT remains essential.

6.5 MASTOID CORTEX

The mastoid cortex forms the lateral bony entry into the mastoid air-cell system.

Its appearance varies according to:

- pneumatisation
- sclerosis
- previous surgery
- age
- disease

A well-pneumatised mastoid and a densely sclerotic mastoid are not the same drilling experience.

The landmarks remain conceptually similar.

The route by which they appear may differ substantially.

6.6 MASTOID AIR-CELL SYSTEM

The mastoid contains a variable network of air cells.

Rather than memorising every cell group independently, the surgeon should understand how air cells relate to:

- antrum
- tegmen
- sigmoid sinus
- posterior canal wall
- mastoid tip
- facial nerve
- labyrinth

Air cells are useful.

But fixed structures are more reliable landmarks.

6.7 MASTOID ANTRUM

The mastoid antrum is an important surgical space, connected to the epitympanum through the aditus ad antrum.

Its identification helps orient the surgeon toward:

- lateral semicircular canal
- short process and body of the incus
- epitympanum
- posterior canal wall

SURGICAL PRINCIPLE

The antrum is not merely a cavity.

It is a gateway to a network of deeper landmarks.

6.8 LATERAL SEMICIRCULAR CANAL

The lateral semicircular canal is one of the most important fixed landmarks in mastoid surgery.

It forms a smooth, dense, yellowish-white prominence in the floor and medial wall of the antrum.

Once identified, it helps orient:

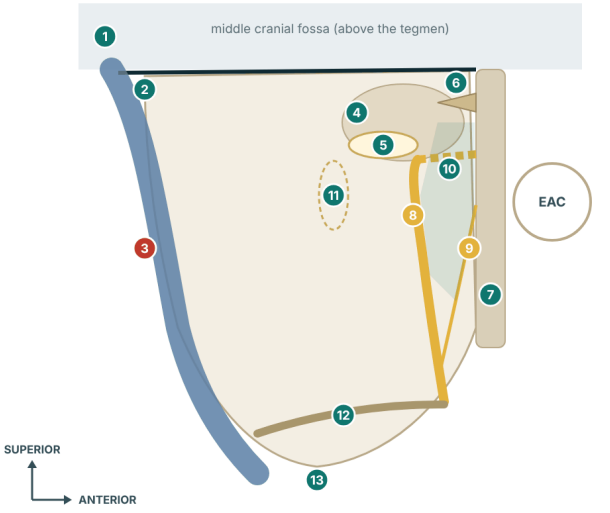
- facial nerve
- antrum
- labyrinth
- facial recess region

Its bony prominence should be respected.

Do not skeletonise more than the operation requires.

Figure 6.2 · The mastoid after cortical mastoidectomy: key landmarks

Schematic, not to scale · Right ear, lateral (surgical) view · superior up, anterior to the right



1. Tegmen / middle fossa dura
2. Sinodural angle
3. Sigmoid sinus
4. Antrum
5. Lateral semicircular canal
6. Short process of incus
7. Posterior canal wall
8. Facial nerve (2nd genu → mastoid)
9. Chorda tympani
10. Facial recess
11. Posterior SCC (deep)
12. Digastric ridge
13. Mastoid tip

The second genu lies just inferior to the lateral canal; the mastoid segment runs medial to the posterior canal wall to the anterior end of the digastric ridge (stylomastoid foramen).

Yellow = facial nerve and chorda (dashed: tympanic segment, deep to the incus) · blue = sigmoid sinus

6.9 THE INCUS AS A LANDMARK

The short process and body of the incus provide important orientation within the epitympanic / antral region.

The short process rests in the fossa incudis and points posteriorly toward the facial recess.

Their relationship helps predict:

- facial recess
- facial nerve, which runs medial and inferior to the short process
- middle-ear anatomy

The ossicular chain should not be manipulated unnecessarily simply because it is visible.

A landmark can be useful without being touched.

6.10 TEGMEN

The tegmen forms an important superior bony boundary separating temporal bone spaces from middle cranial fossa dura.

Its height varies.

A low tegmen may reduce working space.

Disease may:

- erode it
- expose dura
- create intracranial communication

Preoperative CT should define the expected superior boundary.

> **PRINCIPLE**
>
> **Know the roof before drilling toward it.**

6.11 MIDDLE CRANIAL FOSSA DURA

Once tegmen bone becomes thin or deficient, dura may be exposed.

At this point:

- mechanical protection is reduced
- drilling strategy changes
- thermal and traction considerations increase

Dural exposure is not automatically a complication.

Unplanned dural injury is.

The distinction depends upon the procedure and objective.

6.12 SIGMOID SINUS

The sigmoid sinus forms an important posterior mastoid boundary.

Its position varies considerably.

It may be:

- relatively posterior
- anteriorly placed
- superficially located
- associated with limited mastoid working space

CT should be reviewed for its relationship to:

- posterior canal wall
- labyrinth
- mastoid cortex
- jugular bulb

SURGICAL PRINCIPLE

Do not assume the sigmoid sinus is where the last patient's sigmoid sinus was.

6.13 SINODURAL ANGLE

The sinodural (Citelli's) angle is the region where the sigmoid sinus meets the middle fossa dural plate. It provides useful orientation in mastoid surgery.

Understanding this relationship helps define the:

- posterior
- superior

limits of the operative field.

Landmarks become more reliable when understood as intersections rather than isolated points.

6.14 JUGULAR BULB

The jugular bulb lies inferior to the middle ear and medial to the inferior mastoid, where the sigmoid sinus turns down into the internal jugular vein.

Its height is variable.

A high jugular bulb may approach:

- hypotympanum
- round-window region

- middle ear
- internal auditory canal relationships in deeper skull base anatomy

It may also be dehiscent.

Review CT before surgery involving these regions.

6.15 THE FACIAL NERVE

The intratemporal facial nerve is central to temporal bone surgery.

Its course can be considered in segments:

MEATAL (WITHIN THE IAC)

↓

LABYRINTHINE

↓

GENICULATE GANGLION (FIRST GENU)

↓

TYMPANIC / HORIZONTAL

↓

SECOND GENU

↓

MASTOID / VERTICAL

↓

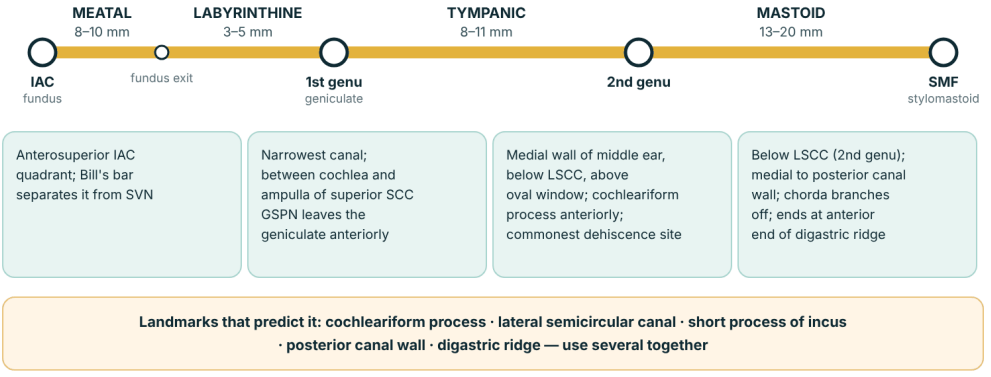
STYLOMASTOID FORAMEN

Approximate lengths: meatal 8–10 mm, labyrinthine 3–5 mm, tympanic 8–11 mm, mastoid 13–20 mm. Individual variation is considerable.

Each segment has different surgical relationships.

Figure 6.3 · The intratemporal facial nerve and its landmarks

Conceptual course map, not to scale — approximate segment lengths vary between individuals



6.16 LABYRINTHINE SEGMENT

The labyrinthine segment extends from the fundus of the internal auditory canal to the geniculate ganglion.

It is:

- short
- the narrowest part of the fallopian canal
- anatomically constrained
- closely related to the cochlea and the ampullae of the superior and lateral canals

Detailed exposure belongs to advanced facial nerve and skull base surgery (see Chapter 21, Facial Nerve Surgery in the Temporal Bone, and Chapter 27, Middle Cranial Fossa Approach).

Its importance here is to understand the continuity of the nerve from IAC to extracranial course.

6.17 GENICULATE GANGLION

The geniculate region represents the first major bend in the facial nerve.

It has important relationships to:

- middle cranial fossa

- greater superficial petrosal nerve
- labyrinthine and tympanic facial nerve segments

Exposure may be approached through different skull base corridors depending upon the pathology.

6.18 TYMPANIC SEGMENT

The tympanic facial nerve runs posteriorly along the medial wall of the middle ear, below the lateral semicircular canal and above the oval window / stapes.

The cochleariform process, from which the tensor tympani tendon turns laterally, lies just below the anterior part of the tympanic segment and is a useful landmark for it.

Potential anatomical variations include:

- dehiscence, most often above the oval window
- prolapse over the stapes
- altered course

This has direct relevance during:

- middle-ear surgery
- cholesteatoma surgery
- stapes surgery

PRINCIPLE

Bone over a nerve is protective — but bone may not always be present.

6.19 SECOND GENU

The second genu marks the transition from tympanic to mastoid facial nerve.

It lies just inferior to the lateral semicircular canal, curving posteriorly and then downward.

Its relationship to the lateral semicircular canal is surgically important.

Once the lateral canal is identified, the surgeon can begin predicting the nerve rather than searching blindly for it.

6.20 MASTOID SEGMENT

The mastoid facial nerve descends toward the stylomastoid foramen, medial to the posterior canal wall.

Useful relationships include:

- lateral semicircular canal
- digastric ridge
- posterior canal wall
- facial recess
- stylomastoid region

LANDMARK NETWORK

Lateral semicircular canal

+

Incus

+

Digastric ridge

+

Posterior canal wall

↓

FACIAL NERVE PREDICTION

Do not depend on one landmark alone.

6.21 DIGASTRIC RIDGE

The digastric ridge provides an important inferior landmark in mastoid and facial nerve surgery.

Its anterior end leads to the stylomastoid foramen and the lower mastoid facial nerve.

Again, its value lies in relationship.

The ridge is useful because it predicts something deeper.

6.22 CHORDA TYMPANI

The chorda tympani usually branches from the mastoid segment of the facial nerve, a few millimetres above the stylomastoid foramen. It runs upward and forward, enters the middle ear, crosses medial to the tympanic membrane between the long process of the incus and the handle of the malleus, and leaves through the petrotympanic fissure.

It is relevant during:

- tympanoplasty
- facial recess approach
- cholesteatoma surgery
- stapes surgery

Preservation should be attempted where appropriate, while recognising that disease or access requirements may occasionally necessitate sacrifice.

Functional consequences — altered taste on the anterior two-thirds of the tongue and, less often, a dry mouth — should be understood and discussed.

6.23 FACIAL RECESS

The facial recess provides a posterior surgical corridor toward the middle ear.

Its boundaries are:

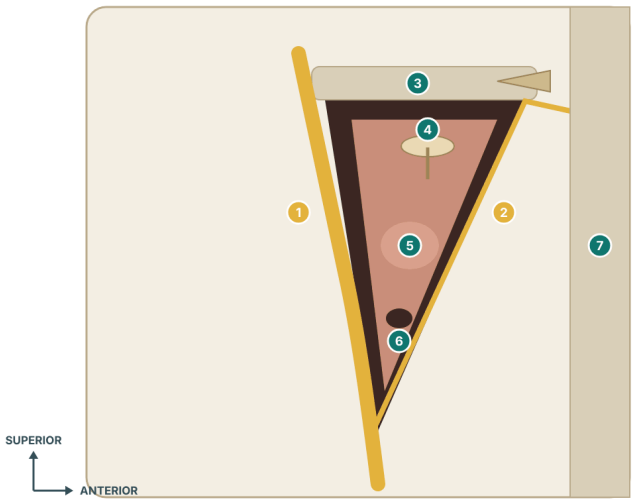
- medially / posteriorly — the mastoid segment of the facial nerve
- laterally / anteriorly — the chorda tympani
- superiorly — the fossa incudis and incus buttress

The practical width varies.

A narrow facial recess increases technical difficulty.

Figure 6.4 · Facial recess boundaries in posterior tympanotomy

Schematic, enlarged · Right ear, lateral (surgical) view · superior up, anterior to the right



1. **Facial nerve**
2. **Chorda tympani**
3. **Fossa incudis / incus buttress**
4. Stapes and incudostapedial joint
5. Promontory (basal turn)
6. Round window niche
7. Posterior canal wall (kept intact)

The three boundaries:

· facial nerve behind / medial
· chorda tympani in front / lateral
· incus buttress above

The recess widens superiorly and narrows to the chorda origin below. Taking the chorda (extended recess) widens the inferior part — a trade-off.

6.24 COCHLEA

The cochlea lies within the petrous temporal bone, anterior to the vestibule, and forms the auditory component of the inner ear.

Surgically important relationships include:

- promontory (formed by the basal turn)
- round window
- oval window region
- facial nerve
- internal auditory canal
- carotid canal

These relationships become particularly important in:

- cochlear implantation
- stapes surgery
- petrous bone surgery

6.25 ROUND WINDOW

The round-window region is a key landmark for cochlear implantation.

The membrane lies deep in its niche, often partly hidden by the overhanging lip.

Its visualisation may be affected by:

- niche anatomy
- facial recess width
- overhang
- orientation of the basal turn
- congenital anomaly

The objective is not simply to "find a hole".

It is to understand the orientation of the basal turn of the cochlea.

6.26 VESTIBULE

The vestibule lies medial to the oval window, between the cochlea anteriorly and the semicircular canals posteriorly.

It has important relationships to:

- oval window
- stapes
- facial nerve
- labyrinth

Violation of inner-ear structures can have major auditory and vestibular consequences.

6.27 SEMICIRCULAR CANALS

The three semicircular canals are:

- lateral
- superior
- posterior

Their relationships help orient deeper temporal bone surgery.

The lateral canal is usually the most immediately useful mastoid landmark.

The superior and posterior canals become increasingly important in deeper labyrinthine and skull base approaches.

6.28 INTERNAL AUDITORY CANAL

The IAC carries:

- facial nerve, with the nervus intermedius
- cochlear nerve
- superior and inferior vestibular nerves
- labyrinthine artery and veins

At the fundus, the transverse (falciform) crest divides the canal into upper and lower compartments, and the vertical crest (Bill's bar) divides the upper compartment.

The facial nerve lies anterosuperiorly, the superior vestibular nerve posterosuperiorly, the cochlear nerve anteroinferiorly and the inferior vestibular nerve posteroinferiorly.

Its orientation within the petrous bone is important during:

- vestibular schwannoma surgery
- facial nerve surgery
- selected skull base approaches

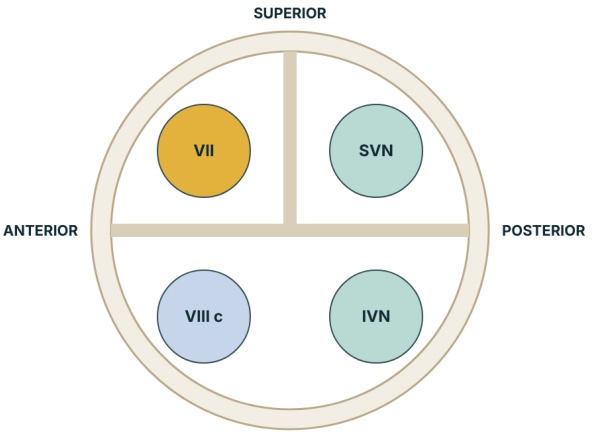
Its relationship to:

- labyrinth
- posterior fossa
- petrous apex

must be understood three-dimensionally.

Figure 6.5 · The fundus of the internal auditory canal

Schematic end-on view of the lateral end of the canal · read the axis labels, not the side



KEY RELATIONSHIPS

Transverse (falciform) crest: divides upper from lower

Vertical crest (Bill's bar): divides upper compartment — facial nerve in front, superior vestibular behind

"Seven-up, Coke down": VII anterosuperior, cochlear anteroinferior

In the translabyrinthine approach the SVN is followed to Bill's bar, and the facial nerve lies just anterior to it.

6.29 INTERNAL CAROTID ARTERY

The petrous internal carotid artery is a critical temporal bone structure.

It ascends in a short vertical segment, turns at the genu, and runs anteromedially in a longer horizontal segment toward the foramen lacerum, lying anterior and medial to the cochlea.

Its proximity becomes relevant in:

- hypotympanum
- Eustachian tube region
- petrous apex
- skull base surgery

CT should be reviewed carefully for:

- canal course
- dehiscence
- asymmetry
- aberrant course
- disease relationship

VASCULAR PRINCIPLE

Know where the carotid is before the operation becomes deep enough for the carotid to matter.

6.30 EUSTACHIAN TUBE

The Eustachian tube connects the middle ear with the nasopharynx and has:

- a bony part (posterolateral one-third, in the temporal bone)
- a cartilaginous part (anteromedial two-thirds)

Its temporal bone relationships are important during:

- middle-ear surgery
- skull base surgery
- selected oncological resections

The petrous carotid relationship becomes particularly important near the bony Eustachian tube, where only a thin plate of bone may separate the two.

6.31 PETROUS APEX

The petrous apex lies medial to the otic capsule and represents one of the deeper regions of temporal bone surgery.

Its relationships include:

- internal carotid artery
- cochlea
- internal auditory canal
- dura
- cranial nerves, including the abducens nerve in Dorello's canal and the trigeminal ganglion in Meckel's cave
- Eustachian tube-related anatomy

Access depends upon which anatomical structures can safely be crossed or preserved.

There is no single "petrous apex approach".

There are corridors selected according to:

hearing

facial nerve

carotid

labyrinth

disease location

These corridors are discussed in Chapter 29, Petrous Apex & Petrosectomy Approaches.

6.32 PNEUMATISATION CHANGES THE OPERATION

Temporal bone pneumatisation varies widely.

A well-pneumatised temporal bone may reveal landmarks through air-cell pathways.

A sclerotic temporal bone may require landmarks to be uncovered almost entirely through drilling.

Therefore:

AIR CELLS ARE VARIABLE.

> **FIXED ANATOMICAL RELATIONSHIPS ARE MORE IMPORTANT.**

6.33 LANDMARK NETWORKS

Temporal bone surgery becomes safer when orientation is built from multiple structures.

Mastoid Network

Tegmen
+ Sigmoid sinus
+ Posterior canal wall
+ Lateral semicircular canal
+ Digastric ridge

Facial Nerve Network

Lateral canal
+ Incus

+ Digastric ridge
+ Posterior canal wall

Middle-Ear Network

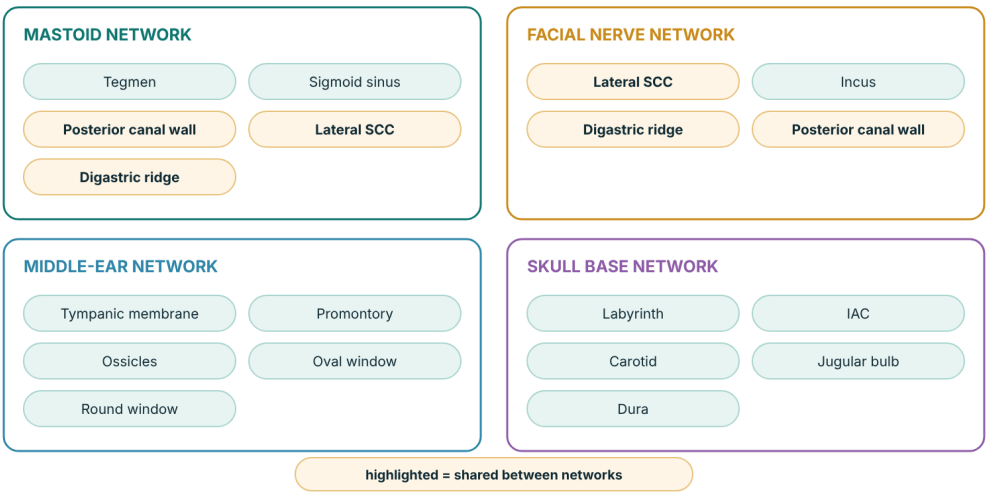
Tympanic membrane
+ Promontory
+ Ossicles
+ Oval window
+ Round window

Skull Base Network

Labyrinth
+ IAC
+ Carotid
+ Jugular bulb
+ Dura

Figure 6.6 · The temporal bone as overlapping landmark networks

Orientation is strongest where several relationships agree; shared landmarks link the networks



6.34 WHAT SHOULD APPEAR NEXT?

During drilling, continuously predict anatomy.

If working through the mastoid:

Cortex

↓

Air cells

↓

Antrum

↓

Lateral semicircular canal / incus

↓

Facial nerve relationships

If expected anatomy does not appear:

STOP.

Do not drill deeper simply because the landmark is "supposed to be there".

Reassess:

- CT
- direction
- depth
- anatomical variation
- disease

6.35 WHAT SHOULD NOT APPEAR YET?

This question is equally important.

Unexpected early appearance of:

- dura
- sigmoid sinus
- facial nerve
- labyrinth
- carotid
- jugular bulb

may indicate:

- anatomical variation

- dehiscence
- disease erosion
- incorrect direction

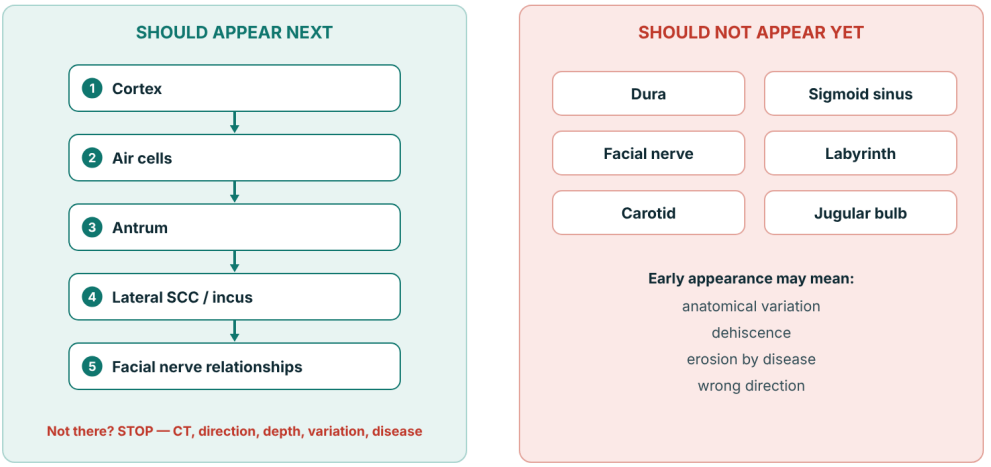
PRINCIPLE

Unexpected anatomy is not an inconvenience.

It is information.

Figure 6.7 · What should appear next, and what should not appear yet

Predict the next landmark — and treat early, unexpected anatomy as information



6.36 THE FOUR-VIEW METHOD

For every major temporal bone structure, learn four views:

3D ANATOMY

Where does it lie?

AXIAL CT

How do I recognise it?

CORONAL CT

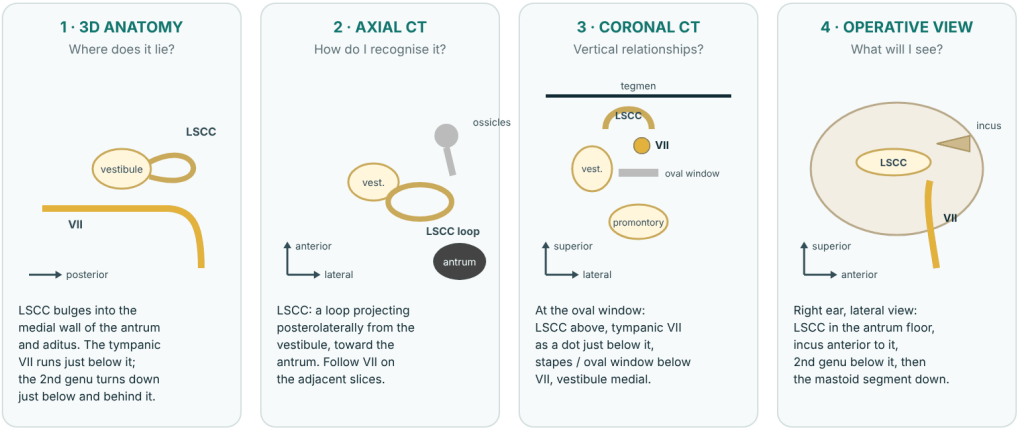
What are its vertical relationships?

OPERATIVE VIEW

What does it look like during surgery?

Figure 6.8 · The four-view method: lateral semicircular canal and facial nerve

Schematics, not to scale — one relationship learned in four views



The same structure, four ways — until the CT and the operative field predict each other.

Use this four-view habit for every structure in the temporal bone chapters that follow.

SURGICAL PERSPECTIVE

At the beginning of temporal bone training, the mastoid can appear to be a block of bone containing structures that must somehow be found.

With experience, that perception changes.

The surgeon no longer searches randomly for the facial nerve.

The lateral canal predicts it.

The digastric ridge predicts it.

The incus helps predict it.

The posterior canal wall contributes another relationship.

The anatomy begins appearing before it is exposed.

That is the purpose of surgical anatomy:

> **not merely to recognise a structure after seeing it,**

> **but to know where it should be before you reach it.**

TAKE IT TO THE OT

Before temporal bone surgery, identify on CT:

TEGMEN

SIGMOID SINUS

JUGULAR BULB

FACIAL NERVE

LABYRINTH

COCHLEA

OSSICLES

INTERNAL AUDITORY CANAL

CAROTID CANAL

PNEUMATISATION

DISEASE

Then ask:

What landmark will I establish first?

What should appear second?

What lies beyond my intended drilling depth?

CHAPTER SUMMARY

The temporal bone is not a collection of isolated cavities.

It is a three-dimensional relationship between hearing, balance, facial function, major vessels, dura and brain.

Read CT before drilling.

Use surface landmarks to enter, but deeper landmark networks to orient.

Treat the lateral semicircular canal, incus, digastric ridge, tegmen and sigmoid sinus as interconnected guides.

Predict the facial nerve rather than searching for it.

Understand the carotid and jugular bulb before approaching deeper bone.

Progress from known structure to known structure.

And throughout temporal bone surgery, repeatedly ask:

WHAT SHOULD I SEE NEXT?

> **And what should I not be seeing yet?**

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CHAPTER 07

Temporal Bone Imaging for the Surgeon

Read the CT Before You Touch the Bone

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- review temporal bone CT systematically before surgery
- correlate axial, coronal and reformatted images with operative anatomy
- assess mastoid pneumatisation and anticipated drilling difficulty
- identify the facial nerve, labyrinth, ossicles, tegmen, sigmoid sinus, jugular bulb and carotid canal
- recognise anatomical variations that alter surgical risk
- evaluate disease according to the surgical corridor it affects
- compare both temporal bones without assuming symmetry
- convert imaging into an operative drilling map

7.1 THE CT IS THE FIRST TEMPORAL BONE DISSECTION

Before the burr touches the cortex, the surgeon should already have travelled through the temporal bone once.

On the scan.

The purpose of reviewing CT is not merely to confirm:

mastoid disease present

or

cholesteatoma suspected.

The surgeon wants to know:

How much bone lies between me and the antrum?

Where is the tegmen?

How anterior is the sigmoid sinus?

How high is the jugular bulb?

Where is the facial nerve?

Is the labyrinth intact?

What has disease destroyed?

The scan should become a mental operation.

The general approach to reading imaging as an operative map is set out in Book 1, Chapter 4, Reading Imaging for the Surgeon.

7.2 USE THE CORRECT STUDY

High-resolution, sub-millimetre-slice temporal bone CT is the study of choice for bony anatomy.

MRI may provide complementary information in selected conditions, including:

- soft-tissue characterisation
- intracranial extension
- inner-ear / neural pathology
- selected cholesteatoma assessment
- skull base lesions

The imaging modality should answer the clinical and surgical question.

7.3 FIRST: ORIENT

Before studying pathology:

RIGHT OR LEFT?

AXIAL OR CORONAL?

ANTERIOR OR POSTERIOR?

SUPERIOR OR INFERIOR?

Then identify normal major structures.

Do not allow obvious disease to pull attention away from orientation.

7.4 SCROLL THROUGH THE TEMPORAL BONE

Never try to understand the temporal bone from one representative image.

Scroll.

Follow.

Trace.

Watch structures:

appear

continue

change direction

disappear.

This is particularly important for:

- facial nerve
- semicircular canals
- carotid canal
- sigmoid sinus
- jugular bulb
- ossicles
- internal auditory canal

IMAGING PRINCIPLE

A structure becomes easier to understand when followed rather than found.

Figure 7.1 · Follow a structure, do not just find it

Schematic of serial slices — a curved structure is understood only by scrolling through it



slice 1 — not yet
slice 2 — APPEARS
slice 3 — CONTINUES
slice 4 — CHANGES DIRECTION
slice 5 — DISAPPEARS

Scroll for: facial nerve · semicircular canals · carotid canal · sigmoid sinus · jugular bulb · ossicles · internal auditory canal

7.5 BEGIN WITH THE NORMAL SIDE

When one ear is predominantly diseased, the opposite temporal bone may provide a useful reference.

Compare:

- pneumatisation
- tegmen
- sigmoid sinus
- jugular bulb
- labyrinth
- facial nerve canal
- ossicles
- carotid canal

But remember:

> **THE TWO SIDES ARE SIBLINGS, NOT TWINS.**

Important anatomical variation can be bilateral or asymmetric.

7.6 MASTOID PNEUMATISATION

Assess whether the mastoid is:

- well pneumatised
- moderately pneumatised
- poorly pneumatised / sclerotic

This predicts aspects of the drilling experience.

WELL PNEUMATISED

Landmarks may emerge through air-cell pathways.

SCLEROTIC

More continuous bone removal may be required and depth can feel less obvious.

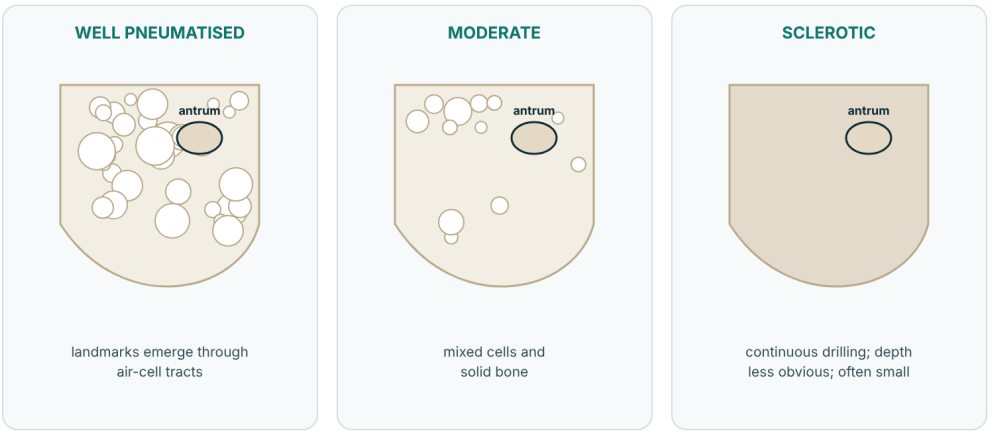
A sclerotic mastoid is often small, with a low tegmen and an anteriorly placed sigmoid sinus.

The anatomical targets remain the same.

The route by which they appear differs.

Figure 7.2 · Pneumatisation changes the route, not the targets

Schematic mastoids — the same landmarks are reached by different amounts of bone removal



Sclerotic mastoids often also have a low tegmen and an anterior sigmoid — check both on CT.

7.7 MASTOID CORTEX TO ANTRUM

Mentally trace:

CORTEX

↓

SUPERFICIAL AIR CELLS

↓

DEEPER CELL SYSTEM

↓

ANTRUM

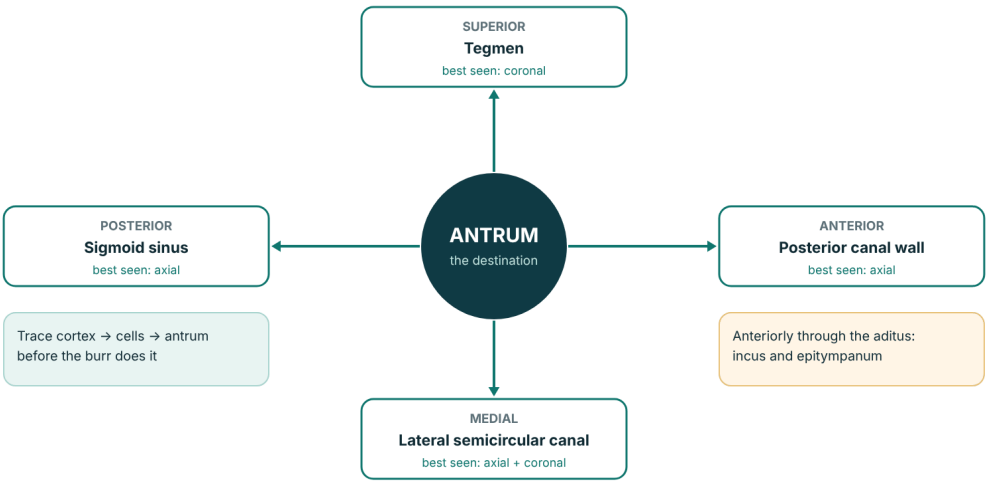
Then identify what surrounds the antrum:

- tegmen superiorly
- sigmoid sinus posteriorly
- posterior canal wall anteriorly
- lateral semicircular canal medially
- incus / epitympanic region anteriorly, through the aditus

This is the CT equivalent of cortical mastoidectomy.

Figure 7.3 · The antrum and its boundaries on CT

Conceptual map — the CT equivalent of a cortical mastoidectomy



7.8 THE TEGMEN

Assess:

- height
- thickness
- symmetry

- dehiscence
- erosion
- relationship to disease

A low tegmen reduces superior working space.

A deficient tegmen may expose dura earlier than expected.

Coronal images show the tegmen best.

ASK:

At what drilling depth should I expect the roof?

7.9 SIGMOID SINUS

Assess:

- anterior–posterior position
- relationship to posterior canal wall
- depth from cortex
- dominance where relevant
- disease relationship

An anterior sigmoid sinus may significantly narrow the mastoid corridor.

ASK:

How much working space exists between canal wall and sinus?

This is more useful than simply identifying the sinus.

7.10 THE SINODURAL REGION

Review the relationship between:

TEGMEN

and

SIGMOID SINUS.

This predicts the superior-posterior boundaries of mastoid work.

A narrow sinodural region can make the surgical field feel considerably smaller than expected.

7.11 JUGULAR BULB

Assess:

- height
- bony covering
- relationship to hypotympanum
- relationship to round-window region
- asymmetry

A high or dehiscent jugular bulb may significantly alter:

- middle-ear surgery
- cochlear implantation
- skull base surgery

> **PRINCIPLE**
>
> **A vascular variation that is obvious on CT should never become an intraoperative surprise.**

7.12 CAROTID CANAL

Trace the petrous internal carotid artery.

Assess:

- canal integrity
- course
- dehiscence
- relationship to middle ear
- Eustachian tube
- cochlea
- petrous apex
- disease

An aberrant carotid crossing the middle ear can mimic a vascular middle-ear mass on otoscopy; CT shows the absent vertical carotid canal.

Do not evaluate only the point nearest pathology.

Understand the vessel as a continuous structure.

7.13 THE OSSICLES

On appropriate CT sections, assess:

- malleus
- incus
- stapes region where visible
- ossicular continuity
- erosion
- displacement
- fixation where suggested indirectly

The long process of the incus is the part most often eroded in chronic ear disease.

In cholesteatoma and chronic ear disease, ossicular status helps predict:

- disease extent
- hearing mechanism
- reconstructive requirement

7.14 SCUTUM

The scutum is an important bony landmark in attic disease.

Assess:

- preservation
- erosion
- epitympanic soft tissue

Scutal erosion can support the suspicion of cholesteatomatous disease in the appropriate clinical context.

But imaging findings should be interpreted with examination and other studies.

7.15 EPITYMPANUM

Review:

- attic
- ossicles

- tegmen
- aditus
- antrum

Ask:

Can disease pass freely between these spaces?

The surgeon should see the epitympanum and antrum as connected operative anatomy.

7.16 MESOTYMPANUM

Assess:

- ossicles
- promontory
- facial nerve canal
- oval-window region
- round-window niche
- sinus tympani and facial recess
- middle-ear soft tissue

CT provides bony relationships.

It does not reliably distinguish cholesteatoma from granulation, fluid or fibrosis.

Interpret accordingly.

7.17 HYPOTYMPANUM

The hypotympanum deserves deliberate review because of its relationship to:

- jugular bulb
- carotid canal
- inferior middle-ear recesses

Disease extending inferiorly may enter anatomy that is less visible through routine microscopic inspection.

7.18 FACIAL NERVE — TRACE IT

Do not simply look for "facial canal dehiscence".

Trace the expected course.

MEATAL SEGMENT (IAC)

↓

LABYRINTHINE SEGMENT

↓

GENICULATE GANGLION

↓

TYMPANIC SEGMENT

↓

SECOND GENU

↓

MASTOID SEGMENT

↓

STYLOMASTOID FORAMEN

Look for:

- course
- bony covering
- disease proximity
- congenital variation
- previous surgical exposure

The nerve should exist mentally as one continuous line.

Figure 7.4 · Tracing the facial nerve: which plane shows which segment

Guide only — scroll through every segment in more than one plane

SEGMENT	AXIAL	CORONAL	SAGITTAL OBLIQUE	WHAT TO LOOK FOR
Meatal (IAC)	●	●	—	anterosuperior quadrant
Labyrinthine	●	○	—	curves forward over the cochlea
Geniculate ganglion	●	○	—	first genu; GSPN anteriorly
Tympanic	●	●	—	along medial wall (axial); dot under LSCC (coronal)
Second genu	●	○	○	posterior to the oval window
Mastoid	○	●	●	length seen on coronal / sagittal
Stylomastoid foramen	●	●	○	at the anterior end of the digastric groove

● best ○ useful — limited

CT under-calls and over-calls small dehiscences — operate as if one may be present.

7.19 FACIAL NERVE DEHISCENCE

Bony dehiscence may be:

- congenital
- disease-related
- postoperative

CT may suggest dehiscence but does not reliably predict small defects; the thin bone over the tympanic segment is easily under- or over-called.

Therefore even when CT appears normal:

> **OPERATE AS THOUGH THE NERVE DESERVES RESPECT.**

Imaging modifies risk awareness.

It does not eliminate surgical caution.

7.20 LATERAL SEMICIRCULAR CANAL

Assess:

- bony integrity
- relationship to disease

- fistula
- surrounding erosion

In cholesteatoma, the lateral canal is by far the commonest site of labyrinthine fistula.

If erosion is suspected preoperatively, the surgeon should enter the operation already knowing:

- where it is
- how extensive it appears
- what change in technique may be required

7.21 SUPERIOR AND POSTERIOR SEMICIRCULAR CANALS

These become increasingly relevant in:

- deeper temporal bone surgery
- labyrinthine approaches
- skull base surgery

Follow their arcs across multiple planes.

Reformats in the planes of the canals (Pöschl and Stenvers) help, for example when superior canal dehiscence is suspected.

Do not attempt to understand a curved three-dimensional structure from a single slice.

7.22 COCHLEA

Assess:

- turns (normally about two and a half)
- ossification
- congenital anomaly
- relationship to facial nerve
- carotid
- internal auditory canal

This becomes particularly important before cochlear implantation and advanced petrous bone surgery.

After meningitis, MRI (heavily T2-weighted) shows fibrous obliteration of the cochlear fluid spaces before CT shows ossification.

7.23 ROUND-WINDOW REGION

For cochlear implantation, review:

- expected round-window location
- facial recess geometry
- cochlear orientation
- overlying bone
- congenital variation

A difficult round-window exposure can sometimes be anticipated before surgery.

7.24 INTERNAL AUDITORY CANAL

Assess:

- length
- orientation
- symmetry
- relationship to labyrinth
- pathology

MRI becomes particularly important for neural and soft-tissue pathology involving the IAC.

CT provides the bony corridor.

The two modalities answer different questions.

7.25 EXTERNAL AUDITORY CANAL

Review:

- anterior wall
- posterior wall
- stenosis

- exostosis
- erosion
- tumour
- relationship to TMJ

Canal disease may significantly alter the approach to deeper temporal bone surgery.

7.26 CHOLESTEATOMA — READ THE ROUTE OF DISEASE

Do not merely identify soft tissue.

Ask:

Where did disease begin?

Where has it travelled?

What has it eroded?

Which spaces communicate?

Assess:

- attic
- mesotympanum
- hypotympanum
- sinus tympani
- facial recess
- aditus
- antrum
- mastoid

CT is particularly valuable for bone.

Non-echo-planar diffusion-weighted MRI is highly sensitive and specific for cholesteatoma, particularly in the postoperative ear, but may miss deposits smaller than about 3 mm.

7.27 LOOK FOR COMPLICATIONS BEFORE OPERATING

Specifically inspect for:

TEGMEN EROSION

LABYRINTHINE FISTULA

FACIAL CANAL EROSION

SIGMOID PLATE EROSION

OSSICULAR DESTRUCTION

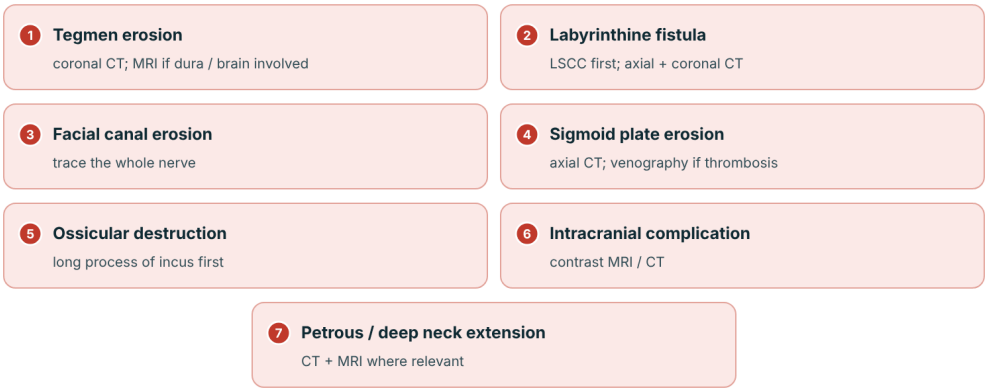
INTRACRANIAL COMPLICATION

DEEP NECK / PETROUS EXTENSION WHERE RELEVANT

The surgeon should know which complication is likely before discovering it under the microscope.

Figure 7.5 · Complications to look for before operating

Know which one is likely before you meet it under the microscope



7.28 CONGENITAL TEMPORAL BONE ANATOMY

Congenital abnormalities may involve:

- cochlea
- vestibule
- semicircular canals
- facial nerve
- internal auditory canal
- ossicles
- external canal

In such cases, normal landmark relationships may not apply.

Preoperative imaging becomes central to operative planning (see Chapter 20, Difficult Cochlear Implantation).

7.29 REVISION SURGERY

In revision temporal bone surgery, CT should answer:

What bone was removed?

What landmarks remain?

Is the facial nerve exposed?

Is dura exposed?

Is the sigmoid sinus exposed?

What disease remains or has recurred?

What reconstructive material is present?

The previous cavity becomes the starting anatomy.

7.30 THE FIVE-IMAGE TEMPORAL BONE REVIEW

After reviewing the entire study, select five images that summarise the operation.

IMAGE 1 — THE DISEASE

Best demonstration of extent.

IMAGE 2 — THE MASTOID CORRIDOR

Tegmen + sinus + canal wall + pneumatisation.

IMAGE 3 — THE FACIAL NERVE / LABYRINTH

Critical neural and inner-ear relationships.

IMAGE 4 — THE VASCULAR RISK

Jugular bulb / carotid / sigmoid as relevant.

IMAGE 5 — THE TARGET

The structure or disease that defines the operation.



7.31 BUILD A DRILLING MAP

Before mastoid drilling, mentally mark:

SUPERIOR LIMIT

Tegmen.

POSTERIOR LIMIT

Sigmoid sinus.

ANTERIOR LIMIT

Posterior canal wall.

INFERIOR ORIENTATION

Mastoid tip / digastric region.

DEEP LANDMARK

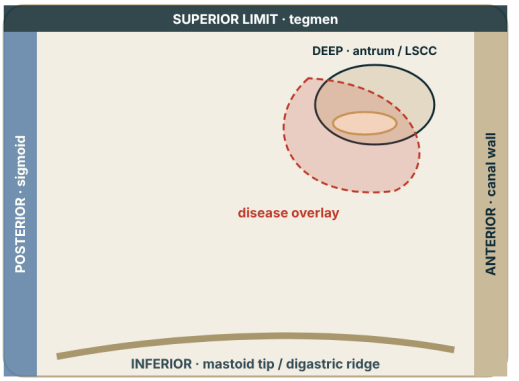
Lateral semicircular canal / antrum.

Then overlay the disease.

This converts CT into a surgical field.

Figure 7.7 · From CT to drilling map

Schematic, right ear, lateral view (superior up, anterior to the right) — boundaries first, then the disease



ORDER OF THE MAP

1. Superior: tegmen
2. Posterior: sigmoid
3. Anterior: canal wall
4. Inferior: tip / digastric
5. Deep: antrum / LSCC
6. Then overlay disease

The map is drawn from the patient's CT, not from memory of the last mastoid.

DECISION POINT

THE CT DOES NOT LOOK LIKE THE OPERATIVE FIELD

Ask:

Am I at the expected depth?

Is the orientation correct?

Is the mastoid more sclerotic than expected?

Has disease destroyed the landmark?

Is there an anatomical variation?

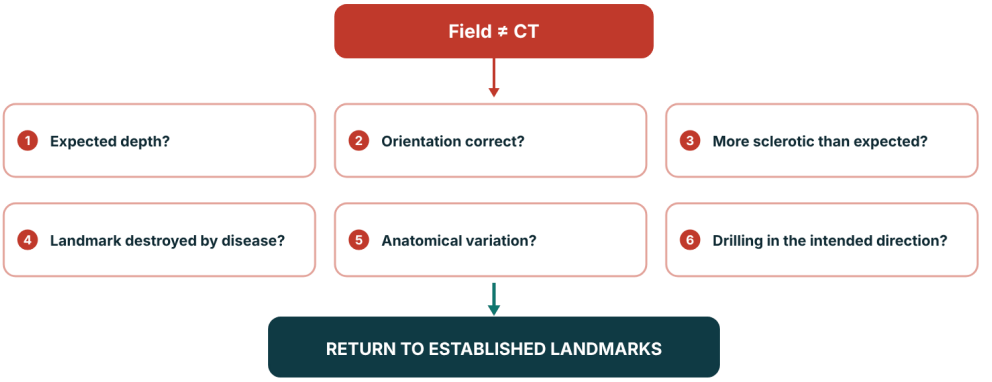
Am I drilling in the intended direction?

Do not continue deeper simply to force the field to resemble the scan.

Return to established landmarks.

Figure 7.8 · When the CT and the field disagree

Do not drill deeper to force the field to resemble the scan



FROM EXPERIENCE

A temporal bone CT initially looks like a series of grey and white sections.

After enough operations, the same images begin to move.

The cortex becomes the starting point.

The antrum becomes a destination.

The sigmoid becomes a posterior boundary.

The tegmen becomes a roof.

The lateral canal predicts the facial nerve.

The round window becomes a trajectory into the cochlea.

That transition is important.

> **The scan stops being a picture of the temporal bone.**

> **It becomes a rehearsal of the operation.**

TAKE IT TO THE OT

Before temporal bone surgery, identify:

PNEUMATISATION

TEGMEN

SIGMOID SINUS

JUGULAR BULB

CAROTID CANAL

FACIAL NERVE

LABYRINTH

COCHLEA

OSSICLES

EXTERNAL CANAL

DISEASE EXTENT

EROSION / DEHISCENCE

PREVIOUS SURGICAL CHANGE

Then answer:

WHERE WILL I BEGIN?

WHAT SHOULD APPEAR NEXT?

> **What structure will make me slow down?**

> **What structure must not surprise me?**

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CHAPTER 08

Myringotomy, Ventilation Tubes & Myringoplasty

Small Procedures • Precise Anatomy

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the surgical anatomy of the tympanic membrane
- select an appropriate site for myringotomy
- understand the principles of ventilation-tube placement
- recognise common causes of tube-related complications
- assess a tympanic-membrane perforation systematically
- understand the biological principles of myringoplasty
- select graft material and technique according to perforation anatomy
- understand the importance of middle-ear status, Eustachian-tube function and infection control
- recognise factors associated with graft failure

PART I — MYRINGOTOMY & VENTILATION TUBES

8.1 A SMALL OPERATION IS STILL AN OPERATION

Myringotomy and ventilation-tube insertion may be among the earliest procedures performed during ENT training.

Their apparent simplicity can create complacency.

But within millimetres of the tympanic membrane lie:

- ossicles
- chorda tympani
- facial nerve
- round window
- promontory
- inner ear

The procedure may be small.

The anatomy is not unimportant.

> **PRINCIPLE**
>
> **Frequency of an operation should increase familiarity — not reduce attention.**

8.2 SURGICAL ANATOMY OF THE TYMPANIC MEMBRANE

The tympanic membrane forms the boundary between the external auditory canal and middle ear.

It is broadly divided into:

PARS TENSA

The larger, taut portion.

PARS FLACCIDA

The smaller superior portion, above the lateral process of the malleus and between the anterior and posterior malleolar folds.

The membrane is oriented obliquely rather than lying perpendicular to the canal, so that the anterior tympanomeatal angle is acute and partly hidden behind the anterior canal wall.

This affects:

- examination
- incision
- graft placement
- endoscopic and microscopic orientation

8.3 LANDMARKS

Important visible landmarks include:

- handle of malleus
- lateral process of malleus
- umbo
- anterior and posterior malleolar folds
- annulus
- pars flaccida

The malleus provides a central orientation point.

Its handle runs downward and backward from the lateral process to the umbo.

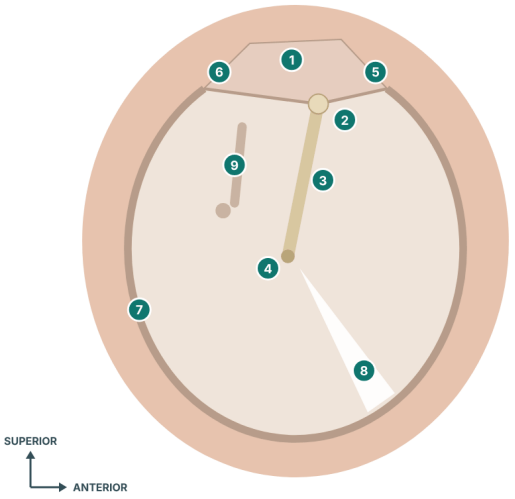
Before performing any membrane procedure:

ORIENT FIRST.

Do not treat the tympanic membrane as a circular white surface.

Figure 8.1 · Landmarks of the tympanic membrane

Schematic · Right ear, otoscopic / microscopic view · superior up, anterior to the right



1. Pars flaccida
2. Lateral process of malleus
3. Handle of malleus
4. Umbo
5. Anterior malleolar fold
6. Posterior malleolar fold
7. Annulus (fibrous)
8. Light reflex (anteroinferior)
9. Incus long process (seen through)

ORIENT FIRST

Find the lateral process and follow the handle down and back to the umbo. The light reflex points anteroinferiorly. In a left ear everything is mirrored.

8.4 QUADRANTS

For descriptive and procedural purposes, the pars tensa can be divided relative to the malleus into:

- anterosuperior
- anteroinferior
- posterosuperior
- posteroinferior

These quadrants do not carry equal surgical risk.

Structures within the middle ear lie close to the membrane, particularly posteriorly and superiorly: the long process of the incus, the stapes and the chorda tympani lie just medial to the posterosuperior quadrant.

Inferiorly, a high or dehiscent jugular bulb may occasionally lie close beneath the membrane.

The selected site for incision should therefore follow the procedure and anatomy.

8.5 MYRINGOTOMY

Myringotomy creates a controlled opening in the tympanic membrane.

Potential indications vary with clinical context and may include selected cases of:

- middle-ear effusion
- acute middle-ear disease requiring drainage
- barotrauma-related problems
- diagnostic middle-ear access

The indication should follow current clinical guidelines and patient factors.

In children, for example, current guidance reserves ventilation tubes mainly for otitis media with effusion persisting for 3 months or longer with documented hearing difficulty, and for recurrent acute otitis media with effusion present at assessment.

8.6 CHOOSE THE SITE BEFORE TOUCHING THE MEMBRANE

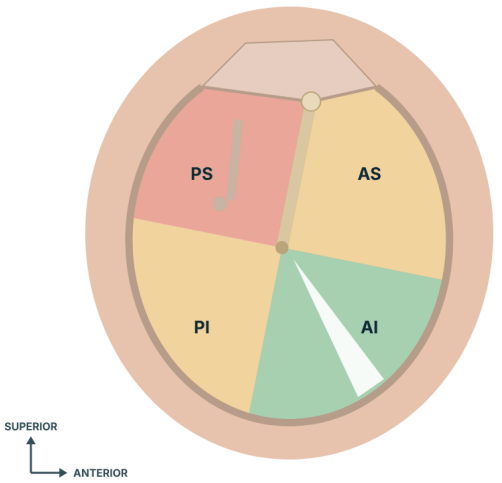
The incision site should provide:

- effective drainage / ventilation
- safe distance from important middle-ear structures
- appropriate position for tube placement if required

A commonly selected region for ventilation-tube insertion is the anteroinferior portion of the pars tensa, although the precise location should be adapted to anatomy and clinical objective.

Figure 8.2 · Quadrants and the choice of site

Schematic · Right ear, otoscopic view · quadrants are defined by the handle of the malleus and a line through the umbo



POSTEROSUPERIOR — AVOID
Incus long process, stapes and chorda lie just behind the membrane

ANTEROSUPERIOR — CAUTION
Close to the malleus and the Eustachian tube orifice region

ANTEROINFERIOR — USUAL TUBE SITE
Away from the ossicles; good view; tube sits well here

POSTEROINFERIOR — CAUTION
Round window niche medially; a high jugular bulb may rarely lie close

PRINCIPLE

The incision should be planned — not placed where the instrument happens to reach first.

8.7 VISUALISATION

Before incision:

- clear obstructing wax or debris
- obtain complete visualisation
- identify the malleus
- identify the annulus
- confirm the intended quadrant

If the membrane cannot be seen adequately:

> **IMPROVE THE VIEW BEFORE MAKING THE INCISION.**

This is the same principle used in major surgery.

8.8 THE INCISION

The myringotomy incision should be:

- controlled
- adequate for the intended purpose
- limited to the membrane

Avoid uncontrolled deep instrument passage into the middle ear.

SEE THE MEMBRANE.

ENTER THE MEMBRANE.

> **DO NOT CONTINUE SIMPLY BECAUSE THE INSTRUMENT CAN.**

8.9 MIDDLE-EAR CONTENT

After myringotomy, middle-ear contents may include:

- serous fluid
- mucoid fluid
- purulent material
- little or no fluid

The character may provide clinical information.

Appropriate suction can clear the middle ear without unnecessarily traumatising the mucosa.

8.10 VENTILATION TUBES

A ventilation tube maintains temporary communication between the external canal and middle ear.

Tube selection may depend upon:

- expected duration of ventilation
- age
- disease pattern
- previous tube history
- surgeon preference

Shorter-term and longer-term designs have different advantages and complications; long-term tubes carry a substantially higher risk of persistent perforation.

The device should match the clinical objective.

8.11 TUBE PLACEMENT

The tube should:

- sit securely across the membrane
- maintain a patent lumen
- avoid unnecessary trauma to the surrounding membrane
- remain appropriately positioned within the intended quadrant

After placement, confirm:

POSITION

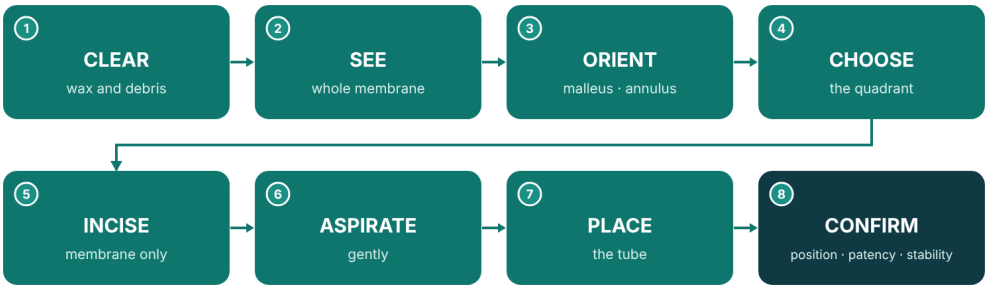
PATENCY

STABILITY

Do not assume successful insertion merely because the tube has disappeared from the forceps.

Figure 8.3 · Myringotomy and tube insertion, step by step

A small operation with the same discipline as a large one



Do not continue simply because the instrument can.

8.12 COMMON TUBE-RELATED PROBLEMS

Potential complications include:

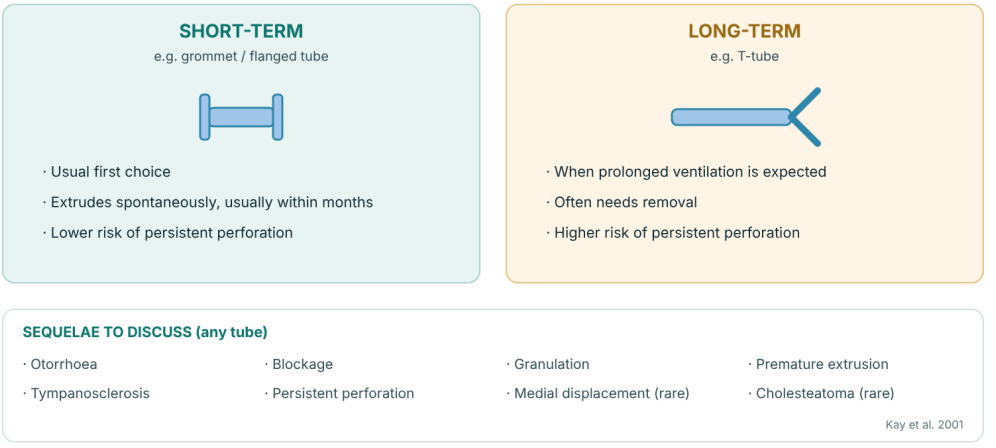
- otorrhoea
- blockage
- premature extrusion
- prolonged retention
- granulation
- tympanosclerosis
- persistent perforation
- medial displacement in rare situations
- cholesteatoma (rare)

The risk profile varies with tube type, duration and patient factors.

The family or patient should understand appropriate follow-up.

Figure 8.4 · Short-term and long-term tubes

Match the device to the expected duration of ventilation



8.13 THE OPERATION CONTINUES AFTER THE TUBE

Ventilation-tube insertion treats a middle-ear ventilation problem.

It does not automatically remove the cause.

Follow-up should consider:

- hearing
- middle-ear status
- tube patency
- recurrent infection
- underlying nasal / nasopharyngeal or other contributing factors where clinically relevant

In an adult with a persistent unilateral middle-ear effusion, examine the nasopharynx to exclude a nasopharyngeal tumour.

The device is part of management — not the entire management.

PART II — MYRINGOPLASTY

8.14 A PERFORATION IS NOT JUST A HOLE

Before repairing a tympanic-membrane perforation, define:

SIZE
Small / moderate / subtotal / total.

SITE
Anterior / posterior / inferior / central / marginal.

EDGE
Healthy / scarred / epithelialised.

ANNULUS
Preserved or involved?

MIDDLE EAR
Healthy, inflamed, adhesive or diseased?

OSSICLES
Intact?

CONTRALATERAL EAR
What does it tell us about middle-ear ventilation?

The perforation is one part of an ear.

Figure 8.5 · Assess the perforation as part of an ear

Seven questions before the graft is chosen



Marginal perforations, and any that reach the annulus, raise the question of cholesteatoma.

8.15 WHY DID THE PERFORATION OCCUR?

Possible causes include:

- chronic middle-ear disease
- trauma
- previous tube
- previous surgery
- infection

The cause influences:

- tissue quality
- middle-ear condition
- expected healing
- operative planning

Closing the perforation without understanding the surrounding ear may produce a technically successful membrane but an unsatisfactory functional result.

8.16 OBJECTIVES OF MYRINGOPLASTY

Potential objectives include:

RESTORE MEMBRANE INTEGRITY

REDUCE RECURRENT CONTAMINATION

IMPROVE HEARING WHERE APPROPRIATE

CREATE A STABLE, SAFE EAR

The primary objective should be clear.

8.17 THE EDGE

A chronic perforation may have an epithelialised edge.

Preparation of the margin — removing the in-turned epithelium to freshen the edge — aims to create tissue capable of integrating with the graft.

The exact method varies.

The principle is:

GRAFT + VIABLE RECIPIENT EDGE + STABILITY = OPPORTUNITY FOR HEALING.

8.18 GRAFT MATERIALS

Common autologous materials include:

TEMPORALIS FASCIA

Widely used, thin and accessible.

TRAGAL / CONCHAL PERICHONDRIUM

Useful in selected situations.

CARTILAGE

Provides greater structural stiffness and may be advantageous in selected high-risk or retraction-prone ears.

Systematic reviews report higher closure rates with cartilage than with fascia, with broadly similar hearing results.

No graft material is universally best.

Selection depends upon:

- perforation
- middle-ear ventilation
- revision status
- retraction tendency
- surgeon technique

8.19 FASCIA OR CARTILAGE?

The question should not become ideological.

Ask:

What does this membrane need?

A relatively uncomplicated perforation may require a thin flexible graft.

A retraction-prone, subtotal or revision situation may benefit from greater structural support.

The graft should solve the mechanical and biological problem of that ear.

8.20 UNDERLAY PRINCIPLE

In an underlay-type reconstruction, graft material is positioned medial to the remaining tympanic membrane and/or annular structures according to the selected technique.

Advantages may include technical simplicity and reliable integration in many perforations.

Challenges may occur particularly with:

- anterior support
- large perforations
- graft displacement

The technique should ensure stable graft contact with viable tissue.

8.21 OVERLAY PRINCIPLE

Overlay-type techniques position the graft more laterally relative to the membrane remnant after appropriate epithelial preparation.

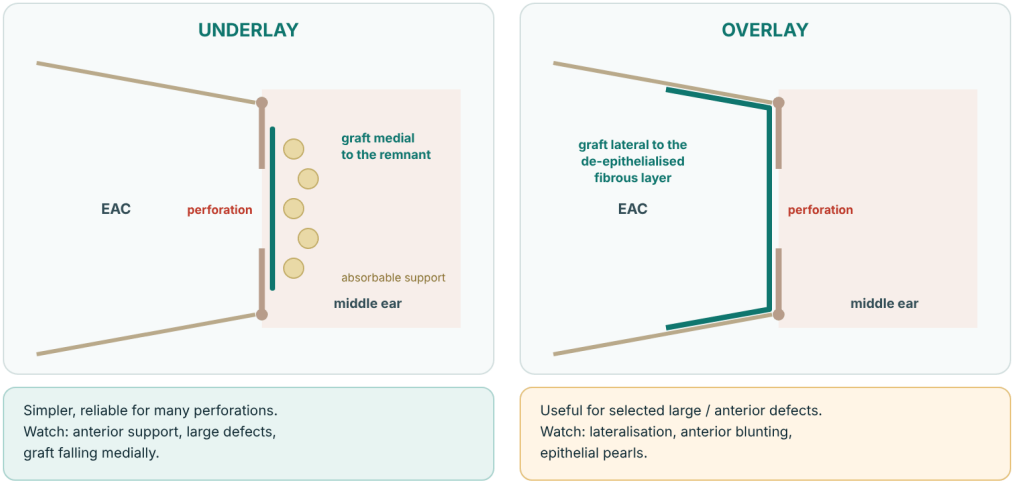
They may provide advantages in selected large or anterior perforations but require careful technique to avoid:

- lateralisation
- blunting
- epithelial problems

Technique selection should follow anatomy and surgeon expertise.

Figure 8.6 · Underlay and overlay grafting

Schematic section through canal and drum · lateral (canal) to the left, medial (middle ear) to the right



Simpler, reliable for many perforations. Watch: anterior support, large defects, graft falling medially.

Useful for selected large / anterior defects. Watch: lateralisation, anterior blunting, epithelial pearls.

8.22 ANTERIOR PERFORATION

Anterior perforations can be technically challenging because of:

- limited visualisation
- canal overhang
- reduced graft support
- tendency for anterior displacement

Before blaming the graft, assess the exposure.

PRINCIPLE

An anterior perforation is sometimes an exposure problem before it is a graft problem.

Canalplasty (see Chapter 4, External Auditory Canal Surgery) or alternative graft-support strategies may be useful in selected cases.

8.23 TYMPANOMEATAL FLAP

Where middle-ear access is required, a tympanomeatal flap may be elevated.

The surgeon should preserve:

- viable canal skin
- annular relationships
- flap orientation

Avoid unnecessary trauma to:

- chorda tympani
- ossicles
- canal skin

The flap should be designed with its final replacement in mind.

8.24 INSPECT THE MIDDLE EAR

When the middle ear is entered, assess:

- mucosa
- ossicular chain
- adhesions
- disease
- Eustachian-tube region where visible
- round-window region as relevant

A membrane repair should not hide untreated middle-ear pathology.

8.25 OSSICULAR STATUS

If conductive hearing loss exceeds what the perforation alone would explain, consider:

- ossicular erosion
- fixation
- discontinuity
- tympanosclerosis

Myringoplasty and ossicular reconstruction may need to be planned together (see Chapter 9, Tympanoplasty, and Chapter 10, Ossicular Reconstruction).

8.26 GRAFT STABILITY

A graft should remain:

- correctly oriented
- in contact with recipient tissue
- supported
- free from significant folding
- appropriately positioned relative to the malleus and annulus

Packing may assist.

But packing should support the reconstruction — not distort it.

8.27 DO NOT OVERPACK

Excessive packing can:

- displace the graft
- produce pressure
- cause discomfort
- obscure postoperative assessment

Use only what the reconstruction requires.

8.28 WHY DOES A GRAFT FAIL?

Potential contributors include:

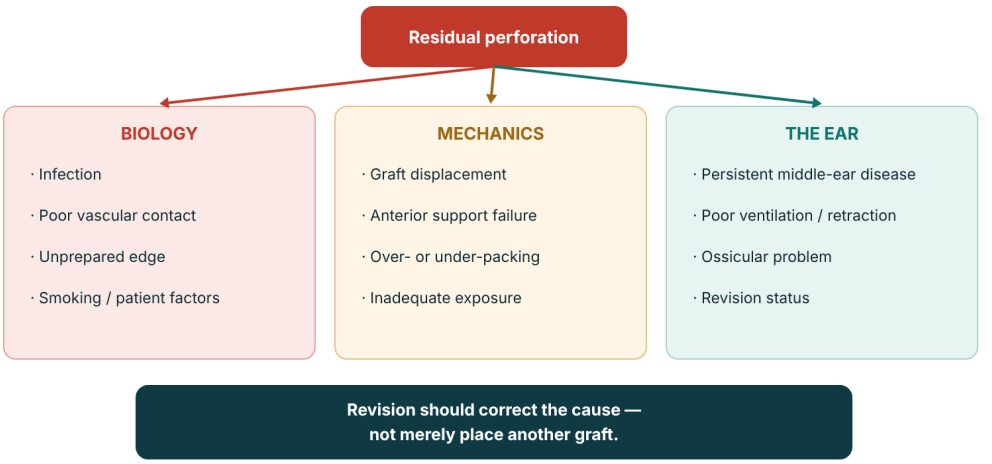
- infection
- poor vascular contact
- inadequate edge preparation
- graft displacement
- persistent middle-ear disease
- poor ventilation
- technical problems
- anterior support failure
- smoking and other patient factors
- revision status

Failure should be analysed according to cause.

> **"THE GRAFT DID NOT TAKE" IS A DESCRIPTION, NOT AN EXPLANATION.**

Figure 8.7 · Why did the graft fail?

"The graft did not take" is a description, not an explanation



8.29 REVISION MYRINGOPLASTY

Before revision, ask:

Where did the previous graft fail?

Why?

Is there anterior blunting?

Is the graft lateralised?

Is the ear retracting?

Is there persistent infection?

Is the ossicular chain normal?

Is the canal adequate?

The revision operation should correct the cause of failure, not merely place another graft.

8.30 HEARING OUTCOME

Hearing depends upon more than membrane closure.

It also depends upon:

- ossicular continuity
- middle-ear aeration
- cochlear function
- graft position
- middle-ear mechanics

Therefore:

ANATOMICAL SUCCESS
and

FUNCTIONAL SUCCESS
should both be assessed.

DECISION POINT

FASCIA, PERICHONDRIUM OR CARTILAGE?

Ask:

How large is the perforation?

Where is it?

Is the ear retracting?

Is this revision surgery?

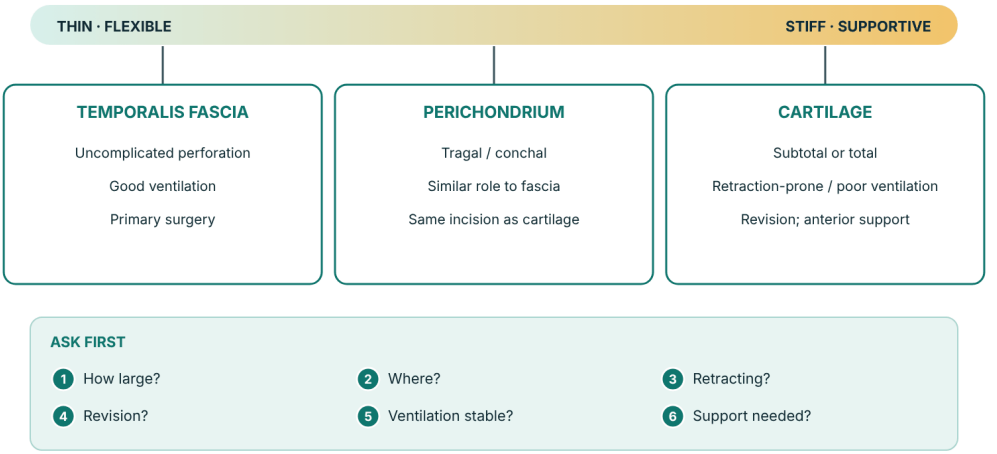
How stable is middle-ear ventilation?

How much structural support is required?

Choose graft material according to the ear — not according to habit.

Figure 8.8 · Fascia, perichondrium or cartilage?

Choose by what the membrane needs — a spectrum of stiffness, not an ideology



FROM EXPERIENCE

Myringoplasty teaches a principle that extends far beyond the tympanic membrane.

The operation appears to be about placing a graft.

But the graft succeeds only if:

the exposure is adequate,

the recipient tissue is viable,

the middle ear is suitable,

the graft remains stable,

and healing is allowed to occur.

The surgeon places the graft.

> **Biology completes the operation.**

TAKE IT TO THE OT

Before myringoplasty, define:

PERFORATION
Size and site.

CANAL
Is exposure adequate?

MIDDLE EAR
Healthy?

OSSICLES
Intact and mobile?

GRAFT
Which material and why?

TECHNIQUE
How will the graft be positioned?

ANTERIOR SUPPORT
Adequate?

PACKING
What is required?

FAILURE RISK
What could prevent healing?

CHAPTER SUMMARY

Myringotomy and myringoplasty may be common procedures, but they demand precise anatomy.

Orient the tympanic membrane before making an incision.

Place ventilation tubes for a defined clinical purpose and follow the underlying ear disease.

Before myringoplasty, analyse the perforation, canal, middle ear and ossicles.

Select graft material according to mechanical need.

Ensure exposure and graft stability.

When repair fails, identify why before repeating it.

And remember:

> **The surgeon places the graft.**

THE EAR HAS TO HEAL IT.

FURTHER READING & REFERENCES

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CHAPTER 09

Tympanoplasty

Reconstructing the Tympanic Membrane–Middle Ear System

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- distinguish myringoplasty from broader tympanoplasty
- define the anatomical and functional objectives of tympanoplasty
- select an operative approach according to perforation, canal anatomy and middle-ear disease
- elevate and replace a tympanomeatal flap safely
- assess the middle ear systematically
- understand the relationship between membrane reconstruction and ossicular mechanics
- select graft material according to the mechanical needs of the ear
- recognise common causes of anatomical and functional failure
- plan revision tympanoplasty according to the reason for previous failure

9.1 TYMPANOPLASTY IS MORE THAN CLOSING A PERFORATION

A tympanic membrane may be closed successfully while hearing remains poor.

Why?

Because sound transmission depends upon a system:

TYMPANIC MEMBRANE

↓

MALLEUS

↓

INCUS

↓

STAPES

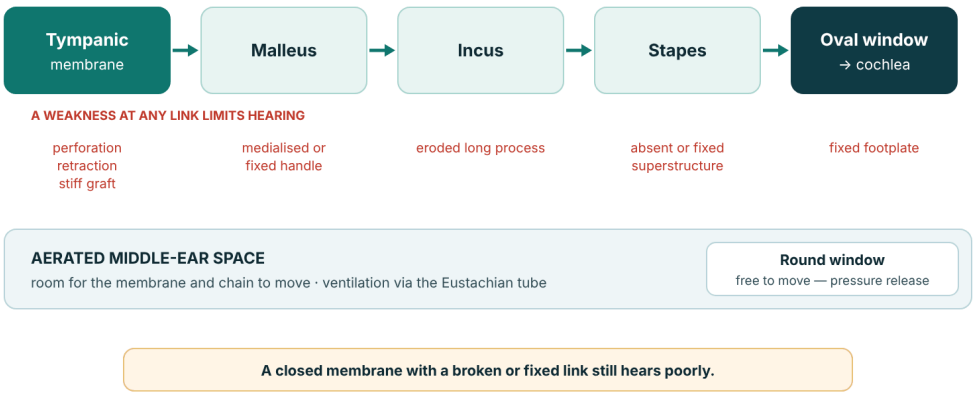
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OVAL WINDOW

and upon an adequately aerated middle-ear space, with a round window that remains free to move.

Figure 9.1 · The tympanic membrane–middle ear system

Schematic — closing the membrane restores only the first link



Tympanoplasty therefore addresses the tympanic membrane **and, where required, the middle-ear sound-conduction mechanism.**

9.2 DEFINE THE OBJECTIVE

Before surgery, determine what the operation needs to accomplish.

Possible objectives include:

CREATE A SAFE, DRY EAR

CLOSE THE TYMPANIC MEMBRANE

RESTORE MIDDLE-EAR AERATION

RECONSTRUCT SOUND TRANSMISSION

REMOVE LIMITED MIDDLE-EAR DISEASE

PREVENT PROGRESSIVE RETRACTION

Not every ear requires every objective.

The operative plan should match the actual pathology.

9.3 PREOPERATIVE ASSESSMENT

Evaluate:

HISTORY

- duration of discharge
- hearing loss
- previous surgery
- trauma
- recurrent infections
- vertigo
- tinnitus

EXAMINATION

- perforation
- retraction
- tympanosclerosis
- granulation
- ossicular visibility
- canal anatomy
- contralateral ear

AUDIOLOGY

- air conduction
- bone conduction
- air–bone gap
- speech measures where appropriate

IMAGING

Not universally required for every uncomplicated perforation, but useful when deeper disease, cholesteatoma, ossicular pathology, congenital abnormality or revision anatomy is suspected.

9.4 THE CONTRALATERAL EAR IS INFORMATION

The opposite ear may provide clues regarding:

- Eustachian-tube function
- retraction tendency
- chronic middle-ear disease
- overall hearing status

A normal opposite ear does not guarantee normal function on the operative side.

But bilateral disease may suggest a more persistent ventilation problem.

9.5 CLASSIFY THE PROBLEM BEFORE CLASSIFYING THE OPERATION

Traditional tympanoplasty classifications remain useful for communication.

But before memorising a type, ask:

WHAT IS DEFECTIVE?

Membrane only?

Malleus?

Incus?

Stapes superstructure?

Stapes footplate mobility?

Middle-ear space?

Then determine what needs reconstruction.

PRINCIPLE

Understand the mechanical problem before assigning the operation a name.

Figure 9.2 · Define the defect, then name the operation

What is missing or fixed determines what must be rebuilt; the type name follows

WHAT IS DEFECTIVE?	WHAT MUST BE REBUILT	USUAL OPTION	WULLSTEIN
Membrane only — chain intact and mobile	Membrane	Myringoplasty / tympanoplasty	**Type I**
Malleus handle eroded; incus and stapes intact	Membrane coupled to incus / remnant	Graft onto incus or remnant	**Type II**
Incus long process eroded; stapes superstructure mobile	Link membrane / malleus to stapes head	Incus interposition or PORP	**Type III**
Stapes superstructure absent; footplate mobile	Link membrane / malleus to footplate	TORP (± shoe)	**Type IV***
Footplate fixed	Address fixation — often staged	Stapes surgery, usually second stage	**Type V***
Middle-ear space unhealthy, poorly aerated	Ventilation and mucosa first	Stage; cartilage; reassess	—

*Historical Wullstein types IV and V (exposed footplate with shielded round window; fenestration) are largely replaced today by TORP reconstruction and stapes surgery. PORP/TORP: partial/total ossicular replacement prosthesis.

9.6 APPROACH SELECTION

Possible approaches include:

TRANS-CANAL

Useful when the canal provides adequate exposure.

ENDAURAL

May provide additional access in selected ears.

POSTAURICULAR

Provides broad exposure and may be useful for:

- large perforations
- difficult anterior access

- narrow canal
- graft harvest
- combined mastoid procedures

ENDOSCOPIC TRANS-CANAL

May improve visualisation of recesses and anterior anatomy in selected cases.

The best approach is the one that provides adequate exposure with appropriate morbidity.

Figure 9.3 · Choosing the approach

Adequate exposure of the whole problem, with appropriate morbidity

TRANSCANAL	ENDAURAL	POSTAURICULAR	ENDOSCOPIC
USEFUL FOR Wide, straight canal Whole margin visible Small or posterior defects	USEFUL FOR Incision between tragus and helical crus Wider lateral canal Attic and posterosuperior	USEFUL FOR Large, anterior, subtotal Narrow canal / canalplasty Fascia harvest in field Combined mastoid work	USEFUL FOR Wide-angle view past the anterior overhang Recesses, retrotympanum No external incision
COST / LIMIT Anterior overhang can hide the anterior rim	COST / LIMIT Limited view of the anterior sulcus	COST / LIMIT External incision; more dissection	COST / LIMIT One-handed; less depth perception; bleeding

If the entire perforation margin cannot be seen, exposure must change — not the extent of the operation.

9.7 THE CANAL DETERMINES WHAT YOU CAN SEE

Before choosing the approach, assess:

- canal width
- anterior overhang
- curvature
- exostosis
- stenosis

If the entire perforation margin cannot be visualised:

EXPOSURE MUST CHANGE.

Do not perform a limited operation simply because the incision has already been chosen.

9.8 TYMPANOMEATAL FLAP

The tympanomeatal flap provides access to the middle ear while preserving canal skin for replacement.

The flap should be designed according to:

- approach
- perforation location
- required middle-ear access
- graft technique

General principles include:

INCISION UNDER VISION

PRESERVE VIABLE SKIN

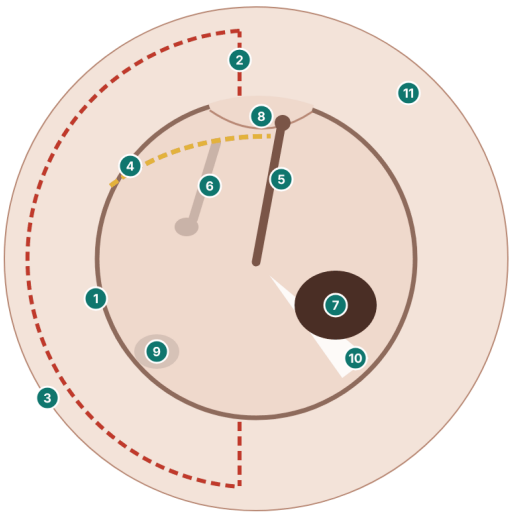
ELEVATE IN A CONTROLLED PLANE

IDENTIFY THE ANNULUS

ENTER THE MIDDLE EAR DELIBERATELY

Figure 9.4 · Tympanomeatal flap, annulus and chorda tympani

Right ear, otoscopic orientation — superior up, anterior to the right · schematic, not to scale



1. Annulus in the tympanic sulcus
2. 12 and 6 o'clock canal incisions
3. Lateral (connecting) incision
4. Chorda tympani (medial to TM)
5. Malleus handle
6. Incus long process / stapes
7. Perforation (anteroinferior)
8. Pars flaccida (no annulus)
9. Round window niche
10. Light reflex
11. Canal skin on bony canal wall

ELEVATING THE FLAP

Incise under vision; keep the skin intact
Elevate on bone in one controlled plane
Find the annulus before lifting it
Lift the annulus first posteroinferiorly, away from the chorda
Then free it superiorly; identify the chorda
Enter the middle ear deliberately

9.9 ANNULUS

The annulus provides important orientation and support for tympanic-membrane reconstruction.

During flap elevation:

- identify the annular plane
- avoid unnecessary trauma
- preserve sufficient tissue for replacement

Anteriorly, anatomy may be less forgiving because exposure and support can be limited.

9.10 CHORDA TYMPANI

The chorda tympani may be encountered during middle-ear access.

Preserve it when reasonably possible.

Avoid:

- excessive traction
- repeated manipulation
- unnecessary skeletonisation

If sacrifice becomes necessary for disease clearance or adequate access, the functional consequence — altered taste on the ipsilateral anterior tongue — should be understood and discussed with the patient beforehand.

9.11 ENTER THE MIDDLE EAR WITH A QUESTION

Once the middle ear is exposed, do not simply look around.

Assess systematically.

MUCOSA

Healthy, oedematous, scarred?

OSSICLES

Present, eroded, fixed, discontinuous?

MALLEUS

Position and mobility?

INCUS

Long process intact?

STAPES

Superstructure and mobility?

WINDOWS

Round and oval-window regions?

DISEASE

Granulation, tympanosclerosis, cholesteatoma?

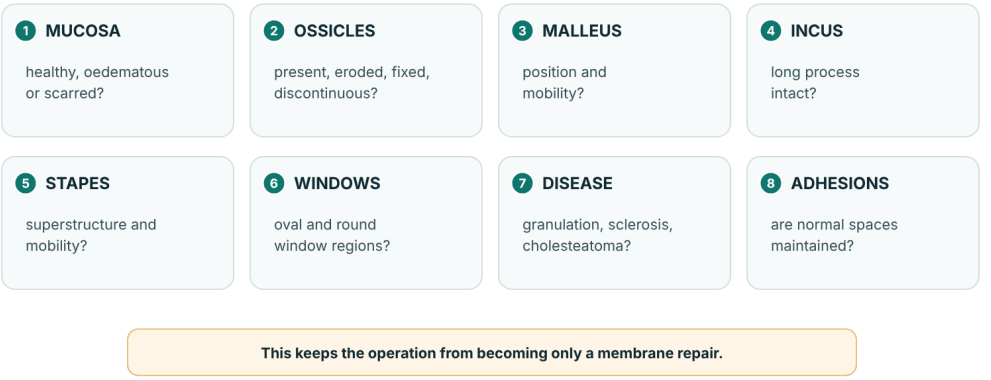
ADHESIONS

Are normal spaces maintained?

This prevents the operation from becoming only a membrane repair.

Figure 9.5 · Enter the middle ear with a question

A systematic survey before any graft or prosthesis is chosen



9.12 THE MALLEUS

The malleus provides:

- structural support
- graft relationship
- sound-conduction role

Assess:

- handle position
- mobility
- medialisation
- adhesions
- relationship to promontory

A graft placed around a severely medialised or abnormal malleus may not recreate normal membrane geometry.

9.13 THE INCUS

The long process of the incus is particularly vulnerable to chronic middle-ear disease.

Assess:

- continuity
- erosion
- mobility
- incudostapedial relationship

A small area of erosion can create a large conductive deficit.

Do not assume ossicular continuity from the presence of an apparently intact tympanic membrane remnant.

9.14 THE STAPES

Determine:

- superstructure present?
- mobile?
- footplate mobile?
- surrounded by disease?

The status of the stapes strongly influences ossicular reconstruction.

PRINCIPLE

Before reconstructing the chain, know what the final mobile structure is.

9.15 TYMPANOSCLEROSIS

Tympanosclerosis may involve:

- tympanic membrane
- ossicles
- ligaments
- middle-ear mucosa

The clinical significance depends upon whether it impairs:

- membrane mobility
- ossicular mobility
- stapes movement

Do not remove plaque merely because it is visible.

Remove or modify only when it contributes to the surgical problem and can be addressed safely.

9.16 ADHESIVE MIDDLE EAR

Adhesions may tether:

- membrane
- ossicles
- promontory
- middle-ear structures

The objective is not simply to separate every adhesion.

Ask:

Which adhesion is causing functional or disease-related consequence?

Excessive manipulation may create more mucosal trauma and subsequent scarring.

9.17 DISEASE CLEARANCE BEFORE RECONSTRUCTION

If middle-ear disease is present:

REMOVE / CONTROL DISEASE FIRST.

Then reconstruct.

A beautiful ossiculoplasty performed in an unsafe diseased ear is not a successful tympanoplasty.

PRIORITY

Safe ear → stable membrane → hearing reconstruction

although individual circumstances may modify sequencing.

9.18 GRAFT SELECTION

Common options include:

TEMPORALIS FASCIA

Thin, flexible and widely used.

PERICHONDRIUM

Useful in selected situations.

CARTILAGE

Provides structural support.

CARTILAGE–PERICHONDRIUM COMPOSITE

May combine support and biological coverage.

The graft should match the mechanical environment.

9.19 WHEN CARTILAGE HELPS

Cartilage may be particularly useful when the reconstructed membrane requires resistance to:

- retraction
- negative middle-ear pressure
- recurrent collapse

Potential settings include selected:

- subtotal perforations

- revision surgery
- adhesive or atelectatic ears
- retraction-prone anatomy

But increased stiffness should be balanced against acoustic requirements.

The correct thickness and configuration matter.

Experimental work suggests that cartilage thinned to about 0.5 mm is a reasonable compromise between mechanical stability and acoustic transfer.

Figure 9.6 · Match the graft to the mechanical environment

Stiffness resists retraction; thinness and compliance favour sound transfer



more compliant — better acoustic transfer

stiffer — better resistance to retraction

Temporalis fascia	Perichondrium	Cartilage–perichondrium	Cartilage
Thin, flexible, widely used	Similar handling; tragal or conchal	Island: support plus biological cover	Plate or palisade; most support
CONSIDER FOR	CONSIDER FOR	CONSIDER FOR	CONSIDER FOR
Primary perforations Healthy ventilation Stable remnant	As for fascia Harvest with cartilage Fascia unavailable	Posterosuperior retraction High-risk perforation	Atelectasis, adhesion Subtotal, revision Cholesteatoma

Cartilage thinned to about 0.5 mm balances stability against acoustic loss.

9.20 UNDERLAY

In underlay reconstruction, graft material lies medial to the membrane remnant and, depending on technique, medial to the annulus.

Important considerations include:

- anterior support
- malleus relationship
- graft stability
- prevention of medialisation

A technically simple method still requires geometric control.

9.21 OVERLAY

Overlay techniques may provide advantages in selected:

- large
- anterior
- subtotal

defects.

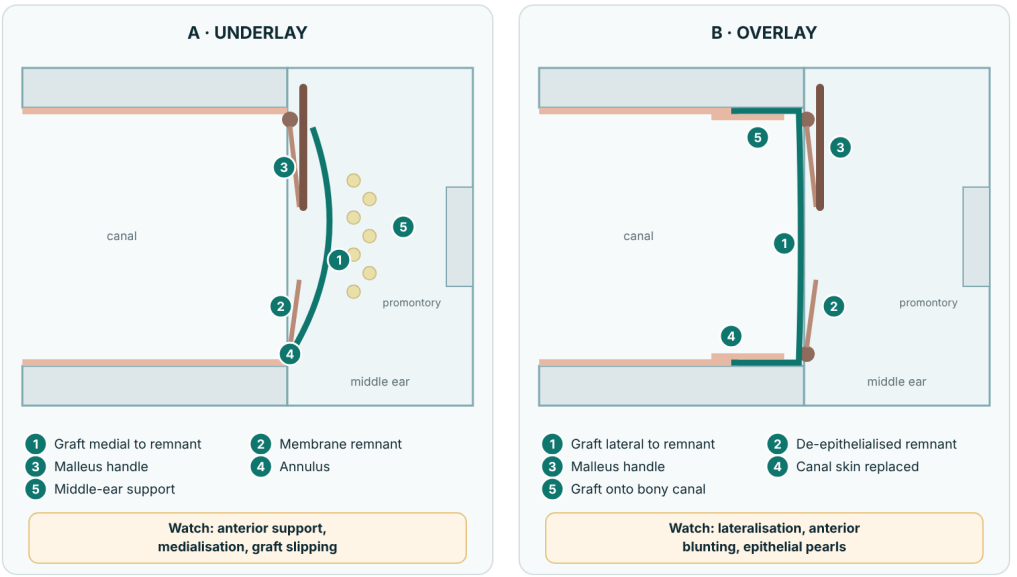
But risks include:

- lateralisation
- anterior blunting
- epithelial inclusion

Meticulous epithelial handling and graft positioning are essential.

Figure 9.7 · Underlay and overlay grafting

Schematic coronal section of the medial canal and middle ear — lateral to the left, not to scale



9.22 MALLEUS RELATIONSHIP

The graft may be positioned relative to the malleus according to the chosen technique.

The objective is:

- stable support
- appropriate membrane contour
- effective sound transmission

Avoid creating:

- excessive lateralisation
- excessive medialisation
- unnatural tenting

9.23 ANTERIOR SUPPORT

Anterior failure is a common technical challenge.

Possible contributors include:

- inadequate exposure
- limited recipient bed
- graft displacement
- poor support
- anterior canal-wall anatomy

If the anterior edge cannot be seen, the surgeon cannot reliably know what the graft is doing there.

> **PRINCIPLE**
> **Visibility is part of graft stability.**

9.24 OSSICULAR RECONSTRUCTION

When ossicular discontinuity exists, reconstruction may be performed during tympanoplasty where appropriate.

The exact technique depends upon:

MALLEUS STATUS

INCUS STATUS

STAPES SUPERSTRUCTURE

FOOTPLATE MOBILITY

MIDDLE-EAR SPACE

Detailed ossiculoplasty principles are discussed in Chapter 10, Ossicular Reconstruction.

9.25 MIDDLE-EAR SPACE

A reconstructed sound-conduction system requires space to move.

Avoid creating a reconstruction that is:

- compressed
- fixed against surrounding bone
- excessively long
- excessively short

The membrane and ossicular reconstruction should function as a mechanical system.

9.26 GRAFT POSITION BEFORE CLOSURE

Before replacing the flap, confirm:

ANTERIOR EDGE

Supported?

POSTERIOR EDGE

Stable?

MALLEUS

Correct relationship?

MIDDLE EAR

No unwanted packing or obstruction?

GRAFT

Flat and appropriately tensioned?

Then replace the tympanomeatal flap without disturbing the reconstruction.

9.27 PACKING

Packing may support:

- graft
- tympanomeatal flap
- canal skin

Use the minimum amount required to maintain stability.

Overpacking may distort the reconstruction.

The goal is support—not compression.

9.28 ENDOSCOPIC ASSISTANCE

An endoscope may help inspect areas that are difficult to visualise microscopically, such as selected:

- anterior recesses
- epitympanic regions
- retrotympanic spaces

This may complement microscopic tympanoplasty.

But additional instrumentation is justified only when the inspection can change management.

9.29 POSTOPERATIVE ASSESSMENT

Evaluate:

ANATOMICAL OUTCOME

- graft integrity
- position
- retraction
- infection

FUNCTIONAL OUTCOME

- hearing
- air–bone gap
- patient-reported benefit

A closed membrane with poor hearing requires further explanation.

9.30 WHY DOES TYMPANOPLASTY FAIL?

Possible anatomical failure:

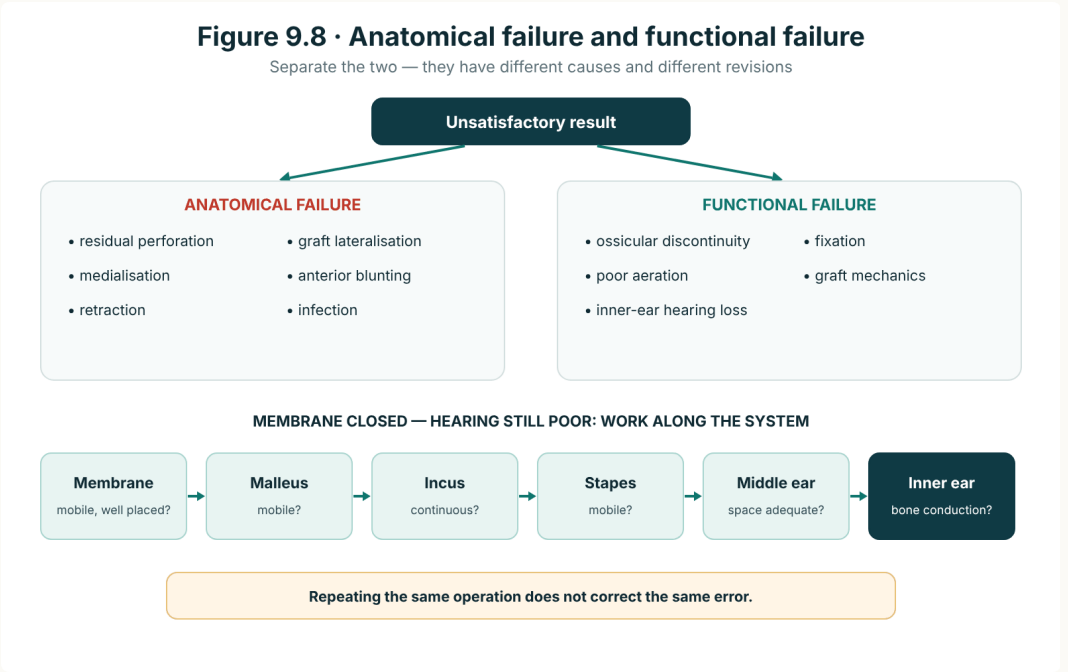
- residual perforation
- graft lateralisation
- medialisation
- anterior blunting
- retraction
- infection

Possible functional failure:

- ossicular discontinuity
- fixation
- poor middle-ear aeration
- graft mechanics
- inner-ear hearing loss

> **PRINCIPLE**
>
> **Separate anatomical failure from functional failure.**

They may have different causes.



9.31 REVISION TYMPANOPLASTY

Before revision, identify the previous failure mechanism.

Ask:

Where did the graft fail?

Is the canal adequate?

Is the malleus abnormal?

Is the ear retracting?

Is the ossicular chain intact?

Is there hidden cholesteatoma?

What graft was previously used?

Then design a different operation if the original mechanics were inadequate.

Repeating the same operation does not correct the same error.

DECISION POINT

MEMBRANE CLOSED — HEARING STILL POOR

Think systematically:

MEMBRANE
Is it mobile and appropriately positioned?

↓

MALLEUS
Mobile?

↓

INCUS
Continuous?

↓

STAPES
Mobile?

↓

MIDDLE-EAR SPACE
Adequate?

↓

INNER EAR
Bone-conduction function?

Do not assume membrane success equals middle-ear success.

FROM EXPERIENCE

Tympanoplasty teaches us to stop seeing the tympanic membrane as an isolated structure.

The membrane is one surface of a mechanical system.

Its shape matters.

Its tension matters.

Its relationship to the malleus matters.

The ossicular chain matters.

The space around the chain matters.

And the middle ear must remain biologically stable enough for the reconstruction to survive.

A graft can close a hole.

> **Tympanoplasty has to reconstruct an ear.**

TAKE IT TO THE OT

Before tympanoplasty, define:

OBJECTIVE

PERFORATION / RETRACTION

CANAL EXPOSURE

MIDDLE-EAR DISEASE

MALLEUS

INCUS

STAPES

GRAFT MATERIAL

GRAFT POSITION

OSSICULAR PLAN

ANTERIOR SUPPORT

POSTOPERATIVE HEARING GOAL

CHAPTER SUMMARY

Tympanoplasty is reconstruction of the tympanic membrane–middle-ear system.

Define the objective before selecting the technique.

Choose an approach that exposes the complete problem.

Assess the middle ear systematically.

Clear disease before reconstructing hearing.

Understand the malleus, incus and stapes individually.

Choose graft material according to the mechanical environment.

Ensure anterior support and stable graft geometry.

Assess anatomical and functional outcomes separately.

And remember:

> **Closing the membrane repairs a perforation.**

> **Reconstructing the sound-conduction system repairs the ear.**

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CHAPTER 10

Ossicular Reconstruction

Restore the Mechanical Link

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the functional mechanics of the ossicular chain
- assess the malleus, incus, stapes superstructure and footplate systematically
- define the reconstructive problem before selecting a prosthesis
- understand the principles of partial and total ossicular reconstruction
- recognise the role of autologous ossicle and cartilage
- determine appropriate prosthesis length and coupling
- create a stable reconstruction with adequate middle-ear space
- recognise common causes of displacement, extrusion and poor hearing outcome
- approach revision ossiculoplasty according to the mechanism of failure

10.1 OSSICULOPLASTY IS A MECHANICAL RECONSTRUCTION

The ossicular chain transfers acoustic energy from the tympanic membrane toward the inner ear.

When continuity or mobility is lost, reconstruction attempts to recreate an effective mechanical connection.

The objective is not simply:

put something between the tympanic membrane and stapes.

The objective is to create a connection that is:

MOBILE

STABLE

APPROPRIATELY TENSIONED

ALIGNED

BIOLOGICALLY TOLERATED
and able to remain so after healing.

10.2 DEFINE THE DEFECT FIRST

Before selecting a reconstructive technique, answer four questions.

1. MALLEUS
Present?

Mobile?

Usable?

2. INCUS
Present?

Long process intact?

Mobile?

Usable for reconstruction?

3. STAPES
Superstructure present?

Stable?

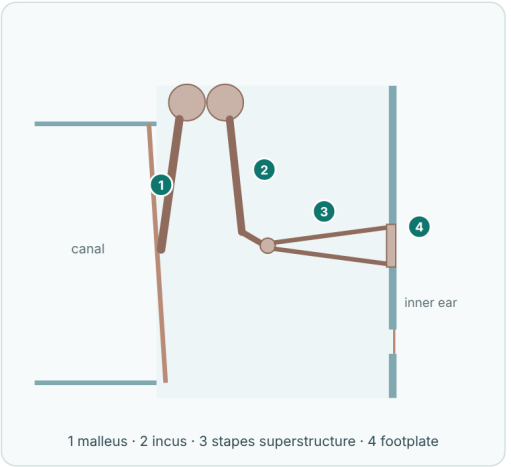
Mobile?

4. FOOTPLATE
Mobile?

These four observations determine much of the reconstructive strategy.

Figure 10.1 · Four questions before reconstruction

Schematic coronal concept of the chain — lateral to the left, not to scale



1 malleus · 2 incus · 3 stapes superstructure · 4 footplate

1 MALLEUS
present? mobile? usable?

2 INCUS
present? long process intact? mobile? usable?

3 STAPES
superstructure present? stable? mobile?

4 FOOTPLATE
mobile?

The answers decide the strategy — not the prosthesis on the tray.

10.3 DO NOT RECONSTRUCT BEFORE CLEARING DISEASE

The priority remains:

SAFE EAR FIRST.

If cholesteatoma, granulation or other significant disease remains:

- clear disease
- establish a stable middle ear
- then decide whether hearing reconstruction is appropriate at the same operation

In selected cases, staged ossicular reconstruction may be preferable.

PRINCIPLE

A prosthesis should not become the most beautiful structure in an unsafe ear.

10.4 SOUND TRANSMISSION REQUIRES MOVEMENT

An ossicular reconstruction can fail even when all components appear anatomically connected.

Why?

Because transmission depends upon movement.

The reconstruction must allow:

TYMPANIC MEMBRANE MOVEMENT

↓

COUPLING

↓

PROSTHESIS / OSSICLE MOVEMENT

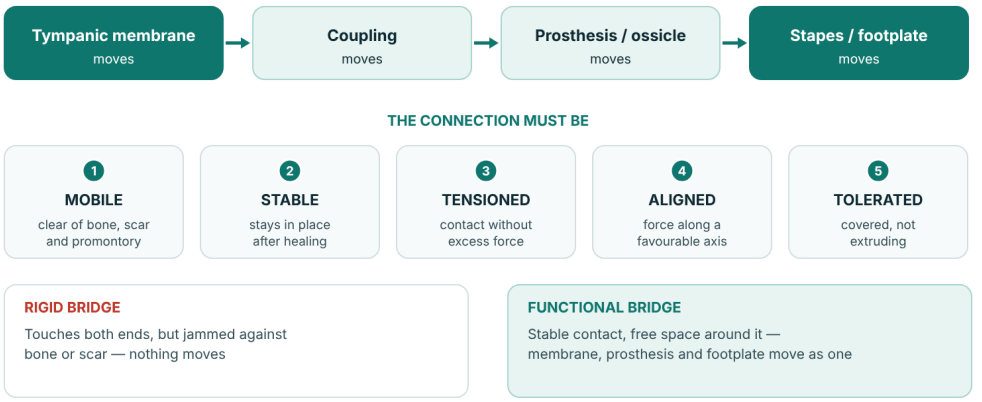
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STAPES / FOOTPLATE MOVEMENT

A rigid bridge is not necessarily a functional bridge.

Figure 10.2 · Connection is not transmission

Every element must move — and move together — after healing



10.5 THE MALLEUS

The malleus can provide:

- coupling
- stability
- alignment
- protection against prosthesis displacement

Assess:

- handle
- mobility
- medialisation
- fixation
- relationship to graft

When usable, malleus preservation may improve reconstructive stability in selected situations.

But a severely fixed or malpositioned malleus can also compromise reconstruction.

10.6 THE INCUS

The long process of the incus is commonly affected by chronic middle-ear disease.

Possible findings include:

- partial erosion
- complete long-process loss
- discontinuity
- fixation
- preserved body with absent distal connection

The remaining incus may sometimes be useful as autologous reconstructive material if healthy and appropriate.

10.7 THE STAPES SUPERSTRUCTURE

The presence of a stable mobile stapes superstructure substantially changes reconstruction.

When present, reconstruction can couple to the stapes head.

When absent, the reconstruction must reach the mobile footplate.

This creates the conceptual distinction between:

PARTIAL OSSICULAR RECONSTRUCTION (PORP)

and

TOTAL OSSICULAR RECONSTRUCTION (TORP).

The abbreviations refer to the partial and total ossicular replacement prostheses, but the same concepts apply when autologous ossicle or cartilage is used.

10.8 FOOTPLATE MOBILITY

Before reconstruction, confirm that the footplate is mobile where clinically appropriate.

A prosthesis placed onto a fixed footplate will not correct the underlying mechanical problem.

PRINCIPLE

Always understand the final mobile interface before building toward it.

10.9 PARTIAL OSSICULAR RECONSTRUCTION

When the stapes superstructure is intact and mobile, reconstruction may connect the tympanic membrane / malleus system to the stapes head.

Options may include:

- autologous ossicle
- cartilage-based techniques
- partial ossicular replacement prosthesis

The exact choice depends upon anatomy and surgeon preference.

The principle remains:

STABLE COUPLING TO A MOBILE STAPES.

10.10 TOTAL OSSICULAR RECONSTRUCTION

When the stapes superstructure is absent but the footplate remains mobile, reconstruction may connect the tympanic membrane / malleus system to the footplate.

This is mechanically more demanding because:

- the reconstruction is longer

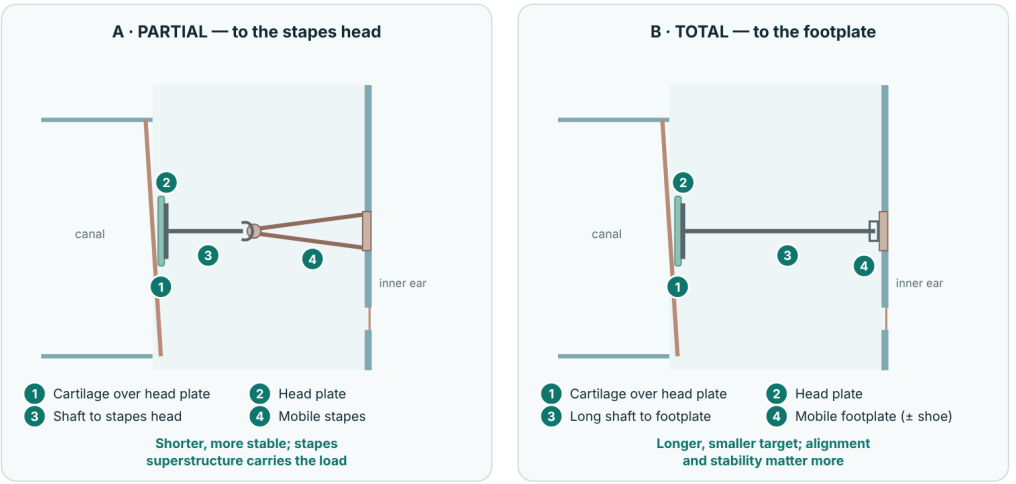
- the distal target is smaller
- stability may be reduced
- displacement risk may increase

PRINCIPLE

The longer the reconstruction, the more important alignment and stability become.

Figure 10.3 · Partial and total ossicular reconstruction

Schematic coronal concept — lateral to the left, not to scale



10.11 AUTOGENOUS INCUS

A healthy incus may be reshaped for reconstruction in selected cases.

Potential advantages include:

- autologous material
- good biological compatibility
- availability within the operative field

Limitations include:

- disease involvement
- limited geometry
- potential fixation
- resorption or displacement

Do not reuse an ossicle if its disease status is uncertain.

10.12 PROSTHETIC MATERIALS

Commercial ossicular prostheses are available in various materials and designs.

The surgeon should understand:

- material
- head-plate design
- shaft
- distal coupling
- adjustability
- manufacturer's recommended handling

The brand is less important than the mechanical principles governing placement.

10.13 LENGTH

Prosthesis length is critical.

TOO SHORT

Poor contact.

Instability.

Loss of coupling.

TOO LONG

Excessive pressure.

Tympanic-membrane lateralisation or tension.

Footplate pressure.

Poor mechanics.

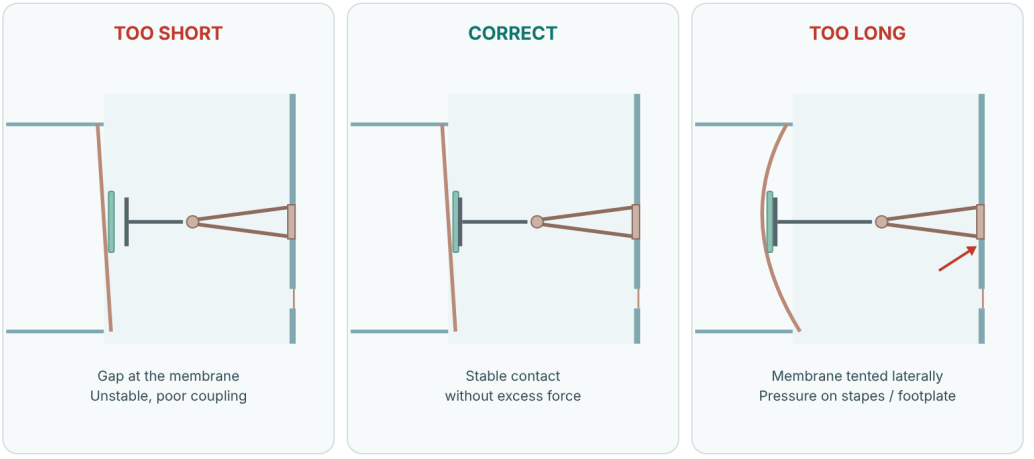
Potential inner-ear risk.

CORRECT LENGTH

Stable contact without excessive force.

Figure 10.4 · Too short, correct and too long

Schematic partial reconstruction — lateral to the left, not to scale



Judge length in the final position of the membrane and graft, not with the flap elevated.

10.14 MEASURE THE SPACE

Do not select length by visual guess alone when a more controlled assessment is available.

Consider the distance between:

TYMPANIC MEMBRANE / MALLEUS

and

STAPES HEAD / FOOTPLATE.

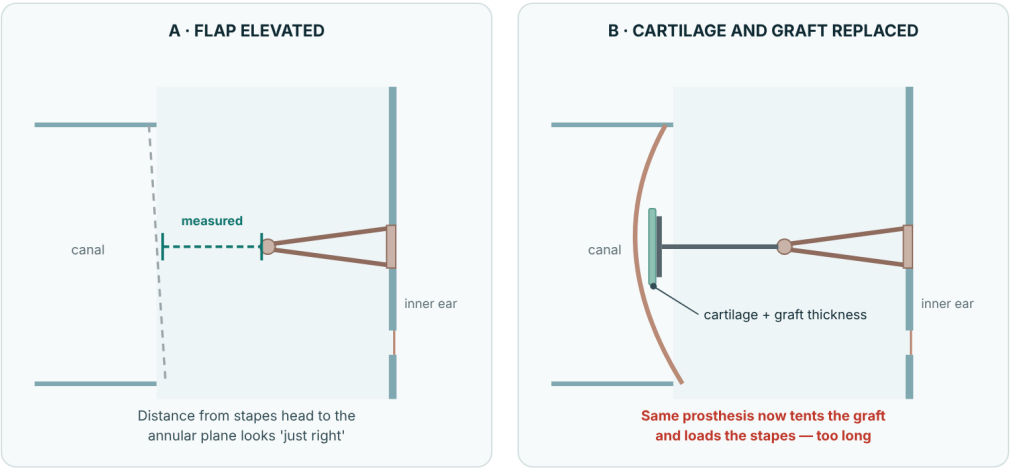
The reconstructed membrane position after closure should also be considered.

A prosthesis that fits perfectly while the tympanomeatal flap is elevated may become too long after the membrane returns to its final position.

The thickness of any cartilage placed over the head plate must be included in this calculation.

Figure 10.5 · Measure for the final geometry

Schematic — the cartilage and the replaced graft add to the length the prosthesis must span



10.15 COUPLING

A prosthesis must contact the appropriate structures securely enough to transmit movement.

Potential coupling points include:

- malleus
- tympanic membrane / graft
- stapes head
- footplate

The contact should be:

STABLE

but

NOT EXCESSIVELY COMPRESSIVE.

10.16 ALIGNMENT

Ideally, force should be transmitted along a mechanically favourable axis.

A markedly oblique reconstruction may:

- slip
- rock
- lose coupling
- transmit energy inefficiently

The surgeon should examine the prosthesis not only from above but conceptually in three dimensions.

10.17 CARTILAGE INTERPOSITION

Cartilage is commonly used between prosthetic material and tympanic membrane in selected techniques.

Potential purposes include:

- distributing pressure
- reducing extrusion risk
- providing structural support

But excessive cartilage thickness or size can affect membrane mechanics.

Use enough to protect and stabilise.

Not enough to immobilise.

10.18 MIDDLE-EAR SPACE

The prosthesis needs space to move.

A reconstruction may fail if it contacts:

- promontory
- canal wall
- facial nerve region
- surrounding scar
- graft in an unfavourable way

Before closure, ask:

DOES THE PROSTHESIS HAVE ROOM TO FUNCTION?

10.19 VENTILATION MATTERS

A technically ideal ossiculoplasty can deteriorate if the middle ear later develops:

- negative pressure
- retraction
- atelectasis
- adhesions

This can:

- tilt the prosthesis
- displace it
- compress it
- change membrane coupling

Therefore the long-term result depends upon both:

RECONSTRUCTION
and

MIDDLE-EAR BIOLOGY.

10.20 STABILITY TEST

Before replacing the tympanomeatal flap:

- gently assess prosthesis position
- confirm distal coupling
- ensure it does not fall with minor movement
- verify that surrounding tissue is not forcing it out of alignment

Do not over-manipulate the reconstruction simply to prove that it is stable.

10.21 REPLACE THE MEMBRANE CAREFULLY

The final position of the tympanic membrane can change prosthesis geometry.

After replacing the flap:

REASSESS.

Has the prosthesis:

- tilted?
- shortened functionally?
- become over-compressed?
- moved off the stapes?

The operation should be judged in its final geometry—not only while the middle ear is open.

10.22 PACKING

Packing should support the tympanic membrane reconstruction without transmitting excessive pressure to the ossicular reconstruction.

The prosthesis should remain stable because of its geometry.

Not because it is being held forcibly in position by packing.

10.23 ONE-STAGE OR STAGED OSSICULOPLASTY

Staging may be considered when:

- extensive cholesteatoma is present
- middle-ear mucosa is poor
- residual disease risk is significant
- anatomy is unstable
- reconstruction would be unreliable

The decision depends upon disease, surgical strategy and follow-up.

PRINCIPLE

Do not reconstruct hearing simply because the middle ear is already open.

Reconstruct when the ear is ready to support the reconstruction.

10.24 HEARING OUTCOME

Postoperative hearing depends upon:

- preoperative cochlear reserve
- presence of the malleus handle
- presence of the stapes superstructure
- mucosal status and previous surgery
- membrane mechanics
- prosthesis coupling
- footplate mobility
- middle-ear aeration
- scar
- prosthesis position

Therefore poor hearing does not automatically mean the prosthesis is "wrong."

The entire mechanical system should be reassessed.

10.25 EXTRUSION

Potential contributors include:

- poor soft-tissue coverage
- chronic inflammation
- membrane retraction
- prosthesis pressure
- infection

Cartilage interposition and stable middle-ear conditions may reduce risk in selected settings.

An extruding prosthesis is often a sign of a larger mechanical or biological problem.

10.26 DISPLACEMENT

A prosthesis may displace because of:

- incorrect length
- unstable coupling

- middle-ear pressure change
- trauma
- scar contraction
- membrane retraction

Revision should determine the mechanism.

Do not simply put the same prosthesis back in the same position.

10.27 FIXATION

A reconstruction can become fixed by:

- scar
- bone contact
- adhesions
- tympanosclerosis

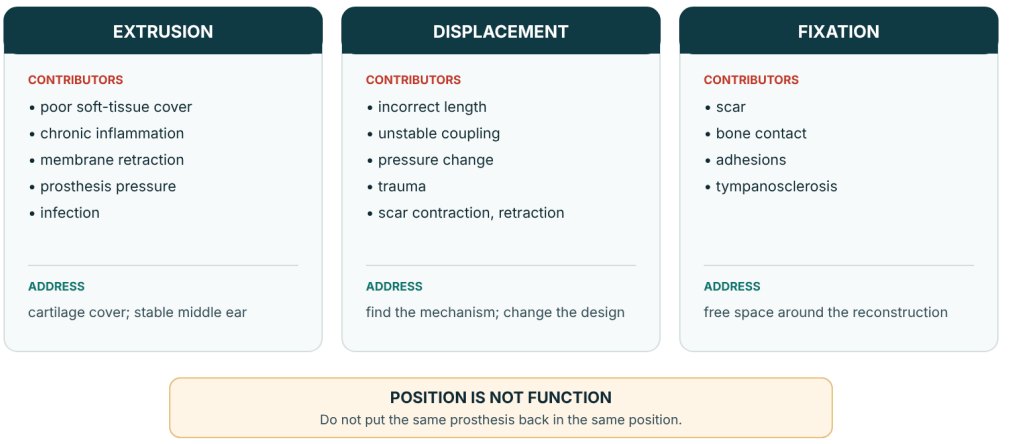
A prosthesis that remains perfectly positioned but cannot move is anatomically successful and functionally unsuccessful.

PRINCIPLE

Position is not function.

Figure 10.6 · Extrusion, displacement and fixation

Three late failures — each usually points to a larger mechanical or biological problem



10.28 REVISION OSSICULOPLASTY

Before revision, evaluate:

MEMBRANE

Intact? Retracted? Lateralised?

MIDDLE EAR

Aerated? Scarred?

PROSTHESIS

Present? Displaced? Extruded? Fixed?

STAPES / FOOTPLATE

Mobile?

HEARING

What does the audiogram suggest?

Then determine why the previous mechanical system failed.

DECISION POINT

WHAT SHOULD I RECONSTRUCT TO?

STAPES SUPERSTRUCTURE PRESENT + MOBILE

→ Partial reconstruction concept.

STAPES SUPERSTRUCTURE ABSENT + MOBILE FOOTPLATE

→ Total reconstruction concept.

FOOTPLATE FIXED

→ Do not assume routine ossiculoplasty solves the problem.

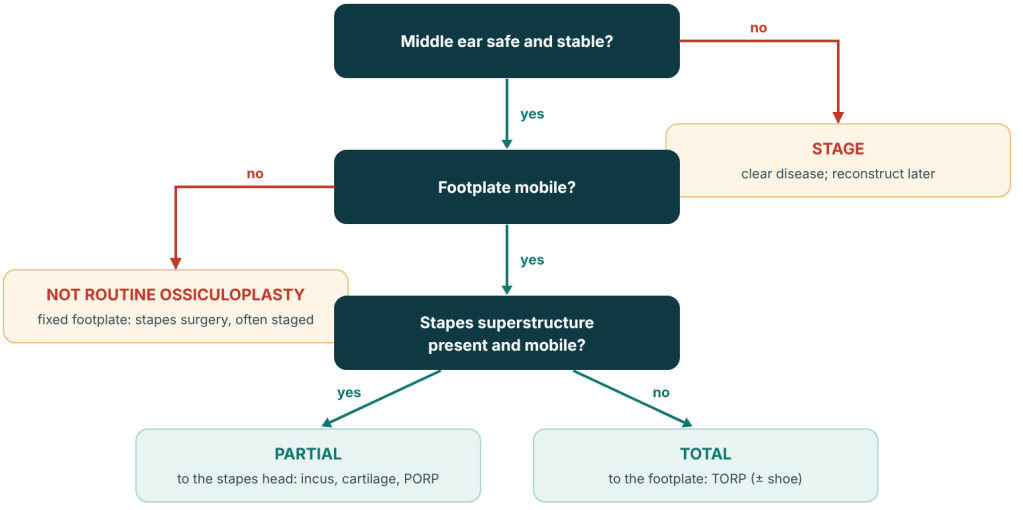
MIDDLE EAR UNSAFE / UNSTABLE

→ Consider whether reconstruction should be staged.

The operation begins with anatomy—not with the prosthesis tray.

Figure 10.7 · What should I reconstruct to?

Decide from the anatomy — the final mobile structure sets the target



Malleus handle present? Use it for stability and alignment — it is a favourable prognostic factor.

FROM EXPERIENCE

Ossiculoplasty can look deceptively simple.

A prosthesis fits.

The membrane closes.

Everything appears aligned.

Yet hearing may remain poor.

Why?

Because the reconstruction is not a photograph.

It is a moving system.

The membrane must move.

The prosthesis must move.

The stapes or footplate must move.

And they must move together.

> **The objective is not contact.**
>
> **IT IS TRANSMISSION.**

TAKE IT TO THE OT

Before ossicular reconstruction, define:

MALLEUS
Present and mobile?

INCUS
Usable?

STAPES SUPERSTRUCTURE
Present?

FOOTPLATE
Mobile?

MIDDLE-EAR SPACE
Adequate?

DISEASE
Completely controlled?

MATERIAL
Autologous or prosthetic?

LENGTH
Correct?

COUPLING
Stable?

CARTILAGE
Required?

FINAL MEMBRANE POSITION
Does it alter prosthesis geometry?

STAGE
Is this ear ready for hearing reconstruction today?

CHAPTER SUMMARY

Ossiculoplasty is mechanical reconstruction of sound transmission.

Define the defect before selecting the device.

Clear disease first.

Know the status of malleus, incus, stapes and footplate.

Choose partial or total reconstruction according to the final mobile structure.

Measure length carefully.

Create stable coupling without excessive pressure.

Preserve enough middle-ear space for movement.

Understand that ventilation and healing can change postoperative geometry.

When hearing remains poor, evaluate the entire mechanical system.

And remember:

> **A prosthesis that touches both ends is not necessarily working.**

> **The goal is not connection. The goal is movement.**

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CHAPTER 11

Cortical Mastoidectomy

Opening the Temporal Bone Through Landmarks

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the objectives and indications of cortical mastoidectomy
- plan the operation using preoperative temporal-bone imaging
- identify surface and deep surgical landmarks
- define the superior, posterior, anterior and inferior boundaries of mastoid drilling
- perform progressive saucerisation rather than narrow cavity drilling
- identify the mastoid antrum, lateral semicircular canal and incus region
- understand the relationships of tegmen, sigmoid sinus, posterior canal wall and digastric ridge
- recognise common directional errors during drilling
- respond appropriately when expected anatomy does not appear

11.1 CORTICAL MASTOIDECTOMY IS AN ANATOMY OPERATION

At first, mastoidectomy can appear to be an operation in which bone is removed until the mastoid air-cell system is opened.

That description misses its purpose.

The surgeon is progressively revealing a set of anatomical boundaries:

TEGMEN

SIGMOID SINUS

POSTERIOR CANAL WALL

ANTRUM

LATERAL SEMICIRCULAR CANAL

DIGASTRIC RIDGE

These landmarks transform an initially featureless block of bone into an oriented surgical field.

PRINCIPLE

Do not drill a hole into the mastoid.

> **Open the mastoid until its anatomy becomes understandable.**

11.2 OBJECTIVES

Depending upon the clinical situation, cortical mastoidectomy may be performed to:

- access mastoid disease
- establish drainage
- provide access to the middle ear
- form part of cholesteatoma surgery
- provide access for cochlear implantation
- expose the facial recess
- support facial nerve surgery
- provide a route toward deeper temporal-bone anatomy

The extent of drilling should match the objective.

A cortical mastoidectomy for one indication does not necessarily require exactly the same exposure as another.

11.3 BEFORE THE OPERATION — READ THE CT

Before drilling, identify:

PNEUMATISATION
Well pneumatised or sclerotic?

TEGMEN
High or low?

SIGMOID SINUS
Posterior or anterior?

POSTERIOR CANAL WALL
Relationship to the mastoid corridor.

ANTRUM
Expected depth and position.

LATERAL SEMICIRCULAR CANAL
Integrity and disease relationship.

FACIAL NERVE
Expected course.

JUGULAR BULB
Height and variation.

DISEASE
What has been altered or eroded?

The CT should allow the surgeon to predict the shape of the mastoid before the incision is made.

11.4 POSITIONING

Position should provide:

- comfortable access to the operative ear
- stable head position
- room for microscope movement
- appropriate drill ergonomics
- anaesthetic access

The surgeon should be able to work without repeatedly twisting the wrist, shoulder or neck.

PRINCIPLE

Position the patient so the drill can follow the anatomy naturally.

11.5 POSTAURICULAR EXPOSURE

A postauricular approach commonly provides broad access to the mastoid cortex.

The incision and flap should expose enough bone to identify:

- temporal line / zygomatic-root region
- external auditory canal
- mastoid tip
- posterior mastoid cortex

Do not begin drilling through a narrow soft-tissue window.

Expose the bone required for the intended mastoidectomy.

11.6 SURFACE LANDMARKS

Important landmarks include:

EXTERNAL AUDITORY CANAL

Provides anterior orientation.

TEMPORAL LINE / ZYGOMATIC ROOT

Approximates the level of the middle cranial fossa floor; contributes superior orientation.

MASTOID TIP

Inferior orientation.

SUPRAMEATAL (MACEWEN'S) TRIANGLE AND SPINE OF HENLE

Provide a surface guide toward the antral region, which lies deep to the triangle.

Surface landmarks initiate the operation.

Deep landmarks confirm it.

11.7 DRAW THE MASTOID BEFORE DRILLING

Mentally—or during training, literally—define:

SUPERIOR

Expected tegmen.

POSTERIOR

Expected sigmoid sinus.

ANTERIOR

Posterior canal wall.

INFERIOR

Mastoid tip / digastric region.

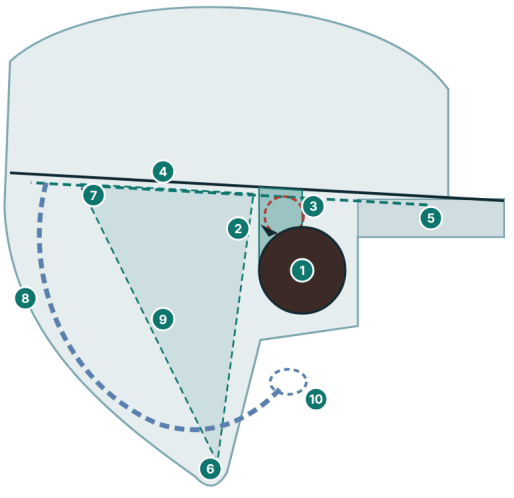
DEEP

Antrum and lateral semicircular canal.

This creates a three-dimensional box within which the early drilling occurs.

Figure 11.1 · The mastoid cortex with its deep boundaries projected

Right temporal bone, lateral (surgical) view — superior up, anterior to the right · schematic



1. External auditory canal
2. Spine of Henle
3. Suprameatal triangle — antrum deep to it
4. Temporal line (supramastoid crest)
5. Zygomatic root
6. Mastoid tip
7. Tegmen (projected)
8. Sigmoid sinus (projected)
9. Initial drilling area
10. Jugular bulb (projected)

THE FIRST BOX

Superior — temporal line ≈ tegmen
Anterior — posterior canal wall
Posterior — sigmoid sinus
Inferior — mastoid tip
Deep — antrum, lateral canal

dashed = deep structure projected onto the surface

11.8 BEGIN BROAD

Early drilling should generally create a broad exposure rather than a narrow deep tunnel.

Why?

A narrow tunnel:

- restricts visualisation
- limits drill movement
- obscures boundaries
- encourages premature depth

A broadly saucerised cavity:

- exposes orientation
- allows safe instrument movement
- progressively reveals landmarks

> **PRINCIPLE**
> **Width before depth.**

11.9 SAUCERISATION

Saucerisation means progressively widening the mastoid cavity so that deeper anatomy remains visible from the surface.

Conceptually:

WIDE LATERAL OPENING

↓

PROGRESSIVE DEEPENING

↓

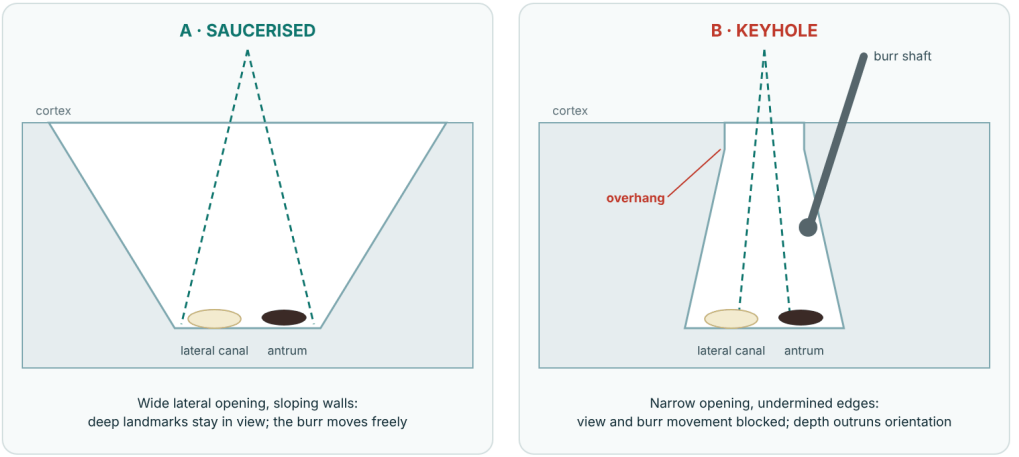
SMOOTH TRANSITION

↓

DEEP LANDMARKS REMAIN VISIBLE

Figure 11.2 · Saucer versus keyhole

Schematic section through the mastoid — the same depth, very different views



The surgeon should not need to look through a bony keyhole created unnecessarily by the drilling technique.

11.10 THE FIRST BONE REMOVAL

In a pneumatised mastoid, superficial air cells may appear early.

In a sclerotic mastoid, the surgeon may encounter continuous dense bone.

Do not allow the absence of air cells to change the anatomical direction.

AIR CELLS VARY.

LANDMARK RELATIONSHIPS REMAIN THE GUIDE.

11.11 DEFINE THE SUPERIOR BOUNDARY

Progressively identify the tegmen region.

The objective is not necessarily to skeletonise dura.

It is to understand where the superior boundary lies.

A low tegmen should already have been anticipated from CT.

As the roof approaches:

- reduce pressure
- improve visualisation
- avoid uncontrolled superior drilling

11.12 DEFINE THE POSTERIOR BOUNDARY

The sigmoid sinus forms the major posterior boundary.

Its position should be anticipated from imaging.

The surgeon may identify the change in bone and progressively define the sigmoid plate according to the requirements of the operation.

Again:

> **IDENTIFY ≠ EXPOSE COMPLETELY.**

Skeletonise only what the procedure requires.

11.13 KEEP THE POSTERIOR CANAL WALL IN VIEW

The posterior canal wall provides anterior orientation.

During cortical mastoidectomy, its relationship to the deep cavity helps guide the surgeon toward:

- antrum
- facial recess region
- middle-ear relationships

Unnecessary violation of the canal wall changes the operation.

Know where it is throughout drilling.

11.14 THE ANTRUM

The mastoid antrum is a key early deep target.

Its expected location is predicted by:

- surface landmarks
- CT

- tegmen
- posterior canal wall
- depth of mastoid pneumatisation

In the adult it typically lies about 12–15 mm deep to the suprameatal triangle, although pneumatisation and age change this depth.

The antrum should be approached through progressive anatomical drilling rather than by creating a blind narrow tunnel toward where it is expected.

11.15 FINDING THE ANTRUM

As the antral region is entered, deeper landmarks begin to appear.

Important structures include:

LATERAL SEMICIRCULAR CANAL

INCUS / SHORT-PROCESS REGION

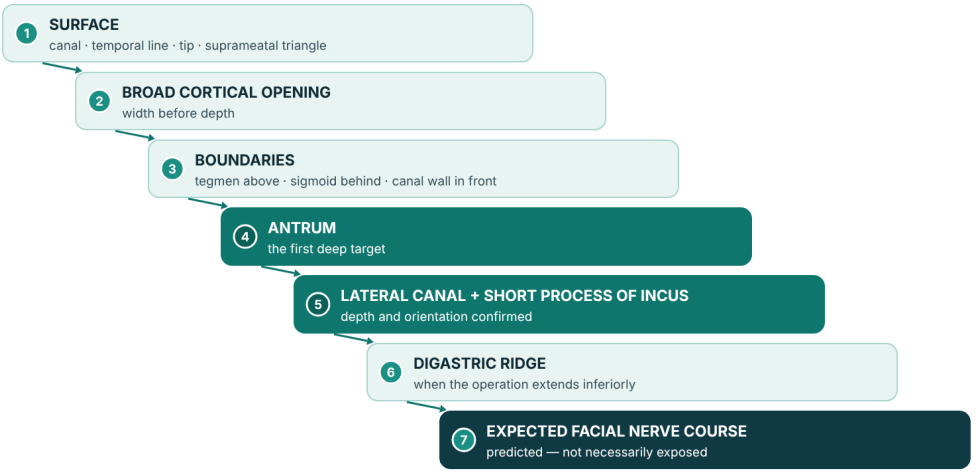
These provide confirmation that the surgeon has reached the expected depth and orientation.

PRINCIPLE

The antrum is useful because of what it reveals next.

Figure 11.3 · From surface to deep landmarks

Each landmark predicts the next — advance from known to unknown



11.16 LATERAL SEMICIRCULAR CANAL

The lateral semicircular canal is one of the most important deep mastoid landmarks.

Once identified, it helps orient:

- labyrinth
- facial nerve
- facial recess
- middle-ear depth

The canal should be identified confidently but not unnecessarily skeletonised.

CAUTION

When disease overlies the canal, consider the possibility of fistula before aggressive removal (see Chapter 14, Cholesteatoma).

11.17 THE INCUS

The incus region provides another important orientation point.

The short process / body helps relate:

- antrum
- epitympanum
- facial recess
- facial nerve

Avoid unnecessary contact with the ossicular chain.

PRINCIPLE

A landmark does not need to be manipulated to be useful.

11.18 THE MASTOID TIP

Inferior mastoid cells may extend into the mastoid tip.

The extent of tip-cell removal depends upon:

- disease

- procedure
- required exposure

The surgeon should understand the relationship of the tip to:

- digastric ridge
- facial nerve
- soft-tissue attachments

11.19 DIGASTRIC RIDGE

The digastric ridge becomes an important inferior landmark.

It helps predict:

- mastoid segment of facial nerve
- stylomastoid region

As the operation extends inferiorly, the ridge provides another point in the landmark network.

11.20 THE FACIAL NERVE IS PRESENT EVEN WHEN YOU CANNOT SEE IT

Routine cortical mastoidectomy does not require exposing the facial nerve simply to prove its location.

But the surgeon should continuously know where it is expected.

Use:

LATERAL SEMICIRCULAR CANAL

+

INCUS REGION

+

POSTERIOR CANAL WALL

+

DIGASTRIC RIDGE

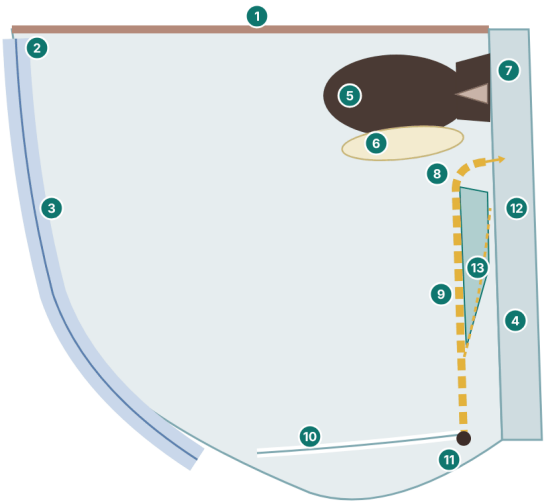
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EXPECTED FACIAL NERVE COURSE

The second genu lies just inferior to the lateral semicircular canal and medial to the short process of the incus; the mastoid segment then descends, roughly parallel to the posterior canal wall, toward the anterior end of the digastric ridge and the stylomastoid foramen.

Figure 11.4 · Predicting the facial nerve in the mastoid

Right ear, lateral surgical view after cortical mastoidectomy — superior up, anterior to the right · schematic



1. Tegmen (middle fossa plate)
2. Sinodural angle
3. Sigmoid sinus plate
4. Posterior canal wall
5. Antrum
6. Lateral semicircular canal
7. Short process of incus
8. Facial nerve — second genu
9. Facial nerve — mastoid segment
10. Digastric ridge
11. Stylomastoid foramen region
12. Chorda tympani
13. Facial recess

THE NERVE IS PREDICTED

Genu: below the lateral canal, medial to the short process
Mastoid segment: parallel to the canal wall, toward the anterior digastric ridge

facial nerve, predicted course (not exposed) · arrow: tympanic segment continues anteriorly

PRINCIPLE

Predict the nerve before seeing the nerve.

11.21 DRILLING DIRECTION

Drill movement should be controlled and directed away from critical anatomy whenever possible.

Consider the burr trajectory relative to:

- facial nerve
- labyrinth
- dura
- sigmoid sinus
- canal wall

The surgeon should know not only:

Where is my burr?

but:

> **Where will it go if it moves farther than intended?**

11.22 CUTTING TO DIAMOND

Efficient early bone removal may be performed with an appropriate cutting burr where safe.

As critical structures approach, many surgeons transition toward finer or diamond drilling according to the anatomy and task.

The conceptual progression is:

EFFICIENCY

when far from critical anatomy

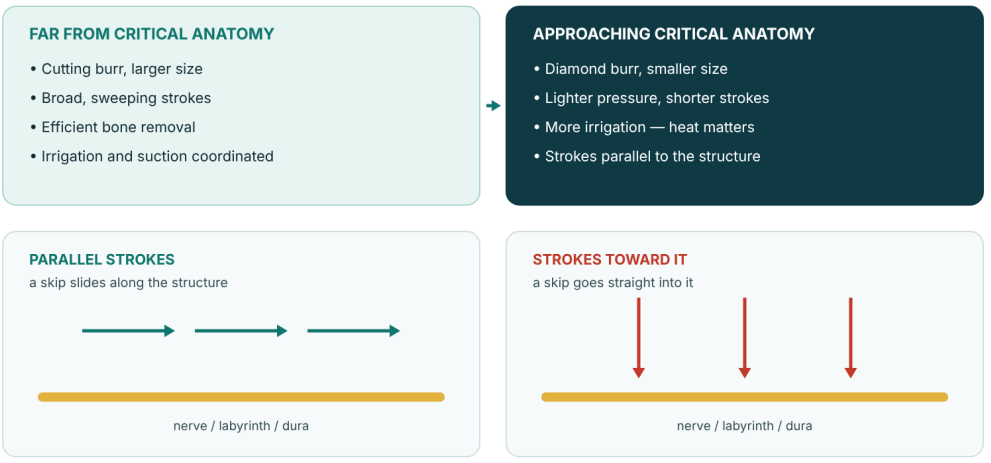
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CONTROL

as risk increases.

Figure 11.5 · Burr choice and stroke direction

Efficiency far from critical anatomy; control as risk increases



Ask continuously: where will the burr go if it moves farther than intended?

11.23 IRRIGATION

Maintain appropriate irrigation to:

- reduce heat
- clear bone dust
- improve visibility

This becomes particularly important near:

- facial nerve
- labyrinth
- dura

The suction and irrigation should be coordinated rather than competing for the operative field.

11.24 THE SCLEROTIC MASTOID

In a sclerotic mastoid:

- air-cell pathways may be absent
- drilling may be slower
- landmarks may appear less naturally
- heat generation may increase

The solution is not deeper blind drilling.

Instead rely more heavily upon:

- CT
- surface boundaries
- progressive saucerisation
- fixed landmarks
- controlled depth

PRINCIPLE

When air cells disappear, anatomy becomes more important—not less.

11.25 THE ANTERIOR SIGMOID SINUS

An anteriorly positioned sigmoid sinus can narrow the mastoid corridor.

If this was identified on CT, it should not be surprising intraoperatively.

The surgeon may need to adapt:

- cavity geometry
- drill angle
- exposure

Do not force an average-sized mastoidectomy into a patient with non-average anatomy.

11.26 LOW TEGMEN

A low tegmen reduces superior working space.

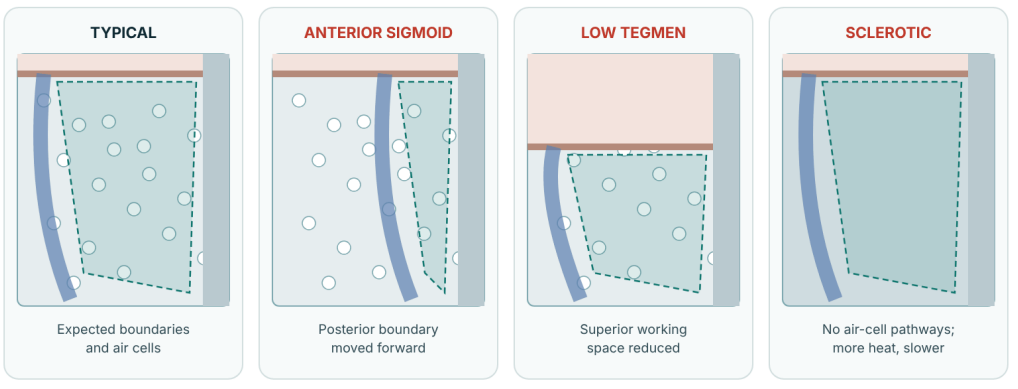
The operation should become:

- more deliberate
- more dependent upon lateral-to-medial orientation
- less tolerant of uncontrolled superior drilling

Again, CT predicts the problem.

Figure 11.6 · When the mastoid is not average

Simplified lateral views of a right mastoid, anterior to the right — the dashed area is the working corridor



Predict it on CT; adapt the cavity and drill angle — do not force an average mastoidectomy.

11.27 BLEEDING DURING MASTOIDECTOMY

Potential sources include:

- soft tissue
- emissary vessels
- bone
- sigmoid sinus or other venous structures

When unexpected bleeding occurs:

STOP DRILLING.
Clear the field.

Identify the source.

Then control appropriately.

Do not continue drilling through unexplained bleeding.

11.28 DURAL EXPOSURE

Small planned or incidental dural exposure without violation may be manageable depending upon the clinical situation.

If dura is injured:

- stop
- define the defect
- assess CSF leak
- manage according to size, site and procedure

The key distinction is:

EXPOSED DURA
versus

VIOLATED DURA.

11.29 SIGMOID SINUS EXPOSURE

A thin bony plate may remain over the sigmoid sinus or the sinus may become exposed depending upon the operation.

If venous bleeding occurs:

- maintain control
- avoid enlarging the injury
- use appropriate pressure/haemostatic technique
- reassess the need for further drilling in that area

The sinus should not be pursued merely to create a textbook-looking cavity.

11.30 LABYRINTHINE INJURY

Unintended injury to the labyrinth can produce significant hearing and vestibular consequences.

Prevention depends upon:

- knowing the expected lateral canal location
- recognising disease-related erosion
- reducing force as the canal approaches
- avoiding blind deep drilling

The best management is prevention through orientation.

11.31 HOW MUCH MASTOIDECTOMY IS ENOUGH?

The answer depends upon the objective.

For one operation, adequate exposure of the antrum and landmarks may be sufficient.

For another, complete disease clearance requires much wider cell removal.

Therefore:

DO NOT DEFINE COMPLETENESS BY CAVITY SIZE.

Define it by whether the surgical objective has been achieved safely.

11.32 THE FINAL CAVITY

Before completing mastoid work, inspect systematically:

TEGMEN

SINODURAL REGION

SIGMOID REGION

POSTERIOR CANAL WALL

ANTRUM

LATERAL CANAL

TIP CELLS AS RELEVANT

DISEASE-BEARING CELLS

The cavity should make anatomical sense.

DECISION POINT

I CANNOT FIND THE ANTRUM

Do not simply drill deeper.

Ask:

Am I too posterior?

Too inferior?

Is the tegmen lower than expected?

Is the mastoid sclerotic?

Where is the posterior canal wall?

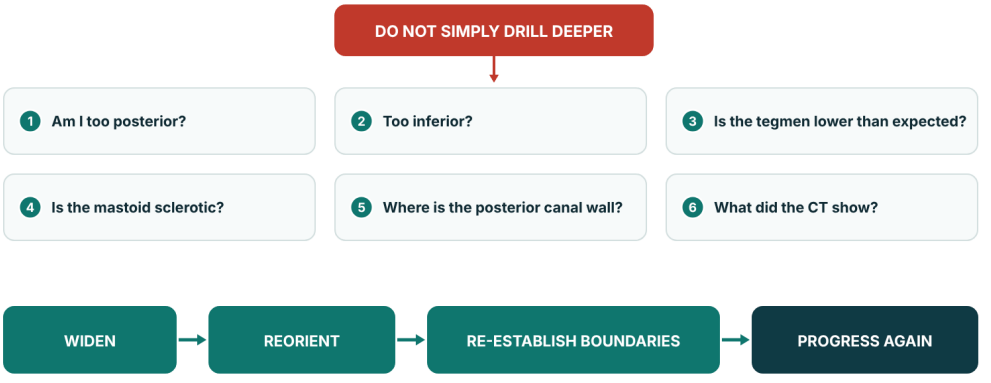
What did the CT show?

Then:

WIDEN → REORIENT → RE-ESTABLISH BOUNDARIES → PROGRESS AGAIN.

Figure 11.7 · I cannot find the antrum

Stop deepening — question the orientation, then widen and re-establish the boundaries



Return to the posterior canal wall and the tegmen; the antrum lies deep to the suprameatal triangle.

FROM EXPERIENCE

Early mastoid drilling can feel like searching for landmarks inside bone.

With experience, the process reverses.

The surgeon begins with the expected landmarks already mapped mentally.

The tegmen should be there.

The sigmoid should be there.

The canal wall defines this side.

The antrum should appear at this depth.

The lateral canal should follow.

The surgeon is no longer asking the bone:

Where is the anatomy?

The surgeon is progressively uncovering anatomy whose relationships were already anticipated.

That is the difference between:

drilling until something appears

and

anatomical drilling.

TAKE IT TO THE OT

Before cortical mastoidectomy, identify:

CT

Pneumatisation
Tegmen
Sigmoid
Jugular bulb
Facial nerve
Labyrinth
Disease

SURFACE

Canal
Temporal line
Mastoid tip
Suprameatal region

BOUNDARIES

Superior — Tegmen
Posterior — Sigmoid
Anterior — Canal wall
Inferior — Tip / digastric region

DEEP LANDMARKS

Antrum
Lateral semicircular canal
Incus

Then ask continuously:

WHAT SHOULD APPEAR NEXT?

CHAPTER SUMMARY

Cortical mastoidectomy is not the creation of a cavity.

It is the progressive exposure of temporal-bone anatomy.

Read the CT before drilling.

Begin broad.

Saucerise rather than tunnel.

Define superior, posterior, anterior and inferior boundaries.

Use the antrum to reach deeper landmarks.

Use the lateral semicircular canal and incus to orient the facial nerve.

Reduce force as critical anatomy approaches.

When expected anatomy does not appear, do not compensate by drilling deeper.

Widen. Reorient. Return to the map.

And remember:

THE BURR REMOVES BONE.

The landmarks perform the mastoidectomy.

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CHAPTER 12

Canal Wall Up Mastoid Surgery

Preserve the Canal • Clear the Disease

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the objectives and limitations of canal wall up mastoid surgery
- select patients according to disease extent, anatomy and follow-up reliability
- use cortical mastoidectomy as the foundation for deeper disease access
- understand the epitympanum, aditus, facial recess and retrotympanum as connected spaces
- preserve the posterior canal wall without compromising disease clearance
- perform posterior tympanotomy using reliable facial nerve landmarks
- recognise hidden sites at risk for residual cholesteatoma
- understand the role of endoscopic assistance and staged surveillance
- reconstruct the tympanic membrane and ossicular system after disease clearance

12.1 CANAL WALL UP: CLEARANCE FIRST, PRESERVATION SECOND

The objective of cholesteatoma surgery is not simply to preserve anatomy.

It is to create a:

SAFE EAR

DRY EAR

> **FUNCTIONAL EAR WHERE POSSIBLE.**

Canal wall up surgery attempts to achieve disease clearance while preserving the posterior external auditory canal wall and near-normal canal anatomy.

That preservation has advantages.

It also creates limitations.

PRINCIPLE

The canal wall should be preserved only when disease can still be treated adequately.

12.2 WHY PRESERVE THE CANAL WALL?

Potential advantages include:

- preservation of external canal anatomy
- avoidance of a large open mastoid cavity
- less dependence on long-term cavity care in many patients
- potential functional advantages in selected ears

Potential disadvantages include:

- reduced visualisation of some recesses
- risk of residual disease
- risk of recurrent retraction / cholesteatoma
- need for surveillance and, in selected strategies, second-look surgery or imaging

Therefore the decision is not:

MODERN VERSUS OLD.

It is:

Does preserving this wall serve this ear?

12.3 PATIENT SELECTION

Consider:

DISEASE EXTENT

Can disease be completely accessed?

CANAL WALL

Intact or extensively eroded?

MIDDLE-EAR / MASTOID ANATOMY

Adequate working space?

EUSTACHIAN-TUBE / RETRACTION ENVIRONMENT

What is the risk of recurrence?

HEARING

What can realistically be preserved or reconstructed?

FOLLOW-UP

Can the patient undergo reliable long-term surveillance?

SURGEON / SYSTEM

Are endoscopic assistance, diffusion-weighted MRI surveillance or staged surgery available when needed?

Technique should match both disease and follow-up system.

12.4 THE OPERATION BEGINS WITH A COMPLETE MAP

Before surgery, define disease on:

OTOSCOPY / MICROSCOPY / ENDOSCOPY

and

CT

with selected MRI where indicated.

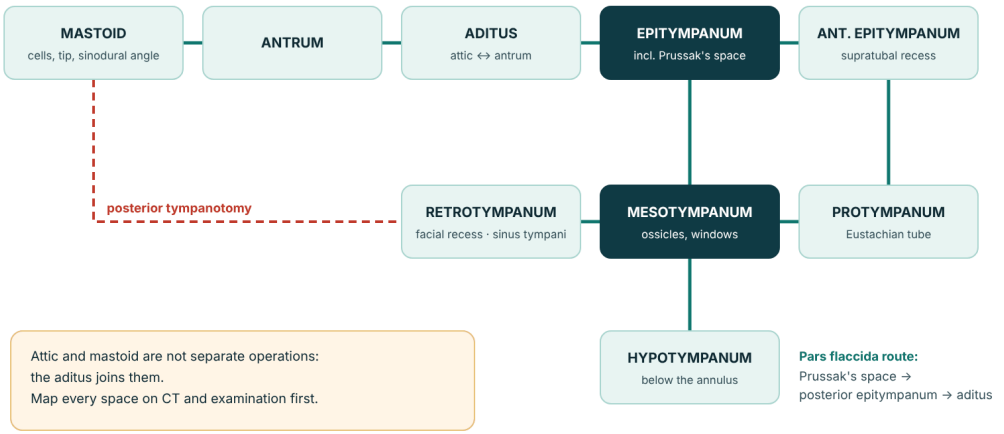
Map:

- pars flaccida
- epitympanum
- mesotympanum
- hypotympanum
- sinus tympani
- facial recess
- aditus
- antrum
- mastoid
- labyrinth
- facial nerve
- tegmen

The operation should be designed around the route of disease.

Figure 12.1 · Connected spaces of the middle ear and mastoid

Conceptual map, posterior to the left and anterior to the right — disease follows the connections



12.5 CORTICAL MASTOIDECTOMY FIRST

The cortical mastoidectomy principles remain:

WIDE EXPOSURE

TEGMEN

SIGMOID

POSTERIOR CANAL WALL

ANTRUM

LATERAL SEMICIRCULAR CANAL

INCUS REGION

Once these landmarks are established, disease surgery begins from a position of orientation.

Do not allow cholesteatoma to pull the burr into an anatomically undefined direction.

12.6 PRESERVE THE POSTERIOR CANAL WALL DELIBERATELY

Preservation does not mean ignoring the wall.

The surgeon must understand:

- thickness
- contour
- medial extent
- relationship to facial nerve
- disease on its medial surface

A wall left excessively thick can restrict access.

A wall thinned excessively or unintentionally violated may become unstable.

> **PRINCIPLE**
>
> **Preservation requires understanding the wall better—not touching it less.**

12.7 EPITYMPANUM

Attic cholesteatoma commonly involves the epitympanic space.

The surgeon should understand:

- scutum

- malleus head
- incus body
- tegmen
- aditus
- facial nerve relationship

Disease clearance may require appropriate epitympanic exposure.

The amount of bone removed should follow disease extent.

12.8 ADITUS

The aditus connects the epitympanum to the mastoid antrum.

Disease can travel through this pathway.

The surgeon should not treat:

ATTIC
and

MASTOID
as separate operations.

They are connected anatomical compartments.

12.9 OSSICLES AND DISEASE

Assess:

MALLEUS
Intact? Involved?

INCUS
Long process eroded? Body involved?

STAPES
Superstructure intact? Disease around it?

Preserve functional ossicles when safe.

Remove ossicles when required for complete disease clearance.

PRINCIPLE

Do not preserve an ossicle at the cost of preserving cholesteatoma around it.

12.10 THE INCUS MAY LIMIT ACCESS

The incus may obstruct visualisation of disease in selected epitympanic or facial-recess regions.

If removal becomes necessary:

- understand the hearing consequence
- preserve the stapes where possible
- plan later ossicular reconstruction

Functional reconstruction follows disease control.

12.11 POSTERIOR TYMPANOTOMY

Posterior tympanotomy provides access from the mastoid into the middle ear through the facial recess.

This corridor is bounded conceptually by:

FACIAL NERVE

Medially and posteriorly.

CHORDA TYMPANI

Laterally and anteriorly, with the posterior canal wall and tympanic annulus.

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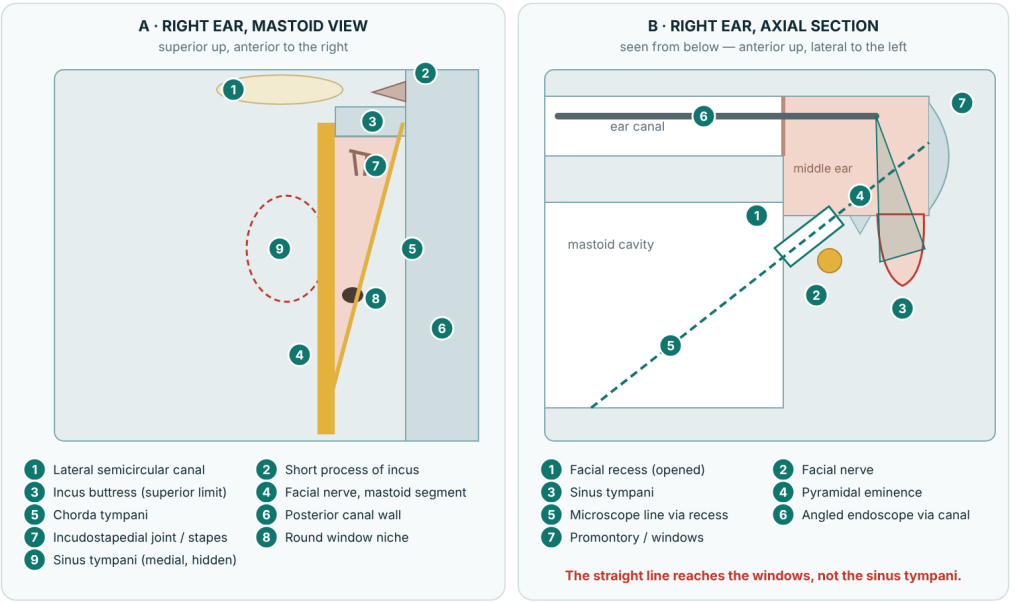
Superiorly.

The exact available space varies.

The sinus tympani lies medial to the facial nerve and is therefore not reached through the facial recess.

Figure 12.2 · The facial recess and the sinus tympani

Schematic, not to scale — the recess lies lateral to the facial nerve; the sinus tympani lies medial to it



12.12 FIND THE FACIAL NERVE WITHOUT NEEDING TO EXPOSE ALL OF IT

Use the landmark network:

LATERAL SEMICIRCULAR CANAL

+

INCUS REGION

+

POSTERIOR CANAL WALL

+

DIGASTRIC RIDGE

↓

EXPECTED MASTOID FACIAL NERVE

The objective is to know where the nerve is while creating the recess—not necessarily to skeletonise its entire length.

12.13 OPENING THE FACIAL RECESS

General principles include:

- establish landmarks first
- thin bone progressively
- maintain irrigation
- reduce burr aggression near the nerve and chorda
- preserve the posterior canal wall
- enlarge only enough to obtain required access

PRINCIPLE

The facial recess is not created by searching for a hole.

It is created by understanding three boundaries and removing the bone between them.

12.14 THE CHORDA TYMPANI

Preserve the chorda where reasonably possible.

However, an extremely narrow recess or disease involvement may limit preservation.

Do not create greater facial nerve risk merely to preserve the chorda at all costs.

The relative functional consequences should be understood.

12.15 WHAT DOES THE FACIAL RECESS PROVIDE?

It may provide access to:

- stapes
- round-window niche
- promontory
- hypotympanum
- posterior mesotympanum

But not every recess becomes fully visible through one straight line.

Angled endoscopes may complement microscopic access.

12.16 HIDDEN DISEASE

Cholesteatoma can remain in areas difficult to visualise.

Important sites include:

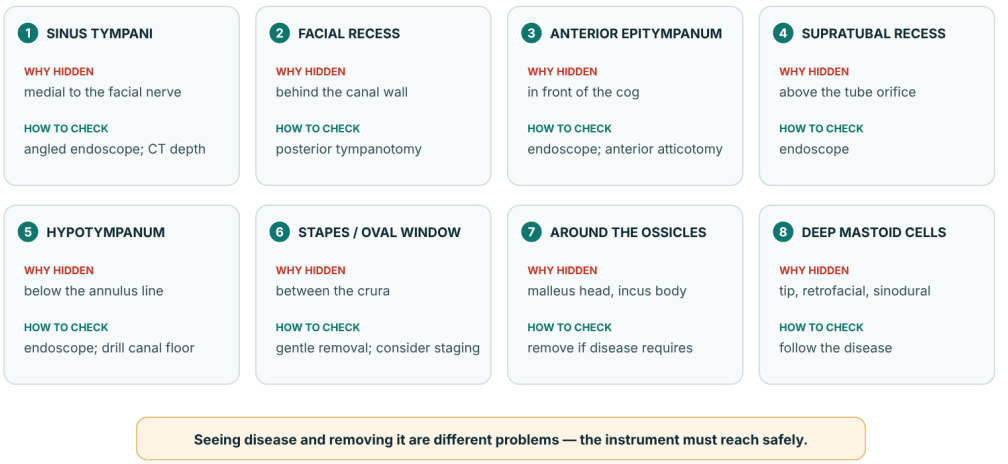
- sinus tympani
- facial recess
- anterior epitympanum
- supratubal recess
- hypotympanum
- around ossicles
- around stapes
- deep mastoid cells depending upon disease

PRINCIPLE

A cavity that looks clean from one angle may still contain disease around the corner.

Figure 12.3 · Where residual disease hides

Sites to inspect deliberately before the operation is called complete



12.17 SINUS TYMPANI

The sinus tympani is a particularly important retrotympanic recess.

It lies between the ponticulus above and the subiculum below, medial to the pyramidal eminence and the facial nerve.

Its depth and geometry vary, and its posterior extension can be predicted on CT.

Microscopic visualisation may be limited.

Endoscopic inspection can improve visualisation in selected cases.

But again:

> **SEEING DISEASE AND REMOVING DISEASE ARE DIFFERENT PROBLEMS.**

The working instrument must reach safely.

12.18 ENDOSCOPIC ASSISTANCE

After microscopic clearance, an angled endoscope can be used selectively to inspect:

- sinus tympani
- facial recess
- anterior epitympanum
- hypotympanum
- other hidden recesses

This may identify residual keratin or matrix not visible through the microscope.

The endoscope should answer a question:

> **What have I not been able to see?**

12.19 MATRIX OVER CRITICAL STRUCTURES

Cholesteatoma matrix may lie over:

- facial nerve
- labyrinth
- dura
- sigmoid sinus
- stapes

Removal strategy should balance:

COMPLETE DISEASE CLEARANCE
against

RISK OF CATASTROPHIC INJURY.
The specific approach depends upon the structure, degree of involvement and clinical context.

12.20 LABYRINTHINE FISTULA

If CT or operative findings suggest fistula:

> **DO NOT PULL THE MATRIX BLINDLY.**

Define:

- site
- size
- remaining bony covering
- hearing status

The management strategy should be planned deliberately.

Detailed fistula management is addressed in Chapter 14, Cholesteatoma.

12.21 FACIAL NERVE DEHISCENCE

If the facial nerve is dehiscent:

- identify its course
- reduce traction
- minimise thermal injury
- avoid blind instrumentation
- remove disease under direct visualisation

The absence of bone means the nerve is already exposed to the operation.

12.22 DURAL EXPOSURE

Disease may erode the tegmen.

If dura is exposed:

- define the defect
- remove disease carefully
- assess for dural violation or CSF leak
- reconstruct where required

Do not assume every tegmen defect requires the same reconstruction.

Management follows the actual defect.

12.23 WHEN PRESERVING THE WALL BEGINS TO COMPROMISE CLEARANCE

This is the critical decision.

Ask:

Can I see the disease?

Can I reach it?

Can I remove it without unsafe blind dissection?

Is the canal wall itself involved or unstable?

If the answers become unacceptable:

> **THE OPERATIVE STRATEGY MUST CHANGE.**

Preserving the wall is not the primary objective.

Creating a safe ear is.

DECISION POINT

KEEP THE WALL OR TAKE IT DOWN?

Consider:

Disease extent

Canal-wall erosion

Hidden recess involvement

Facial nerve / labyrinth risk

Follow-up reliability

Contralateral hearing

Patient factors

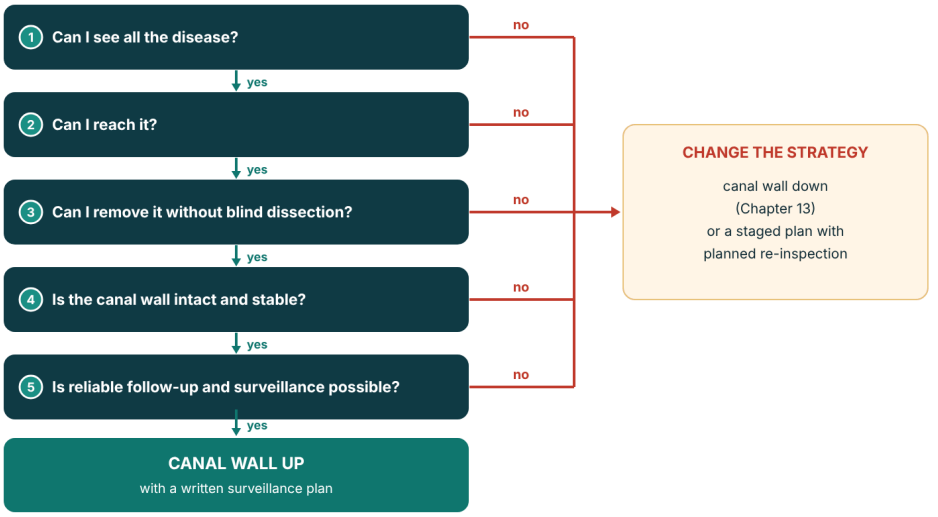
Surveillance resources

Then choose the operation that provides the best balance of:

> **DISEASE CONTROL + FUNCTION + LONG-TERM SAFETY.**

Figure 12.4 · Keep the wall or take it down?

Preserving the wall is not the objective; a safe ear is



12.24 TYMPANIC-MEMBRANE RECONSTRUCTION

After disease clearance:

- assess membrane defect
- assess attic / scutum
- consider cartilage support where appropriate
- reconstruct the tympanic membrane according to remaining anatomy

In retraction-prone ears, reconstruction should account for the mechanism that produced the original disease.

Simply replacing a thin membrane into the same mechanical environment may recreate the same problem.

12.25 ATTIC RECONSTRUCTION

Where scutum or lateral attic support has been removed, reconstruction may help restore canal-wall geometry and resist recurrent retraction in selected cases.

Materials and techniques vary.

The principle is:

> **RESTORE THE BARRIER THAT MATTERS.**

Do not reconstruct bone merely because bone was removed.

Reconstruct when it improves function or long-term disease control.

12.26 OSSICULAR RECONSTRUCTION

After complete disease clearance, assess:

- malleus
- stapes
- middle-ear space
- mucosa
- recurrence risk

Ossiculoplasty may be:

PRIMARY
or

STAGED.
The decision should be based on whether the ear can support a stable hearing reconstruction.

12.27 SECOND-LOOK STRATEGY

Historically, planned second-look surgery has been used in selected canal wall up cholesteatoma cases because residual disease may remain hidden.

Modern surveillance may also incorporate appropriate non-echo-planar diffusion-weighted MRI in selected patients.

The follow-up strategy depends upon:

- disease extent
- age
- reconstruction
- intraoperative confidence
- imaging availability
- institutional practice

PRINCIPLE

Canal wall up surgery includes a surveillance plan.

The operation and follow-up cannot be separated.

12.28 RESIDUAL VERSUS RECURRENT DISEASE

These concepts should be distinguished.

RESIDUAL

Disease left behind at the original operation.

RECURRENT

New cholesteatoma developing after surgery, often through recurrent retraction or altered epithelial migration.

Prevention strategies differ.

Residual disease relates primarily to clearance.

Recurrent disease relates additionally to the reconstructed ear's long-term mechanics.

Figure 12.5 · Residual and recurrent disease

Different origins, different prevention, different detection

	RESIDUAL	RECURRENT
WHAT IT IS	disease left behind at the operation	new cholesteatoma after surgery
MECHANISM	incomplete clearance of a hidden site	retraction from persistent poor ventilation
TYPICAL LOOK	pearl behind an intact membrane	retraction pocket visible on otoscopy
PREVENTION	clearance, endoscopic inspection	cartilage support, attic reconstruction
DETECTION	non-EPI diffusion-weighted MRI, second look	otoscopy / endoscopy; imaging as needed

A normal-looking canal does not exclude deeper residual disease.

12.29 POSTOPERATIVE FOLLOW-UP

Assess:

- tympanic membrane
- retraction
- hearing
- infection
- canal
- imaging where indicated

A normal-looking canal does not guarantee absence of deeper residual disease.

That is one of the trade-offs of preserving the posterior canal wall.

12.30 WHY DOES CANAL WALL UP SURGERY FAIL?

Possible reasons include:

RESIDUAL DISEASE

Hidden recess not cleared.

RECURRENT RETRACTION

Underlying ventilation problem persists.

RECONSTRUCTION FAILURE

Attic or membrane support inadequate.

FOLLOW-UP FAILURE

Residual/recurrent disease not detected early.

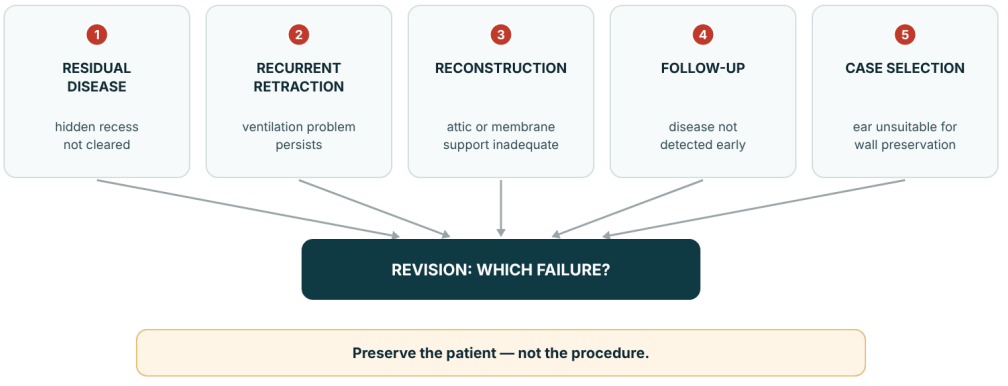
CASE-SELECTION FAILURE

Disease was not suitable for reliable clearance with wall preservation.

The revision operation should identify which failure occurred.

Figure 12.6 · Why canal wall up surgery fails

The revision operation should name which failure occurred



FROM EXPERIENCE

Canal wall up surgery can become technically seductive.

The anatomy is preserved.

The canal looks normal.

The ear may function well.

But preservation has value only when disease control remains uncompromised.

The posterior canal wall should therefore never become something the surgeon feels obligated to save.

It is an anatomical structure with advantages.

Not a measure of surgical success.

> **The successful operation is the one that leaves the patient with the safest ear possible.**

TAKE IT TO THE OT

Before canal wall up surgery, define:

DISEASE MAP

Attic
Middle ear
Sinus tympani
Facial recess
Aditus
Antrum
Mastoid

LANDMARKS

Tegmen
Sigmoid
Lateral canal
Incus
Facial nerve

CANAL WALL

Intact and preservable?

HIDDEN RECESSES

How will they be inspected?

OSSICLES

What can be preserved?

RECONSTRUCTION

Membrane / attic / ossicles.

SURVEILLANCE

Second look? Imaging? Long-term follow-up?

CONVERSION

What finding would make wall preservation inappropriate?

CHAPTER SUMMARY

Canal wall up mastoid surgery attempts to preserve external canal anatomy while achieving complete disease clearance.

Begin with a well-oriented cortical mastoidectomy.

Understand the epitympanum, aditus, mastoid and middle ear as connected spaces.

Use a landmark network to create the facial recess safely.

Inspect hidden recesses deliberately.

Use endoscopic assistance where it adds meaningful visualisation.

Reconstruct the membrane and attic according to the mechanism of disease.

Plan long-term surveillance.

And when wall preservation begins to compromise clearance:

> **preserve the patient—not the procedure.**

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CHAPTER 13

Canal Wall Down Mastoid Surgery

Disease Clearance • Cavity Design • Long-Term Safety

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the principles and indications of canal wall down mastoid surgery
- recognise when posterior canal-wall preservation may compromise disease clearance or long-term safety
- understand the anatomical consequences of removing the posterior canal wall
- create a cavity with appropriate saucerisation and smooth geometry
- understand the importance of the facial ridge, mastoid tip and meatoplasty
- identify common causes of a chronically discharging or poorly functioning mastoid cavity
- understand the principles of cavity obliteration and canal-wall reconstruction
- plan hearing reconstruction without compromising disease control

13.1 CANAL WALL DOWN IS NOT SIMPLY CANAL WALL UP WITH MORE BONE REMOVED

Removing the posterior canal wall changes the anatomy of the ear.

The external auditory canal and mastoid become part of a common postoperative space.

The objective is therefore not merely:

REMOVE THE WALL.

It is to create a new anatomical configuration that is:

SAFE

DISEASE-FREE

> **SELF-CLEANING OR ACCESSIBLE FOR CARE**

WELL EPITHELIALISED

> **FUNCTIONALLY ACCEPTABLE WHERE POSSIBLE.**

A poorly designed canal wall down cavity can become a chronic problem even after complete cholesteatoma removal.

13.2 WHY TAKE THE WALL DOWN?

Possible considerations include:

- extensive cholesteatoma
- major posterior canal-wall erosion
- difficult hidden disease
- recurrent disease
- anatomy preventing reliable clearance with wall preservation
- complications
- limited reliability of long-term surveillance in selected circumstances

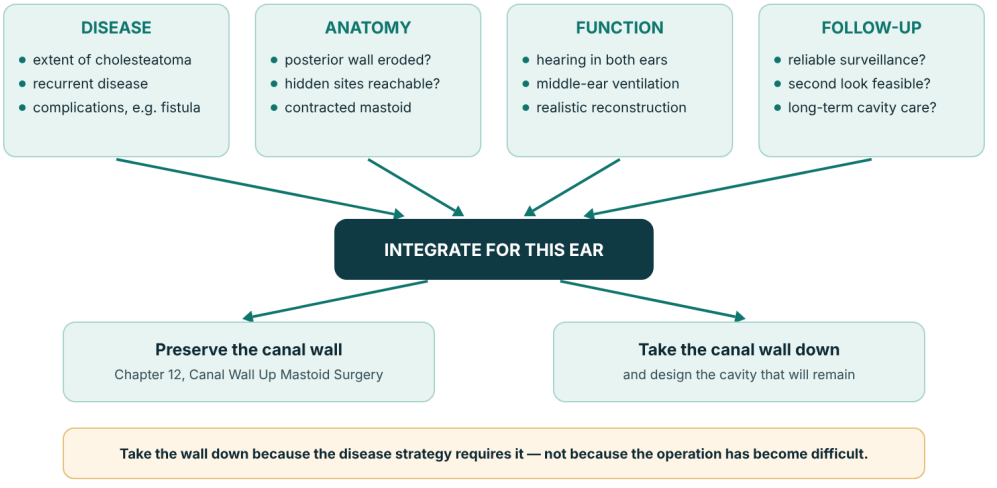
No single finding automatically mandates the same procedure in every patient.

The decision integrates:

DISEASE + ANATOMY + FUNCTION + FOLLOW-UP.

Figure 13.1 · Why take the wall down?

No single finding decides — four questions are integrated before the wall is removed



13.3 THE PRIMARY OBJECTIVE REMAINS A SAFE EAR

Canal wall down surgery should not be considered a failure to preserve normal anatomy.

In an appropriate ear, it may provide the safest route to complete disease clearance and long-term surveillance.

Conversely, removing the wall unnecessarily creates avoidable cavity morbidity.

PRINCIPLE

Take down the wall because the disease strategy requires it—not because the operation has become difficult.

13.4 PLAN THE FINAL CAVITY BEFORE REMOVING THE WALL

Before drilling:

What will the final cavity look like?

How will it communicate with the external canal?

Will the meatus permit access?

Will any deep recess trap debris?

How low must the facial ridge be?

Will the mastoid tip create a dependent pocket?

The final geometry should exist mentally before the wall is removed.

13.5 BEGIN WITH ORIENTATION

As in cortical mastoidectomy (Chapter 11, Cortical Mastoidectomy), establish:

TEGMEN

SIGMOID SINUS

LATERAL SEMICIRCULAR CANAL

INCUS / EPITYMPANIC REGION

DIGASTRIC RIDGE

EXPECTED FACIAL NERVE COURSE

Disease clearance should proceed within a known anatomical map.

Canal wall removal does not eliminate the need for landmarks.

It makes them even more important.

13.6 POSTERIOR CANAL-WALL REMOVAL

The posterior canal wall is progressively lowered while preserving critical deeper anatomy.

The surgeon should continuously know:

- where the facial nerve lies
- where the lateral semicircular canal lies
- where the middle ear begins
- how much wall remains

The operation should progress from:

THICK WALL

↓

THINNED WALL

↓

CONTROLLED REMOVAL

rather than uncontrolled entry into deeper anatomy.

13.7 DO NOT LOSE THE FACIAL NERVE WHILE LOSING THE WALL

As the posterior wall is removed, the facial nerve becomes an increasingly important boundary.

Use:

- lateral semicircular canal
- second genu relationship
- digastric ridge
- middle-ear landmarks

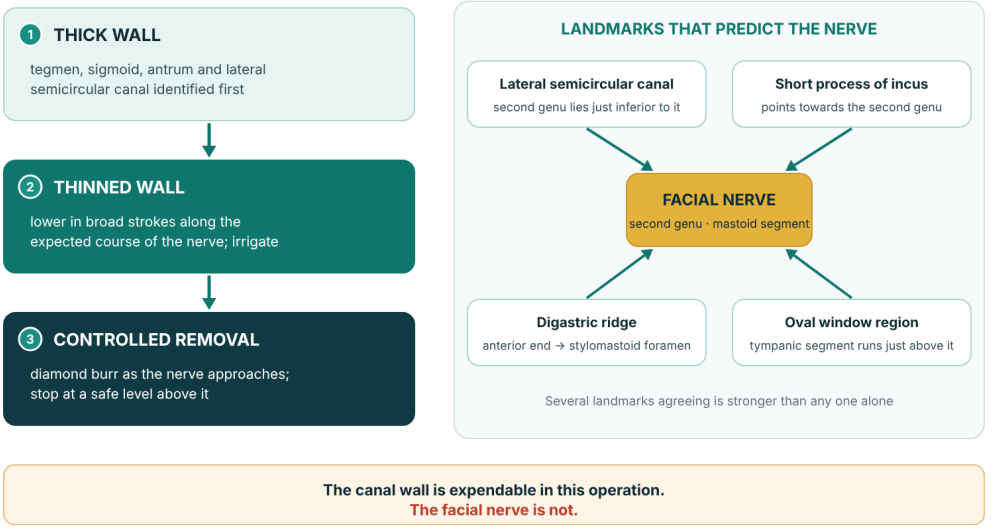
to predict its course.

> PRINCIPLE
>
> **The canal wall is expendable in this operation.**

THE FACIAL NERVE IS NOT.

Figure 13.2 · Lowering the posterior canal wall without losing the facial nerve

Progress from thick wall to controlled removal while landmarks keep predicting the nerve



13.8 FACIAL RIDGE

After wall removal, an excessively high facial ridge can create:

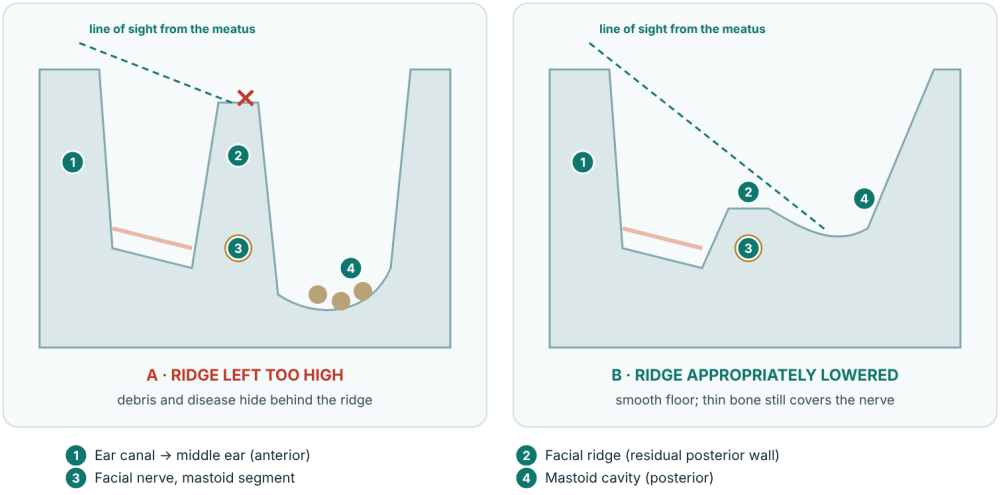
- poor visualisation
- retained debris
- difficulty cleaning the cavity
- hidden disease
- poor communication between mastoid and canal

The ridge should be lowered adequately while preserving the facial nerve.

This requires knowing the nerve's course—not simply drilling until the ridge “looks low.”

Figure 13.3 · The facial ridge: too high versus appropriately lowered

Right ear, schematic horizontal section seen from above — lateral at top, anterior to the left; not to scale



Lower the ridge by knowing the nerve's course — not by drilling until it "looks low".

13.9 LOW ENOUGH — NOT LOWER THAN SAFE

The objective is a smooth transition between:

MASTOID CAVITY
and

EXTERNAL AUDITORY CANAL.
Once adequate access and drainage geometry are achieved, further bone removal provides no benefit and may increase neural risk.

PRINCIPLE

Adequate lowering is an anatomical objective—not a competition in depth.

13.10 SAUCERISATION

A good cavity should have:

- broad access
- smooth contours

- minimal overhangs
- no unnecessarily deep inaccessible pockets

Conceptually:

NARROW DEEP CAVITY

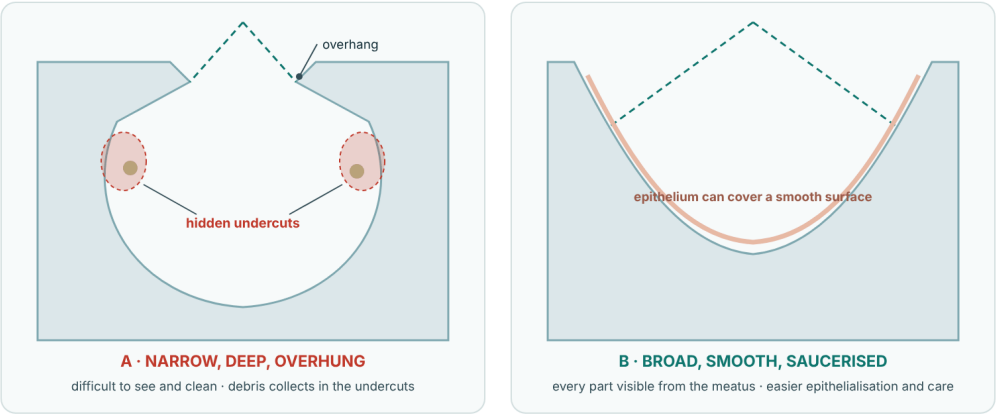
= difficult visualisation + debris retention

BROAD SAUCERISED CAVITY

= improved access + easier epithelialisation and care

Figure 13.4 · Saucerisation

Schematic section through a mastoid cavity — not to scale; the surgeon's view is from the top



Narrow deep cavity = difficult visualisation + debris retention

Broad saucerised cavity = improved access + easier epithelialisation and care

The aim is the smallest cavity that still allows complete clearance and reliable long-term access.

13.11 REMOVE OVERHANGS

Bony overhangs can create hidden recesses.

Common areas requiring attention may include:

- tegmen-related overhang
- posterior cavity
- mastoid tip
- facial ridge
- anterior attic region

The cavity should be inspected from the direction from which it will later be examined clinically.

SURGICAL PERSPECTIVE

If you cannot see a recess easily at the end of surgery, consider how difficult it may be to inspect in clinic months later.

13.12 MASTOID TIP

A deep mastoid-tip pocket can collect:

- keratin
- debris
- moisture

The extent of tip-cell removal and cavity contouring should be adapted to anatomy and disease.

In selected cases, tip reduction may improve cavity geometry.

But unnecessary removal should be avoided.

13.13 SINODURAL CELLS

Disease-bearing cells around the:

- tegmen
- sigmoid sinus
- sinodural region

should be addressed according to disease extent.

The objective is complete disease clearance while maintaining safe bony or soft-tissue protection of critical structures where possible.

13.14 ATTIC

The epitympanum should be opened sufficiently to eliminate hidden disease.

Assess:

- malleus head

- incus body
- tegmen
- anterior epitympanum
- supratubal region where relevant

An open mastoid cavity does not guarantee that every attic recess is visible.

Disease mapping still matters.

13.15 SINUS TYMPANI AND RETROTYMPANUM

Even in canal wall down surgery, the sinus tympani may remain a hidden site.

Use:

- appropriate microscopic angles
- endoscopic inspection where useful
- deliberate retrotympanic assessment

PRINCIPLE

Removing the canal wall improves access. It does not abolish three-dimensional anatomy.

13.16 OSSICLES

Disease clearance determines ossicular preservation.

Assess:

- malleus
- incus
- stapes

Preserve functioning uninvolved structures where possible.

Remove structures when required for complete clearance.

Hearing reconstruction should follow the safe-ear objective.

13.17 THE STAPES REGION

Disease around the stapes requires fine technique.

Potential risks include:

- stapes injury
- footplate trauma
- facial nerve injury
- inner-ear injury

As the surgeon moves from broad mastoid work towards the stapes:

BURR SIZE / FORCE ↓

PRECISION ↑

The operation changes scale within the same cavity.

13.18 LABYRINTHINE FISTULA

Canal wall down surgery may be selected in ears with extensive cholesteatoma and labyrinthine complications.

If a fistula is present:

- define it
- understand hearing status
- avoid uncontrolled matrix traction
- manage according to the specific fistula and disease

Detailed management is discussed in Chapter 14, Cholesteatoma.

13.19 FACIAL NERVE DEHISCENCE

When the facial nerve is exposed by disease:

- identify the nerve
- avoid traction
- minimise thermal injury
- remove disease under direct visualisation

Do not allow the wider cavity to create false confidence around an exposed nerve.

13.20 MEATOPLASTY

A canal wall down cavity must communicate adequately with the external meatus.

A narrow meatus can convert a well-designed internal cavity into a poorly accessible postoperative ear.

The meatus should allow:

- ventilation
- inspection
- cleaning
- drainage

> **PRINCIPLE**
>
> **The cavity is only as accessible as its entrance.**

13.21 MEATOPLASTY IS NOT SIMPLY "MAKE IT LARGE"

Over-enlargement may produce:

- cosmetic deformity
- discomfort
- unnecessary alteration of conchal anatomy

Under-enlargement may produce:

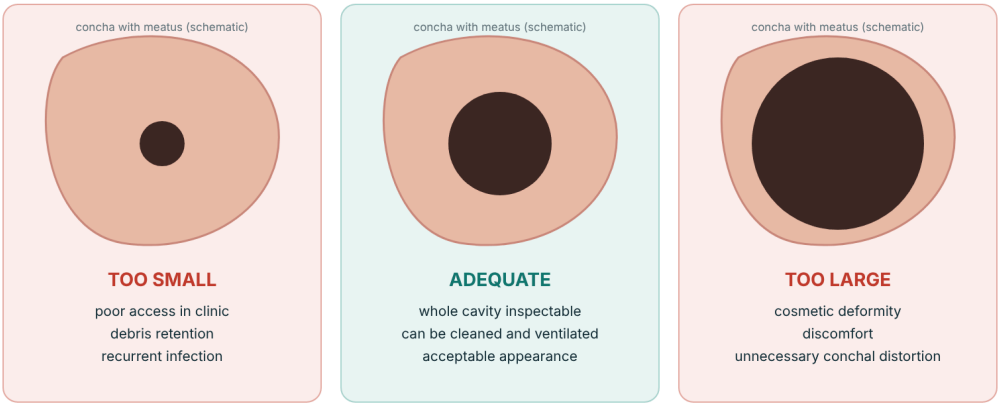
- poor access
- debris retention
- recurrent infection

The objective is:

ADEQUATE ACCESS WITH ACCEPTABLE FORM.

Figure 13.5 · Meatoplasty: adequate access with acceptable form

Schematic — the cavity is only as accessible as its entrance



Size the meatus to the cavity behind it — enough to see and clean every part, no larger.

13.22 SKIN FLAPS

Canal and meatal skin should be preserved and repositioned to maximise epithelial coverage.

A cavity containing extensive exposed bone heals more slowly and may granulate.

RECONSTRUCTIVE PRINCIPLE

The operation is not finished when the bone work is finished.

The new cavity needs a viable epithelial surface.

13.23 CAVITY SIZE

A larger cavity is not automatically better.

Very large cavities may be associated with:

- prolonged epithelialisation
- caloric vertigo with cold air or water
- water intolerance
- chronic debris
- maintenance requirements

The aim is:

> **The smallest cavity that still permits complete disease clearance and reliable long-term access.**

This is different from leaving hidden recesses.

13.24 OBLITERATION

Mastoid obliteration aims to reduce or eliminate selected portions of the postoperative cavity.

Potential objectives include:

- reducing cavity volume
- eliminating deep recesses
- improving epithelialisation
- reducing long-term cavity problems

Materials and techniques vary and may include:

- autologous soft tissue
- bone
- cartilage
- other appropriate materials

The chosen material should be suitable for the disease status and reconstructive objective.

Materials and techniques are discussed in Chapter 16, Mastoid Obliteration & Canal Wall Reconstruction.

13.25 DO NOT OBLITERATE DISEASE

Before obliteration:

> **DISEASE CLEARANCE MUST BE RELIABLE.**

Obliterating a cavity can also hide residual disease.

Therefore the surgeon should consider:

- extent of cholesteatoma

- confidence of clearance
- surveillance strategy
- imaging availability

PRINCIPLE

Obliteration should remove a cavity problem—not conceal a disease problem.

13.26 CANAL-WALL RECONSTRUCTION

In selected procedures, the posterior canal wall may be reconstructed after disease clearance.

This attempts to combine:

- wide access during disease removal
- restoration of canal anatomy afterwards

The success depends upon:

- complete clearance
- stable reconstruction
- vascularised coverage
- long-term surveillance

It should not be viewed simply as "putting the wall back."

The reconstructed wall must become durable anatomy.

13.27 HEARING RECONSTRUCTION

Hearing reconstruction may involve:

- tympanic-membrane reconstruction
- ossiculoplasty
- staged reconstruction
- hearing devices where appropriate

The priority remains:

1. SAFE EAR

2. STABLE EAR

3. FUNCTIONAL HEARING WHERE POSSIBLE

The sequence matters.

13.28 THE FINAL CAVITY CHECK

Before closure, inspect systematically.

SUPERIOR
Tegmen and attic.

POSTERIOR
Sigmoid / sinodural region.

INFERIOR
Tip and dependent spaces.

MEDIAL
Labyrinth, facial nerve, middle ear.

ANTERIOR
Anterior attic, supratubal recess and protympanum (Eustachian tube orifice) as relevant.

ENTRANCE
Meatoplasty and canal access.

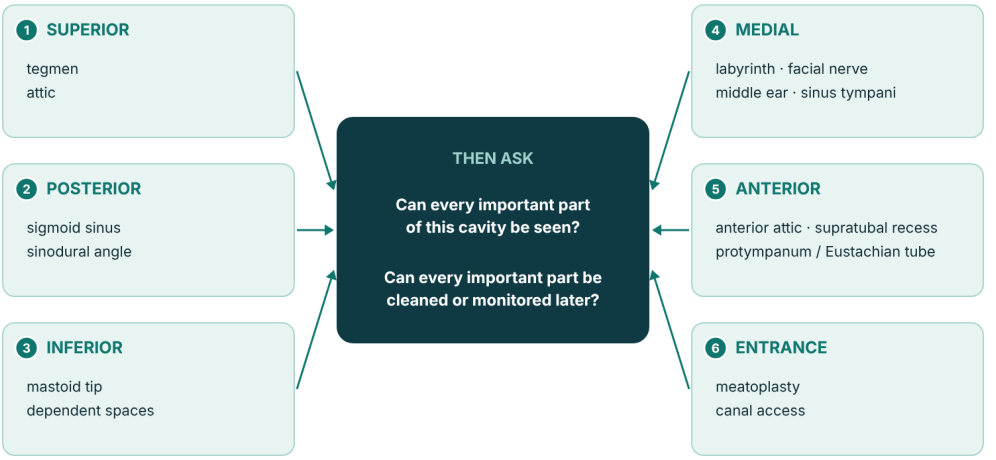
Then ask:

Can every important part of this cavity be seen?

Can every important part be cleaned or monitored later?

Figure 13.6 · The final cavity check

Inspect systematically before closure — direction by direction



13.29 WHY DOES A MASTOID CAVITY DISCHARGE?

Possible causes include:

- residual disease
- recurrent disease
- high facial ridge
- narrow meatus
- deep mastoid tip
- bony overhang
- exposed bone
- poor epithelialisation
- granulation
- foreign material
- middle-ear mucosal disease
- water contamination

> **"CAVITY DISCHARGE" IS A SYMPTOM.**

Find the anatomical reason.

13.30 REVISION OF A TROUBLESOME CAVITY

Before revision, map the cavity.

Ask:

IS THE MEATUS TOO SMALL?

IS THE FACIAL RIDGE TOO HIGH?

IS THERE A DEEP TIP?

IS THERE AN OVERHANG?

IS THERE RESIDUAL CHOLESTEATOMA?

IS BONE EXPOSED?

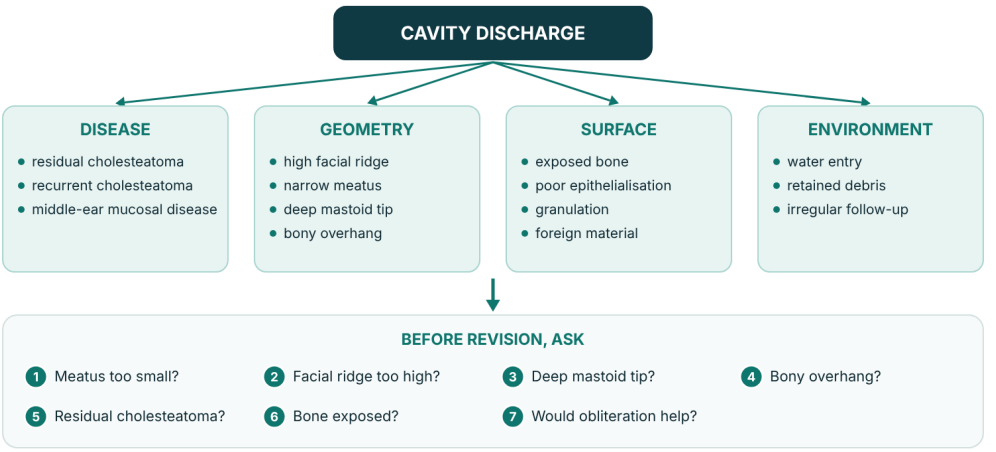
WOULD OBLITERATION HELP?

Revision should correct the geometry that failed.

Not merely clean the cavity more aggressively.

Figure 13.7 · The discharging cavity: a symptom with an anatomical cause

Map the cavity, find the reason, then correct the geometry that failed



Revision should correct the geometry that failed — not merely clean the cavity more aggressively.

DECISION POINT

PRESERVE THE CANAL WALL OR CREATE AN OPEN CAVITY?

Consider:

DISEASE
Can it be completely cleared?

WALL
Intact or eroded?

HIDDEN RECESSES
Can they be accessed?

HEARING
What function is realistically preservable?

FOLLOW-UP
Can reliable surveillance occur?

PATIENT
Can long-term cavity care be maintained if required?

RECONSTRUCTION
Can cavity morbidity be reduced?

The operation should serve the ear—not the surgeon's preference.

FROM EXPERIENCE

A canal wall down operation can appear complete when all visible cholesteatoma has been removed.

But the patient's experience begins after that.

If the meatus is narrow, the cavity cannot be cleaned.

If the facial ridge is high, debris hides behind it.

If the tip is deep, moisture collects.

If raw bone remains, granulation develops.

The disease may be gone, yet the ear remains a problem.

So the operation has two objectives:

REMOVE THE DISEASE.

> **DESIGN THE EAR THAT WILL REMAIN.**

TAKE IT TO THE OT

Before completing canal wall down surgery, confirm:

DISEASE
Completely addressed?

TEGMEN
No hidden cells / disease?

SIGMOID / SINODURAL REGION
Adequately exposed for the disease?

ATTIC
Open and inspectable?

FACIAL RIDGE
Appropriately lowered?

FACIAL NERVE
Protected?

MASTOID TIP
No deep dependent pocket?

MEATUS
Adequate?

SKIN
Can the cavity epithelialise?

OBLITERATION
Required or useful?

HEARING
Reconstruct now or stage?

CHAPTER SUMMARY

Canal wall down mastoid surgery creates a new postoperative anatomy.

Remove the posterior canal wall only when it serves disease control and long-term safety.

Orient the operation around the facial nerve, labyrinth, tegmen and sigmoid sinus.

Lower the facial ridge sufficiently but safely.

Saucerise the cavity.

Eliminate inaccessible pockets and unnecessary overhangs.

Create an adequate meatus.

Preserve and restore epithelial coverage.

Consider obliteration only after reliable disease clearance.

And before finishing, look at the cavity not only as the surgeon who created it—

> **but as the clinician who will need to examine it years later.**

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CHAPTER 14

Cholesteatoma

Map the Disease • Choose the Operation • Create a Safe Ear

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand cholesteatoma as a three-dimensional disease rather than a simple sac
- map disease across middle-ear and mastoid compartments
- distinguish residual from recurrent disease
- select surgical strategy according to disease, anatomy, hearing and follow-up
- understand when canal wall up, canal wall down, endoscopic or combined strategies may be appropriate
- manage disease around the ossicles, facial nerve, labyrinth, dura and venous structures
- understand the principles of labyrinthine fistula management
- recognise hidden sites of residual disease
- plan reconstruction and postoperative surveillance as part of the original operation

14.1 CHOLESTEATOMA IS A DISEASE OF SPACES

Cholesteatoma does not simply occupy the middle ear.

It travels through connected anatomical spaces.

It may extend through:

PARS FLACCIDA / PRUSSAK'S SPACE

↓

POSTERIOR EPITYMPANUM

↓

ADITUS

↓

ANTRUM

↓

MASTOID

or into the following spaces — the mesotympanum, facial recess and sinus tympani particularly from the posterior pars tensa; the hypotympanum and anterior epitympanum from either route:

MESOTYMPANUM

HYPOTYMPANUM

FACIAL RECESS

SINUS TYMPANI

ANTERIOR EPITYMPANUM

The operation begins by understanding this map.

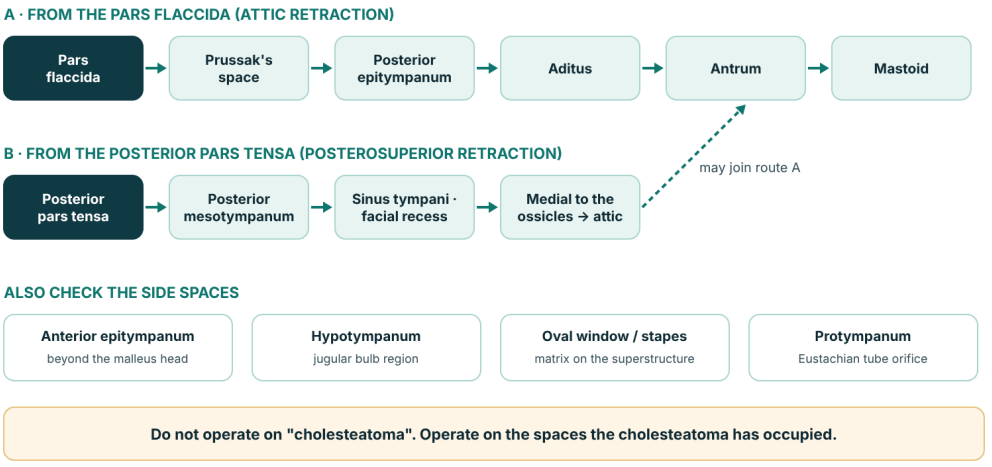
PRINCIPLE

Do not operate on "cholesteatoma."

Operate on the spaces the cholesteatoma has occupied.

Figure 14.1 · Cholesteatoma is a disease of connected spaces

Conceptual map of common routes of spread — not an anatomical drawing



14.2 SAFE EAR FIRST

The priorities of cholesteatoma surgery can be considered:

1. ERADICATE DISEASE
2. CREATE A SAFE, STABLE EAR

3. PRESERVE OR RESTORE HEARING WHERE POSSIBLE

The third objective should not compromise the first.

A hearing reconstruction can be revised.

An unsafe residual cholesteatoma can cause progressive harm.

14.3 ACQUIRED CHOLESTEATOMA

Acquired disease may arise in association with:

- retraction pockets
- tympanic-membrane pathology
- previous perforation or surgery

Its pattern of spread often follows anatomical pathways of least resistance.

Understanding the site of origin helps predict where disease may have travelled.

14.4 CONGENITAL CHOLESTEATOMA

Congenital cholesteatoma may present behind an intact tympanic membrane, classically in the anterosuperior quadrant, but can involve other middle-ear locations.

Surgical planning depends upon:

- location
- size
- ossicular involvement
- mastoid extension
- hearing

The intact membrane should not create an assumption that the disease is necessarily limited.

14.5 CLINICAL ASSESSMENT

Examine:

PARS FLACCIDA

Retraction? Keratin?

PARS TENSA

Retraction? Perforation?

ATTIC

Scutum erosion? Debris?

POSTEROSUPERIOR REGION

Disease?

CANAL WALL

Erosion?

FACIAL NERVE

Function?

HEARING

Conductive, mixed or sensorineural component?

The visible disease is the entry point to the map—not necessarily the full map.

14.6 IMAGING

High-resolution temporal-bone CT is valuable for defining:

- mastoid pneumatisation
- ossicular erosion
- scutum
- tegmen
- lateral semicircular canal
- facial canal
- sigmoid plate
- disease extent through bony spaces

MRI, particularly appropriate diffusion-weighted techniques, may be useful in selected primary and postoperative situations.

PRINCIPLE

CT tells us particularly well what the disease has done to bone.

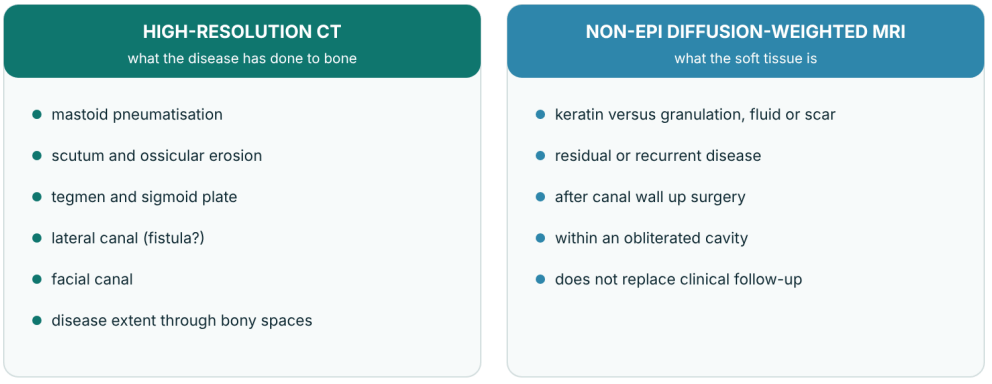
MRI can answer additional soft-tissue questions.

Use each for the question it can answer.

Imaging is discussed in detail in Chapter 7, Temporal Bone Imaging for the Surgeon.

Figure 14.2 · CT and MRI answer different questions

Use each investigation for the question it can answer



CT shows bone well; MRI answers additional soft-tissue questions.

14.7 MAP BEFORE OPERATING

Before surgery, create a compartment map.

Compartment	Suspected Disease
Attic	Yes / No / Uncertain
Anterior epitympanum	Yes / No / Uncertain
Mesotympanum	Yes / No / Uncertain
Hypotympanum	Yes / No / Uncertain
Sinus tympani	Yes / No / Uncertain
Facial recess	Yes / No / Uncertain
Aditus	Yes / No / Uncertain
Antrum	Yes / No / Uncertain
Mastoid	Yes / No / Uncertain

Then ask:

> **Which corridor allows me to inspect and clear every involved space?**

Formal staging systems, such as the EAONO/JOS classification and the ChOLE classification, can supplement this map and make outcomes comparable between surgeons.

Figure 14.3 · The preoperative compartment map

Mark every space before choosing the corridor

COMPARTMENT	YES	NO	UNCERTAIN
Attic	☐	☐	☐
Anterior epitympanum	☐	☐	☐
Mesotympanum	☐	☐	☐
Hypotympanum	☐	☐	☐
Sinus tympani	☐	☐	☐
Facial recess	☐	☐	☐
Aditus	☐	☐	☐
Antrum	☐	☐	☐
Mastoid	☐	☐	☐

Then ask:
Which corridor allows me to inspect and clear every involved space?

14.8 MATRIX AND CONTENT

The keratin content and cholesteatoma matrix should be conceptually distinguished.

Removing visible debris improves exposure.

But the disease is not treated until the matrix and involved epithelium have been appropriately addressed.

> **PRINCIPLE**
>
> **An empty cholesteatoma sac is still a cholesteatoma sac.**

14.9 DO NOT PULL BEFORE YOU KNOW WHAT IS UNDERNEATH

Matrix may overlie:

- facial nerve
- lateral semicircular canal
- dura
- sigmoid sinus
- stapes

- ossicles

Blind traction can convert an existing erosion into:

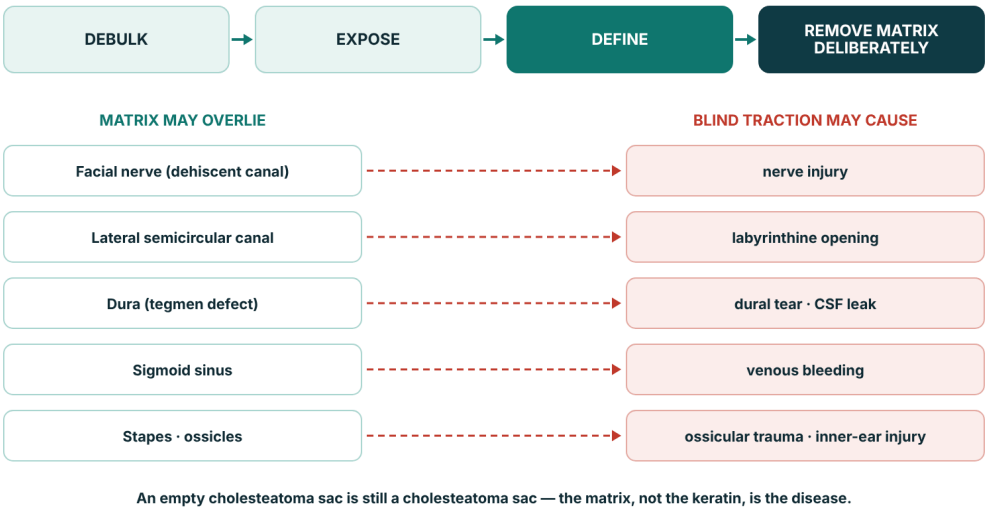
- nerve injury
- labyrinthine opening
- dural tear
- venous bleeding
- ossicular trauma

Therefore:

> **DEBULK → EXPOSE → DEFINE → THEN REMOVE MATRIX DELIBERATELY.**

Figure 14.4 · Do not pull before you know what is underneath

Matrix lying on a critical structure turns blind traction into injury



An empty cholesteatoma sac is still a cholesteatoma sac — the matrix, not the keratin, is the disease.

14.10 CHOOSE THE OPERATION AFTER MAPPING THE DISEASE

Potential strategies may include:

TRANSCANAL / ENDOSCOPIC

for selected limited disease.

CANAL WALL UP
when complete clearance can reasonably be achieved while preserving the wall (Chapter 12, Canal Wall Up Mastoid Surgery).

CANAL WALL DOWN
when open access provides a safer and more durable strategy (Chapter 13, Canal Wall Down Mastoid Surgery).

COMBINED / RECONSTRUCTIVE / OBLITERATIVE

in selected situations (Chapter 16, Mastoid Obliteration & Canal Wall Reconstruction).

The procedure name should be the conclusion of planning.

Not the starting point.

14.11 CANAL WALL UP OR CANAL WALL DOWN?

This question is often presented as a debate.

A more useful framework is:

DISEASE EXTENT
Where is it?

ACCESS
Can every involved space be reached?

CANAL WALL
Healthy, eroded or involved?

COMPLICATIONS
Fistula? Facial nerve? Dura?

HEARING
What can realistically be preserved?

RECURRENCE RISK
What is the retraction environment?

FOLLOW-UP
Can reliable surveillance occur?

PATIENT

Age, comorbidity, lifestyle and ability to maintain follow-up.

Then select the strategy.

14.12 THE OPERATION CAN CHANGE

A planned canal wall up procedure may need conversion if:

- disease is more extensive than expected
- the canal wall is significantly eroded
- hidden disease cannot be safely accessed
- complications alter the operative field

Likewise, selected ears may permit reconstruction after wide disease clearance.

PRINCIPLE

The preoperative plan guides the operation.

> **The intraoperative anatomy decides whether the plan remains appropriate.**

14.13 OSSICULAR INVOLVEMENT

Common disease effects include:

- long-process incus erosion
- stapes-superstructure involvement
- malleus involvement
- fixation by disease

Preserve an ossicle only if preservation permits complete clearance.

If removal is necessary:

REMOVE DELIBERATELY.

Then plan hearing reconstruction according to the remaining chain.

14.14 DISEASE AROUND THE STAPES

This is a high-precision stage.

Risks include:

- stapes dislocation
- footplate injury
- facial nerve injury
- inner-ear trauma

Use:

- excellent visualisation
- fine instrumentation
- controlled matrix dissection

> **PRINCIPLE**
>
> **The operation should become smaller as the anatomy becomes more delicate.**

14.15 FACIAL NERVE DEHISCENCE

Cholesteatoma may erode the facial canal.

When dehiscence is present:

- identify the course of the nerve
- avoid traction
- minimise thermal spread
- dissect matrix under direct vision

If preoperative facial weakness exists, evaluate whether this represents:

- compression
- inflammation
- erosion
- more extensive involvement

The operative plan should account for functional status.

14.16 FACIAL PARALYSIS

Facial weakness associated with cholesteatoma requires urgent and careful evaluation.

Management depends upon:

- onset
- severity
- disease extent
- intraoperative findings
- nerve continuity

Disease clearance and neural management should be planned together.

The nerve should not be decompressed blindly without understanding where disease is affecting it.

Facial nerve management in the temporal bone is discussed in Chapter 21, Facial Nerve Surgery in the Temporal Bone.

14.17 LABYRINTHINE FISTULA

Cholesteatoma may erode the bony labyrinth, most commonly involving the lateral semicircular canal.

Preoperative clues may include:

- vertigo
- fistula symptoms
- sensorineural component
- CT erosion

But some fistulae are clinically silent.

SURGICAL PRINCIPLE

When CT suggests a fistula, the matrix over the labyrinth is no longer ordinary matrix.

Treat it as a protective layer until the anatomy has been defined.

14.18 APPROACH TO A SUSPECTED FISTULA

A conceptual strategy is:

CLEAR DISEASE ELSEWHERE FIRST

↓

LEAVE MATRIX OVER THE SUSPECTED FISTULA TEMPORARILY

↓

DEFINE THE SURROUNDING LABYRINTH

↓

ASSESS SIZE AND LOCATION

↓

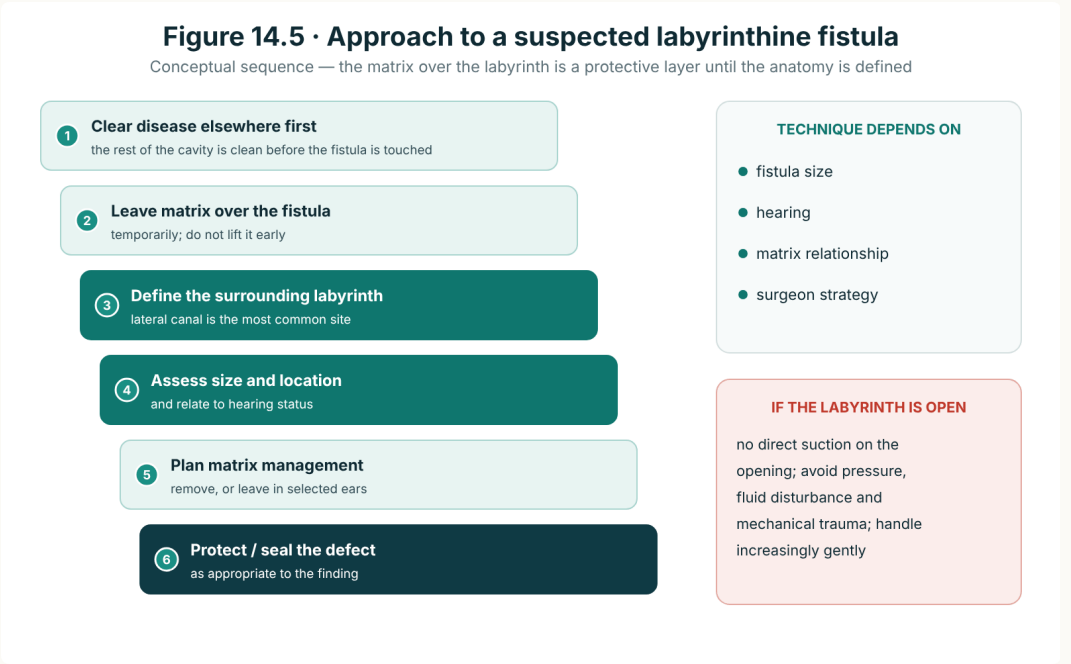
PLAN MATRIX MANAGEMENT

↓

PROTECT / SEAL THE DEFECT AS APPROPRIATE

The exact technique depends upon:

- fistula size
- hearing
- matrix relationship
- surgeon strategy



14.19 DO NOT SUCTION THE OPEN LABYRINTH

If the labyrinth is exposed or opened, avoid unnecessary direct suction and mechanical trauma.

The inner ear is sensitive to:

- pressure
- fluid disturbance
- mechanical injury

Control should become increasingly gentle.

14.20 TEGMEN EROSION

Cholesteatoma may erode the tegmen and expose dura.

Assess:

BONE DEFECT

DURAL INTEGRITY

CSF LEAK

INTRACRANIAL COMPLICATION

Disease should be removed carefully from the dural interface.

Reconstruction depends upon the actual defect.

14.21 SIGMOID PLATE EROSION

Disease may expose the sigmoid sinus.

Matrix removal should avoid:

- forceful traction
- thermal injury
- uncontrolled venous injury

The sinus may remain covered by soft tissue even when bone is absent.

Recognise the anatomy before attempting removal.

14.22 INTRACRANIAL COMPLICATIONS

Potential complications of advanced ear disease include:

- meningitis
- extradural abscess
- subdural empyema
- brain abscess
- venous sinus thrombosis

These situations require multidisciplinary management.

The ear operation becomes part of a broader treatment strategy involving:

- imaging
- antimicrobial therapy
- neurosurgical / neurological input where appropriate
- source control

14.23 SINUS TYMPANI

The sinus tympani is a classic site for residual disease.

Its depth varies.

Microscopic visualisation may be incomplete.

Endoscopic inspection can be particularly valuable.

QUESTION:

Have I cleared what I can see—or have I seen what I need to clear?

The distinction matters.

14.24 ANTERIOR EPITYMPANUM

Anterior attic disease can hide beyond the obvious epitympanic exposure.

The surgeon should understand:

- malleus relationship
- tensor fold / supratubal anatomy
- tegmen
- facial nerve / geniculate relationships in deeper anatomy

A clean antrum does not prove a clean anterior epitympanum.

14.25 HYPOTYMPANUM

Inferior disease may extend into recesses around:

- hypotympanum
- jugular-bulb region
- inferior middle ear

Preoperative imaging should warn the surgeon when vascular anatomy reduces working space.

14.26 ENDOSCOPIC ASSISTANCE

After conventional microscopic clearance, use angled endoscopes selectively to inspect:

- sinus tympani
- facial recess
- anterior epitympanum
- hypotympanum
- other recesses

The endoscope may reveal residual disease.

The principles of endoscopic work are discussed in Book 1, Chapter 12, Principles of Endoscopic Surgery.

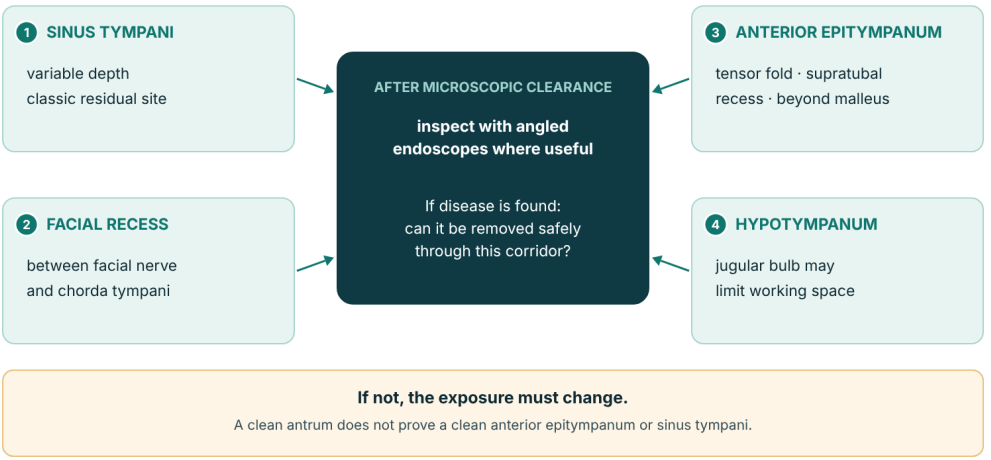
But if disease is found:

> **CAN IT BE REMOVED SAFELY THROUGH THE AVAILABLE CORRIDOR?**

If not, exposure must change.

Figure 14.6 · Hidden sites of residual disease

Have I cleared what I can see — or have I seen what I need to clear?



14.27 RESIDUAL DISEASE

Residual cholesteatoma means disease remained after surgery.

Risk increases in:

- hidden recesses
- extensive disease
- difficult anatomy
- paediatric ears
- limited exposure

Prevention depends upon:

DISEASE MAPPING

ADEQUATE EXPOSURE

SYSTEMATIC INSPECTION

APPROPRIATE SURVEILLANCE.

14.28 RECURRENT DISEASE

Recurrent cholesteatoma develops after initial clearance, often through new retraction or epithelial migration.

Contributors may include:

- persistent Eustachian-tube dysfunction
- attic reconstruction failure
- tympanic-membrane retraction
- canal-wall problems

Prevention therefore requires reconstruction of the **mechanism**, not merely removal of the original sac.

Figure 14.7 · Residual versus recurrent cholesteatoma

Different mechanisms — different prevention

	RESIDUAL	RECURRENT
What it is	disease left behind at surgery	new disease after complete clearance
Mechanism	matrix remnant, often a pearl	new retraction or epithelial migration
Where	hidden recesses, sites of limited exposure	attic / posterosuperior retraction
Risk	extensive disease, children, difficult anatomy	persistent Eustachian-tube dysfunction
Prevention	mapping · exposure · systematic inspection	reconstruct the mechanism, not only the sac
Detection	DWI MRI · planned second look · clinic	clinical surveillance · DWI MRI

Ask first: residual or recurrent? Where? Why?

14.29 RECONSTRUCT THE EAR THAT PRODUCED THE DISEASE

After clearance, ask:

Why did this cholesteatoma develop?

If the ear had:

- attic retraction
- pars tensa collapse
- poor support

then reconstruction should address that environment where possible.

Otherwise the operation may remove today's cholesteatoma while preserving tomorrow's mechanism.

14.30 HEARING RECONSTRUCTION

After disease clearance:

STAPES PRESENT?

MALLEUS PRESENT?

MIDDLE-EAR SPACE HEALTHY?

RESIDUAL-DISEASE CONCERN?

RECONSTRUCTION STABLE?

Then decide:

PRIMARY OSSICULOPLASTY

or

STAGED RECONSTRUCTION.

Do not let the desire for immediate hearing restoration reduce confidence in disease clearance.

Ossicular reconstruction is discussed in Chapter 10, Ossicular Reconstruction.

14.31 SECOND LOOK

A planned second-look procedure may be appropriate in selected patients, particularly when residual disease risk is significant.

Its purpose may include:

- detecting residual cholesteatoma
- completing hearing reconstruction
- reassessing middle-ear stability

The decision should be individualised.

14.32 DIFFUSION-WEIGHTED MRI SURVEILLANCE

Appropriate non-echo-planar diffusion-weighted MRI has become important in postoperative cholesteatoma surveillance.

Its role depends upon:

- lesion size
- timing
- imaging quality

- reconstruction
- clinical context

Imaging does not eliminate the need for clinical follow-up.

Nor does a negative study at one point guarantee permanent absence of disease.

14.33 THE CHILD WITH CHOLESTEATOMA

Paediatric cholesteatoma may present particular challenges because of:

- aggressive disease patterns in some patients
- long life expectancy
- Eustachian-tube dysfunction
- recurrence risk
- follow-up requirements

The desire to preserve anatomy should be balanced against long-term disease control.

14.34 REVISION CHOLESTEATOMA

Before revision, determine:

RESIDUAL OR RECURRENT?

WHERE?

WHY?

Was there:

- hidden sinus tympani disease?
- retained attic disease?
- recurrent retraction?
- high facial ridge?
- narrow meatus?
- inadequate cavity?
- reconstruction failure?

Revision should correct the mechanism of failure.

Revision surgery is discussed in Chapter 15, Difficult & Revision Mastoid Surgery.

DECISION FRAMEWORK

CHOOSING THE SURGICAL STRATEGY

MAP THE DISEASE

↓

DEFINE CRITICAL STRUCTURE INVOLVEMENT

Facial nerve? Labyrinth? Dura? Sinus?

↓

ASSESS CANAL WALL

Preservable and useful?

↓

ASSESS ACCESS TO HIDDEN RECESSES

↓

ASSESS HEARING & RECONSTRUCTIVE POTENTIAL

↓

ASSESS FOLLOW-UP RELIABILITY

↓

SELECT

Transcanal / Endoscopic

or

Canal Wall Up

or

Canal Wall Down

or

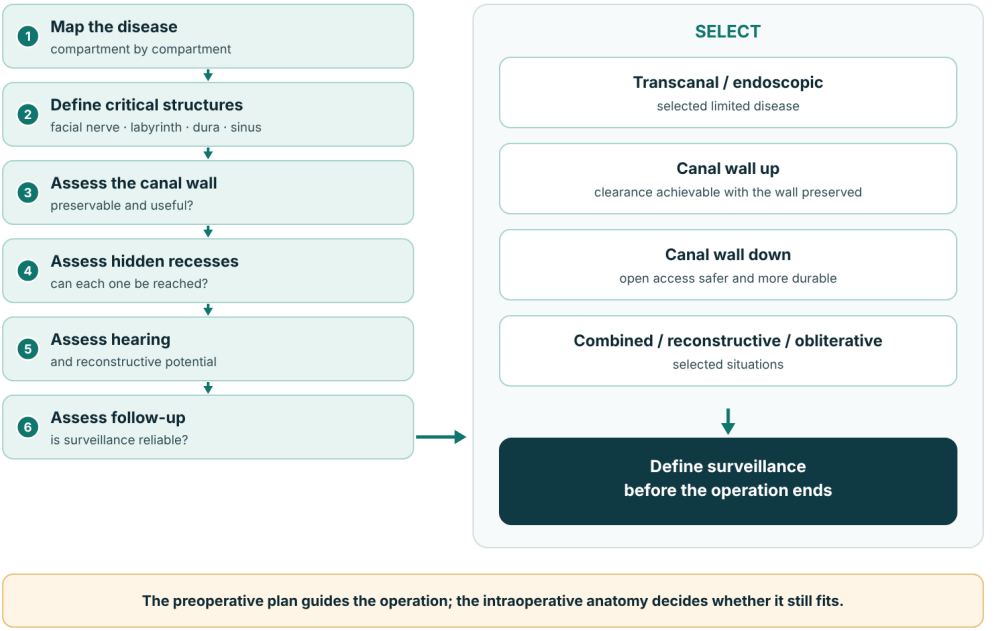
Combined / Reconstructive Strategy

↓

DEFINE SURVEILLANCE BEFORE THE OPERATION ENDS

Figure 14.8 · Choosing the surgical strategy for cholesteatoma

The procedure name is the conclusion of planning, not its starting point



The preoperative plan guides the operation; the intraoperative anatomy decides whether it still fits.

FROM EXPERIENCE

Cholesteatoma teaches an important lesson about procedure names.

A surgeon may begin by asking:

Should I do canal wall up or canal wall down?

But the disease has not read those chapters.

It has travelled wherever anatomy allowed it to travel.

The better sequence is:

Where is the disease?

What structures has it reached?

Which spaces can I safely clear?

What anatomy can I preserve without compromising clearance?

Only then does the operation acquire a name.

DISEASE FIRST.

PROCEDURE SECOND.

TAKE IT TO THE OT

Before cholesteatoma surgery, define:

ORIGIN

ATTIC

MESOTYMPANUM

SINUS TYMPANI

FACIAL RECESS

HYPOTYMPANUM

ADITUS / ANTRUM

MASTOID

OSSICLES

FACIAL NERVE

LABYRINTH

TEGMEN / DURA

SIGMOID

HEARING

SURGICAL STRATEGY

RECONSTRUCTION

SURVEILLANCE

CHAPTER SUMMARY

Cholesteatoma is a three-dimensional disease of connected spaces.

Map the disease before choosing the operation.

Remove matrix deliberately rather than pulling blindly from critical structures.

Preserve ossicles and canal wall only when disease clearance remains reliable.

Treat facial nerve, labyrinth, dura and venous exposure as changes in surgical risk.

Inspect hidden recesses.

Use endoscopy where it improves meaningful visualisation.

Reconstruct the mechanism that produced the disease where possible.

Plan surveillance before completing surgery.

And remember:

> **Do not make the cholesteatoma fit your operation.**

> **Make the operation fit the cholesteatoma.**

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CHAPTER 15

Difficult & Revision Mastoid Surgery

When the Landmarks Are Narrowed, Distorted or Gone

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- recognise anatomical and disease-related factors that make mastoid surgery difficult
- plan surgery in a sclerotic or contracted mastoid
- adapt to a low tegmen, anterior sigmoid sinus and high jugular bulb
- understand the principles of revision after canal wall up and canal wall down surgery
- identify remaining reliable landmarks when normal anatomy has been altered
- approach an exposed or displaced facial nerve safely
- distinguish residual disease from recurrent disease and cavity failure
- understand when another corridor or surgical strategy is safer than continuing through scarred anatomy
- apply the principle of progressing from known anatomy towards altered anatomy

15.1 DIFFICULT MASTOID SURGERY IS NOT ONE CONDITION

A mastoid may be difficult because of:

BONE

Dense sclerosis.

SPACE

Narrow corridor.

ANATOMY

Low tegmen, anterior sigmoid, high jugular bulb.

DISEASE

Extensive cholesteatoma, fistula, erosion.

PREVIOUS SURGERY

Missing landmarks and scar.

COMBINATION

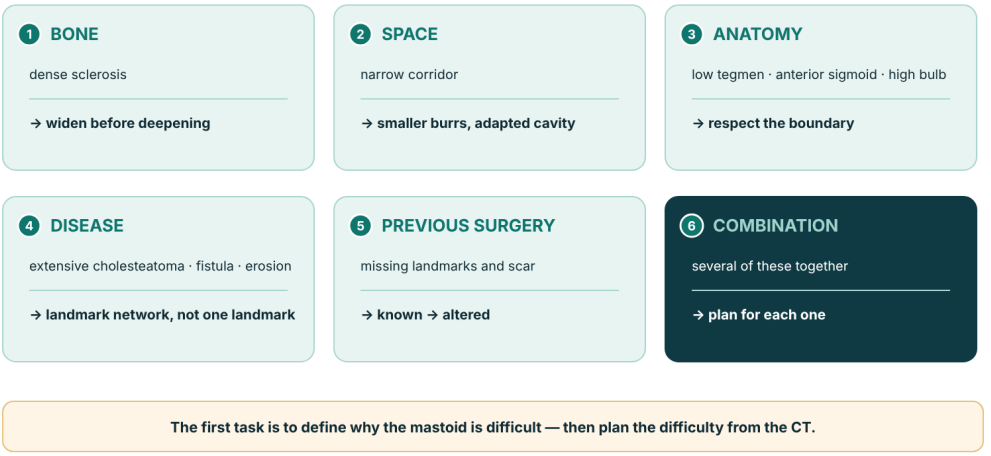
Several of these together.

The first task is therefore to define **why** the mastoid is difficult.

The solution depends upon the reason.

Figure 15.1 · Why is this mastoid difficult?

Difficult mastoid surgery is not one condition — the solution depends on the reason



15.2 DIFFICULTY SHOULD BE PREDICTED BEFORE SURGERY

Review CT specifically for:

- mastoid pneumatisation
- tegmen height
- sigmoid position

- jugular bulb
- facial nerve
- labyrinth
- canal-wall anatomy
- previous drilling
- disease extent
- bony erosion

PRINCIPLE

An anatomical difficulty visible on CT should become a planned difficulty—not an intraoperative surprise.

15.3 THE SCLEROTIC MASTOID

A sclerotic mastoid provides fewer air-cell pathways.

Instead of moving from one air cell to another, the surgeon may need to uncover landmarks through continuous bone.

This creates several challenges:

- depth is less visually obvious
- drilling generates more heat
- the antrum may feel more difficult to locate
- landmarks appear later

The solution is not to drill a narrow tunnel towards the presumed antrum.

WIDEN FIRST.

15.4 SCLEROTIC MASTOID — OPERATIVE STRATEGY

Use:

BROAD CORTICAL EXPOSURE

↓

DEFINE SUPERIOR BOUNDARY

↓

DEFINE POSTERIOR BOUNDARY

↓

KEEP POSTERIOR CANAL WALL ORIENTATION

↓

PROGRESSIVELY DEEPEN

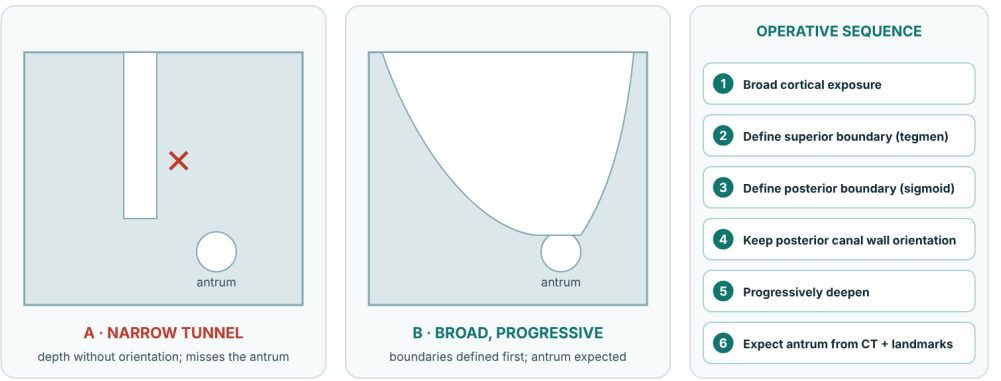
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EXPECT ANTRUM FROM CT + LANDMARKS

The absence of air cells increases the value of geometric orientation.

Figure 15.2 · The sclerotic mastoid: widen first, then deepen

Schematic section through a sclerotic mastoid — not to scale; the surgeon's view is from the top



Without air cells, depth is less obvious, drilling is hotter and landmarks appear later.

The absence of air cells increases the value of geometric orientation.

Widen first.

15.5 DO NOT SEARCH FOR THE ANTRUM WITH DEPTH

If the antrum does not appear:

STOP.

Ask:

Am I too posterior?

Too inferior?

Too lateral?

Is the tegmen low?

Is the sigmoid anterior?

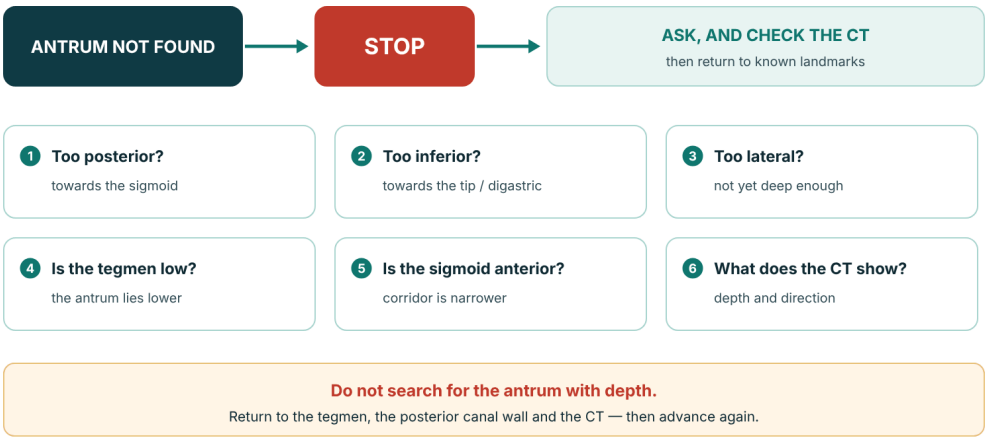
What does the CT show?

PRINCIPLE

When a landmark is missing, increase orientation—not depth.

Figure 15.3 · The antrum has not appeared

When a landmark is missing, increase orientation — not depth



15.6 THE CONTRACTED MASTOID

Sometimes the mastoid corridor is physically narrow because:

- sigmoid sinus is anterior
- tegmen is low
- posterior canal wall lies close to sinus
- pneumatisation is poor

The surgeon may have very little working space.

This should change:

- burr size
- drill direction

- expectations of cavity geometry
- threshold for alternative access

Do not attempt to create the cavity of an average temporal bone inside a contracted one.

15.7 ANTERIOR SIGMOID SINUS

An anterior sigmoid sinus may substantially reduce the posterior mastoid working corridor.

Before surgery, define:

- distance from posterior canal wall
- depth from cortex
- relationship to labyrinth

During drilling:

- identify the sinus early enough to understand the boundary
- avoid repeatedly working towards it blindly
- adapt the cavity to the available anatomy

> **PRINCIPLE**
>
> **The sinus is a boundary to work with—not an obstacle to defeat.**

15.8 LOW TEGMEN

A low tegmen reduces superior space and may make the antral route feel lower and narrower.

Avoid compensating by drilling superiorly into the cranial boundary.

Use:

- CT
- posterior canal wall
- antral relationships
- progressive lateral-to-medial orientation

The roof determines the available space.

The operation must respect it.

15.9 HIGH JUGULAR BULB

A high jugular bulb may alter:

- hypotympanic access
- round-window exposure
- inferior middle-ear work
- selected cochlear-implant and skull-base procedures

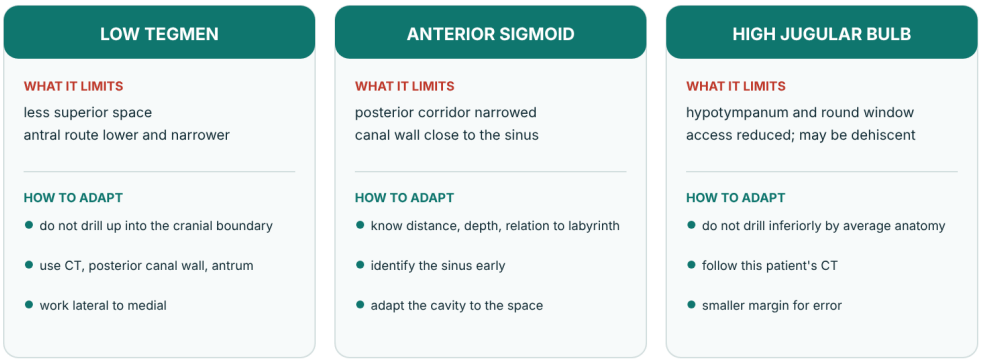
If dehiscent, the margin for error becomes smaller.

CAUTION

Do not drill inferiorly according to remembered average anatomy when CT has already shown that the patient's vascular anatomy is different.

Figure 15.4 · Three anatomical constraints seen on CT

Plan the difficulty before surgery — the boundary decides the corridor



The sinus, the tegmen and the bulb are boundaries to work with — not obstacles to defeat.

15.10 NARROW FACIAL RECESS

A narrow facial recess may result from:

- close facial nerve–chorda relationship
- thick posterior canal wall
- altered middle-ear geometry

The surgeon should not enlarge the corridor by sacrificing safety.

Ask:

Is this corridor essential?

Can exposure be improved elsewhere?

Can an endoscope provide additional visualisation?

Would another approach be safer?

15.11 DISEASE HAS DESTROYED THE LANDMARK

Cholesteatoma may erode:

- lateral semicircular canal
- ossicles
- canal wall
- tegmen
- facial canal

A landmark that is normally used for orientation may therefore be abnormal or absent.

In that situation, do not depend upon it.

Build orientation from remaining structures.

LANDMARK NETWORK > SINGLE LANDMARK.

15.12 REVISION MASTOID SURGERY

Revision surgery begins with a different question:

WHAT ANATOMY REMAINS?

Not:

> **What anatomy should normally be here?**

The previous operation may have:

- removed bone
- exposed dura

- exposed sinus
- altered canal wall
- skeletonised facial nerve
- obliterated spaces
- inserted reconstructive material

The previous cavity is now the starting anatomy.

The general principles of re-entering an operated field are discussed in Book 1, Chapter 19, Revision Surgery & Altered Anatomy.

15.13 REVIEW THE PREVIOUS OPERATION

Whenever possible, obtain:

- old operative note
- previous CT
- current CT
- pathology
- previous reconstruction details
- hearing results
- previous complications

Ask:

CWU or CWD?

Was the facial recess opened?

Was the canal wall reconstructed?

Was the mastoid obliterated?

Were ossicles removed?

Was dura or sinus exposed?

These details change the revision map.

15.14 OLD CT + NEW CT

Compare the studies.

OLD CT

What anatomy existed before surgery?

POSTOPERATIVE / CURRENT CT

What has been removed?

CURRENT DISEASE

What is new?

This can help distinguish:

- postoperative cavity
- reconstruction
- recurrent disease
- residual disease
- scar

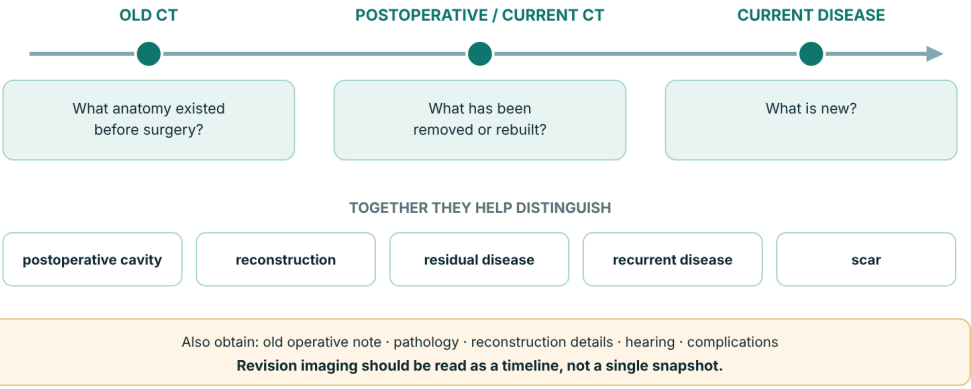
PRINCIPLE

Revision imaging should be read as a timeline, not as a single snapshot.

Postoperative imaging is discussed in Chapter 7, Temporal Bone Imaging for the Surgeon.

Figure 15.5 · Read revision imaging as a timeline

Old CT, current CT and current disease answer three different questions



15.15 RE-ENTRY

During revision:

- expose broadly
- identify the edges of previous bone work
- understand where normal cortex transitions into operated cavity
- expect soft tissue to be adherent to exposed structures

Do not plunge directly into the deepest part of the old cavity.

KNOWN → ALTERED.

15.16 START WHERE THE FIRST SURGEON DID NOT OPERATE

Where possible, identify relatively untouched anatomy.

For example:

- intact cortical edge
- tegmen away from scar
- sigmoid boundary away from disease
- digastric ridge
- remaining canal wall

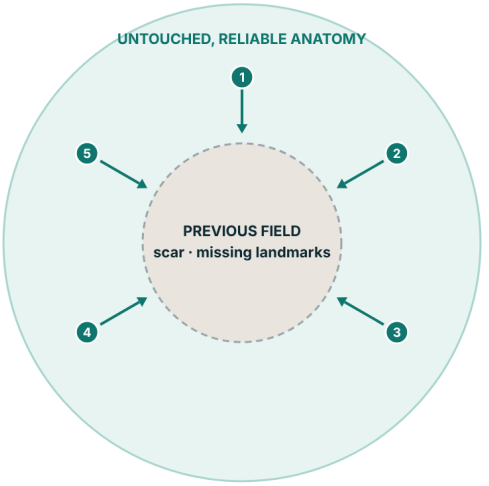
Then work towards the previous field.

REVISION PRINCIPLE

Normal anatomy should lead you into abnormal anatomy—not the other way around.

Figure 15.6 · Start where the first surgeon did not operate

Conceptual — normal anatomy leads into abnormal anatomy, not the other way round



BEGIN FROM

1. Intact cortical edge
2. Tegmen away from scar
3. Sigmoid boundary away from disease
4. Digastric ridge
5. Remaining canal wall

RE-ENTRY

expose broadly; find the edges of the old bone work; expect adherent soft tissue; do not plunge into the deepest part of the old cavity

15.17 SCAR OVER DURA

In revision surgery, dura may be:

- already exposed
- adherent to scar
- covered by thin fibrous tissue

Do not assume a bony layer remains.

Sharp controlled dissection may be safer than forceful elevation in selected areas.

If CSF leak occurs, define and repair according to the defect.

15.18 SCAR OVER SIGMOID SINUS

A previously skeletonised or exposed sinus may lie immediately beneath scar.

Aggressive curettage or blind elevation can cause venous injury.

Use:

- CT
- known bony edges

- gentle dissection
- deliberate exposure

PRINCIPLE

In revision surgery, soft tissue may be the only remaining cover over a major structure.

15.19 THE EXPOSED FACIAL NERVE

The facial nerve may have been:

- skeletonised intentionally
- dehiscent from disease
- exposed during prior surgery
- surrounded by scar

Do not search for a bony facial canal that no longer exists.

Instead:

- identify the nerve from a reliable segment
- understand its expected direction
- reduce traction
- minimise thermal injury
- use monitoring where appropriate

15.20 FACIAL NERVE MONITORING

Monitoring may be particularly useful in selected revision cases.

But scar can make stimulation and interpretation complex.

Monitoring should complement:

- imaging
- landmarks
- direct visualisation

MONITORING PRINCIPLE

A silent monitor does not make uncertain tissue safe to divide.

Intraoperative monitoring is discussed in Book 1, Chapter 14, Technology in the Operating Room.

15.21 REVISION AFTER CANAL WALL UP SURGERY

Possible problems include:

- residual cholesteatoma
- recurrent retraction
- recurrent cholesteatoma
- ossicular failure
- hidden mastoid disease

Ask:

Why did the original CWU strategy fail?

If the problem was inadequate access or recurrent disease, simply repeating the same exposure may reproduce the same result.

15.22 REVISION AFTER CANAL WALL DOWN SURGERY

Common problems include:

- residual disease
- recurrent cholesteatoma
- high facial ridge
- narrow meatus
- deep mastoid tip
- bony overhang
- exposed bone
- chronic granulation
- poor epithelialisation

The revision operation should correct the cavity geometry.

Not merely remove today's debris.

Cavity design and the causes of a discharging cavity are discussed in Chapter 13, Canal Wall Down Mastoid Surgery.

15.23 THE TROUBLESOME CAVITY

Map the cavity like a new anatomical region.

ENTRANCE
Is the meatus adequate?

ANTERIOR
Is the facial ridge high?

SUPERIOR
Is there an attic overhang?

POSTERIOR
Is there a hidden recess?

INFERIOR
Is the tip deep?

SURFACE
Is it epithelialised?

MIDDLE EAR
Is there persistent mucosal disease?

The cavity itself often explains its symptoms.

15.24 PREVIOUS OBLITERATION

Revision after mastoid obliteration can be challenging.

The surgeon must understand:

- material used
- location
- disease surveillance
- possibility of hidden residual/recurrent cholesteatoma

Preoperative imaging becomes particularly important.

Do not assume obliteration material is normal bone or normal soft tissue.

Obliteration and canal-wall reconstruction are discussed in Chapter 16, Mastoid Obliteration & Canal Wall Reconstruction.

15.25 PREVIOUS CANAL-WALL RECONSTRUCTION

A reconstructed wall may:

- remain stable
- resorb
- displace
- retract
- conceal recurrent disease

Before revision, determine whether the reconstructed anatomy should be:

- preserved
- revised
- removed

The decision follows disease and stability.

15.26 LABYRINTHINE FISTULA IN REVISION SURGERY

Previous surgery may leave:

- exposed labyrinth
- repaired fistula
- matrix or scar over a fistula

Before manipulation:

- review CT
- assess hearing
- identify the labyrinth
- avoid direct suction
- avoid uncontrolled traction

A previously treated fistula deserves the same respect as a new one.

Fistula management is discussed in Chapter 14, Cholesteatoma.

15.27 HEARING IN THE REVISION EAR

Before revision, document:

- air conduction
- bone conduction
- speech measures where appropriate
- contralateral hearing

The revision objective may be:

DISEASE CONTROL
with hearing preservation where possible.

Do not risk a stable inner ear merely to improve a modest conductive deficit unless the expected benefit justifies the risk.

15.28 WHEN TO CHANGE STRATEGY

Revision may require:

CWU → CWD

OPEN CAVITY → OBLITERATION

MICROSCOPIC → MICROSCOPIC + ENDOSCOPIC

LIMITED → WIDER EXPOSURE

SINGLE-STAGE → STAGED
The previous operation should not dictate the next one.

The reason it failed should.

Figure 15.7 · When to change strategy

The reason the previous operation failed should decide the next one

PREVIOUS	REVISION	CONSIDER WHEN
CWU	CWD	inadequate access or recurrent retraction
Open cavity	Obliteration	troublesome cavity with reliable clearance
Microscopic	+ Endoscopic	hidden recesses beyond the line of sight
Limited	Wider exposure	landmarks cannot be identified safely
Single-stage	Staged	clearance or middle-ear stability uncertain

Simply repeating the same exposure may reproduce the same result.

DECISION POINT

I CANNOT IDENTIFY THE EXPECTED LANDMARK

Do not continue searching in scar.

STOP.

Ask:

Was the landmark removed previously?

Was it destroyed by disease?

Can I identify another landmark?

Can I approach from normal bone?

What does CT show?

Would navigation or monitoring add useful information?

Should the approach change?

Then re-enter the problem from certainty.

15.29 WHEN TO STOP

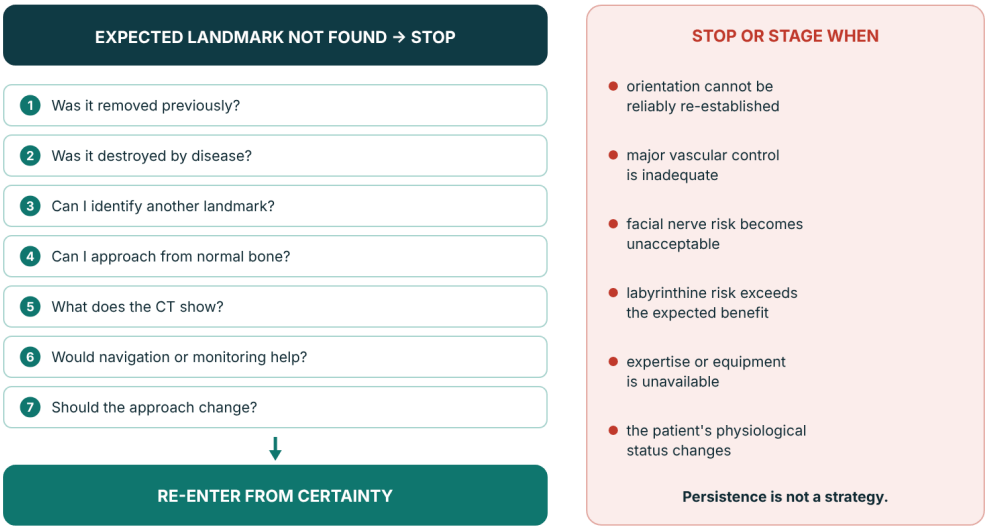
Stop or stage the procedure when:

- orientation cannot be reliably re-established
- major vascular control is inadequate
- facial nerve risk becomes unacceptable
- labyrinthine injury risk exceeds expected benefit
- required expertise or equipment is unavailable
- the patient's physiological status changes

Revision surgery does not reward persistence for its own sake.

Figure 15.8 · I cannot identify the expected landmark

Re-enter the problem from certainty — and know when to stop or stage



FROM EXPERIENCE

Primary mastoid surgery teaches us landmarks.

Revision mastoid surgery tests whether we actually understand them.

The canal wall may be gone.

The incus may be gone.

The lateral canal may already be exposed.

The facial nerve may have no bony covering.

The dura may lie directly beneath scar.

If our understanding depended only upon seeing the textbook landmarks in their textbook form, orientation disappears with them.

But if we understand their **relationships**, one remaining structure can lead us towards another.

That is why anatomy must be learned as a network.

TAKE IT TO THE OT

Before difficult or revision mastoid surgery, define:

WHY IS IT DIFFICULT?

Bone? Space? Disease? Previous surgery?

OLD OPERATION

What was removed?

CT

What remains?

TEGMEN

Normal, low, exposed?

SIGMOID

Anterior, exposed, scarred?

JUGULAR BULB

High?

FACIAL NERVE

Covered, dehiscent, previously exposed?

LABYRINTH

Intact, fistula, previously treated?

CANAL WALL

Present, absent, reconstructed?

MEATUS

Adequate?

HEARING

What function must be protected?

BAILOUT

What will make the strategy change?

CHAPTER SUMMARY

Difficult mastoid surgery begins by defining the source of difficulty.

Predict anatomical constraints on CT.

In the sclerotic mastoid, widen before deepening.

Respect the boundaries created by a low tegmen, anterior sigmoid and high jugular bulb.

In revision surgery, study the previous operation as part of the anatomy.

Begin in untouched or reliably identifiable anatomy.

Work towards scar.

Do not search for landmarks that have already been removed.

Use multiple relationships to regain orientation.

Change the surgical strategy when the previous strategy no longer serves the ear.

And remember:

> **Primary surgery asks, "Where should the anatomy be?"**

> **Revision surgery asks, "What anatomy remains—and how do I reach it safely?"**

FURTHER READING & REFERENCES

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CHAPTER 16

Mastoid Obliteration & Canal Wall Reconstruction

Rebuilding the Postoperative Ear

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the objectives of mastoid obliteration
- distinguish obliteration from simple cavity filling
- recognise which postoperative cavity problems may benefit from obliteration
- understand the importance of complete disease clearance before reducing cavity access
- analyse available autologous and other reconstructive materials conceptually
- understand the principles of posterior canal-wall reconstruction
- preserve vascularity and epithelial coverage during reconstruction
- plan surveillance after obliteration or canal-wall reconstruction
- recognise common mechanisms of reconstructive failure

16.1 WHY OBLITERATE A MASTOID?

A canal wall down cavity can provide excellent disease access.

But some cavities may develop long-term problems such as:

- recurrent debris
- chronic moisture
- recurrent infection
- difficulty with water exposure
- caloric-induced vertigo

- dependence upon repeated cleaning
- poor epithelialisation

Mastoid obliteration attempts to reduce selected cavity volume and eliminate problematic recesses.

The objective is not simply:

FILL THE HOLE.

It is:

> **CREATE A SMALLER, STABLE, WELL-COVERED AND SURVEILLABLE POSTOPERATIVE EAR.**

16.2 OBLITERATION DOES NOT REPLACE GOOD CAVITY SURGERY

Before considering obliteration, correct basic cavity geometry.

Ask:

Is the meatus adequate?

Is the facial ridge appropriately lowered?

Are overhangs removed?

Is the mastoid tip excessively deep?

Has disease been completely cleared?

A poorly designed cavity filled with material remains a poorly designed operation.

PRINCIPLE

Obliteration should solve a volume problem—not hide a geometry problem.

Cavity geometry is discussed in Chapter 13, Canal Wall Down Mastoid Surgery.

16.3 THE FIRST REQUIREMENT: DISEASE CONTROL

The greatest concern with obliteration is obvious:

THE RECONSTRUCTION CAN HIDE WHAT LIES BENEATH IT.

Therefore, before obliteration:

- map disease carefully
- clear cholesteatoma
- inspect hidden recesses
- assess critical structures
- define surveillance strategy

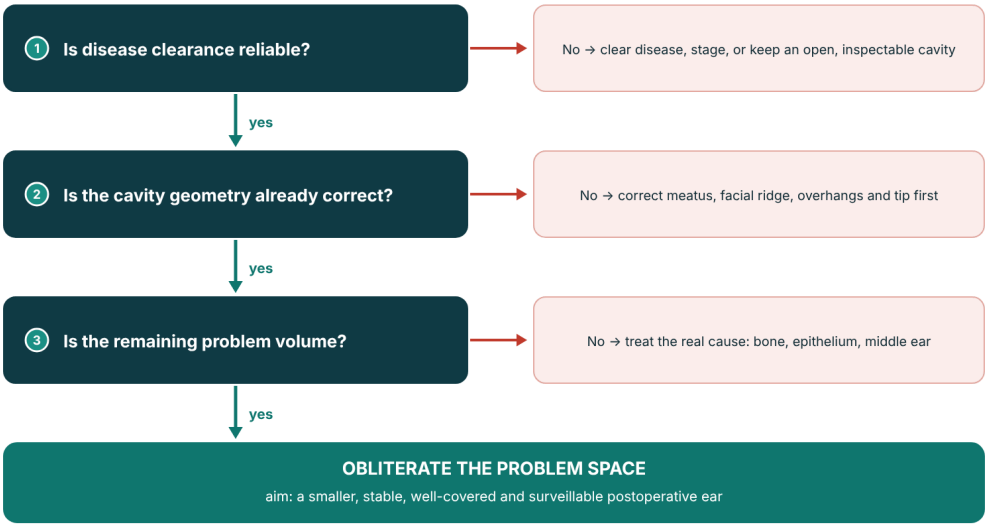
SURGICAL PRINCIPLE

Never use obliteration to create confidence in disease clearance.

Achieve confidence in clearance before obliteration.

Figure 16.1 · Before obliterating: three gates

Obliteration should solve a volume problem — not hide a geometry or disease problem



16.4 INDICATIONS ARE INDIVIDUAL

Obliteration may be considered in selected situations such as:

- primary surgery where a large cavity would otherwise remain
- revision of a troublesome open cavity
- selected canal-wall reconstruction strategies

- defects requiring soft-tissue filling
- skull-base or temporal-bone reconstruction (Chapter 31, Skull Base Reconstruction after Temporal Bone Resection)

The technique should follow the specific problem.

Not every canal wall down cavity requires obliteration.

16.5 ANALYSE THE CAVITY

Before reconstructing, divide the postoperative mastoid into regions.

ATTIC

ANTRUM

SINODURAL REGION

POSTERIOR CAVITY (RETROSIGMOID CELLS WHERE PRESENT)

MASTOID TIP

FACIAL RIDGE

EXTERNAL CANAL

Then ask:

Which spaces need to remain accessible?

Which spaces can safely be reduced?

Which spaces create the cavity problem?

Where must epithelial lining remain?

Figure 16.2 · Zoning the postoperative mastoid

Decide region by region what must stay open, what may be reduced and what must stay lined

REGION	STAYS ACCESSIBLE?	CAN BE REDUCED?	CAUSING THE PROBLEM?	NEEDS EPITHELIUM?
Attic	☐	☐	☐	☐
Antrum	☐	☐	☐	☐
Sinodural region	☐	☐	☐	☐
Posterior cavity	☐	☐	☐	☐
Mastoid tip	☐	☐	☐	☐
Facial ridge	☐	☐	☐	☐
External canal	☐	☐	☐	☐

Fill only the spaces that create the problem; keep the spaces that need to be watched or to function.

16.6 OBLITERATION AND EXTERIORISATION ARE OPPOSITE CONCEPTS

Canal wall down surgery traditionally exteriorises disease-bearing spaces so they can be inspected.

Obliteration intentionally reduces some of those spaces.

Therefore the surgeon is exchanging:

DIRECT ACCESS

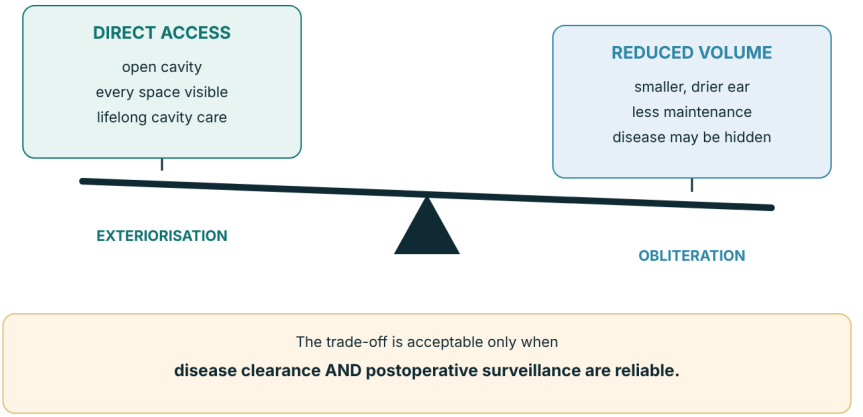
for

REDUCED CAVITY VOLUME.

This trade-off is acceptable only when disease clearance and postoperative surveillance are reliable.

Figure 16.3 · Exteriorisation and obliteration are opposite concepts

The surgeon exchanges direct access for reduced cavity volume



16.7 MATERIAL SELECTION

An obliteration material should ideally provide:

- biological compatibility
- stability
- appropriate volume
- resistance to infection
- predictable healing

Materials may broadly include:

AUTOGENOUS

Bone pâté / chips
Cartilage
Muscle
Fascial tissue
Vascularised local flaps

OTHER MATERIALS

Selected synthetic or biologic materials, such as hydroxyapatite and bioactive glass, have been used in different reconstructive strategies.

The choice depends upon:

- disease
- defect
- vascularity
- surgeon experience
- evidence
- surveillance considerations

Figure 16.4 · Choosing the obliteration material

Biology, stability and surveillance — no material compensates for residual disease or poor geometry

MATERIAL	STRENGTHS	CAUTIONS
Bone pâté / chips	available; fills irregular spaces; autologous	not from diseased bone; resorbs; needs cover
Cartilage	structure and contour; resists resorption	limited volume; donor site (tragus, concha)
Muscle / fascia	fills dead space; covers bone	volume shrinks with time
Vascularised local flap	brings blood supply: revision, irradiated, exposed dura	pedicle, arc of rotation, tension
Synthetic / biologic	no donor site; e.g. hydroxyapatite, bioactive glass	infection, exposure, imaging interpretation

Obliteration is controlled volume replacement — not maximal filling.

16.8 AUTOGENOUS BONE

Bone dust, pâté or chips may be harvested during drilling and used in selected obliteration techniques.

Potential advantages include:

- availability
- autologous origin
- ability to fill irregular spaces

Important considerations include:

- contamination by disease
- stability

- resorption
- need for vascularised coverage

PRINCIPLE

Do not recycle diseased bone into the reconstruction.

16.9 CARTILAGE

Cartilage may provide:

- structural support
- contour
- resistance to resorption
- canal-wall reconstruction

Possible donor sites include:

- tragus
- concha
- other appropriate autologous sources

The amount and geometry should match the reconstructive requirement.

16.10 MUSCLE AND SOFT TISSUE

Vascularised soft tissue can:

- fill dead space
- cover bone
- improve vascularity
- protect exposed critical structures

Local muscle or fascial flaps may be useful depending upon the defect.

But muscle volume can change with time.

The surgeon should anticipate long-term contour rather than only immediate filling.

16.11 VASCULARISED FLAPS

A vascularised flap offers an important advantage:

IT BRINGS BLOOD SUPPLY INTO THE RECONSTRUCTION.

This may be particularly useful in:

- revision surgery
- irradiated tissue
- exposed dura
- vascular exposure
- poorly healing cavities

Examples include the meatally based (Palva) musculoperiosteal flap and local temporalis muscle or temporoparietal fascia flaps.

Flap design should respect:

- pedicle
- arc of rotation
- final position
- tension

16.12 DO NOT COMPRESS THE RECONSTRUCTION

Overpacking an obliterated mastoid can create:

- pressure
- tissue ischaemia
- displacement
- canal narrowing

The reconstruction should fill the intended space without becoming a source of pressure.

PRINCIPLE

Obliteration is controlled volume replacement—not maximal filling.

16.13 CANAL WALL RECONSTRUCTION

Posterior canal-wall reconstruction attempts to recreate the boundary between:

EXTERNAL AUDITORY CANAL
and

MASTOID.
Potential objectives include:

- restoration of canal anatomy
- reduction of open-cavity morbidity
- improved hearing-aid use in selected patients
- improved water tolerance
- reduced maintenance

The reconstructed wall must be:

STABLE

WELL COVERED

APPROPRIATELY POSITIONED

> **COMPATIBLE WITH SURVEILLANCE.**

16.14 RECONSTRUCT THE GEOMETRY, NOT JUST THE WALL

The posterior canal wall has:

- height
- curvature
- thickness
- relationship to tympanic membrane
- relationship to facial ridge

A flat plate placed between canal and mastoid does not automatically reproduce normal canal anatomy.

RECONSTRUCTIVE PRINCIPLE
A wall is a three-dimensional boundary—not merely a barrier.

16.15 MATERIALS FOR WALL RECONSTRUCTION

Depending upon technique, reconstruction may use:

- cartilage
- bone
- composite grafts
- selected prosthetic materials

The material should provide:

- adequate structural support
- biological compatibility
- stable contour
- reliable coverage

No material compensates for residual disease or poor geometry.

16.16 EPITHELIAL COVERAGE

The reconstructed canal requires viable epithelial lining.

Without appropriate coverage, the patient may develop:

- granulation
- exposed material
- infection
- restenosis

Preserve:

- canal skin
- tympanomeatal flaps
- vascularised soft tissue

where possible.

PRINCIPLE

A reconstructed wall without a healthy surface is an unfinished reconstruction.

16.17 RECONSTRUCTION OF THE ATTIC

Attic reconstruction may help:

- restore lateral epitympanic support
- reduce recurrent retraction in selected ears
- reconstruct canal contour

But the reconstruction should not create a new hidden pocket.

The surgeon should think about:

> **WHAT WILL HAPPEN IF THE TYMPANIC MEMBRANE RETRACTS AGAIN?**

A reconstruction that creates an inaccessible recess may convert recurrence into concealed recurrence.

16.18 TYMPANIC MEMBRANE AND OSSICULAR RECONSTRUCTION

After mastoid reconstruction, the surgeon must still consider:

- membrane position
- malleus
- stapes
- middle-ear space
- ventilation
- prosthesis stability

Obliteration does not automatically improve hearing.

The sound-conduction system must still be reconstructed independently (Chapter 9, Tympanoplasty; Chapter 10, Ossicular Reconstruction).

16.19 DO NOT OVER-OBLITERATE THE MIDDLE EAR

The mastoid can be reduced.

The middle-ear sound-conduction space still requires adequate geometry.

Avoid reconstruction that:

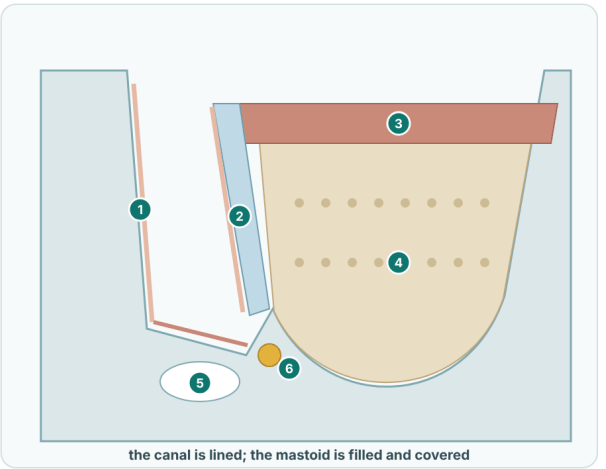
- compresses ossicles
- contacts prosthesis
- restricts tympanic-membrane movement
- obstructs necessary aeration

PRINCIPLE

Fill the cavity that should disappear. Preserve the space that needs to function.

Figure 16.5 · Canal wall reconstruction with mastoid obliteration

Right ear, schematic horizontal section seen from above — lateral at top, anterior to the left; not to scale



1. **Canal skin** — viable epithelial lining
2. **Reconstructed posterior wall** — cartilage or bone; 3-D contour
3. **Vascularised flap** — brings blood supply, covers
4. **Obliteration material** — e.g. bone pâté / chips
5. **Middle-ear space** — kept free for sound conduction
6. **Facial nerve** — beneath the facial ridge

Fill the cavity that should disappear. Preserve the space that needs to function.

A wall is a three-dimensional boundary — not merely a barrier.

16.20 REVISION TROUBLESOME CAVITY

In revision surgery, first identify why the cavity is problematic.

NARROW MEATUS?

Correct the entrance.

HIGH FACIAL RIDGE?

Correct the ridge.

DEEP TIP?

Correct the dependent space.

EXPOSED BONE?
Restore coverage.

LARGE CAVITY?
Consider volume reduction.

RESIDUAL DISEASE?
Treat the disease first.

Obliteration is one component of revision—not the answer to every cavity problem.

16.21 SURVEILLANCE AFTER OBLITERATION

A reconstructed mastoid can no longer be inspected in exactly the same way as an open cavity.

Follow-up may include:

- clinical examination
- otoscopy / microscopy / endoscopy
- hearing assessment
- imaging when indicated

Non-echo-planar diffusion-weighted MRI may be useful in selected postoperative cholesteatoma surveillance (Chapter 14, Cholesteatoma).

The surveillance plan should be decided when the reconstruction is planned.

16.22 IMAGING AFTER OBLITERATION

Postoperative imaging can be difficult to interpret without knowledge of:

- material used
- location
- operative technique
- timing

Document reconstruction clearly.

The radiologist evaluating the ear years later should not have to guess what was placed inside the mastoid.

16.23 DOCUMENT THE MATERIAL

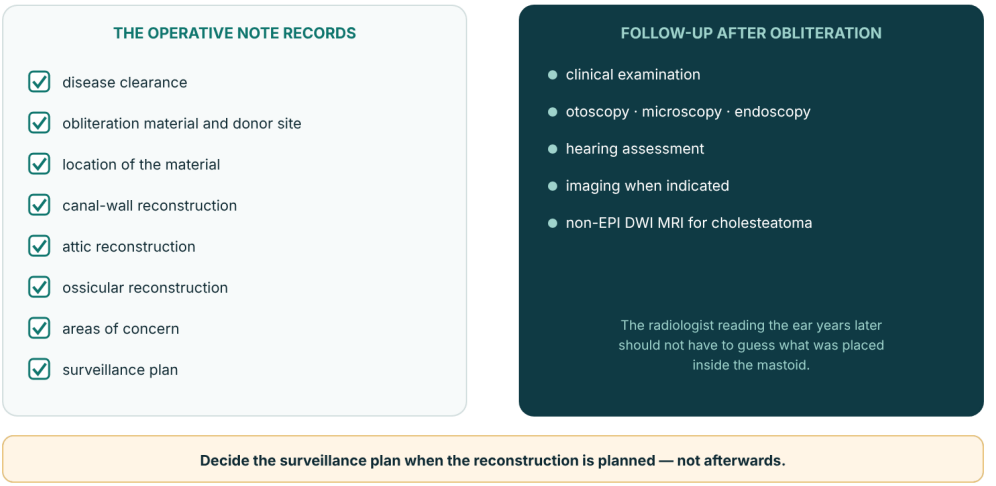
The operative note should record:

- disease clearance
- obliteration material
- donor site
- location
- canal-wall reconstruction
- attic reconstruction
- ossicular reconstruction
- areas of concern
- surveillance plan

This becomes part of the patient's future anatomy.

Figure 16.6 · Document the reconstruction, plan the surveillance

Reconstruction changes the method of follow-up — it does not remove the need for it



16.24 FAILURE OF OBLITERATION

Potential failure mechanisms include:

- residual cholesteatoma
- recurrent cholesteatoma
- infection

- material exposure
- resorption
- cavity recurrence
- canal stenosis
- wall displacement
- retraction

The revision operation should identify which component failed.

> **"THE OBLITERATION FAILED" IS NOT ENOUGH.**

What failed?

Disease control?

Material?

Coverage?

Geometry?

Ventilation?

16.25 FAILURE OF CANAL WALL RECONSTRUCTION

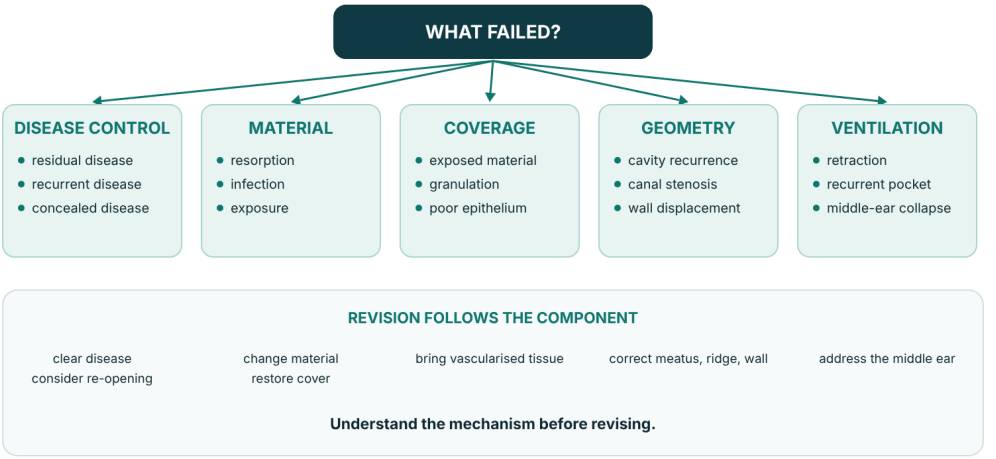
Potential problems include:

- wall resorption
- displacement
- canal narrowing
- recurrent pocket formation
- exposed reconstruction
- concealed disease

Again, understand the mechanism before revising.

Figure 16.7 · "The obliteration failed" is not enough

Identify which component failed before revising



16.26 PRIMARY OR SECONDARY OBLITERATION?

PRIMARY

Performed during initial disease surgery.

Potential advantage:

Cavity morbidity may be prevented.

SECONDARY

Performed later for an established problematic cavity.

Potential advantage:

The specific cavity problem is already known.

Both strategies can be appropriate in selected patients.

The choice depends upon disease, anatomy, surveillance and reconstructive philosophy.

16.27 OBLITERATION DOES NOT ELIMINATE FOLLOW-UP

A dry, reconstructed ear may require less routine cavity care.

But it does not become an ear that no longer needs surveillance.

Particularly after cholesteatoma surgery:

RECONSTRUCTION CHANGES THE METHOD OF FOLLOW-UP.

It does not remove the need for follow-up.

DECISION POINT

SHOULD I OBLITERATE THIS MASTOID?

Ask:

Is disease clearance reliable?

What problem will obliteration solve?

Is cavity geometry already appropriate?

What material will be used?

Is vascularised coverage adequate?

Will the middle-ear space remain functional?

Can recurrent disease still be monitored?

What is the surveillance plan?

If these questions cannot be answered, the reconstruction needs further planning.

FROM EXPERIENCE

The temptation after creating a large cavity is to fill it.

But volume alone is rarely the entire problem.

A troublesome cavity may actually be caused by:

a high facial ridge,

a narrow meatus,

a deep tip,

an overhang,

exposed bone,

or residual disease.

If those problems remain, filling the mastoid does not necessarily solve the ear.

The better question is not:

What can I put into this cavity?

It is:

> **What postoperative anatomy am I trying to create?**

Once that is clear, the reconstructive material becomes a tool rather than the strategy.

TAKE IT TO THE OT

Before mastoid obliteration or canal-wall reconstruction, define:

DISEASE
Completely cleared?

CAVITY PROBLEM
What exactly needs correction?

GEOMETRY
Meatus, ridge, tip, overhangs satisfactory?

VOLUME
Which space actually needs obliteration?

MATERIAL
What will fill or reconstruct it?

VASCULARITY
How will it remain covered and viable?

CANAL WALL
Does it need reconstruction?

MIDDLE EAR
Will hearing mechanics remain free?

EPITHELIUM
How will the surface heal?

SURVEILLANCE
How will residual/recurrent disease be detected?

CHAPTER SUMMARY

Mastoid obliteration is not simply filling a postoperative cavity.

First create appropriate cavity geometry.

Clear disease completely.

Identify which space actually needs to disappear.

Select reconstructive material according to biology, stability and surveillance.

Bring vascularised tissue where it adds value.

Reconstruct the canal wall as a three-dimensional boundary.

Preserve epithelial coverage.

Do not compromise the functional middle-ear space.

Document what has been reconstructed.

And remember:

> **Do not ask, "How do I fill this cavity?"**

> **Ask, "What ear do I want to leave behind?"**

FURTHER READING & REFERENCES

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CHAPTER 17

Otosclerosis & Stapes Surgery

Restore Motion at the Oval Window

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the clinical and audiological features that suggest otosclerosis
- select patients appropriately for stapes surgery
- recognise when imaging is useful
- understand the surgical anatomy of the oval-window region
- distinguish the principles of stapedotomy and stapedectomy
- understand prosthesis selection, length and coupling
- recognise major intraoperative challenges such as narrow oval-window anatomy, facial nerve variation and floating footplate
- understand the causes of postoperative vertigo, sensorineural hearing loss and prosthesis failure
- approach revision stapes surgery according to the mechanism of failure

17.1 THE PROBLEM IS FIXATION

In a functioning middle ear, sound reaches the inner ear through movement.

The stapes transmits energy to the oval window.

In otosclerosis, pathological fixation may reduce stapes mobility and produce conductive hearing loss.

The operative problem is therefore mechanical:

TYMPANIC MEMBRANE MOVES

↓

OSSICULAR CHAIN MOVES

↓

STAPES DOES NOT MOVE ADEQUATELY

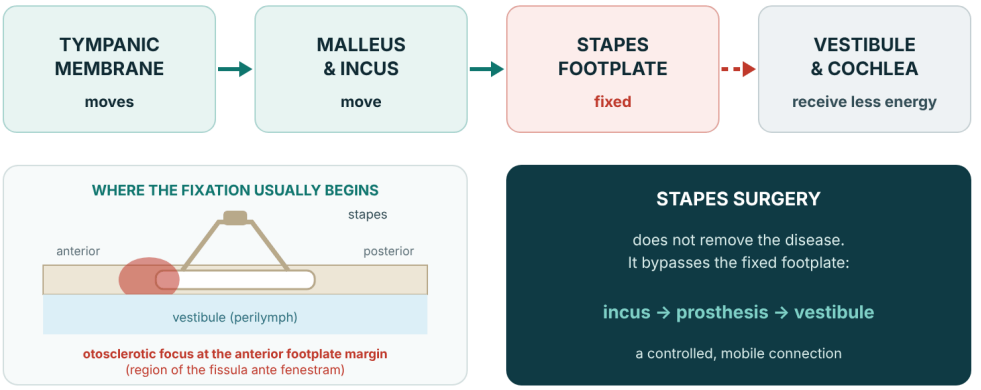
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SOUND TRANSMISSION FALLS

Stapes surgery attempts to restore a controlled pathway for mechanical transmission into the inner ear.

Figure 17.1 · The problem is fixation

Schematic — the chain moves until the stapes; surgery restores a mobile link into the vestibule



17.2 DIAGNOSIS BEFORE SURGERY

Clinical assessment should include:

- progressive hearing loss
- otoscopic examination
- tuning-fork findings
- pure-tone audiometry
- speech testing where appropriate
- tympanometry and acoustic reflex assessment as relevant
- family and previous ear history

The diagnosis should be coherent across:

> **HISTORY + EXAMINATION + AUDIOLOGY.**

Do not select an operation from one audiometric pattern alone.

17.3 AIR–BONE GAP

A conductive component may support the diagnosis.

But the hearing loss may also contain a sensorineural component — a mixed loss.

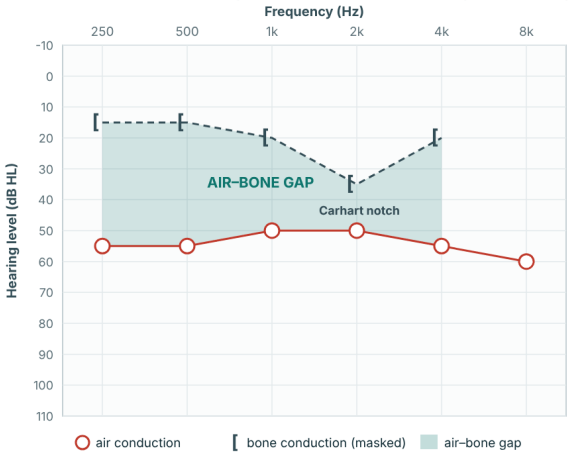
The surgeon should understand what portion of hearing loss is realistically correctable by stapes surgery.

> **PRINCIPLE**
>
> **The operation can improve the conductive mechanism.**

It does not reverse unrelated cochlear loss.

Figure 17.2 · What stapes surgery can and cannot correct

Schematic audiogram, one ear — the air–bone gap is the surgical target; the bone line is the ceiling



CAN BE IMPROVED

the conductive component — the gap between the air and bone lines

CANNOT BE RESTORED

cochlear loss — the bone line sets the best hearing that surgery can achieve

Carhart notch (bone dip near 2 kHz) is a mechanical effect of fixation and often lessens after successful surgery.

17.4 COUNSEL THE EXPECTED GAIN

Before surgery, explain:

- likely hearing benefit
- possibility of incomplete air–bone gap closure
- uncertain effect on tinnitus
- transient or persistent vertigo
- taste disturbance
- tympanic membrane complications
- prosthesis problems
- rare but important sensorineural hearing loss

The patient should understand both:

> **WHAT THE OPERATION MAY IMPROVE**

and

WHAT IT CANNOT GUARANTEE.

17.5 CT — WHEN DOES IT HELP?

High-resolution temporal-bone CT is not mandatory for every classic uncomplicated case.

It may be useful when:

- diagnosis is uncertain
- congenital ossicular abnormality is considered
- revision surgery is planned
- facial nerve or oval-window anatomy may be abnormal
- other temporal-bone pathology is suspected

Imaging should answer a surgical question.

Reading the temporal bone CT is discussed in Chapter 7, Temporal Bone Imaging for the Surgeon.

17.6 OVAL-WINDOW SURGICAL ANATOMY

Important structures include:

STAPES

Head

Crura

Footplate

INCUS

Long process

FACIAL NERVE

Tympanic segment

OVAL WINDOW

PROMONTORY

ROUND-WINDOW REGION

CHORDA TYMPANI

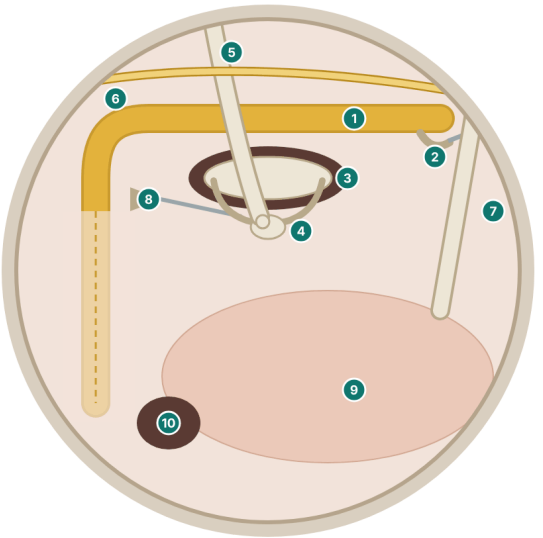
The working space is small.

The structures are delicate.

A millimetre is not a small distance here.

Figure 17.3 · The oval-window region through the ear canal

Schematic, not to scale · Right ear, transcanal view after elevating the tympanomeatal flap · superior up, anterior to the right



1. Facial nerve — tympanic segment
2. Cochleariform process, tensor tendon
3. Oval window and footplate
4. Stapes crura and head
5. Long process of incus
6. Chorda tympani
7. Malleus handle
8. Pyramidal eminence, stapedius tendon
9. Promontory
10. Round-window niche

posterior ◀ left of the field

anterior right of the field ▶

The facial nerve runs just above the oval window; a low or dehiscent nerve narrows the working space. Dashed: mastoid segment, behind the posterior canal wall.

17.7 THE FACIAL NERVE

The tympanic facial nerve may:

- lie in its expected position
- be dehiscent
- hang low over the oval window

This can reduce access to the stapes footplate.

PRINCIPLE

Do not force an average stapes operation through non-average anatomy.

If the oval window is inadequately accessible, the strategy must adapt.

17.8 THE INCUS

Before prosthesis placement, assess:

- long-process integrity
- mobility
- diameter
- previous erosion in revision cases

A prosthesis relies upon secure coupling.

A compromised incus changes the reconstructive problem.

17.9 STAPES MOBILITY

Before committing to footplate surgery, confirm that the stapes is genuinely fixed.

Assess the ossicular chain systematically.

MALLEUS

Mobile?

INCUS

Mobile?

STAPES

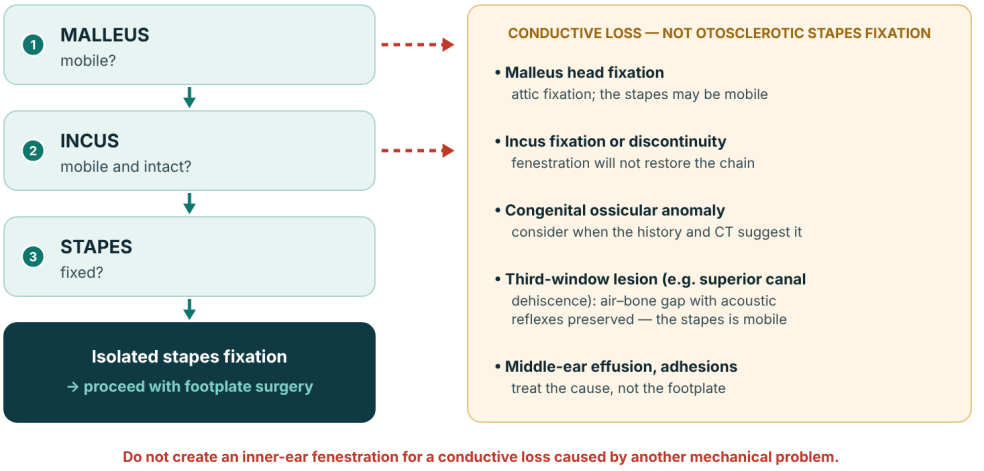
Fixed?

Do not create an inner-ear fenestration for a conductive loss caused by another mechanical problem.

Remember also that an inner-ear "third window", such as superior semicircular canal dehiscence, can produce an air–bone gap with a mobile stapes; preserved acoustic reflexes in a patient with an apparent conductive loss should raise this question before surgery.

Figure 17.4 · Confirm the cause before opening the vestibule

Palpate the chain systematically; consider the mimics of stapes fixation



Do not create an inner-ear fenestration for a conductive loss caused by another mechanical problem.

17.10 STAPEDOTOMY AND STAPEDECTOMY

Conceptually:

STAPEDOTOMY

Creates a small fenestration in the fixed footplate through which a prosthesis transmits movement.

STAPEDECTOMY

Removes a larger portion of the footplate before reconstruction.

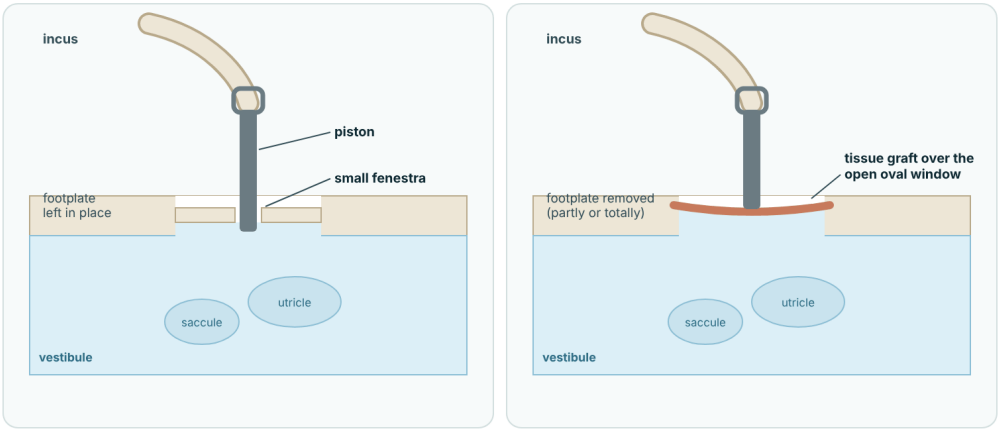
Modern practice commonly favours small-fenestra stapedotomy, but the technique should reflect surgeon experience, anatomy and evidence.

The underlying principle is the same:

RESTORE A CONTROLLED MOBILE CONNECTION TO THE INNER EAR.

Figure 17.5 · Stapedotomy and stapedectomy

Schematic section through the oval window · lateral (middle ear) up, medial (vestibule) down · not to scale



A · STAPEDOTOMY

small hole in the fixed footplate
most of the footplate stays as a barrier
piston slightly narrower than the fenestra

B · STAPEDECTOMY

larger part of the footplate removed
window sealed with tissue
prosthesis rests on the graft

17.11 EXPOSURE

Adequate visualisation of:

- incus long process
- stapes superstructure
- oval-window region
- facial nerve

is essential.

Canal overhang may need controlled removal.

PRINCIPLE

Do not perform fine stapes work through inadequate exposure merely to avoid canalplasty.

A small amount of well-planned bone removal may make the critical step substantially safer.

17.12 CHORDA TYMPANI

The chorda tympani may limit exposure.

Preserve it where reasonably possible.

If mobilised:

- minimise traction
- avoid repeated manipulation
- understand that taste disturbance may occur even without transection

As always:

> **ANATOMICAL CONTINUITY DOES NOT GUARANTEE NORMAL FUNCTION.**

17.13 SEQUENCE MATTERS

A general operative sequence may include:

EXPOSURE

↓

CONFIRM FIXATION

↓

PREPARE PROSTHESIS / MEASURE

↓

MANAGE STAPES SUPERSTRUCTURE

↓

> **CREATE CONTROLLED FOOTPLATE FENESTRATION**

↓

PLACE AND COUPLE PROSTHESIS

↓

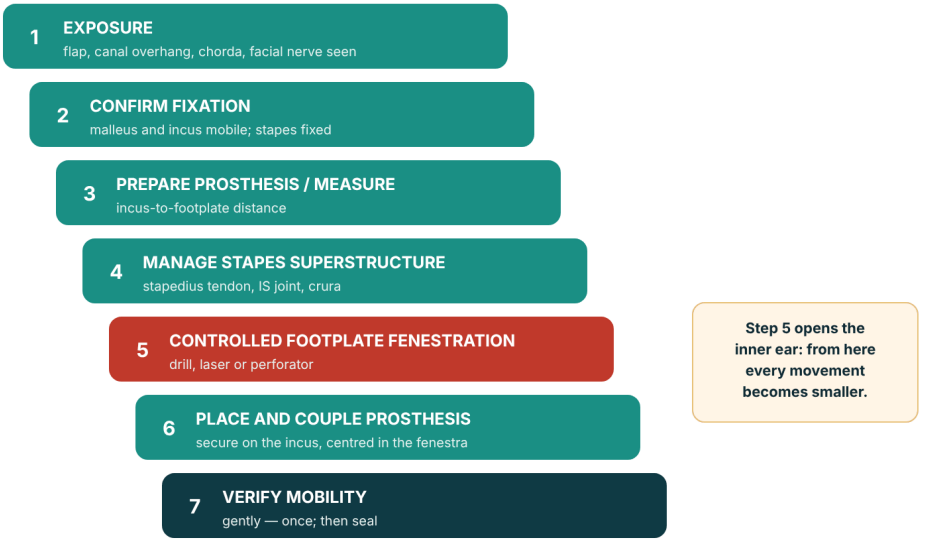
VERIFY MOBILITY

The precise sequence varies by technique.

What matters is maintaining control at each stage.

Figure 17.6 · A controlled operative sequence

The order varies with technique; control at each stage does not



IS joint = incudostapedial joint. Some surgeons fenestrate before removing the superstructure (reversal steps).

17.14 PROSTHESIS LENGTH

Length is critical.

TOO SHORT

Poor coupling or later displacement.

TOO LONG

Excessive vestibular penetration or pressure.

Potential vertigo or inner-ear injury.

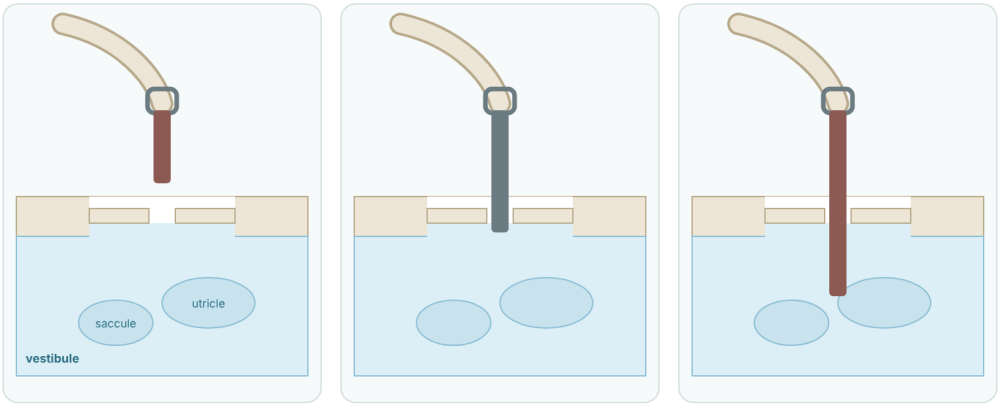
The correct length should create stable coupling without excessive intrusion.

PRINCIPLE

Measure the mechanical distance — do not select length by habit.

Figure 17.7 · Prosthesis length

Schematic section · lateral up, vestibule down · not to scale



Measure from the incus long process to the footplate; the piston should just enter the vestibule — typically a fraction of a millimetre.

17.15 PROSTHESIS DIAMETER

Different prosthesis diameters and materials are available.

Selection depends upon:

- fenestra size
- technique
- surgeon preference
- device characteristics

The goal is a stable, mobile connection with minimal inner-ear trauma.

The device should serve the mechanics — not become the focus of the operation.

17.16 FOOTPLATE FENESTRATION

The fenestra should be:

- controlled
- appropriately positioned
- compatible with the prosthesis
- created with minimal trauma

Methods may include:

- microdrill
- laser
- perforator techniques

Each has advantages and limitations.

The key principle is:

> **CONTROLLED ENTRY INTO THE VESTIBULE.**

17.17 DO NOT PUSH THROUGH RESISTANCE

If footplate fenestration becomes unexpectedly difficult:

STOP.
Ask:

Is the footplate unusually thick?

Is the instrument angle correct?

Is the drill appropriate?

Is the footplate moving?

More force at the oval window is rarely the safest first answer.

17.18 FLOATING FOOTPLATE

A mobile or "floating" footplate during manipulation changes the operation immediately.

The risk is uncontrolled displacement into the vestibule.

Response should prioritise:

- stopping further forceful manipulation
- maintaining visualisation
- minimising pressure
- adapting the technique

PRINCIPLE

Once the footplate moves unexpectedly, the operation is no longer routine.

17.19 OBLITERATIVE / THICK FOOTPLATE DISEASE

In selected ears, the oval-window region may be heavily involved or difficult to fenestrate.

This may require:

- modified technique
- more controlled drilling
- reconsideration of feasibility

Do not let the desire to complete the procedure create uncontrolled inner-ear risk.

17.20 PERILYMPH

The inner ear should be treated as a sensitive fluid system.

Avoid:

- unnecessary suction at the fenestra
- repeated vestibular manipulation
- excessive fluid loss
- uncontrolled instrument penetration

INNER-EAR PRINCIPLE

Once the vestibule is open, every movement should become smaller.

17.21 PROSTHESIS COUPLING

The prosthesis should couple securely to the incus.

Depending upon design, fixation may involve:

- crimping
- self-crimping
- other coupling mechanisms

The goal is:

> **STABLE ENOUGH TO TRANSMIT MOTION**

but

> **NOT SO TIGHT AS TO INJURE OR STRANGLE THE INCUS.**

17.22 CHECK THE MECHANICAL SYSTEM

After reconstruction, assess gently:

INCUS MOVEMENT

↓

PROSTHESIS MOVEMENT

↓

> **FOOTPLATE / FENESTRA COUPLING**

Do not repeatedly manipulate the chain merely to demonstrate mobility.

The inner ear has already been entered.

17.23 SEALING THE FENESTRA

Depending upon technique, tissue may be used around the prosthesis to help seal the fenestra.

The objective is to:

- reduce perilymph leak
- stabilise the interface

without immobilising the prosthesis.

> **PRINCIPLE**
> **Seal around the moving structure. Do not bury it into immobility.**

17.24 POSTOPERATIVE VERTIGO

Transient disequilibrium may occur after stapes surgery.

Persistent or severe vertigo raises concern for complications such as:

- prosthesis-related vestibular irritation
- perilymph fistula
- inner-ear injury
- other causes

The clinical context and timing matter.

Do not dismiss severe persistent vertigo as routine.

17.25 SENSORINEURAL HEARING LOSS

Sensorineural loss is one of the most significant feared complications.

Possible mechanisms include:

- inner-ear mechanical trauma
- excessive prosthesis penetration
- acoustic / drill trauma
- labyrinthine injury
- inflammatory or other inner-ear insult

Prevention depends upon:

GENTLE ENTRY

CONTROLLED PROSTHESIS DEPTH

MINIMAL VESTIBULAR MANIPULATION

APPROPRIATE TECHNIQUE.

17.26 TASTE DISTURBANCE

Chorda tympani manipulation may cause:

- altered taste
- metallic taste

- a dry mouth or altered tongue sensation

These often improve over time but may persist in some patients.

Patients should be counselled appropriately.

17.27 TYMPANIC MEMBRANE COMPLICATIONS

Potential problems include:

- canal skin tear
- tympanic membrane perforation
- flap displacement

These should be repaired and supported appropriately when recognised.

Even in a stapes operation, soft-tissue handling still matters.

17.28 POOR HEARING AFTER SURGERY

Possible causes include:

PROSTHESIS TOO SHORT

PROSTHESIS DISPLACED

INCUS NECROSIS / EROSION

REFIXATION

WRONG ORIGINAL DIAGNOSIS

COCHLEAR LOSS

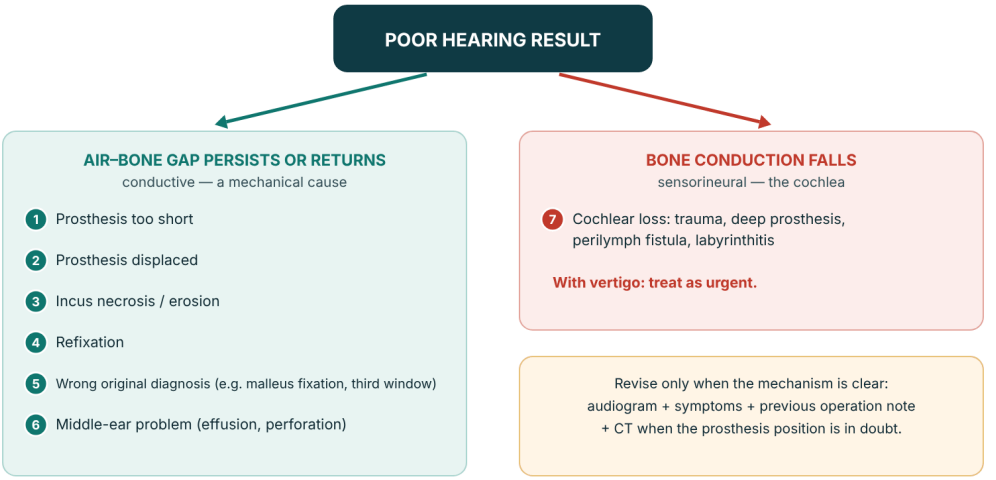
MIDDLE-EAR PROBLEM

Do not assume every failed hearing result means the prosthesis needs replacement.

First identify the mechanism.

Figure 17.8 · Poor hearing after stapes surgery: find the mechanism

Read the new audiogram first — is the gap back, or has the bone line fallen?



17.29 REVISION STAPES SURGERY

Revision surgery may be more difficult because of:

- scar
- prosthesis displacement
- incus erosion
- altered oval-window anatomy
- prior fenestration
- uncertain footplate status

Preoperative assessment should include:

- current audiology
- previous operative note
- CT when appropriate
- symptom history including vertigo

REVISION PRINCIPLE

Do not enter the oval window until you know why the first operation failed.

17.30 PROSTHESIS DISPLACEMENT

A displaced prosthesis may:

- lose contact with the incus
- move away from the fenestra
- migrate too deeply
- become fixed by scar

The revision should correct:

> **POSITION + CAUSE OF DISPLACEMENT.**

Simply replacing it without understanding why it moved may reproduce the failure.

17.31 INCUS EROSION

Chronic prosthesis contact may contribute to long-process incus erosion in some cases.

Revision options depend upon:

- remaining incus
- malleus
- prosthesis system
- footplate

The reconstruction may need to change fundamentally rather than simply use another standard incus-coupled prosthesis — for example, to a malleus-coupled prosthesis (see Chapter 10, Ossicular Reconstruction).

DECISION POINT

SHOULD I PROCEED WITH STAPES SURGERY?

Confirm:

DIAGNOSIS
Does the clinical and audiological picture fit?

COCHLEAR RESERVE
What hearing gain is realistically possible?

STAPES FIXATION
Confirmed?

OVAL-WINDOW EXPOSURE
Adequate?

FACIAL NERVE
Normal relationship?

INCUS
Suitable for coupling?

PATIENT EXPECTATION
Appropriate?

If one of these is uncertain, resolve it before entering the vestibule.

FROM EXPERIENCE

Stapes surgery is a useful example of how the apparent size of an operation can mislead.

The incision is small.

The field is small.

The bone removed is minimal.

Yet the surgeon is working at the interface between:

MIDDLE-EAR MECHANICS
and

INNER-EAR FUNCTION.
The margin for excessive force is correspondingly small.

The operation rewards precision far more than speed.

TAKE IT TO THE OT

Before stapes surgery, define:

DIAGNOSIS

AUDIOLOGY

MALLEUS MOBILITY

INCUS MOBILITY & INTEGRITY

STAPES FIXATION

FACIAL NERVE RELATIONSHIP

OVAL-WINDOW EXPOSURE

PROSTHESIS TYPE

PROSTHESIS LENGTH

FENESTRA STRATEGY

INNER-EAR RISK

REVISION PLAN IF NEEDED

CHAPTER SUMMARY

Stapes surgery treats a mechanical fixation at the oval window.

Confirm the diagnosis before operating.

Understand what portion of hearing loss is correctable.

Expose the oval window adequately.

Respect the facial nerve and chorda tympani.

Confirm stapes fixation.

Create a controlled fenestra.

Measure prosthesis length rather than guessing.

Couple securely without excessive pressure.

Minimise vestibular manipulation.

When hearing results are poor, identify the mechanism before revising.

And remember:

> **The operation is small because the anatomy is small.**

> **The precision required is not.**

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CHAPTER 18

Implantable Hearing Devices

Match the Technology to the Hearing Problem

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- classify implantable hearing devices according to the part of the auditory pathway they stimulate
- understand the broad indications for bone-conduction and middle-ear implantable systems
- distinguish conductive, mixed and sensorineural hearing problems when considering implantation
- integrate audiology, anatomy and patient factors into device selection
- understand the surgical principles of implant positioning and soft-tissue management
- recognise the importance of preoperative trial and realistic counselling where applicable
- understand common device-related and surgical complications
- plan long-term device follow-up as part of the original operation

18.1 START WITH THE HEARING PROBLEM — NOT THE DEVICE

Hearing technology changes rapidly.

New processors appear.

Implant designs evolve.

Coupling systems change.

But the first question should remain stable:

> **Which part of the hearing pathway is failing, and which part can still be used?**

Only after answering that should the surgeon ask:

> **Which device can best use the remaining pathway?**

18.2 THE AUDITORY PATHWAY AS A DEVICE MAP

Conceptually:

EXTERNAL EAR

↓

TYMPANIC MEMBRANE

↓

OSSICULAR CHAIN

↓

COCHLEA

↓

AUDITORY NERVE

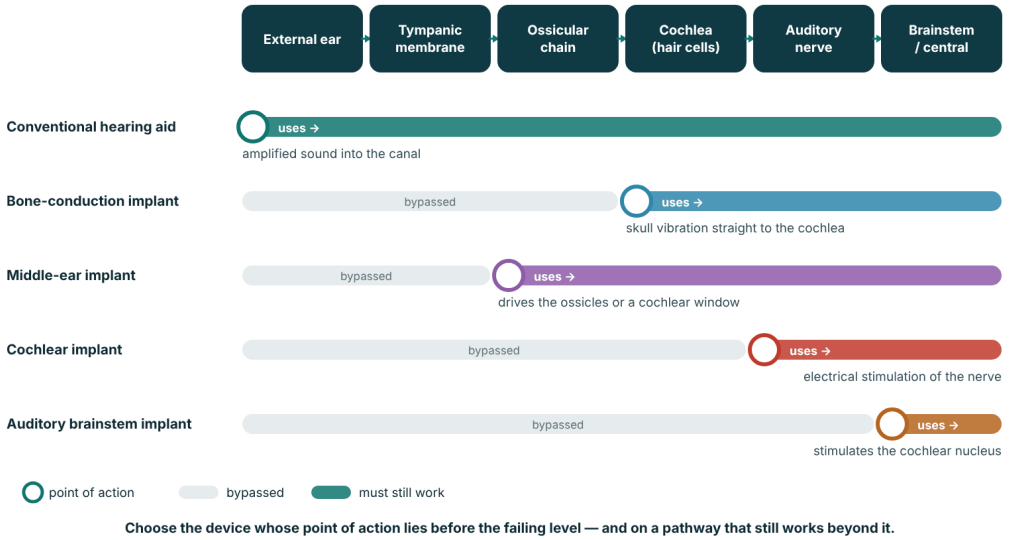
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CENTRAL AUDITORY PATHWAY

Different devices bypass or stimulate different levels of this pathway.

Figure 18.1 · The auditory pathway as a device map

Each device enters the pathway at a different level and depends on everything beyond that point



Choose the device whose point of action lies before the failing level — and on a pathway that still works beyond it.

18.3 CONVENTIONAL HEARING AID FIRST

An implantable device should not be chosen merely because surgery is possible.

Where conventional amplification provides adequate:

- hearing benefit
- comfort
- reliability
- usability

it may remain the simplest solution.

Implantation becomes relevant when conventional amplification is:

- ineffective
- poorly tolerated
- anatomically difficult
- medically unsuitable
- unable to provide adequate functional benefit

PRINCIPLE

Implantability is not itself an indication for implantation.

18.4 DEFINE THE HEARING LOSS

Before device selection, establish whether hearing loss is primarily:

CONDUCTIVE
Sound is not transmitted efficiently through the external or middle ear.

SENSORINEURAL
Cochlear or neural function is impaired.

MIXED
Both conductive and sensorineural components are present.

The same audiogram label does not automatically produce the same device choice.

Anatomy matters.

18.5 THE FOUR-PART CANDIDACY MODEL

Consider:

HEARING
What is the type and degree of loss?

ANATOMY
Can the external ear, middle ear, cochlea and nerve support the device?

PATIENT
Age, dexterity, expectations, lifestyle, medical status.

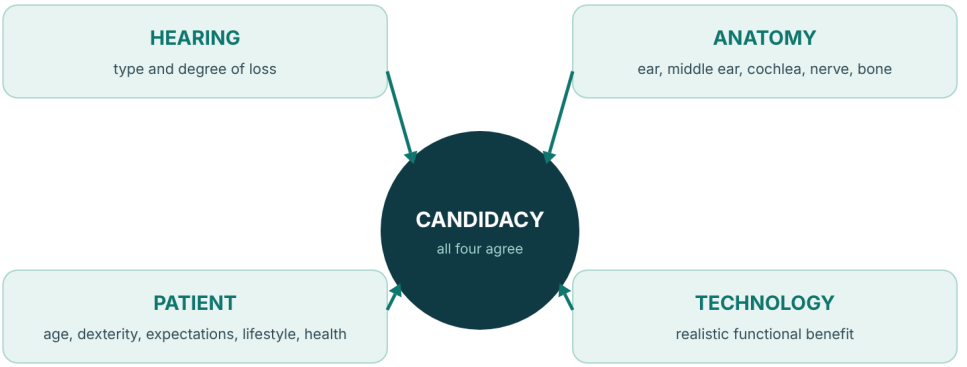
TECHNOLOGY
What functional benefit can the system realistically provide?

↓

CANDIDACY
Device selection is therefore not an audiogram-only decision.

Figure 18.2 · The four-part candidacy model

Device selection is not an audiogram-only decision



A device that suits the audiogram but not the anatomy, the patient or the technology is not the right device.

18.6 BONE-CONDUCTION PRINCIPLE

Bone-conduction systems transmit vibration through the skull to stimulate the cochlea while bypassing much or all of the external and middle-ear conductive pathway.

This can be useful when the cochlea retains sufficient function but conventional air-conduction transmission is problematic.

Potential clinical settings may include selected patients with:

- congenital external-ear / canal abnormality
- chronic ear disease
- conductive hearing loss
- mixed hearing loss
- single-sided deafness depending upon device and candidacy criteria

Exact indications vary by system and regulatory guidance.

18.7 TRANSCUTANEOUS AND PERCUTANEOUS CONCEPTS

Bone-conduction systems may transmit energy through different coupling strategies.

PERCUTANEOUS

A skin-penetrating connection directly couples the external processor to the implanted fixture.

Potential advantage:

Direct mechanical coupling.

Potential limitation:

Long-term skin interface requiring care.

TRANSCUTANEOUS

Energy is transmitted across intact skin using passive magnetic or active implanted components depending upon system.

Potential advantage:

No permanent skin-penetrating abutment.

Potential limitation:

Different transmission and implant-related considerations.

Device-specific details evolve.

The biological principles remain.

18.8 ACTIVE BONE-CONDUCTION IMPLANTS

In active systems, the vibrating transducer itself is implanted and drives the bone directly; the external processor sends signal and power across intact skin.

This avoids the loss of energy that occurs when vibration must pass through the skin, as in passive transcutaneous systems.

However, surgery may require:

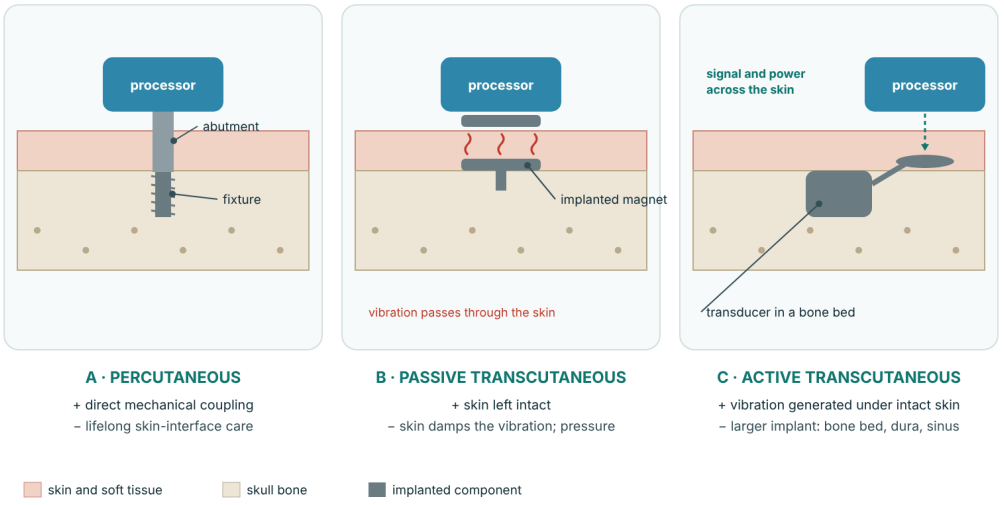
- greater implant volume
- specific bony positioning
- attention to adjacent dura, sigmoid sinus or other temporal-bone structures

PRINCIPLE

As the implanted component becomes larger, surgical anatomy becomes more important.

Figure 18.3 · Three ways to couple a bone-conduction device

Schematic section · skin above, skull bone below · generic, not any specific product



As the implanted component grows, the bone bed and what lies beneath it matter more.

18.9 PREOPERATIVE CT

CT may be useful when implant positioning depends upon temporal-bone anatomy.

Assess:

- bone thickness
- mastoid pneumatisation
- sigmoid sinus
- dura
- previous mastoid surgery
- congenital abnormality
- available implant bed

Do not design the implant position only on the skin.

The device must also fit the bone beneath it.

18.10 PLAN THE DEVICE IN THREE DIMENSIONS

Before incision, understand:

EXTERNAL PROCESSOR POSITION

Where should it sit?

IMPLANT

Where does it lie within or on bone?

SKIN

What tissue thickness and quality exist?

INTERNAL ANATOMY

What lies beneath the proposed implant bed?

FUTURE ACCESS

Will the device interfere with another possible operation?

Implant surgery is an interaction between technology and anatomy.

18.11 SOFT-TISSUE MANAGEMENT

For systems involving a skin interface or magnetic coupling, soft tissue affects:

- transmission
- pressure
- wound healing
- cosmesis
- device comfort

Avoid:

- excessive thinning
- compromised vascularity
- unnecessary tension
- poor scar placement

The skin is part of the device system.

18.12 IMPLANT POSITION

Poor positioning can lead to:

- processor discomfort

- difficulty wearing glasses or headgear
- cosmetic dissatisfaction
- skin pressure
- poor coupling
- surgical difficulty

Before incision, consider the patient's:

- ear
- scalp
- hairline
- glasses
- daily activities

PRINCIPLE

The implant must fit the patient's life as well as the patient's skull.

18.13 CONGENITAL EAR ABNORMALITY

Patients with microtia or canal atresia require coordinated planning.

Consider:

- hearing rehabilitation
- future auricular reconstruction
- implant location
- skin availability
- reconstructive incisions

A hearing implant placed without considering future auricular reconstruction may occupy tissue needed later.

TEAM PRINCIPLE

Plan hearing and auricular reconstruction together whenever both are expected.

Auricular reconstruction is discussed in Chapter 3, Otoplasty & Reconstruction of Auricular Defects.

18.14 PREVIOUS MASTOID SURGERY

In a patient with previous mastoid surgery, CT should determine:

- cavity
- remaining bone
- sigmoid position
- dura
- reconstruction
- obliteration material

The normal implant site may no longer contain normal anatomy.

The device position should be redesigned accordingly.

18.15 SINGLE-SIDED DEAFNESS

Some bone-conduction systems pick up sound on the deaf side and route it through skull vibration to the functioning contralateral cochlea.

This does not restore normal binaural hearing.

Patients should understand limitations involving:

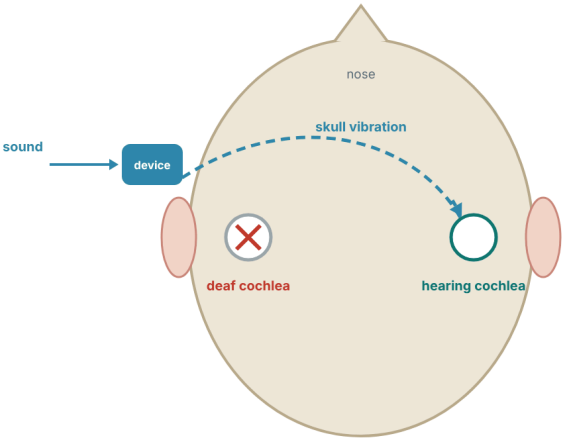
- localisation
- binaural processing
- hearing in complex noise

COUNSELLING PRINCIPLE

A device can improve access to sound without recreating normal physiology.

Figure 18.4 · Single-sided deafness: routing sound across the skull

Schematic head seen from above, nose at the top



WHAT IT CAN DO

- reduce the head-shadow effect
- give access to sound arriving on the deaf side

WHAT IT CANNOT RESTORE

- two-eared (binaural) hearing
- sound localisation
- full benefit in complex noise

Everything is heard by one cochlea.

Counsel before surgery: access to sound is not the same as normal binaural physiology.

18.16 MIDDLE-EAR IMPLANTS

Middle-ear implant systems provide mechanical stimulation to the ossicular chain or directly to the inner-ear windows.

Depending upon device design, coupling may involve:

- ossicular structures
- round-window-related interfaces
- other approved coupling strategies

Potential candidates may include selected patients who cannot obtain adequate benefit from conventional amplification.

These systems require a cochlea with enough function to use the mechanical input delivered to it.

18.17 THE COUPLING SITE

For a middle-ear implant, the surgical question becomes:

> **Where will mechanical energy enter the auditory system?**

The coupling site must be:

- anatomically accessible
- mechanically stable
- compatible with the device
- biologically safe

Poor coupling can produce poor hearing even when the implant is functioning electronically.

18.18 MECHANICAL COUPLING

As with ossiculoplasty (Chapter 10, Ossicular Reconstruction):

CONTACT IS NOT ENOUGH.

The implanted transducer must transfer energy effectively.

Performance depends upon:

- coupling angle
- stability
- pressure
- tissue interface
- mobility of the stimulated structure

A device can be correctly implanted yet poorly coupled.

18.19 THE ROUND-WINDOW INTERFACE

Selected implant systems may use the round-window region for mechanical stimulation.

This requires detailed understanding of:

- niche anatomy
- membrane orientation
- facial recess / middle-ear access
- surrounding bone

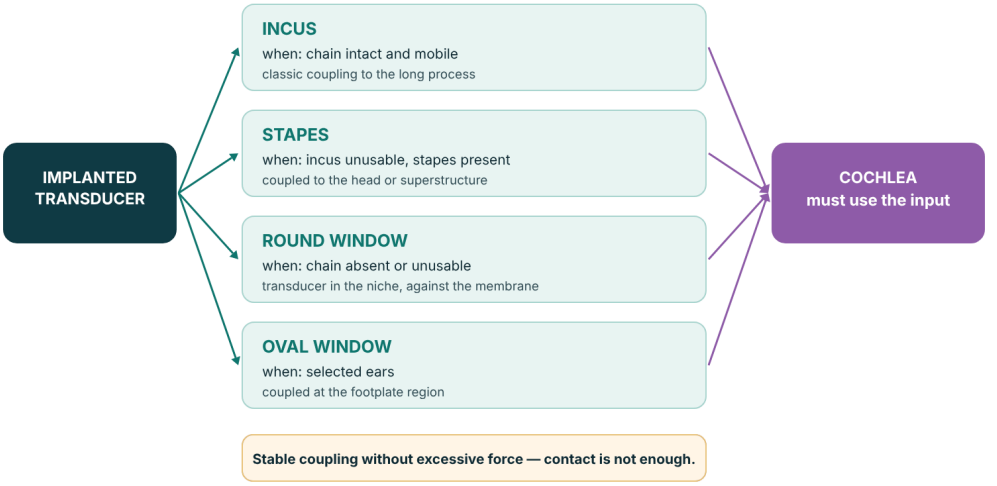
Excessive pressure or poor alignment can compromise performance or create injury.

The general principle remains:

STABLE COUPLING WITHOUT EXCESSIVE FORCE.

Figure 18.5 · Where can a middle-ear implant couple?

Conceptual — the choice depends on which structures are present, mobile and accessible



18.20 MRI COMPATIBILITY

Implanted hearing systems can affect future MRI access and imaging quality.

Before implantation, understand the specific device's:

- MRI conditions
- magnet requirements
- artefact characteristics
- manufacturer guidance

This is particularly important in patients who may require future:

- neurological imaging
- tumour surveillance
- skull-base imaging

PRINCIPLE

An implant is not only a hearing decision for today.

It becomes part of the patient's future medical imaging environment.

18.21 PATIENT EXPECTATIONS

Before implantation, discuss:

WHAT THE DEVICE MAY IMPROVE

Hearing access
Communication
Selected listening situations

WHAT IT MAY NOT NORMALISE

Localisation
Speech in noise
Binaural hearing
Tinnitus
Every listening environment

Expectations should reflect the patient's auditory pathway and device mechanism.

18.22 PREOPERATIVE TRIAL

Where an external simulation or trial is possible and clinically appropriate, it can help the patient understand:

- sound quality
- expected benefit
- limitations

A successful trial does not guarantee identical implanted performance.

But it can improve decision-making.

18.23 DEVICE SELECTION SHOULD NOT BE BRAND-FIRST

The sequence should be:

HEARING PROBLEM

↓

AUDITORY PATHWAY

↓

ANATOMY

↓

CANDIDATE DEVICE CATEGORY

↓

SPECIFIC DEVICE

Not:

DEVICE AVAILABLE

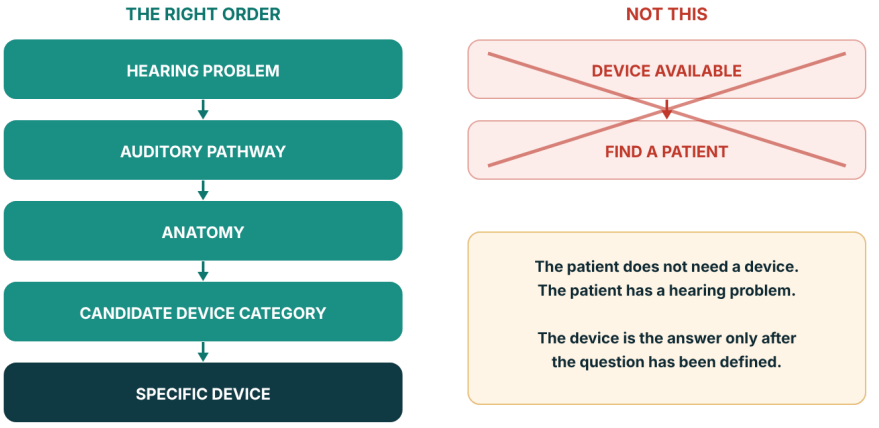
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FIND A PATIENT.

This distinction protects clinical judgment from technology-driven decision-making.

Figure 18.6 · Pathway first, device second

The order of the questions protects judgment from technology-driven decisions



18.24 THE OPERATION INCLUDES THE DEVICE TEAM

Successful implantation may require coordination between:

- surgeon
- audiologist
- anaesthetist
- nursing team
- implant representative / technical support where appropriate

- rehabilitation team

Everyone should know:

- device
- side
- components
- required instruments
- activation pathway
- postoperative plan

18.25 VERIFY THE DEVICE

Before implantation:

CONFIRM PATIENT

CONFIRM SIDE

CONFIRM DEVICE

CONFIRM COMPONENTS

> **CONFIRM SERIAL / TRACEABILITY INFORMATION ACCORDING TO LOCAL SYSTEMS**

> **CONFIRM FUNCTIONAL TESTING REQUIREMENTS**

Implant surgery has an additional safety layer:

> **The correct operation with the wrong implant is still the wrong operation.**

18.26 WOUND AND IMPLANT COMPLICATIONS

Potential complications vary by device but may include:

- infection
- skin breakdown
- implant exposure
- pain
- poor coupling

- device migration
- failure of osseointegration in relevant systems
- hardware failure
- magnet-related problems

The complication should be classified as:

BIOLOGICAL
or

MECHANICAL
or

ELECTRONIC
or

COMBINATION.
This guides management.

18.27 DEVICE FAILURE IS NOT ALWAYS SURGICAL FAILURE

Poor performance may result from:

- programming
- processor malfunction
- coupling
- implant position
- progressive hearing loss
- patient factors

Evaluation should therefore include both:

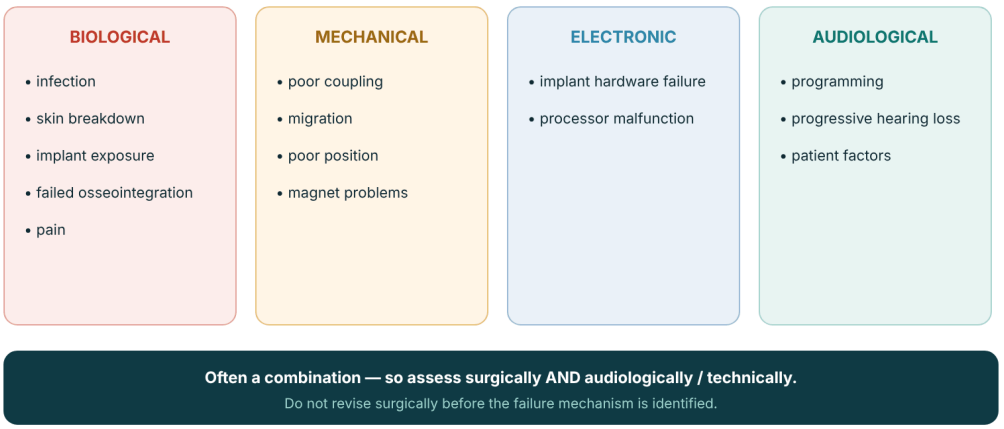
SURGICAL
and

AUDIOLOGICAL / TECHNICAL
assessment.

Do not revise surgically before identifying the failure mechanism.

Figure 18.7 · Classify the problem before managing it

Poor performance or a complication is not automatically a surgical failure



18.28 LONG-TERM FOLLOW-UP

An implant creates a long-term relationship between:

PATIENT

DEVICE

AUDIOLOGY TEAM

SURGICAL TEAM.

Follow-up may include:

- wound assessment
- activation
- programming
- hearing outcomes
- hardware review
- skin / magnet interface
- rehabilitation

The operation is the beginning of device use.

Not the end.

DECISION FRAMEWORK

WHICH HEARING PATHWAY SHOULD BE USED?

CAN SOUND BE AMPLIFIED THROUGH THE EXTERNAL / MIDDLE EAR EFFECTIVELY?

Yes → Conventional amplification may remain appropriate.

No / poorly tolerated ↓

IS COCHLEAR FUNCTION SUFFICIENT FOR BONE-CONDUCTION STIMULATION?

Yes → Consider appropriate bone-conduction options.

↓

IS A MIDDLE-EAR MECHANICAL COUPLING STRATEGY APPROPRIATE?

Selected patients → Middle-ear implant options.

↓

IS COCHLEAR HAIR-CELL FUNCTION INADEQUATE BUT THE AUDITORY NERVE FUNCTIONALLY USABLE?

→ Cochlear implant evaluation.

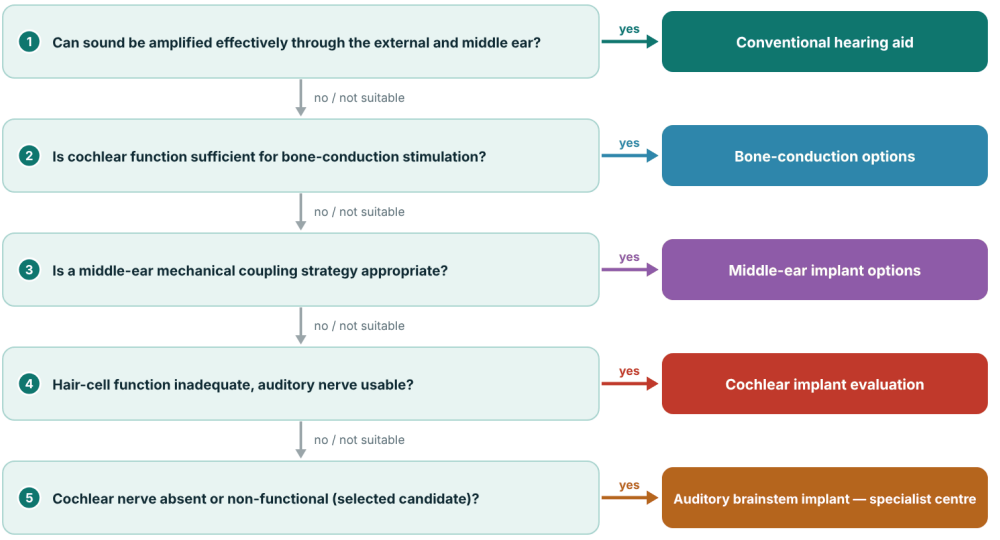
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IS THE COCHLEAR NERVE ABSENT OR NONFUNCTIONAL IN A SELECTED CANDIDATE?

→ Consider a specialised central auditory implant, such as an auditory brainstem implant, in an experienced centre.

Figure 18.8 · Hearing-device selection pathway

A simplified sequence of questions; exact criteria vary with device and regulation



Several answers can be 'yes' — then compare options with the four-part candidacy model.

FROM EXPERIENCE

Implantable hearing technology can easily attract attention because the devices are sophisticated.

But the sophistication of the device should not reverse the clinical sequence.

The patient does not need a device.

The patient has a hearing problem.

Our task is first to understand:

where the hearing pathway fails

and

which part of it still works.

Only then does technology become useful.

> **The device is the answer only after the question has been defined.**

TAKE IT TO THE OT

Before implantable hearing-device surgery, confirm:

HEARING LOSS

Type and degree.

CONVENTIONAL AMPLIFICATION

Adequate or unsuitable?

COCHLEAR RESERVE

Usable?

ANATOMY

Can the device be positioned safely?

CT

Required?

SKIN / SOFT TISSUE

Adequate?

FUTURE SURGERY

Any reconstructive conflict?

MRI

What are the device-specific implications?

DEVICE

Correct side and components?

EXPECTATION

Does the patient understand realistic benefit?

FOLLOW-UP

Who will activate, program and monitor it?

CHAPTER SUMMARY

Implantable hearing devices should be selected according to the auditory pathway — not technological enthusiasm.

Define the hearing loss.

Understand which part of the pathway remains usable.

Use conventional amplification when it provides appropriate benefit.

Match bone-conduction or middle-ear implant systems to suitable anatomy and hearing function.

Plan the device in three dimensions.

Protect skin and soft tissue.

Consider future surgery and MRI requirements.

Verify the correct implant before insertion.

And remember:

> **Do not begin with the device.**

> **Begin with the hearing pathway.**

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CHAPTER 19

Cochlear Implantation

From Candidacy to Auditory Rehabilitation

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the basic indication for cochlear implantation
- integrate audiology, imaging and developmental or communication needs into candidacy
- assess cochlear and cochlear-nerve anatomy preoperatively
- understand the surgical sequence from receiver placement to cochlear access
- perform a landmark-based cortical mastoidectomy and facial recess approach
- understand round-window and cochleostomy concepts
- appreciate the mechanics of atraumatic electrode insertion
- recognise important anatomical variations and difficult cochlear situations
- understand the principles of intraoperative device testing
- recognise complications such as CSF leak, facial nerve stimulation, electrode malposition and wound problems
- understand that implantation is only the beginning of auditory rehabilitation

19.1 A COCHLEAR IMPLANT BYPASSES THE DAMAGED SENSORY INTERFACE

A cochlear implant does not amplify sound in the same way as a conventional hearing aid.

Instead, it converts acoustic information into electrical stimulation delivered within the cochlea to activate the auditory neural pathway.

Conceptually:

SOUND

↓

EXTERNAL PROCESSOR

↓

SIGNAL ENCODING

↓

> **IMPLANTED RECEIVER / STIMULATOR**

↓

ELECTRODE ARRAY

↓

COCHLEAR NERVE

↓

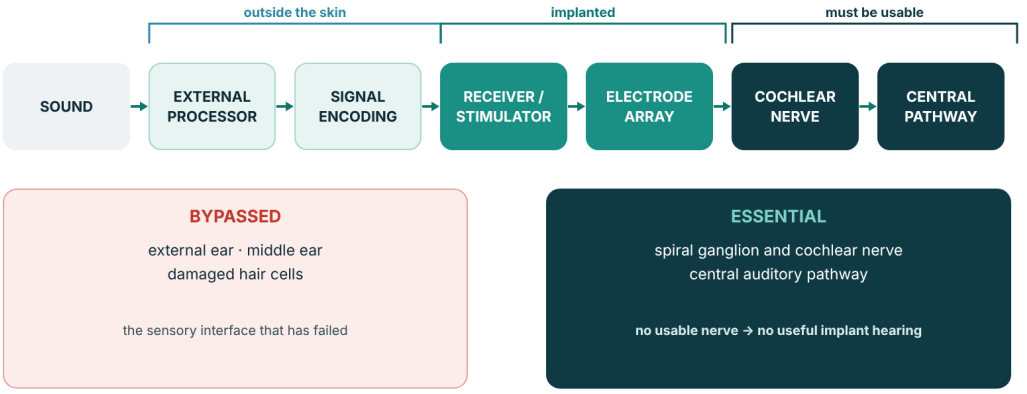
CENTRAL AUDITORY PATHWAY

The operation therefore depends upon one essential biological requirement:

> **There must be a usable neural pathway beyond the cochlea.**

Figure 19.1 · How a cochlear implant bypasses the sensory interface

Sound is converted to electrical stimulation delivered inside the cochlea



19.2 CANDIDACY IS NOT AN AUDIOGRAM NUMBER ALONE

Cochlear-implant candidacy is determined by a combination of factors.

These may include:

HEARING

Degree and type of hearing loss.

BENEFIT FROM APPROPRIATE AMPLIFICATION

Is aided speech understanding inadequate?

ANATOMY

Is the cochlea implantable?

Is the cochlear nerve present and functionally plausible?

AGE / DEVELOPMENTAL CONTEXT

Particularly important in children.

LANGUAGE AND COMMUNICATION

What has the patient already developed?

MEDICAL FACTORS

Can surgery and rehabilitation be undertaken safely?

EXPECTATIONS

What benefit is realistically achievable?

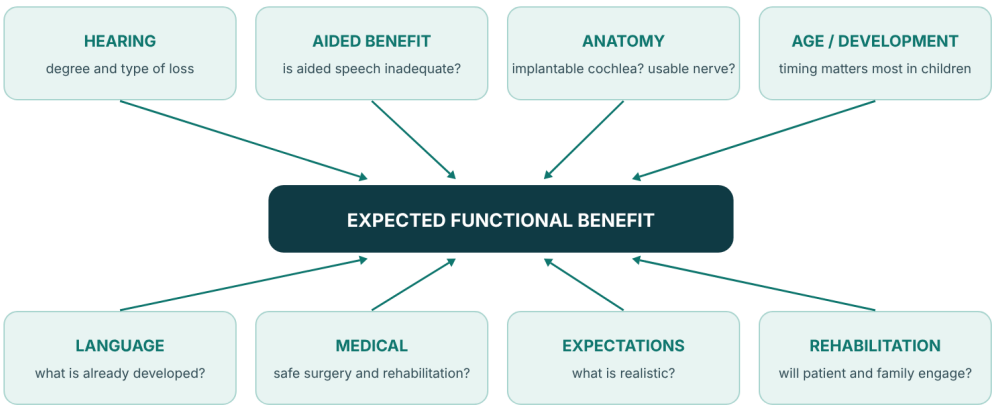
REHABILITATION

Will the patient and family engage in the post-implant pathway?

Exact candidacy thresholds evolve with evidence, regulatory criteria and implant technology.

Figure 19.2 · Candidacy is expected functional benefit

Eight domains feed the decision; the audiogram is only one of them



Benefit is shaped by duration of deprivation, age at onset, prior aid use, nerve integrity and motivation.

19.3 THE BEST CANDIDATE IS NOT ALWAYS THE PATIENT WITH THE WORST AUDIOGRAM

The potential benefit of implantation depends upon:

- duration of auditory deprivation
- age at onset of deafness
- prior hearing-aid use
- speech and language development
- auditory-nerve integrity
- central auditory development
- patient motivation

A profoundly deaf ear may be technically implantable but functionally limited by prolonged deprivation.

Conversely, patients with meaningful residual hearing may still derive substantial benefit under contemporary candidacy criteria.

PRINCIPLE

Candidacy is about expected functional benefit — not simply the severity of loss.

19.4 PAEDIATRIC CANDIDACY

In children, timing is particularly important because auditory input interacts with speech and language development.

Assessment should involve:

- paediatric audiology
- developmental history
- hearing-aid trial where appropriate
- speech and language assessment
- imaging
- family counselling

The child is not merely undergoing an ear operation.

The intervention may influence years of language development.

19.5 ADULT CANDIDACY

Adults may present with:

- progressive sensorineural hearing loss
- post-lingual deafness
- asymmetric hearing loss
- single-sided deafness in selected candidacy pathways
- long-standing auditory deprivation

Counselling should address:

- expected speech understanding
- hearing in noise
- telephone use
- music perception
- localisation
- adaptation period

The goal is functional communication — not simply detection of sound.

19.6 PREOPERATIVE AUDIOLOGICAL ASSESSMENT

Depending upon age and clinical context, evaluation may include:

- pure-tone audiometry
- aided thresholds
- speech perception testing
- tympanometry
- otoacoustic emissions
- auditory brainstem responses
- other electrophysiological testing where indicated

The surgeon should understand the audiological conclusion rather than relying only on the label "CI candidate."

19.7 IMAGING

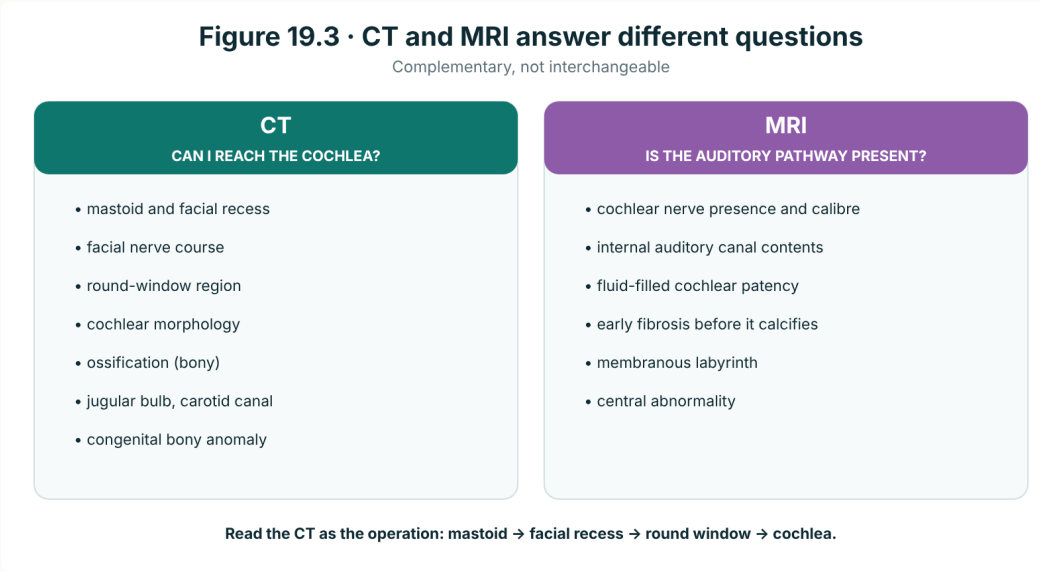
Preoperative imaging typically seeks answers to two broad questions:

CAN I REACH THE COCHLEA?

and

IS THE AUDITORY PATHWAY ANATOMICALLY PRESENT?

CT and MRI provide complementary information.



The principles of reading temporal bone imaging are discussed in Chapter 7, Temporal Bone Imaging for the Surgeon.

19.8 CT

CT is useful for assessing:

- mastoid anatomy
- facial recess
- middle ear
- round-window region
- cochlear morphology
- ossification
- facial nerve course
- jugular bulb
- carotid canal
- congenital bony anomaly

Read the scan as the operation:

MASTOID → FACIAL RECESS → ROUND WINDOW → COCHLEA.

19.9 MRI

MRI is particularly important for assessing:

- cochlear nerve
- internal auditory canal contents
- membranous labyrinth
- cochlear patency
- central abnormalities where relevant

In congenital hearing loss, the presence and calibre of the cochlear nerve can be crucial.

PRINCIPLE

A cochlea that can accept an electrode is not enough if the neural pathway beyond it is absent or severely deficient.

19.10 COCHLEAR NERVE DEFICIENCY

When the cochlear nerve appears:

- absent
- severely hypoplastic

expected cochlear-implant benefit may be reduced.

These cases require careful multidisciplinary assessment and counselling.

In selected situations, other auditory implant strategies, such as the auditory brainstem implant, may be considered at specialised centres.

The imaging finding should not be reduced to “nerve seen / not seen” without clinical correlation.

19.11 VACCINATION AND MENINGITIS RISK

Cochlear implantation is associated with specific infectious considerations, including bacterial meningitis risk.

Preoperative planning should ensure vaccination and preventive measures follow current national and international recommendations for the patient's age, implant status and medical context — particularly pneumococcal vaccination, and *Haemophilus influenzae* type b vaccination in young children.

Because schedules change, follow the current national guidance rather than a fixed schedule remembered from a textbook.

19.12 CHOOSE THE SIDE DELIBERATELY

When both ears are candidates, consider:

- hearing history
- duration of deafness
- residual hearing
- anatomical differences
- previous surgery
- cochlear patency
- patient preference
- future bilateral implantation strategy

Do not select the side solely because it appears technically easier.

The functional rehabilitation strategy matters.

19.13 DEVICE PLANNING

Before surgery, confirm:

MANUFACTURER / SYSTEM

SIDE

ELECTRODE TYPE

RECEIVER LOCATION

MAGNET / MRI CONSIDERATIONS

BACKUP DEVICE AVAILABILITY ACCORDING TO LOCAL PROTOCOL

The specific device may influence:

- incision
- receiver bed
- electrode routing
- insertion technique

19.14 SURGICAL SEQUENCE

A conventional mastoid–facial recess approach can be conceptualised as:

INCISION

↓

RECEIVER / STIMULATOR SITE

↓

CORTICAL MASTOIDECTOMY

↓

FACIAL RECESS

↓

ROUND-WINDOW REGION

↓

COCHLEAR ACCESS

↓

ELECTRODE INSERTION

↓

FIXATION

↓

INTRAOPERATIVE TESTING

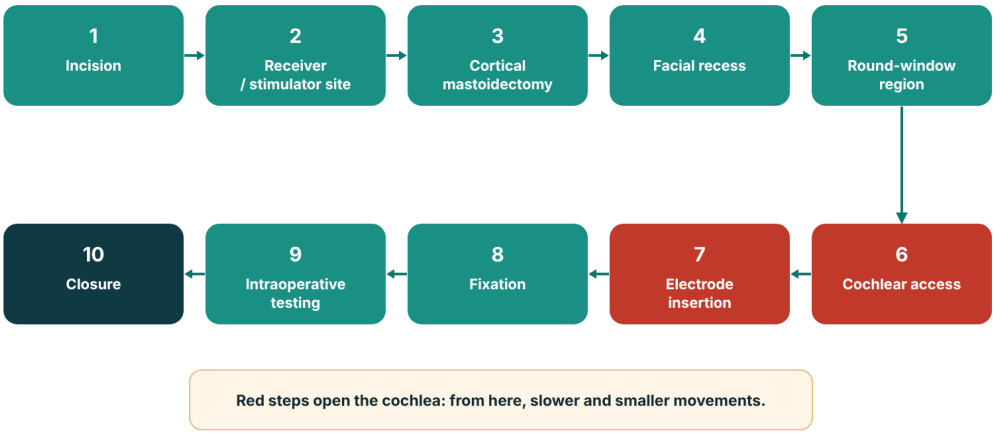
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CLOSURE

The operation should progress through known landmarks.

Figure 19.4 · The surgical sequence

Conventional mastoid–facial recess approach; progress through known landmarks



19.15 INCISION

The incision should provide:

- adequate access
- vascularised soft-tissue coverage
- appropriate relationship to receiver
- avoidance of unnecessary tension

Older large-incision concepts have progressively shifted toward smaller, tissue-preserving approaches in many centres.

But minimal incision should not compromise visualisation or flap viability.

19.16 RECEIVER / STIMULATOR POSITION

The receiver should be positioned so that it:

- sits stably
- has adequate soft-tissue coverage
- does not create excessive prominence
- permits electrode routing without tension
- is compatible with the external processor and magnet position

Depending upon implant design and surgeon preference, techniques may include a defined bony well, a shallow seat or other fixation strategies.

PRINCIPLE

The implant should remain stable because it has been planned into the skull — not because closure is pressing it into position.

19.17 MASTOIDECTOMY

Cortical mastoidectomy should establish:

TEGMEN

SIGMOID SINUS

POSTERIOR CANAL WALL

ANTRUM

LATERAL SEMICIRCULAR CANAL

INCUS REGION

The landmark-based technique is described in Chapter 11, Cortical Mastoidectomy.

The cochlear implant does not justify bypassing mastoid anatomy.

It depends upon it.

19.18 FACIAL RECESS

The facial recess becomes the working corridor to the round-window region.

Boundaries include:

FACIAL NERVE

Posteromedially — the mastoid segment.

CHORDA TYMPANI

Anterolaterally — running up toward the tympanic annulus.

INCUS BUTTRESS / FOSSA INCUDIS

Superiorly.

The recess should be opened enough to provide safe visualisation and electrode passage.

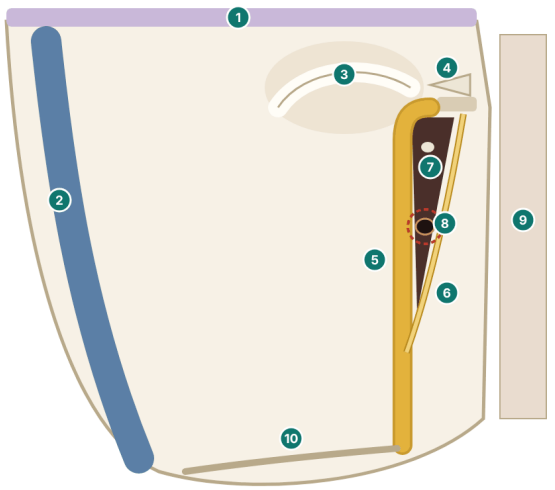
PRINCIPLE

Do not make the recess larger than the operation needs.

But do not keep it so narrow that the electrode must be inserted blindly.

Figure 19.5 · The facial recess as the working corridor

Schematic, not to scale · Right ear, surgical view through a cortical mastoidectomy · superior up, anterior to the right



1. Tegmen (middle fossa dura)
2. Sigmoid sinus
3. Lateral semicircular canal
4. Short process of incus, buttress
5. Facial nerve — mastoid segment
6. Chorda tympani
7. Facial recess opening
8. Round-window niche (deep)
9. Posterior canal wall (preserved)
10. Digastric ridge

Recess: facial nerve posteromedially, chorda anterolaterally, incus buttress superiorly. The electrode passes through it, lateral to the nerve, to the round window (red ring). Open it enough to see the window — no more.

19.19 ROUND-WINDOW ORIENTATION

The round window is not simply a circular opening facing directly toward the surgeon.

Its:

- niche
- overhang
- membrane
- orientation

vary.

Before cochlear entry, define:

WHERE IS THE MEMBRANE?

WHAT DIRECTION DOES THE BASAL TURN TAKE?

The insertion trajectory should follow cochlear anatomy.

19.20 THE ROUND WINDOW AS A DOORWAY

For many implants, the round-window membrane or an extended round-window route provides a natural access to the scala tympani.

The conceptual advantage is:

USE THE EXISTING ANATOMICAL ENTRY

where technically appropriate.

But exposure may be limited by:

- bony overhang
- narrow facial recess
- rotated cochlea
- congenital anomaly

The route should be adapted to the individual anatomy.

19.21 COCHLEOSTOMY

A cochleostomy creates a separate opening into the basal turn when indicated.

Classically it is placed anteroinferior to the round-window membrane, so that it enters the scala tympani away from the osseous spiral lamina and scala vestibuli.

The key requirement is correct location and trajectory.

An incorrectly positioned cochleostomy can enter:

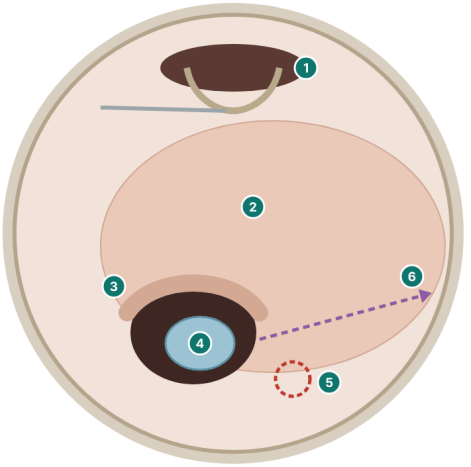
- wrong scala
- vestibule
- other unintended structures

PRINCIPLE

Cochlear access should be based on anatomy, not simply on a fixed number of millimetres from a landmark.

Figure 19.6 · Round-window and cochleostomy access

Schematic, not to scale · Right ear, view through the facial recess · superior up, anterior to the right



1. Oval window, stapes
2. Promontory (basal turn)
3. Round-window niche overhang
4. Round-window membrane
5. Cochleostomy site — anteroinferior
6. Basal turn runs anteriorly

ROUND WINDOW

natural entry to the scala tympani; drill the overhang to see the membrane; follow its orientation

COCHLEOSTOMY

anteroinferior to the membrane; too high or too anterior risks the scala vestibuli and spiral lamina

19.22 PRESERVE THE COCHLEA

Modern cochlear-implant surgery increasingly emphasises atraumatic technique and preservation of intracochlear structures.

This matters because:

- residual hearing may be present
- future technology may benefit from preserved anatomy
- intracochlear trauma can affect outcome

Therefore cochlear entry should minimise:

- mechanical trauma
- excessive drilling
- blood / bone dust entry
- uncontrolled suction
- unnecessary fluid disturbance

19.23 ELECTRODE INSERTION IS NOT PUSHING A WIRE

The electrode is entering a curved, fluid-filled sensory organ.

Insertion should be:

CONTROLLED

SLOW

ALIGNED

MINIMALLY TRAUMATIC

Resistance is information.

PRINCIPLE

The electrode should follow the cochlea.

> **The cochlea should not be forced to accept the electrode.**

19.24 INSERTION TRAJECTORY

Good alignment begins before the electrode reaches the cochlea.

The:

- facial recess
- round-window exposure
- electrode entry angle
- receiver position

all influence the final trajectory.

A difficult insertion may therefore reflect a poor corridor rather than a difficult cochlea.

19.25 RESISTANCE DURING INSERTION

If unexpected resistance occurs:

STOP.

Do not automatically push harder.

Consider:

- poor angle
- obstruction
- ossification
- electrode buckling
- anatomical anomaly
- scala mismatch

Reorient and reassess.

INNER-EAR PRINCIPLE

Resistance at the cochlea should decrease force — not increase it.

19.26 ELECTRODE ARRAY TYPES

Electrode arrays vary in:

- length
- stiffness
- scalar design
- lateral-wall or perimodiolar configuration
- insertion technique

The device should be selected according to:

- cochlear anatomy
- residual hearing
- surgeon technique
- clinical indication

Technology will evolve.

The fundamental aim remains atraumatic neural stimulation.

19.27 ELECTRODE FIXATION

After insertion, the electrode should be secured to reduce:

- migration
- extrusion

- transmitted movement

The fixation strategy should avoid:

- excessive tension
- sharp angulation
- compression
- displacement during closure

Leave enough slack where required, but not uncontrolled redundant loops.

19.28 INTRAOPERATIVE TESTING

Testing may include device-specific measures such as:

- electrode impedance
- neural response telemetry or analogous measures
- other manufacturer-specific objective testing

These can help confirm:

- device integrity
- electrode function
- neural response

But testing should be interpreted alongside:

> **SURGICAL ANATOMY + INSERTION QUALITY + DEVICE FUNCTION.**

A normal test does not prove ideal electrode position.

19.29 INTRAOPERATIVE IMAGING

Selected centres use:

- radiography
- fluoroscopy
- cone-beam CT
- other intraoperative imaging

to confirm electrode position when indicated.

Imaging may be particularly useful when:

- anatomy is abnormal
- insertion is difficult
- tip fold-over or malposition is suspected

The method should answer a specific concern.

19.30 CSF GUSHER

A significant CSF/perilymphatic gusher may occur in selected congenital inner-ear malformations.

This possibility should be anticipated from imaging when possible.

If encountered:

MAINTAIN CONTROL

COMPLETE INSERTION IF APPROPRIATE

SEAL THE COCHLEAR ENTRY

MANAGE CSF LEAK

MODIFY POSTOPERATIVE OBSERVATION

The exact strategy depends upon anatomy and severity.

> PRINCIPLE
>
> **A gusher should be anticipated as part of the malformation — not discovered as an inexplicable complication.**

19.31 INNER-EAR MALFORMATIONS

Congenital anomalies may alter:

- cochlear turns
- modiolus
- round window
- facial nerve
- internal auditory canal

- CSF communication

These cases require:

- high-quality CT and MRI
- modified surgical planning
- specific electrode strategy
- careful counselling

The usual landmarks may not have their usual relationships.

These situations are discussed in Chapter 20, Difficult Cochlear Implantation.

19.32 FACIAL NERVE ANOMALY

In congenital ear malformations, the facial nerve may have an atypical course.

This can narrow or obstruct the conventional facial-recess route.

Do not assume the standard corridor is safe simply because the operation is a cochlear implant.

> **PRINCIPLE**
>
> **An abnormal cochlea may come with an abnormal facial nerve.**

19.33 COCHLEAR OSSIFICATION

Ossification may follow:

- meningitis
- labyrinthitis
- trauma
- other inner-ear pathology

It can partially or completely obstruct cochlear insertion.

Imaging should assess:

- site
- extent
- residual patency

Surgical options may include:

- modified cochlear access
- drill-out techniques
- alternative electrode strategies

These cases should be planned before entering the cochlea.

19.34 POST-MENINGITIC DEAFNESS

Post-meningitic patients require particular attention because cochlear ossification can progress.

Timing of implantation may therefore become important.

Imaging should evaluate both:

NEURAL PATHWAY
and

COCHLEAR PATENCY.
The ear that is more difficult today may become impossible later if ossification progresses.

19.35 REVISION COCHLEAR IMPLANTATION

Revision may be required for:

- device failure
- infection
- electrode migration
- trauma
- receiver problem
- poor performance
- magnet-related issue
- skin breakdown

Before revision, determine:

IS THE PROBLEM ELECTRONIC?

MECHANICAL?

SURGICAL?

AUDIOLOGICAL?

Do not explant a functioning device to solve a programming problem.

19.36 ELECTRODE REMOVAL

Electrode removal during revision can be delicate because intracochlear fibrosis may develop.

The surgeon should anticipate:

- resistance
- risk of intracochlear trauma
- need for immediate reinsertion
- preservation of cochlear patency

If reimplantation is planned, maintaining the cochlear route becomes important.

19.37 WOUND AND RECEIVER COMPLICATIONS

Potential complications include:

- infection
- haematoma
- skin-flap necrosis
- implant exposure
- device migration
- pain

Soft-tissue problems can threaten a perfectly functioning electronic device.

PRINCIPLE

A cochlear implant is only as secure as the tissue covering it.

19.38 FACIAL NERVE STIMULATION

Unwanted facial stimulation may occur because of:

- electrode position
- abnormal bone conductivity
- otosclerosis
- congenital anatomy
- high stimulation requirements

Management may involve:

- reprogramming
- electrode deactivation
- further assessment
- revision in selected cases

Not every facial twitch after activation is a surgical indication.

19.39 POSTOPERATIVE IMAGING

Imaging may be used in selected settings to assess:

- electrode position
- complications
- difficult insertion
- abnormal anatomy

Routine practice varies by centre and technology.

Imaging should be tailored to what needs to be confirmed.

19.40 ACTIVATION

The implant is not generally “turned on” as the operation ends.

After healing, activation begins the audiological phase.

The processor is programmed according to:

- thresholds
- comfort levels

- objective measures
- behavioural responses
- device-specific strategies

The surgical wound can heal before the patient has meaningful auditory benefit.

19.41 MAPPING

Programming is dynamic.

It changes as:

- the patient adapts
- neural response evolves
- auditory perception develops

Repeated mapping sessions may be required.

PRINCIPLE

The surgeon implants the electrode.

> **The audiology team teaches the system how to use it.**

19.42 REHABILITATION

Auditory rehabilitation may involve:

- auditory training
- speech and language therapy
- family participation
- school support in children
- communication strategies

Particularly in prelingually deaf children, rehabilitation is central to outcome.

The implant provides access to auditory information.

The brain must learn to interpret it.

19.43 OUTCOME IS MORE THAN PURE-TONE THRESHOLD

Meaningful outcomes include:

- speech understanding
- language development
- educational participation
- communication
- hearing in noise
- quality of life
- independence

The most important outcome may differ between patients.

DECISION POINT

THE ELECTRODE DOES NOT ADVANCE

Do not push harder automatically.

Ask:

Is the cochlear entry correct?

Is the insertion angle aligned with the basal turn?

Is there ossification?

Is the electrode folding?

Is the cochlea malformed?

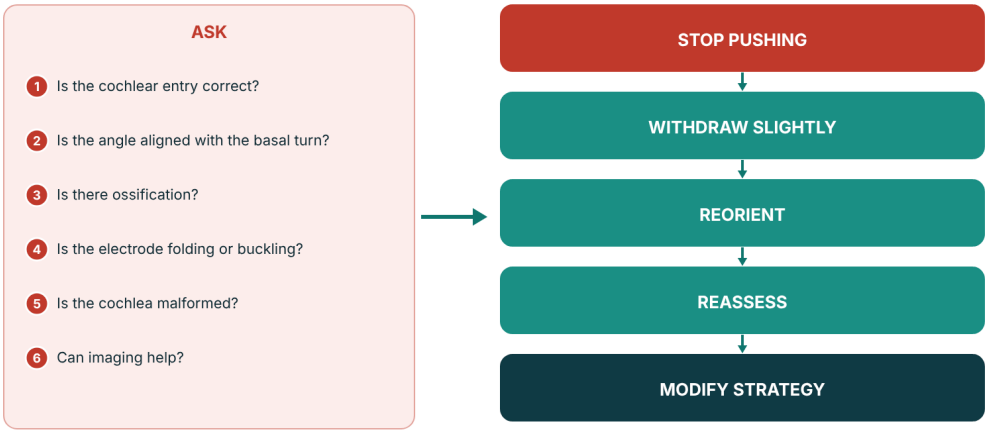
Can imaging help?

Then:

WITHDRAW SLIGHTLY → REORIENT → REASSESS → MODIFY STRATEGY.

Figure 19.7 · The electrode does not advance

Resistance at the cochlea should decrease force — not increase it



Modify: other entry, other electrode, partial insertion, imaging — not more force.

FROM EXPERIENCE

Cochlear implantation can look like a sequence of technical steps:

mastoidectomy,

facial recess,

round window,

electrode.

But the real operation begins much earlier.

Was the patient the right candidate?

Is the cochlear nerve present?

Which ear should be implanted?

What does the CT predict?

What if the cochlea is ossified?

What if a gusher occurs?

And after surgery:

who will map,

who will rehabilitate,

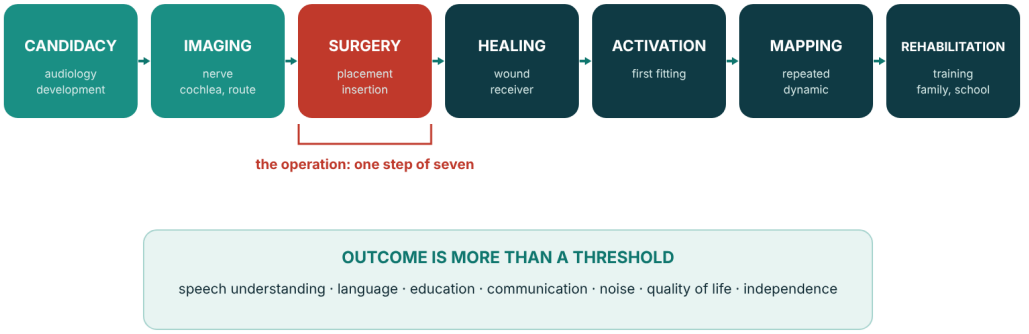
and what does success mean for this patient?

The electrode is only one part of the pathway.

> **Cochlear implantation is surgery placed inside a much larger rehabilitation system.**

Figure 19.8 · Surgery inside a rehabilitation system

The operation places the implant; rehabilitation creates the hearing outcome



TAKE IT TO THE OT

Before cochlear implantation, confirm:

CANDIDACY

SIDE

AUDIOLOGY

COCHLEAR NERVE

COCHLEAR PATENCY

FACIAL NERVE ANATOMY

MASTOID / FACIAL RECESS

ROUND-WINDOW ORIENTATION

INNER-EAR MALFORMATION

GUSHER RISK

OSSIFICATION

DEVICE & ELECTRODE

BACKUP PLAN

INTRAOPERATIVE TESTING

ACTIVATION & REHABILITATION PATHWAY

CHAPTER SUMMARY

Cochlear implantation bypasses damaged cochlear sensory function and stimulates the auditory neural pathway electrically.

Select candidates according to expected functional benefit, not the audiogram alone.

Use CT and MRI to understand both the surgical corridor and neural pathway.

Perform mastoidectomy and facial recess surgery through reliable landmarks.

Define the round-window and cochlear orientation before insertion.

Advance the electrode gently and treat resistance as information.

Anticipate gusher, malformation and ossification from imaging.

Verify implant function.

Protect the device with healthy soft tissue.

And remember:

> **The operation places the implant.**

> **Rehabilitation creates the hearing outcome.**

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CHAPTER 20

Difficult Cochlear Implantation

When the Standard Route Does Not Fit the Anatomy

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- identify preoperative factors that predict a difficult cochlear implantation
- understand the surgical implications of cochlear ossification and fibrosis
- recognise inner-ear malformations associated with CSF gusher risk
- anticipate aberrant facial nerve anatomy and a narrow facial recess
- modify the standard surgical route when exposure is inadequate
- understand the challenges of implantation after previous mastoid or middle-ear surgery
- recognise electrode insertion problems and malposition
- choose between persistence, alternate access, modified electrode strategy and staged surgery
- preserve the cochlea and facial nerve when the standard anatomy is absent

20.1 A DIFFICULT COCHLEAR IMPLANT SHOULD USUALLY BE DIFFICULT ON THE SCAN FIRST

Many difficult cases announce themselves preoperatively.

Look for:

- cochlear ossification
- cochlear fibrosis

- congenital malformation
- narrow or absent cochlear turns
- enlarged internal auditory canal or abnormal CSF communication
- aberrant facial nerve
- high jugular bulb
- contracted mastoid
- narrow facial recess
- previous mastoid surgery
- previous canal wall down cavity
- previous cochlear implantation
- temporal-bone fracture

PRINCIPLE

If the imaging is unusual, the operation should not begin with a routine mental script.

20.2 DEFINE WHY THE CASE IS DIFFICULT

The challenge may be:

ACCESS

Can I reach the cochlea safely?

IDENTIFICATION

Can I identify the round-window region?

PATENCY

Can the cochlea accept an electrode?

ANATOMY

Is the cochlea malformed?

FACIAL NERVE

Is the standard facial recess safe?

CSF

Is abnormal fluid communication expected?

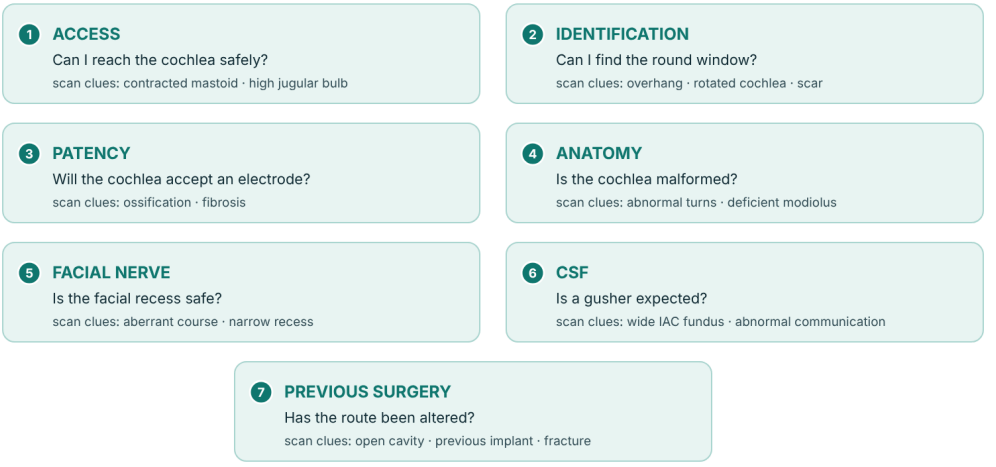
PREVIOUS SURGERY

Has the normal route been altered?

Each problem requires a different solution.

Figure 20.1 · Define why the case is difficult

Most difficult implants are difficult on the scan first — name the problem, then choose the solution



Each problem requires a different solution.

20.3 THE STANDARD APPROACH IS A ROUTE, NOT A RULE

The conventional route:

CORTICAL MASTOIDECTOMY

↓

FACIAL RECESS

↓

ROUND WINDOW

↓

ELECTRODE INSERTION

works because normal anatomy allows it.

When the anatomy does not allow it, the surgeon should not force the patient to fit the approach.

SURGICAL PRINCIPLE

The safest route to the cochlea matters more than preserving the name of the approach.

The standard route is described in Chapter 19, Cochlear Implantation.

20.4 COCHLEAR OSSIFICATION

Ossification may occur after:

- meningitis
- labyrinthitis
- trauma
- otologic surgery
- other inner-ear injury

It may begin focally and progress.

The surgeon should know:

WHERE IS THE COCHLEA STILL PATENT?

HOW MUCH INSERTION IS LIKELY TO BE POSSIBLE?

WHAT ELECTRODE STRATEGY IS AVAILABLE?

The answer affects both timing and technique.

20.5 POST-MENINGITIC OSSIFICATION

Post-meningitic deafness deserves particular attention because ossification may progress over time.

Imaging may show:

- basal-turn obstruction
- diffuse labyrinthine ossification
- partial residual patency

MRI may demonstrate loss of fluid signal before dense ossification is obvious on CT.

PRINCIPLE

In progressive cochlear obliteration, time can change surgical feasibility.

20.6 LIMITED OSSIFICATION

When obstruction is limited, controlled removal of obstructing bone or fibrous tissue may permit electrode insertion.

The objective is not to recreate a normal cochlea.

It is to establish a safe pathway for the electrode while minimising further intracochlear trauma.

20.7 EXTENSIVE OSSIFICATION

When ossification is extensive, options may include specialised:

- drill-out techniques
- alternative electrode arrays
- partial insertion strategies
- multi-array approaches in selected circumstances

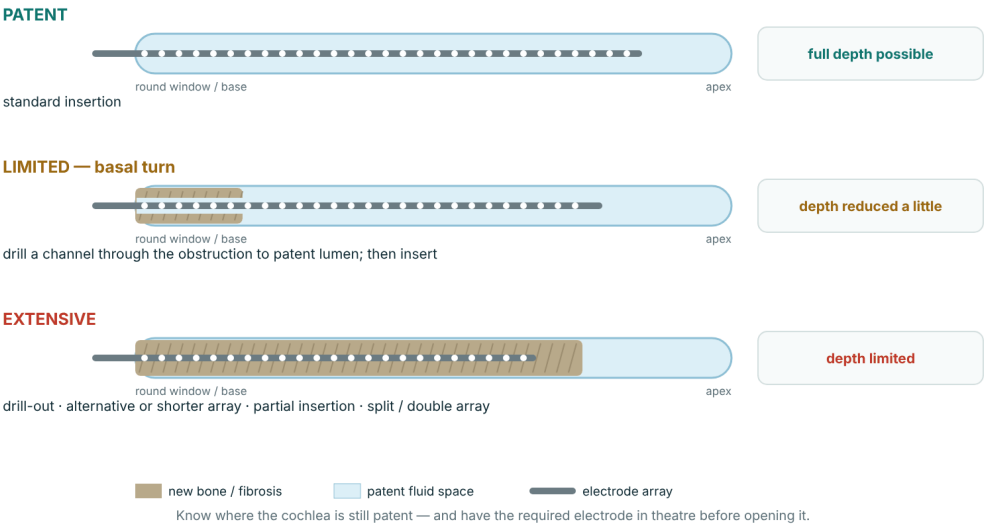
These are advanced cases requiring preoperative planning, appropriate implant availability and detailed counselling.

PRINCIPLE

Do not discover after opening the cochlea that the required electrode is not available.

Figure 20.2 · Ossification changes the electrode strategy

Schematic: cochlear duct drawn unrolled, base on the left, apex on the right



Know where the cochlea is still patent — and have the required electrode in theatre before opening it.

20.8 COCHLEAR FIBROSIS

A cochlea may be obstructed by fibrous tissue without dense bony ossification.

Insertion resistance may therefore occur even when CT appears relatively open.

MRI and clinical history may provide additional clues.

Again:

RESISTANCE IS INFORMATION.

Do not solve it with force.

20.9 INNER-EAR MALFORMATIONS

Congenital malformations can alter:

- cochlear turns
- modiolus
- round window
- vestibule
- internal auditory canal
- facial nerve

- CSF pathways

The important question is not only:

What is the malformation called?

It is:

> **How does this malformation change the operation?**

20.10 MALFORMATION CHANGES ELECTRODE BEHAVIOUR

In an abnormal cochlea:

- the electrode may not follow the expected spiral
- the modiolus may be deficient
- scalar anatomy may be altered
- insertion depth may be unpredictable
- facial nerve stimulation risk may change

Electrode selection should therefore be individualised.

Figure 20.3 · How a malformation changes the operation

Not only 'what is it called?' but 'what does it change?'

FINDING	WHAT IT CHANGES	RESPONSE
Deficient modiolus / wide IAC fundus	gusher risk; array may enter the IAC	**sealing ready; image the array**
Abnormal or reduced turns	insertion depth unpredictable	**individualised array length**
Displaced round window	standard window not where expected	**find it from relationships**
Rotated cochlea	insertion axis and cochleostomy site move	**re-plan the trajectory on CT**
Aberrant facial nerve	facial recess may be unsafe	**define the nerve before drilling**
Abnormal bone–nerve relationship	facial nerve stimulation more likely	**counsel; program around it**

High-quality CT and MRI before surgery; electrode choice individualised.

20.11 CSF GUSHER

A significant CSF gusher may occur in selected malformations with abnormal communication between the subarachnoid and inner-ear spaces — typically where the modiolus or the fundus of the internal auditory canal is deficient, as in incomplete partition types I and III and the common cavity.

Preoperative imaging may suggest increased risk.

The surgeon should enter the operation with:

SEALING MATERIAL READY

ELECTRODE PLAN READY

ANAESTHESIA INFORMED

POSTOPERATIVE PLAN READY

20.12 WHEN THE GUSHER OCCURS

The immediate objectives are:

MAINTAIN ORIENTATION

↓

COMPLETE ELECTRODE INSERTION IF APPROPRIATE

↓

SEAL AROUND THE ELECTRODE

↓

CONTROL PERSISTENT LEAK

↓

REASSESS CLOSURE AND POSTOPERATIVE MONITORING

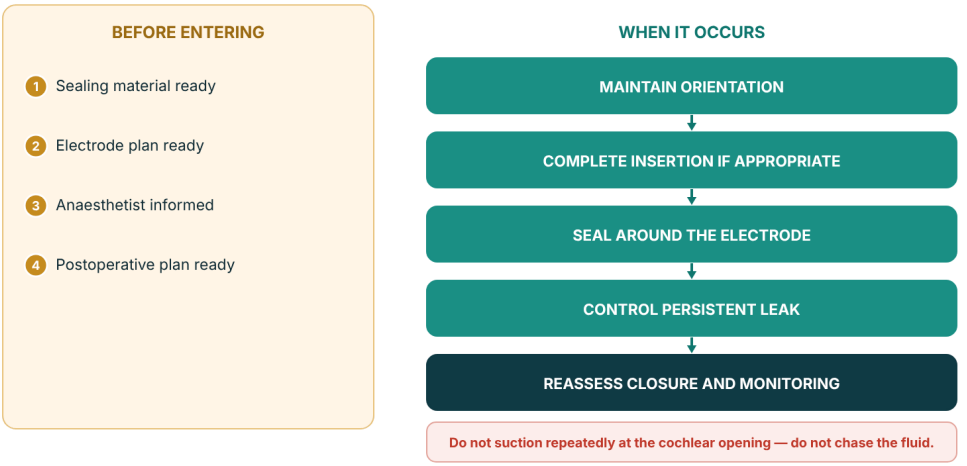
Do not repeatedly suction directly from the cochlear opening.

PRINCIPLE

Control the pathway. Do not chase the fluid.

Figure 20.4 · Prepare for the gusher; then control the pathway

Anticipated from imaging — not discovered as an unexplained complication



20.13 ABERRANT FACIAL NERVE

Congenital inner-ear abnormalities may coexist with abnormal facial nerve anatomy.

The nerve may:

- run more anteriorly
- cross the expected round-window corridor
- narrow the facial recess
- obscure conventional access

The standard facial-recess boundaries may therefore be unreliable.

20.14 DO NOT DRILL A STANDARD FACIAL RECESS AROUND A NONSTANDARD NERVE

If imaging or intraoperative anatomy suggests aberrancy:

STOP.

Define the nerve.

Use:

- imaging

- monitoring
- alternative landmarks
- direct visualisation

Then decide whether the conventional route remains safe.

PRINCIPLE

The round window is not worth a facial nerve injury.

20.15 NARROW FACIAL RECESS

A narrow facial recess may arise from:

- close facial nerve–chorda relationship
- anterior facial nerve
- thick canal wall
- congenital anatomy

Possible responses include:

- optimised drilling
- limited chorda sacrifice where clinically justified
- endoscopic visualisation
- modified approach

The objective is adequate electrode access without excessive neural risk.

20.16 CHORDA TYMPANI SACRIFICE

In selected difficult cases, preserving the chorda may make the facial recess dangerously narrow.

The decision should balance:

TASTE CONSEQUENCE

against

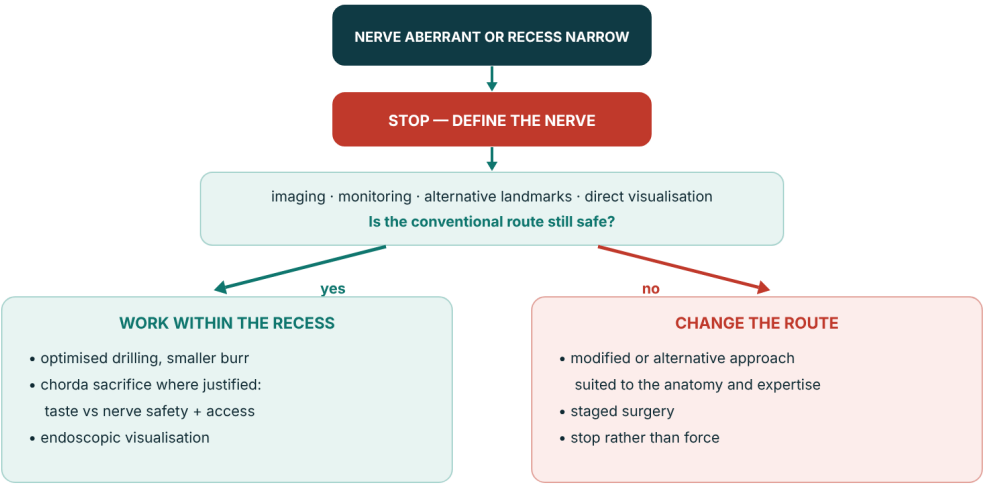
FACIAL NERVE SAFETY + COCHLEAR ACCESS.

Preservation is desirable.

It should not become an absolute objective that creates greater risk.

Figure 20.5 · An abnormal or narrow facial recess

The round window is not worth a facial nerve injury



20.17 HIGH JUGULAR BULB

A high jugular bulb may alter:

- hypotympanic anatomy
- round-window access
- drilling trajectory

If dehiscent, the margin for error narrows further.

This should already be visible on CT.

PRINCIPLE

A vessel seen preoperatively should never be treated as an unexpected intraoperative obstacle.

20.18 CONTRACTED MASTOID

A narrow mastoid corridor may be created by:

- poor pneumatisation
- anterior sigmoid
- low tegmen
- combined anatomy

The surgeon should:

- widen exposure laterally
- maintain landmarks
- avoid tunnelling
- adapt drill size
- reconsider the route if the facial recess cannot be safely developed

A cochlear implant does not require a textbook-sized mastoid cavity.

It requires a safe pathway.

20.19 PREVIOUS CANAL WALL DOWN MASTOIDECTOMY

Implantation in an open mastoid cavity creates additional concerns:

- electrode exposure
- chronic infection
- cavity contamination
- soft-tissue coverage
- long-term device safety

Possible strategies may include selected:

- cavity revision
- obliteration
- canal closure
- staged surgery

depending upon ear status and surgeon strategy.

PRINCIPLE

Do not place a permanent implant into an unstable chronic cavity without first solving the cavity problem.

Cavity management is discussed in Chapter 13, Canal Wall Down Mastoid Surgery, and Chapter 16, Mastoid Obliteration & Canal Wall Reconstruction.

20.20 SUBTOTAL PETROSECTOMY CONCEPT

In selected complex ears, subtotal petrosectomy with closure of the external auditory canal and obliteration may create a stable environment for implantation.

This may be considered in situations such as:

- chronically infected ears
- problematic open cavities
- selected congenital or revision anatomy

It is a major reconstructive strategy, not simply a wider mastoidectomy.

The technique is described in Chapter 29, Petrous Apex & Petrosectomy Approaches.

Figure 20.6 · Subtotal petrosectomy: making the ear safe for an implant

A major reconstructive strategy, not simply a wider mastoidectomy



CONSIDER WHEN

- chronically infected ear
- problematic open cavity
- selected congenital, ossified or revision ears

THE TRADE-OFF

- the ear can no longer be examined directly
- surveillance relies on imaging
- residual disease can hide under the fat

Technique: Chapter 29, Petrous Apex & Petrosectomy Approaches.

20.21 PREVIOUS MIDDLE-EAR SURGERY

Previous tympanoplasty or mastoid surgery may alter:

- canal
- tympanic membrane
- facial recess

- ossicles
- scar
- landmarks

Before surgery, determine exactly what was done previously.

The old operation becomes part of the implant route.

20.22 PREVIOUS COCHLEAR IMPLANTATION

Revision implantation may be required for:

- device failure
- infection
- electrode migration
- trauma
- poor device performance
- receiver or lead problems

The revision surgeon should know:

> **WHY IS THE DEVICE BEING REMOVED?**

IS THE COCHLEA STILL PATENT?

> **CAN THE OLD ELECTRODE BE REMOVED SAFELY?**

> **IS IMMEDIATE REIMPLANTATION PLANNED?**

20.23 PRESERVE THE COCHLEAR TRACK

During explantation, fibrosis may make electrode removal difficult.

If reimplantation is planned, avoid unnecessary trauma that could compromise the existing cochlear path.

Have the replacement system ready where appropriate.

> **PRINCIPLE**
>
> **Do not remove the bridge until you know how you will cross again.**

20.24 ROUND WINDOW NOT VISIBLE

If the round window cannot be identified:

> **DO NOT DRILL RANDOMLY TOWARD THE COCHLEA.**

Reassess:

- promontory
- stapes / oval window
- facial nerve
- hypotympanum
- CT orientation

Consider:

- bony overhang
- rotated cochlea
- congenital anomaly
- scar

The round window should be predicted from relationships.

20.25 ROTATED COCHLEA

In congenital malformation, the cochlea may not have the expected orientation.

This affects:

- round-window position
- insertion axis
- cochleostomy site

> **PRINCIPLE**
>
> **When the cochlea rotates, the safe trajectory rotates with it.**

Do not use memorised surface distances in distorted anatomy.

20.26 ELECTRODE DOES NOT ADVANCE

This is one of the most important moments.

Potential causes include:

- poor insertion angle
- wrong cochlear entry
- ossification
- fibrosis
- malformation
- electrode fold-over
- mechanical obstruction

Response:

STOP

↓

WITHDRAW SLIGHTLY

↓

REASSESS ENTRY

↓

REORIENT

↓

CONSIDER IMAGING

↓

> **CHANGE ELECTRODE / TECHNIQUE IF NEEDED**

NEVER BEGIN WITH MORE FORCE.

The same sequence is shown in Chapter 19, Cochlear Implantation (Figure 19.7).

20.27 PARTIAL INSERTION

A complete insertion is desirable when anatomically appropriate.

But forcing an electrode to achieve a nominal full insertion can create more harm than accepting a limited insertion in selected abnormal cochleae.

The functional significance depends upon:

- electrode design
- anatomy
- stimulation strategy

> **PRINCIPLE**
>
> **Insertion depth is not a competition.**

The objective is the safest useful neural interface.

20.28 TIP FOLD-OVER

Tip fold-over may occur when the distal electrode bends back on itself.

Clues may arise from:

- insertion resistance
- intraoperative testing
- imaging

If suspected, confirm promptly.

A malpositioned array should not be accepted simply because electrical impedances appear normal.

20.29 EXTRACOCHLEAR ELECTRODE

Electrode contacts may remain outside the cochlea in difficult insertions.

This can occur with:

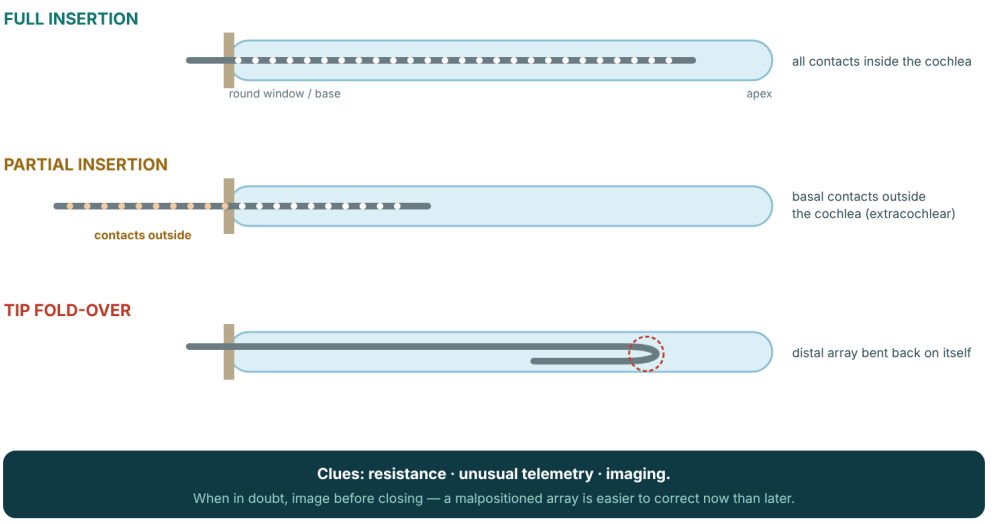
- partial insertion
- resistance
- incorrect entry
- migration

The significance should be understood before activation.

Documentation and imaging may be important.

Figure 20.7 · Electrode position problems

Schematic: cochlear duct unrolled, base on the left · normal impedances do not prove position



Clues: resistance · unusual telemetry · imaging.

When in doubt, image before closing — a malpositioned array is easier to correct now than later.

20.30 FACIAL NERVE STIMULATION IN MALFORMED COCHLEA

Abnormal bone and neural relationships can increase unwanted facial stimulation.

Management may include:

- programming adjustments
- selective electrode deactivation
- further evaluation
- revision in selected cases

This should be anticipated during counselling in high-risk anatomy.

20.31 INTRAOPERATIVE TESTING — INTERPRET IN CONTEXT

In difficult cases, device telemetry becomes particularly useful.

But remember:

- normal impedance does not prove scalar position
- neural response does not prove full insertion
- absent response does not automatically mean device failure

Use:

> **OPERATIVE FINDINGS + TESTING + IMAGING**

together.

20.32 INTRAOPERATIVE IMAGING

Imaging can be especially valuable when:

- anatomy is malformed
- insertion is difficult
- fold-over is suspected
- array position is uncertain

The purpose is not routine technology display.

It is to answer:

> **Where is the electrode actually located?**

20.33 WHEN TO ABANDON THE STANDARD ROUTE

Consider changing strategy when:

- facial nerve cannot be safely protected
- round window remains inaccessible
- vascular anatomy blocks the corridor
- previous surgery has destroyed the route
- cochlear access through the standard pathway would require unacceptable risk

Potential solutions may include modified approaches appropriate to the individual anatomy and expertise available.

> **PRINCIPLE**
>
> **Persistence is valuable only while the route remains safe.**

20.34 STAGING

Staged surgery may be appropriate when:

- chronic infection must first be controlled
- cavity obliteration is required
- tissue quality is poor
- uncertain anatomy requires further assessment
- device implantation should wait for a safer environment

One-stage surgery is convenient.

It is not inherently better.

DECISION POINT

THE STANDARD CI PATHWAY IS NOT SAFE

Ask:

What is blocking the route?

Bone?
Facial nerve?
Vessel?
Scar?
Malformation?

Can the obstacle be safely modified?

Is another route available?

Can the operation be staged?

Would continuing risk facial nerve, inner ear or major vascular injury?

Then choose:

MODIFY

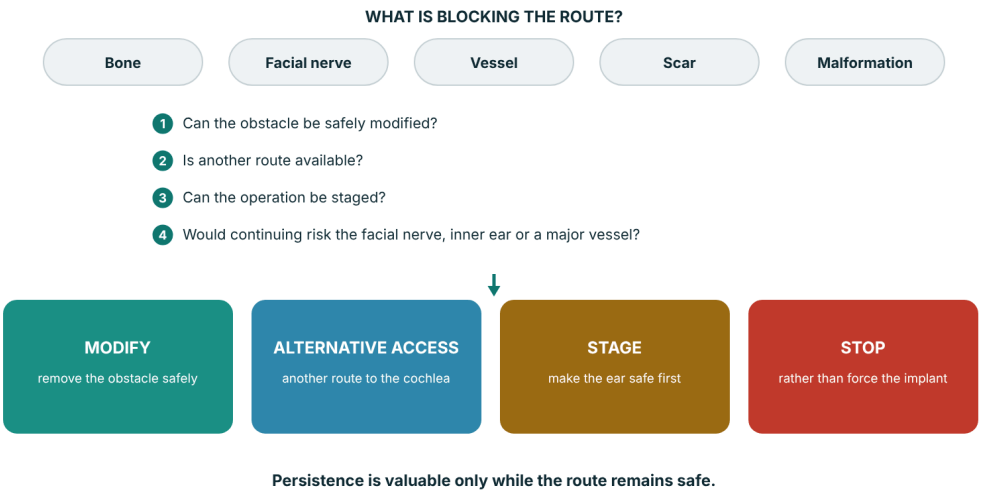
ALTERNATIVE ACCESS

STAGE

STOP

Figure 20.8 · The standard pathway is not safe

Name what is blocking the route; then choose deliberately



FROM EXPERIENCE

A routine cochlear implant is a highly structured operation.

That structure is useful.

But it can become dangerous if the surgeon begins expecting every temporal bone to conform to it.

A malformed cochlea does not know where the round window is supposed to be.

An aberrant facial nerve does not respect the textbook facial recess.

An ossified cochlea will not open because the electrode is pushed harder.

The difficult implant therefore tests something deeper than technical repetition.

It tests whether the surgeon understands why the standard operation works.

Because once the standard anatomy disappears, only the principles remain.

TAKE IT TO THE OT

Before a difficult cochlear implant, define:

WHY DIFFICULT?

Access / cochlea / nerve / CSF / previous surgery?

CT

Mastoid
Facial nerve
Jugular bulb
Round window
Cochlear ossification
Malformation

MRI

Cochlear patency
Cochlear nerve

ELECTRODE

Standard or specialised?

GUSHER

Expected?

FACIAL RECESS

Safe?

ALTERNATIVE ROUTE

What if not?

INTRAOPERATIVE IMAGING

Available if needed?

STAGING

Would a two-stage strategy be safer?

BAILOUT

At what point will you stop rather than force the implant?

CHAPTER SUMMARY

Difficult cochlear implantation should begin with difficult-case recognition before surgery.

Define whether the challenge lies in access, cochlear patency, facial nerve anatomy, CSF pathways or previous surgery.

Use CT and MRI to redesign the operation.

Do not force a standard facial recess around an aberrant nerve.

Treat electrode resistance as information.

Plan for gusher in malformed ears.

Adapt electrode strategy in ossification.

Use intraoperative testing and imaging to answer specific questions.

Stage surgery when the ear is not ready for a permanent implant.

And remember:

> **When the standard anatomy disappears, do not hold more tightly to the standard operation.**

> **Hold more tightly to the surgical principles.**

FURTHER READING & REFERENCES

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CHAPTER 21

Facial Nerve Surgery in the Temporal Bone

Identify • Decompress • Repair • Restore Function

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the intratemporal course of the facial nerve from the internal auditory canal to the stylomastoid foramen
- localise facial nerve dysfunction clinically and radiologically
- recognise common traumatic, inflammatory, iatrogenic and tumour-related mechanisms of injury
- understand the principles and limitations of facial nerve decompression
- identify the nerve safely using multiple temporal-bone landmarks
- understand when direct repair, interposition grafting or nerve transfer may be required
- use facial nerve monitoring appropriately
- recognise the importance of eye protection and rehabilitation
- distinguish anatomical nerve preservation from meaningful facial function

21.1 THE FACIAL NERVE IS A FUNCTIONAL PATHWAY

Facial nerve surgery is not simply surgery upon a visible white structure.

The nerve carries functions that influence:

EYE CLOSURE

ORAL COMPETENCE

FACIAL EXPRESSION

SPEECH AND EATING

SOCIAL COMMUNICATION

Through the nervus intermedius it also carries taste fibres from the anterior two-thirds of the tongue and parasympathetic secretomotor fibres to the lacrimal, submandibular and sublingual glands; within the temporal bone it gives the nerve to stapedius.

The objective of surgery is therefore not merely:

KEEP THE NERVE CONTINUOUS.

It is:

> **Preserve or restore the best possible facial function.**

21.2 INTRATEMPORAL COURSE

The facial nerve enters the temporal bone through the internal auditory canal and travels through:

LABYRINTHINE SEGMENT

↓

> **GENICULATE GANGLION (FIRST GENU)**

↓

> **TYMPANIC / HORIZONTAL SEGMENT**

↓

SECOND GENU

↓

MASTOID / VERTICAL SEGMENT

↓

STYLOMASTOID FORAMEN

The nerve then enters the extracranial facial pathway.

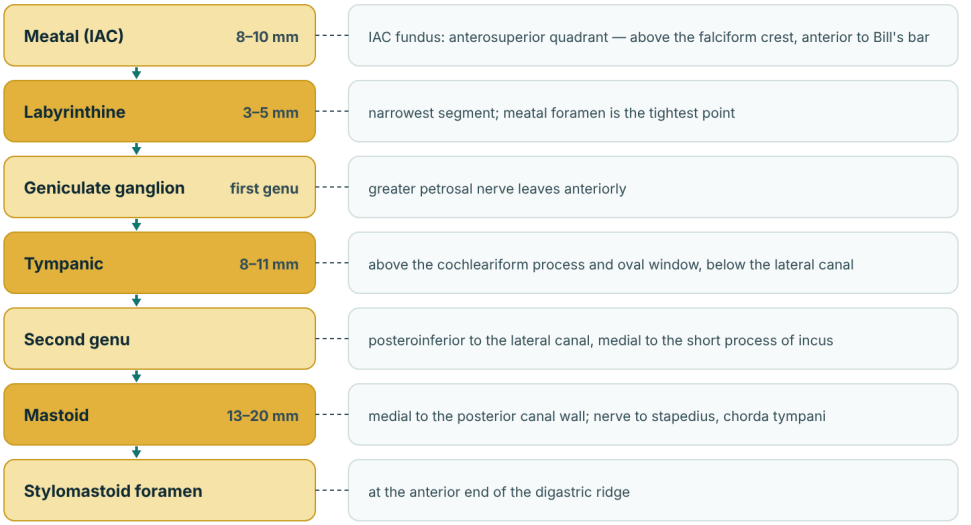
Approximate lengths: labyrinthine segment 3–5 mm, tympanic segment 8–11 mm, mastoid segment 13–20 mm.

The labyrinthine segment is the narrowest part of the fallopian canal, and its entrance, the meatal foramen, is the tightest point of all.

Each segment has different surgical landmarks, vulnerabilities and approaches.

Figure 21.1 · Intratemporal course of the facial nerve

Segment by segment — approximate lengths and the landmark that predicts each one (schematic, not to scale)



Intracranial (cerebellopontine angle) segment proximal to the IAC is not shown.

21.3 LANDMARK NETWORK

Do not identify the facial nerve from one landmark alone.

For the mastoid segment, useful relationships include:

LATERAL SEMICIRCULAR CANAL

+

INCUS / FOSSA INCUDIS REGION

+

POSTERIOR CANAL WALL

+

DIGASTRIC RIDGE

↓

EXPECTED MASTOID FACIAL NERVE

For the tympanic segment:

COCHLEARIFORM PROCESS

+

OVAL WINDOW

+

LATERAL SEMICIRCULAR CANAL

+

SECOND GENU

↓

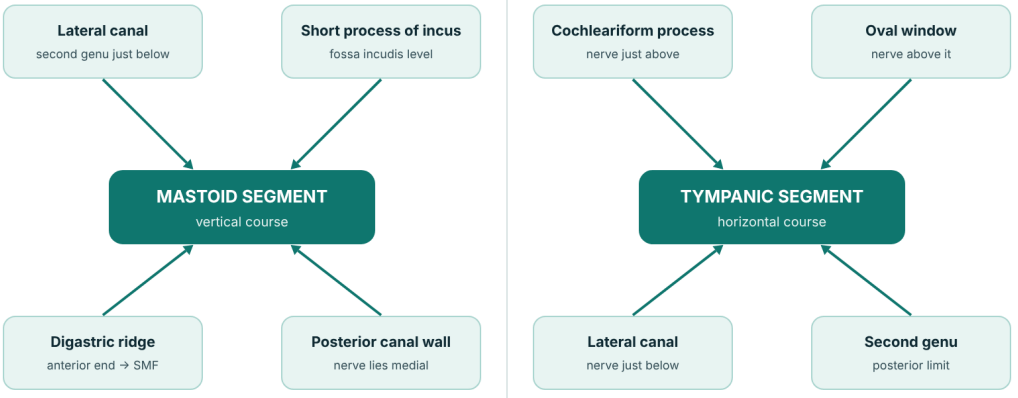
EXPECTED HORIZONTAL FACIAL NERVE

PRINCIPLE

Predict the nerve before exposing it.

Figure 21.2 · Landmark networks for the mastoid and tympanic segments

Several landmarks agreeing predict the nerve before it is exposed



Add the patient's own CT: expected depth, dehiscence and displacement.

21.4 CLINICAL LOCALISATION

Before operating, document facial function carefully.

Assess:

- forehead movement
- eye closure
- nasolabial fold
- oral commissure movement
- resting symmetry
- synkinesis where present

Depending upon context, also assess:

- hearing
- vestibular symptoms
- taste complaints
- lacrimation
- other cranial nerves

A standardised facial grading system, such as the House–Brackmann or Sunnybrook scale, assists documentation and follow-up.

21.5 TIMING MATTERS

The meaning of facial weakness depends upon:

- sudden or gradual onset
- immediate or delayed after trauma
- complete or incomplete paralysis
- progressive or stable course
- duration

These features help distinguish:

- compression
- inflammation
- transection
- tumour
- iatrogenic injury

The operative indication should not be separated from the natural history of the condition.

21.6 IMAGING

CT is particularly useful for:

- temporal-bone fracture
- facial canal disruption
- bony disease
- cholesteatoma
- surgical anatomy

MRI is particularly useful for:

- nerve enhancement
- tumour
- internal auditory canal / cerebellopontine angle pathology
- soft-tissue and neural assessment

Imaging should answer:

WHERE IS THE LESION?

WHAT IS THE MECHANISM?

> **Can surgery change the outcome?**

21.7 ELECTRODIAGNOSTIC ASSESSMENT

Selected tests may assist in evaluating nerve degeneration or recovery.

The exact role depends upon:

- timing
- severity
- clinical setting
- available expertise

Electroneurography (ENoG) and voluntary electromyography (EMG) are most informative in complete paralysis, broadly between the third day and the third week after onset.

Electrodiagnostic information should support — not replace — clinical assessment and imaging.

21.8 DECOMPRESSION — THE CONCEPT

Facial nerve decompression aims to relieve pressure within the bony facial canal in selected conditions.

The rationale may involve:

- oedema
- haematoma
- bony compression
- traumatic impingement

But decompression is not indicated simply because facial paralysis exists.

PRINCIPLE

There must be a plausible compressive mechanism and a meaningful opportunity for surgery to alter outcome.

21.9 WHICH SEGMENT?

Before decompression, define:

LABYRINTHINE?

GENICULATE?

TYMPANIC?

MASTOID?

MULTIPLE SEGMENTS?

The surgical approach depends upon the segment requiring access.

Do not perform wider decompression than the pathology justifies.

21.10 APPROACH SELECTION

Possible approaches may include:

TRANSMASTOID

Useful for selected tympanic and mastoid segments.

MIDDLE CRANIAL FOSSA

Provides access to labyrinthine / geniculate regions while preserving the labyrinth in selected settings.

TRANSLABYRINTHINE OR OTHER SKULL-BASE CORRIDORS

May be used when hearing is already absent or pathology requires deeper access.

The approach is chosen according to:

LOCATION + HEARING + PATHOLOGY + REQUIRED EXPOSURE.

Figure 21.3 · Approach selection by segment and hearing

Location + hearing + pathology + required exposure

	TRANSMASTOID hearing preserved	MIDDLE CRANIAL FOSSA hearing preserved	TRANSLABYRINTHINE hearing already lost
Mastoid segment	direct access	not reached	direct access
Second genu / tympanic	direct access	limited access	direct access
Geniculate ganglion	limited access	direct access	direct access
Labyrinthine / meatal foramen	not reached	direct access	direct access
Internal auditory canal	not reached	direct access	direct access

Transmastoid + middle fossa together expose the whole intratemporal nerve with hearing preserved.

Schematic guide only — the extent of exposure also depends on the pathology and the individual anatomy.

21.11 TRANSMASTOID IDENTIFICATION

A landmark-driven mastoidectomy is essential.

Establish:

TEGMEN

SIGMOID

LATERAL SEMICIRCULAR CANAL

INCUS REGION

DIGASTRIC RIDGE

Then define the expected facial nerve course.

Do not start by drilling directly where the nerve is presumed to lie.

21.12 SKELETONISE BEFORE DECOMPRESSING

A useful principle is to progressively thin bone over the nerve until its course is clearly defined.

Conceptually:

THICK BONE

↓

THIN SHELL

↓

NERVE COURSE VISIBLE / PREDICTABLE

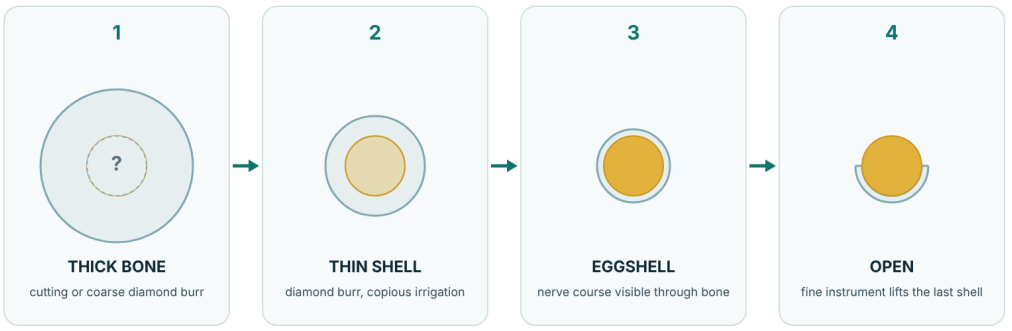
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CONTROLLED REMOVAL OF FINAL BONE

The goal is controlled exposure rather than sudden entry onto the nerve.

Figure 21.4 · Thin, eggshell, then open

Cross-section schematic of the facial canal — the last layer is not removed like the first



As the shell thins: lighter touch · smaller diamond burr · more irrigation · drill parallel.
The nerve should appear gradually, not explosively.

21.13 EGGSHELL THE FACIAL CANAL

As the bony covering becomes thin:

- reduce burr aggression
- maintain irrigation
- control drill direction
- use fine diamond drilling where appropriate
- consider completing the final layer with a fine instrument

PRINCIPLE

The last layer over the nerve is not removed the same way as the first layer of mastoid cortex.

21.14 DRILL PARALLEL TO THE NERVE

Where anatomy permits, drilling should minimise the risk that a slip travels directly across the nerve.

Think about:

BURR VECTOR

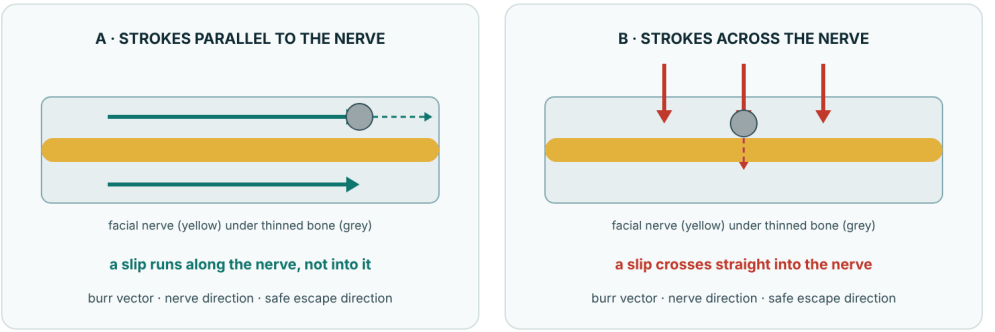
NERVE DIRECTION

SAFE ESCAPE DIRECTION

The drill should reveal the nerve without repeatedly threatening it.

Figure 21.5 · Drill parallel to the nerve

Schematic — the direction a slip would travel matters as much as where the burr is



Where anatomy permits, choose the burr direction so that the escape path is away from or along the nerve.

21.15 THERMAL INJURY

The facial nerve can be damaged without direct transection.

Avoid:

- prolonged stationary drilling
- excessive pressure
- poor irrigation
- unnecessary bipolar or monopolar heat near the exposed nerve

PRINCIPLE

A nerve can be anatomically intact and physiologically injured.

21.16 OPENING THE FACIAL CANAL

Once the canal is adequately thinned, the remaining bony shell can be removed in a controlled fashion.

Avoid:

- sharp pressure onto the nerve
- lifting bone fragments into the nerve
- unnecessary manipulation

The nerve should appear gradually.

Not explosively.

21.17 THE NERVE SHEATH

Whether and how the epineurial sheath is opened during decompression depends upon:

- pathology
- segment
- surgical philosophy
- evidence

Routine sheath incision is not universally necessary.

The surgeon should understand the specific indication rather than treating "decompression" as one fixed manoeuvre.

21.18 TRAUMATIC FACIAL PARALYSIS

Temporal-bone trauma may cause:

- nerve compression
- intraneural oedema
- bony impingement
- partial injury
- complete transection

Important clinical distinctions include:

IMMEDIATE COMPLETE PARALYSIS

versus

DELAYED OR INCOMPLETE PARALYSIS.

These patterns may imply different mechanisms and management.

Delayed-onset or incomplete paralysis usually recovers well without surgery; immediate complete paralysis carries a greater likelihood of significant nerve injury.

Surgical decisions should integrate:

- clinical course
- imaging
- electrodiagnostic findings
- hearing status
- fracture anatomy

21.19 FRACTURE PATTERN

Temporal-bone fractures can cross the facial canal at different levels.

The perigeniculate region is the most frequently injured site.

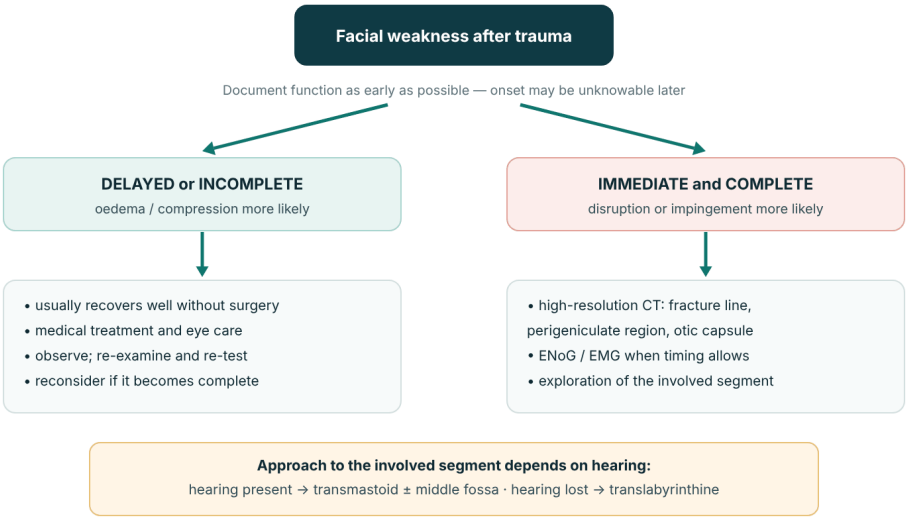
CT should define:

- fracture line
- geniculate region
- tympanic segment
- mastoid segment
- otic capsule
- ossicular injury

The operation should target the involved segment rather than simply expose the easiest segment.

Figure 21.6 · Facial paralysis after temporal-bone trauma

Onset and completeness come first; imaging and electrodiagnosis refine the decision



21.20 IATROGENIC FACIAL NERVE INJURY

Possible mechanisms include:

- drill injury
- thermal injury
- sharp transection
- traction
- crush
- cautery
- inadvertent incorporation in ligature or closure

Immediate recognition is valuable.

If new postoperative facial paralysis occurs after ear surgery:

> **DO NOT ASSUME IT WILL RECOVER WITHOUT INVESTIGATION.**

Review:

- timing
- operative events
- nerve monitoring

- imaging where appropriate
- severity

21.21 IF THE NERVE IS VISIBLY TRANSECTED

If a transection is recognised:

STOP

↓

> **DEFINE PROXIMAL AND DISTAL ENDS**

↓

> **REMOVE CLEARLY NONVIABLE / CRUSHED SEGMENT AS APPROPRIATE**

↓

ASSESS DEFECT LENGTH

↓

> **DIRECT REPAIR IF TENSION-FREE**

or

> **INTERPOSITION GRAFT IF REQUIRED**

The goal is the best possible neural continuity.

21.22 PRIMARY REPAIR

Direct repair requires:

- viable nerve ends
- precise approximation
- minimal trauma
- no significant tension

FUNDAMENTAL PRINCIPLE

Never create a “direct repair” by stretching the nerve ends together.

If tension-free approximation is impossible, another strategy is preferable.

21.23 INTERPOSITION GRAFT

A graft may bridge a segmental defect.

Common donor nerves are the great auricular nerve and, for longer defects, the sural nerve, chosen according to required length and calibre.

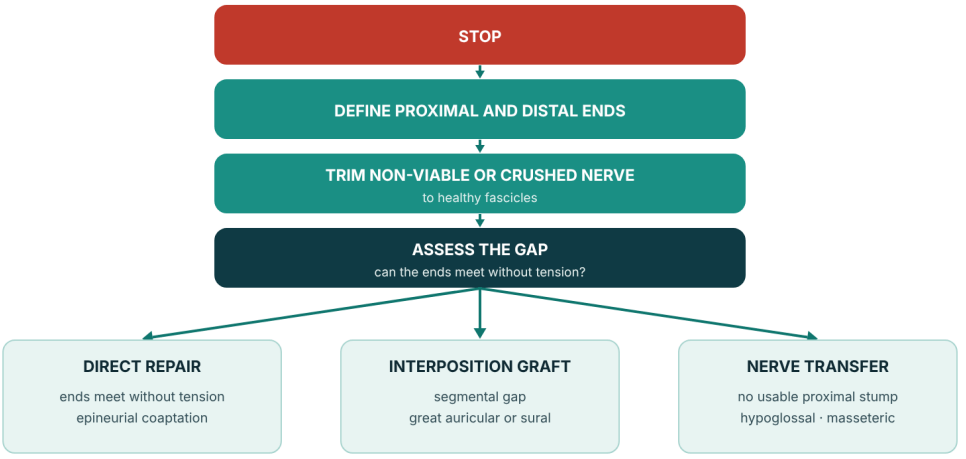
Important considerations:

- healthy proximal and distal nerve
- graft length
- calibre matching
- orientation
- minimal tension
- number of coaptation sites

The patient should understand that recovery is slow and rarely identical to normal facial function.

Figure 21.7 · When the nerve is transected

Neural continuity without tension is the goal



Never create a "direct repair" by stretching the ends together.

21.24 NERVE GRAFTING COSTS TIME

Regeneration must travel from the proximal repair toward distal muscles.

Outcome depends upon:

- injury level
- graft length
- patient age
- time since denervation
- muscle viability

Therefore immediate or early reconstruction is often preferable when sacrifice or transection is known and oncologically appropriate.

21.25 NERVE TRANSFER

When the proximal facial nerve is unavailable or useful recovery through grafting is unlikely, nerve transfer may provide another route to facial reinnervation.

Potential donor motor nerves include the hypoglossal and masseteric nerves.

The principle is:

FUNCTIONING MOTOR SOURCE

↓

FACIAL NERVE / FACIAL MUSCLE PATHWAY

↓

REANIMATION

Facial reanimation procedures are discussed in Chapter 22, Facial Reanimation & Functional Rehabilitation.

21.26 TUMOUR-RELATED FACIAL NERVE SURGERY

Tumours may:

- compress
- displace
- encase

- invade

the facial nerve.

Management depends upon:

- tumour biology
- preoperative facial function
- nerve involvement
- resection goals
- reconstructive options

ONCOLOGICAL PRINCIPLE

Preserve a functioning uninvolved nerve when oncologically safe.

> **If meaningful clearance requires sacrifice, plan reanimation before division whenever possible.**

21.27 CHOLESTEATOMA AND FACIAL NERVE

Cholesteatoma may cause facial weakness through:

- canal erosion
- inflammation
- compression
- direct neural involvement

Surgery should prioritise:

- disease clearance
- nerve identification
- gentle decompression where indicated

Avoid unnecessary manipulation of an already vulnerable nerve.

21.28 BELL'S PALSY AND DECOMPRESSION

Most Bell's palsy is managed non-surgically.

Facial nerve decompression has a limited and controversial role in highly selected circumstances and should not be presented as routine treatment.

Current guidelines make no recommendation for or against surgical decompression.

Where it has been reported to help, it was performed through a middle cranial fossa approach, including the meatal foramen, within 14 days of complete paralysis, in patients with more than 90% degeneration on ENoG and no voluntary EMG activity.

PRINCIPLE

A technically possible operation is not automatically an evidence-supported operation.

21.29 FACIAL NERVE MONITORING

Monitoring may assist with:

- localisation
- mapping
- identification of neural tissue
- detecting changes during manipulation

Before relying on it:

- confirm electrode placement
- establish baseline
- understand anaesthetic factors, particularly neuromuscular blockade
- verify system function

The monitor is most useful when the surgeon already understands where the nerve should be.

21.30 LOSS OF SIGNAL

If monitoring response falls unexpectedly:

STOP

↓

RELEASE TRACTION

↓

CHECK TECHNICAL FACTORS

↓

REVIEW THE LAST MANOEUVRE

↓

INSPECT THE NERVE

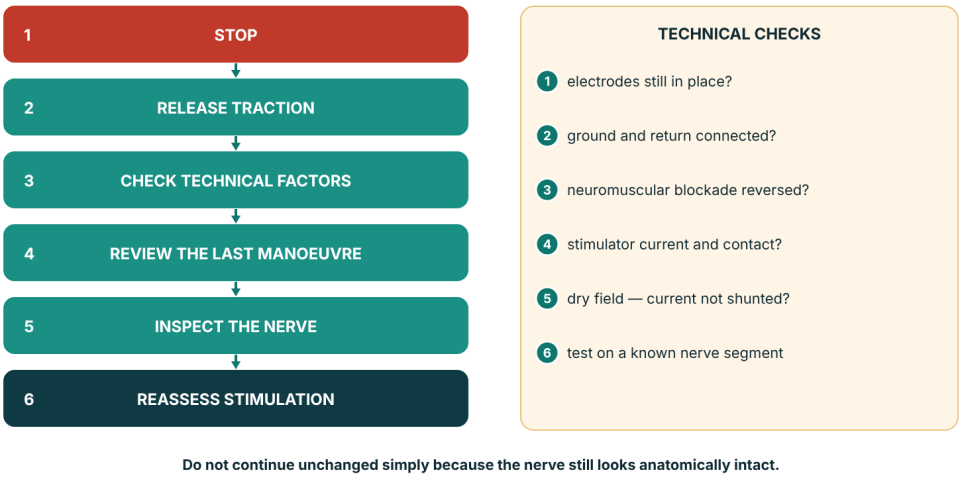
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REASSESS STIMULATION

Do not continue unchanged simply because the nerve still looks anatomically intact.

Figure 21.8 · Loss of monitoring signal

An intact-looking nerve is not proof of an intact pathway



21.31 EYE PROTECTION

When facial weakness compromises eye closure, corneal protection becomes an immediate priority.

Management may include:

- lubrication
- taping / moisture protection
- ophthalmic assessment
- temporary or definitive procedures in selected cases

FUNCTIONAL PRINCIPLE

Before restoring facial symmetry, protect the eye.

21.32 FACIAL REHABILITATION

Recovery may require:

- facial physiotherapy
- neuromuscular retraining
- management of synkinesis
- eye rehabilitation
- speech / oral competence support
- secondary reanimation procedures

The operation may restore neural continuity.

Rehabilitation helps convert that continuity into useful movement.

21.33 SYNKINESIS

As nerves regenerate, aberrant reinnervation may produce unwanted linked movements.

Patients may develop:

- eye closure with oral movement
- facial tightness
- asymmetry

Management may involve:

- therapy
- chemodenervation in selected cases
- surgical strategies when appropriate

Facial recovery is not simply graded as “movement present or absent.”

Quality matters.

21.34 DOCUMENTATION

Record:

PREOPERATIVE FUNCTION

SEGMENT INVOLVED

NERVE CONTINUITY

DECOMPRESSION EXTENT

REPAIR / GRAFT

MONITORING FINDINGS

POSTOPERATIVE FUNCTION

This becomes essential for longitudinal assessment.

DECISION POINT

THE FACIAL NERVE IS NOT WHERE I EXPECTED IT

Do not keep drilling toward the expected line.

Ask:

Are my landmarks correct?

Is this congenital variation?

Has disease displaced the nerve?

Was the nerve altered by previous surgery?

What does CT show?

Can monitoring help localise it?

Then:

> **RETURN TO RELIABLE ANATOMY → RE-PREDICT THE COURSE → REAPPROACH.**

FROM EXPERIENCE

The facial nerve teaches an important surgical lesson.

At first, a trainee wants to **find** the nerve.

With experience, the goal becomes to know where the nerve is before exposing it.

The lateral canal predicts it.

The incus predicts it.

The digastric ridge predicts it.

The CT predicts it.

The disease tells us how it may have moved.

By the time the nerve appears, its location should feel like confirmation rather than discovery.

That is safer surgery.

TAKE IT TO THE OT

Before facial nerve surgery, define:

FUNCTION

Preoperative grade and distribution.

MECHANISM

Trauma / tumour / cholesteatoma / iatrogenic / other.

SEGMENT

Where is the lesion?

IMAGING

CT / MRI findings.

HEARING

What approach preserves or sacrifices hearing?

LANDMARKS

How will the nerve be found?

MONITORING

Required and functioning?

DECOMPRESSION

Which segment and why?

REPAIR

Direct / graft / transfer?

EYE

Is protection needed?

REHABILITATION

What happens after the operation?

CHAPTER SUMMARY

Facial nerve surgery is surgery for function, not merely continuity.

Localise the lesion before selecting the approach.

Use multiple temporal-bone landmarks to predict the nerve.

Thin bone progressively.

Reduce force and heat as the nerve approaches.

Decompress only when there is a meaningful indication.

Recognise traumatic and iatrogenic injury early.

Repair transection without tension.

Use grafting or transfer when direct repair is not feasible.

Protect the eye.

Plan rehabilitation from the beginning.

And remember:

> **Do not search for the facial nerve.**

> **Build enough anatomical certainty that you already know where it must be.**

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CHAPTER 22

Facial Reanimation & Functional Rehabilitation

Protect the Eye • Restore Movement • Recover Function

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- evaluate facial paralysis according to cause, duration, nerve continuity and muscle viability
- understand why timing determines reconstructive options
- prioritise corneal protection and oral competence
- distinguish nerve repair, nerve grafting, nerve transfer, dynamic muscle transfer and static suspension
- understand the conceptual roles of masseteric and hypoglossal donor pathways
- recognise when native facial musculature may no longer be suitable for reinnervation
- understand the principles of eyelid rehabilitation
- recognise and manage synkinesis as a functional disorder
- integrate surgery with long-term facial neuromuscular rehabilitation

22.1 FACIAL REANIMATION IS NOT ONE OPERATION

A patient with facial paralysis may require:

- no surgery
- nerve repair
- nerve graft
- nerve transfer

- eyelid procedure
- static suspension
- muscle transfer
- therapy
- chemodenervation
- combination treatment

The correct choice depends upon one central question:

> **What part of the facial motor system is still usable?**

22.2 DEFINE THE FAILURE

Facial movement requires:

FUNCTIONING MOTOR SOURCE

↓

FUNCTIONING NERVE PATHWAY

↓

NEUROMUSCULAR JUNCTION

↓

VIABLE FACIAL MUSCLE

↓

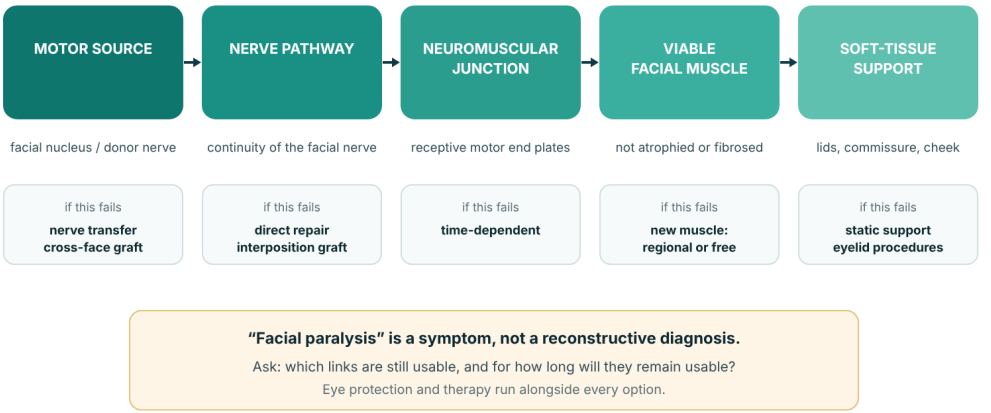
> **APPROPRIATE MECHANICAL SOFT-TISSUE SUPPORT**

Failure may occur at any level.

Therefore “facial paralysis” is not a complete reconstructive diagnosis.

Figure 22.1 · Define the failure in the facial motor system

Movement needs every link; the reconstruction depends on which link has failed



"Facial paralysis" is a symptom, not a reconstructive diagnosis.

Ask: which links are still usable, and for how long will they remain usable?

Eye protection and therapy run alongside every option.

22.3 FIVE QUESTIONS BEFORE REANIMATION

Ask:

1. WHY IS THE FACE PARALYSED?

Trauma? Tumour? Iatrogenic injury? Other?

2. HOW LONG?

Recent or longstanding?

3. IS THE FACIAL NERVE CONTINUOUS?

4. ARE THE NATIVE FACIAL MUSCLES STILL VIABLE?

5. WHAT FUNCTION MATTERS MOST TO THIS PATIENT?

Eye closure? Oral competence? Smile? Resting symmetry?

These questions define the reconstructive pathway.

22.4 TIMING CHANGES EVERYTHING

The reconstructive options available soon after nerve injury differ from those available after prolonged denervation.

Conceptually:

EARLY

Native nerve and muscles may still be salvageable.

INTERMEDIATE

Reinnervation may remain possible, but time matters.

LONG-STANDING

Native muscles may become progressively less responsive to reinnervation, and alternative muscle strategies may be required.

Reinnervation of native facial muscle is often quoted as most reliable within about 12–24 months of denervation; beyond that, results become less predictable.

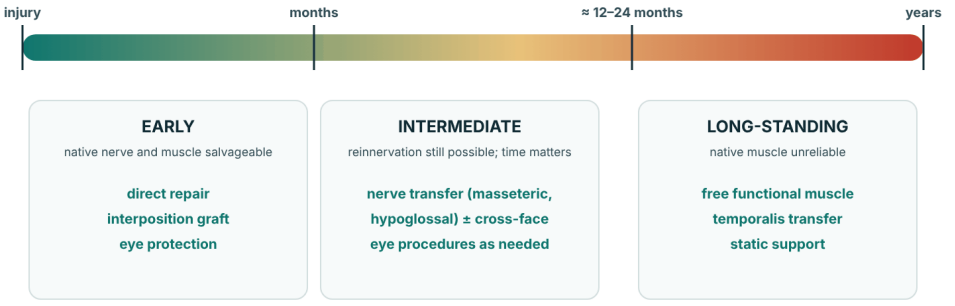
Exact timing thresholds vary and should not be treated as absolute biological cut-offs.

PRINCIPLE

In facial paralysis, time is part of the anatomy.

Figure 22.2 · Time since denervation changes the options

Conceptual timeline — thresholds vary between patients and are not absolute biological cut-offs



Therapy, eye care and documentation continue across the whole timeline.

22.5 PROTECT THE EYE FIRST

Before discussing smile symmetry, assess:

EYE CLOSURE

CORNEAL EXPOSURE

TEAR FUNCTION

LOWER-LID POSITION

BELL'S PHENOMENON

CORNEAL SENSATION

The immediate priority is prevention of:

- exposure keratopathy
- ulceration
- visual loss

FUNCTIONAL PRIORITY

Vision before symmetry.

22.6 NON-SURGICAL EYE PROTECTION

Depending upon severity, measures may include:

- lubrication
- moisture protection
- taping
- ophthalmic follow-up

These measures can be essential while waiting for neural recovery or definitive reanimation.

Temporary treatment is not trivial when it protects vision.

22.7 UPPER-EYELID LOADING

Selected patients may benefit from an upper-eyelid loading procedure, usually with a gold or platinum weight.

The objective is to assist eyelid closure while preserving:

- opening
- contour

- comfort
- visual field

Implant selection and positioning should be individualised.

Overcorrection can create:

- ptosis
- visible contour
- discomfort

Under-correction may fail to protect the cornea adequately.

22.8 LOWER-LID SUPPORT

Lower-lid laxity or ectropion may contribute substantially to ocular symptoms.

Management may require:

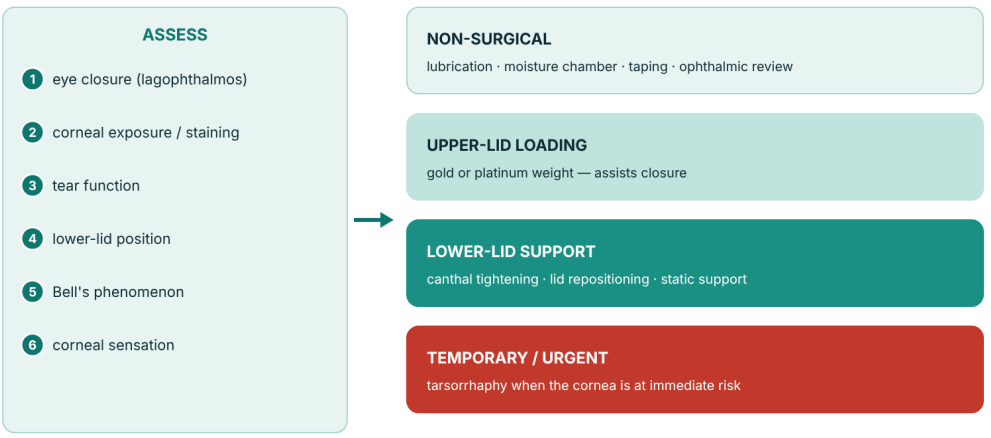
- canthal tightening
- lid repositioning
- static support

Upper-eyelid treatment alone does not solve every paralytic eye problem.

Treat the complete eyelid system.

Figure 22.3 · Protecting the paralytic eye

Assess the whole eyelid system; escalate according to risk to the cornea



Vision before symmetry. Poor Bell's phenomenon or reduced corneal sensation raises the risk.

22.9 IF THE NERVE WAS JUST DIVIDED

When a recent facial nerve transection is recognised and both ends are available:

DIRECT REPAIR
is generally preferred where tension-free approximation is possible.

If not:

INTERPOSITION GRAFTING
may be considered.

The opportunity for native facial motor recovery is strongest when reconstruction occurs before prolonged denervation.

The intratemporal techniques are described in Chapter 21, Facial Nerve Surgery in the Temporal Bone.

22.10 DIRECT REPAIR

Principles include:

- healthy nerve ends
- minimal handling
- precise approximation
- no significant tension

PRINCIPLE

Never trade a nerve gap for a stretched nerve repair.

Tension-free reconstruction is more important than avoiding a graft at all costs.

22.11 INTERPOSITION GRAFT

A nerve graft bridges the gap between functioning proximal facial nerve and distal facial nerve.

Common donor nerves are the great auricular and sural nerves, chosen according to:

- required length
- calibre

- donor morbidity

The graft creates a route for regeneration.

It does not create immediate movement.

22.12 WHEN THE PROXIMAL FACIAL NERVE IS UNAVAILABLE

If the proximal facial nerve cannot provide useful motor input, another functioning motor nerve may be connected to the distal facial pathway.

This is the principle of:

NERVE TRANSFER

> **FUNCTIONING DONOR MOTOR NERVE**

↓

DISTAL FACIAL NERVE

↓

NATIVE FACIAL MUSCLES

This requires that the facial muscles remain capable of responding to reinnervation.

22.13 MASSETERIC NERVE TRANSFER

The motor nerve to the masseter provides a strong nearby donor source in selected patients.

Potential advantages include:

- strong motor input
- relatively close anatomy
- rapid reinnervation compared with longer graft pathways in some settings
- limited donor morbidity in appropriately selected patients

Initially, smile activation may require intentional jaw contraction.

With training, some patients develop more natural activation.

PRINCIPLE

The nerve provides power. Rehabilitation teaches the brain how to use it.

22.14 HYPOGLOSSAL–FACIAL TRANSFER

The hypoglossal nerve can provide motor input to the facial nerve.

Modern strategies, such as partial (split) hypoglossal transfer or an interposition "jump" graft, aim to reduce donor tongue morbidity compared with complete traditional transfer.

Potential considerations include:

- facial tone
- movement
- tongue weakness
- swallowing and speech consequences

The reconstructive design should balance:

FACIAL GAIN
against
DONOR FUNCTIONAL COST.

22.15 CROSS-FACE NERVE GRAFT

A cross-face nerve graft uses motor input from the functioning contralateral facial nerve.

Potential advantage:

> **FACIAL MOVEMENT DRIVEN BY THE NORMAL SMILE SYSTEM.**

Challenges include:

- long regeneration distance
- staged procedures
- limited axonal input
- time required

It may be used alone or as part of a dynamic muscle-transfer strategy.

22.16 DUAL INNERVATION CONCEPTS

Selected reconstructive strategies may combine donor pathways.

Conceptually:

STRONG MOTOR SOURCE

+

SPONTANEOUS FACIAL SOURCE

↓

POWER + POTENTIAL SPONTANEITY

These are specialised procedures requiring careful patient selection and microsurgical expertise.

Figure 22.4 · Donor motor sources compared

Each source trades power, spontaneity, time and donor cost differently (conceptual)

	Ipsilateral facial repair / graft	Masseteric nerve to masseter, CN V	Hypoglossal full, split or jump graft	Cross-face graft contralateral facial
Power	good	strong	good tone	limited axons
Spontaneous smile	best	learned (bite)	learned (tongue)	yes
Speed of reinnervation	depends on gap	relatively fast	moderate	slow, often staged
Donor cost	graft site only	low	tongue weakness	low

Combinations (e.g. masseteric + cross-face) aim for power and spontaneity together.

Nerve transfers need native facial muscle that can still be reinnervated.

22.17 WHEN THE NATIVE MUSCLE IS NO LONGER RELIABLE

After prolonged denervation, facial muscles may undergo irreversible atrophy and fibrosis.

At that stage, connecting another nerve to the old facial nerve may no longer create useful movement.

The reconstructive question changes from:

HOW DO I REINNERVATE THIS MUSCLE?

to:

WHAT NEW MOTOR UNIT CAN I BRING TO THE FACE?

22.18 DYNAMIC MUSCLE TRANSFER

Dynamic reconstruction introduces functioning muscle capable of generating movement.

Options may include:

- regional muscle transfer
- free functional muscle transfer

The chosen muscle requires:

BLOOD SUPPLY

MOTOR INNERVATION

CORRECT VECTOR

SECURE FIXATION

REHABILITATION

The operation reconstructs a motor system — not simply tissue volume.

22.19 TEMPORALIS-BASED TRANSFER

Temporalis-based strategies, such as lengthening temporalis myoplasty or orthodromic temporalis tendon transfer, can provide dynamic movement using a regional functioning muscle innervated by the trigeminal nerve.

Potential advantages include:

- regional tissue
- no requirement for free muscle transfer in selected techniques
- relatively immediate mechanical movement

The movement vector and oral commissure attachment are critical.

A strong muscle pulling in the wrong direction does not recreate a natural smile.

22.20 FREE FUNCTIONAL MUSCLE TRANSFER

Free muscle transfer may be considered for long-standing paralysis when native facial musculature is no longer functional.

The transferred muscle requires:

- vascular anastomosis
- motor nerve source
- appropriate length and tension
- correct vector

Potential donor muscles vary by reconstructive strategy; the gracilis is the most commonly used.

The muscle must become:

ALIVE

INNERVATED

MECHANICALLY ALIGNED

TRAINED.

22.21 THE SMILE IS A VECTOR

Smile reconstruction should not be planned merely as "pulling the corner of the mouth upward."

Normal smile movement varies between individuals.

Assess the normal side for:

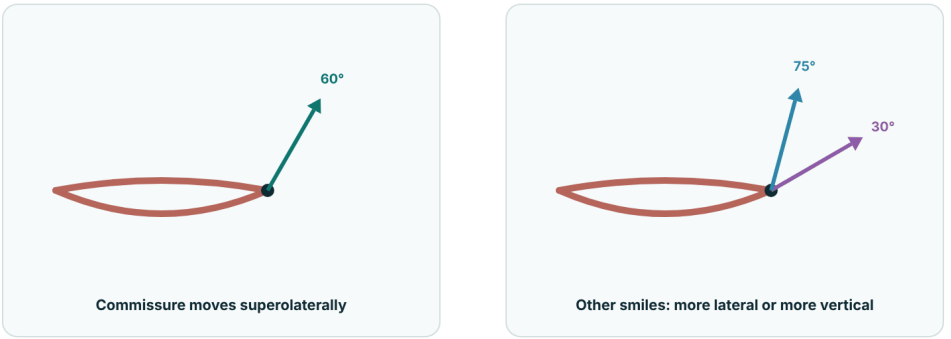
- direction
- excursion
- upper-lip movement
- dental show
- cheek movement

PRINCIPLE

Reconstruct the patient's smile — not a generic diagonal pull.

Figure 22.5 · The smile is a vector

Schematic, frontal view — match the reconstructed pull to the patient's own normal side



Measure on the normal side: direction · excursion · upper-lip lift · dental show · cheek movement.

Angles from the horizontal are illustrative only — smile vectors vary between individuals.

22.22 STATIC SUSPENSION

Static procedures improve resting position without creating active neural movement.

They may improve:

- oral commissure position
- symmetry
- oral competence
- lower-face support

Materials include autologous fascia lata or tendon, or other appropriate suspension materials.

Static suspension can be useful:

- when dynamic reconstruction is unsuitable
- as an adjunct to dynamic reconstruction
- in medically complex patients

> **STATIC DOES NOT MEAN USELESS.**

Resting function matters.

22.23 ORAL COMPETENCE

Facial paralysis can cause:

- drooling
- difficulty retaining food
- speech difficulty
- biting of cheek
- asymmetric smile

Reconstruction should therefore assess:

FUNCTION AT REST
and

FUNCTION DURING MOVEMENT.
A smile is only one component of lower-face rehabilitation.

22.24 BROW

Frontalis paralysis may cause brow ptosis and visual-field symptoms.

Selected patients may benefit from brow-position procedures.

Again, the objective may be:

> **FUNCTIONAL VISUAL IMPROVEMENT**

as much as cosmetic symmetry.

22.25 SYNKINESIS

Recovery after facial nerve injury may produce unwanted linked movements.

Examples include:

- eye closure during smiling
- oral movement during blinking
- facial tightness
- neck activation

Synkinesis means the nerve has recovered imperfectly — not that the nerve has failed completely.

Treatment should therefore be different from treatment of flaccid paralysis.

22.26 FACIAL NEUROMUSCULAR RETRAINING

Specialised therapy can help patients:

- improve movement control
- reduce excessive co-contraction
- improve symmetry
- retrain smile
- manage synkinesis

Therapy is not merely an adjunct after surgery.

In many patients it is a major part of treatment.

22.27 CHEMODENERVATION

Selected muscles contributing to synkinesis or asymmetry may be treated with chemodenervation, usually with botulinum toxin.

The objective is controlled reduction of unwanted activity.

This may improve:

- eye–mouth synkinesis
- facial tightness
- asymmetry

Treatment should be individualised and integrated with therapy.

22.28 MEASURE THE FACE

Document outcomes using:

- standardised photographs
- video
- facial grading systems

- patient-reported outcomes
- functional measures

Take views at:

REST

BROW ELEVATION

GENTLE EYE CLOSURE

FORCEFUL EYE CLOSURE

SMILE

LIP PUCKER

A single photograph at rest does not measure facial function.

22.29 PATIENT GOALS

Different patients may prioritise different outcomes.

One may want:

eye comfort.

Another:

less drooling.

Another:

resting symmetry.

Another:

spontaneous smile.

Another:

ability to appear symmetric during professional interaction.

PRINCIPLE

Facial reanimation should reconstruct the function that matters to the patient — not merely the function easiest to photograph.

22.30 COMBINATION RECONSTRUCTION

Many patients benefit from combinations such as:

NERVE TRANSFER

+

EYELID PROCEDURE

+

STATIC SUPPORT

+

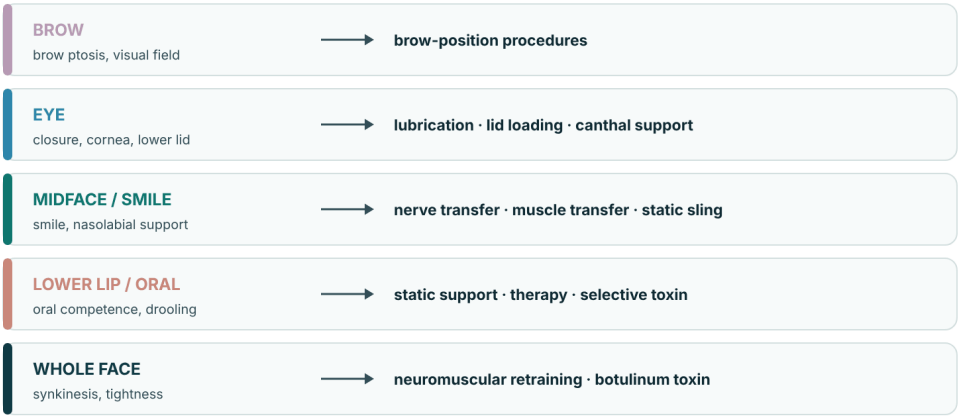
THERAPY

The face contains multiple functional regions.

One operation rarely solves every component.

Figure 22.6 · One face, several functional zones

Combine targeted treatments; one operation rarely solves every component



Plan by zone, prioritise by the patient's goals, and keep therapy running throughout.

DECISION FRAMEWORK

FACIAL PARALYSIS RECONSTRUCTION

FIRST — PROTECT THE EYE

↓

HOW LONG HAS PARALYSIS BEEN PRESENT?

↓

IS THE FACIAL NERVE CONTINUOUS?

Yes → assess recovery potential / cause.

No ↓

ARE PROXIMAL AND DISTAL ENDS AVAILABLE?

Yes → direct repair or graft where appropriate.

No ↓

ARE NATIVE FACIAL MUSCLES STILL VIABLE?

Yes → nerve transfer strategies may be considered.

No / longstanding denervation ↓

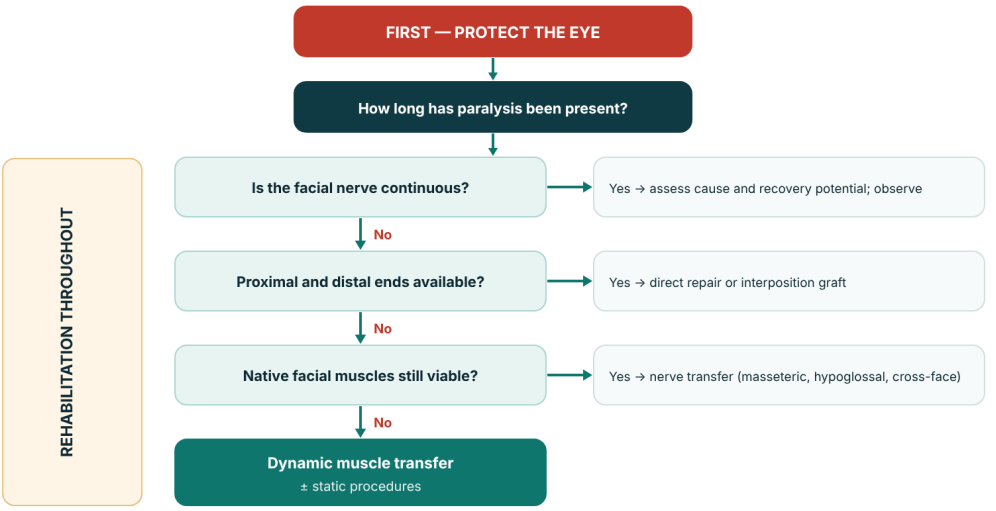
DYNAMIC MUSCLE TRANSFER ± STATIC PROCEDURES

↓

REHABILITATION THROUGHOUT

Figure 22.7 · Facial reanimation decision pathway

Protect the eye first; rehabilitation runs throughout



Static support and eyelid procedures can be added at any stage.

FROM EXPERIENCE

Facial nerve surgery initially makes us focus on the nerve.

But the patient does not see the nerve.

The patient experiences:

the eye that will not close,

the mouth that leaks,

the smile that has disappeared,

the face that no longer moves with emotion.

So a technically perfect nerve graft that does not ultimately restore useful function cannot be the only measure of success.

Facial reanimation asks us to move beyond anatomy.

FROM NERVE TO MOVEMENT.

FROM MOVEMENT TO FUNCTION.

> **From function back to the person.**

TAKE IT TO THE CLINIC & OT

Before facial reanimation, define:

CAUSE

DURATION

PREOPERATIVE FUNCTION

EYE PROTECTION

NERVE CONTINUITY

PROXIMAL FACIAL NERVE

DISTAL FACIAL NERVE

NATIVE MUSCLE VIABILITY

DONOR MOTOR NERVE

SMILE VECTOR

ORAL COMPETENCE

STATIC SUPPORT NEED

PATIENT PRIORITY

REHABILITATION PLAN

CHAPTER SUMMARY

Facial reanimation begins by defining what remains functional.

Timing determines options.

Protect the cornea first.

Repair a recently divided nerve directly when tension-free repair is possible.

Use grafting when a gap prevents direct repair.

Consider nerve transfers while native facial muscles remain viable.

For longstanding denervation, dynamic muscle transfer may be required.

Use static procedures to restore resting function where appropriate.

Treat synkinesis differently from flaccid paralysis.

Integrate neuromuscular retraining throughout recovery.

And remember:

THE NERVE IS THE PATHWAY.

> **Movement is the operation's output.**

> **Function is the patient's outcome.**

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CHAPTER 23

Lateral Skull Base Surgical Anatomy

Labyrinth • IAC • Jugular Foramen • Petrous Carotid • Dura

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the lateral skull base as a three-dimensional region rather than a collection of named foramina
- identify the major relationships of the labyrinth, internal auditory canal and petrous apex
- understand the sigmoid sinus–jugular bulb–jugular foramen continuum
- recognise the surgical relationships of the lower cranial nerves
- trace the petrous internal carotid artery through the temporal bone
- understand the relationships of middle and posterior fossa dura
- correlate skull-base anatomy with CT, MRI and operative corridors
- select surgical landmarks according to the approach being used
- understand how preservation of hearing, facial nerve function, lower cranial nerves and vascular flow determines approach selection

23.1 THE LATERAL SKULL BASE IS A CROSSROAD

The lateral skull base lies at the meeting point of:

TEMPORAL BONE

INNER EAR

POSTERIOR FOSSA

MIDDLE CRANIAL FOSSA

INTERNAL CAROTID ARTERY

SIGMOID–JUGULAR VENOUS SYSTEM

CRANIAL NERVES

DEEP NECK

This explains why a lesion only a few centimetres in size may affect:

- hearing
- balance
- facial movement
- swallowing
- voice
- shoulder function
- tongue function
- cerebral circulation

The anatomy is compact.

The consequences are not.

23.2 DO NOT LEARN THE SKULL BASE AS HOLES IN BONE

Named structures such as:

- internal auditory canal
- jugular foramen
- carotid canal
- stylomastoid foramen

are useful.

But surgery requires understanding what connects them.

The better question is:

> **What travels from one compartment to another, and what lies between those pathways?**

23.3 THE SURGICAL MAP

A useful conceptual map is:

LABYRINTH
central otic capsule landmark

↓

INTERNAL AUDITORY CANAL
medial neural corridor

↓

PETROUS CAROTID
anteromedial vascular boundary

↓

JUGULAR BULB / FORAMEN
inferomedial neurovascular region

↓

SIGMOID SINUS
posterior venous boundary

↓

MIDDLE & POSTERIOR FOSSA DURA

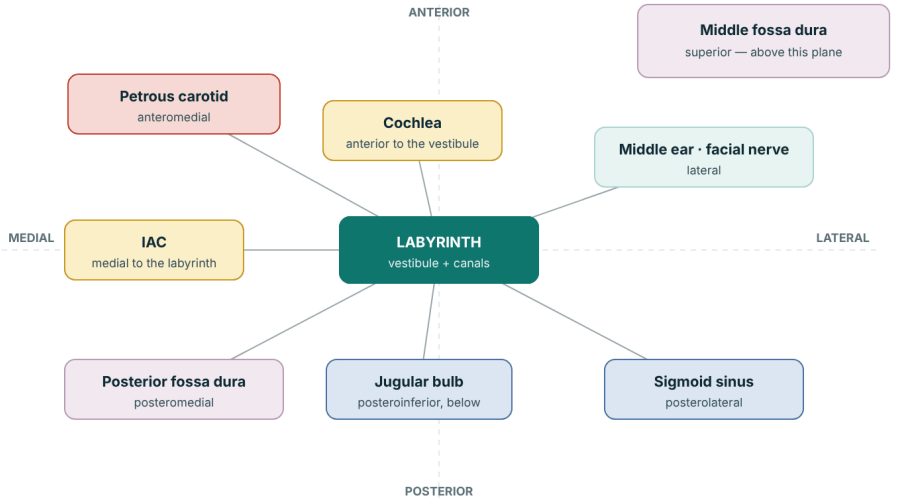
superior and medial cranial boundaries

These structures define many of the major lateral skull-base corridors.

The bony anatomy behind this map is described in Chapter 6, Surgical Anatomy of the Temporal Bone.

Figure 23.1 · The lateral skull base organised around the labyrinth

Conceptual relationship map, right side, axial frame (seen from above): anterior at the top, lateral to the right — not to scale



Preserve the labyrinth → work around it. Sacrifice it → work through it.

Each named corridor is a route between these structures.

23.4 THE LABYRINTH AS A CENTRAL LANDMARK

The otic capsule contains:

- cochlea
- vestibule
- semicircular canals

For skull-base surgery, the labyrinth is not only a functional organ.

It is a major geometric reference.

Its preservation or sacrifice determines which corridors become available.

HEARING-PRESERVATION APPROACH

works around the labyrinth.

HEARING-SACRIFICING APPROACH

may pass through it.

Therefore approach selection frequently begins with:

> **Is useful hearing present and worth preserving?**

23.5 SEMICIRCULAR CANALS

The three canals are:

LATERAL

Useful mastoid landmark.

SUPERIOR

Important in superior petrous and middle-fossa relationships.

POSTERIOR

Important in posterior petrous and retrosigmoid relationships.

Together, the canals define a three-dimensional bony framework around the vestibule.

When progressively skeletonised, their relationships help orient deeper skull-base drilling.

23.6 THE COCHLEA

The cochlea lies anterior to the vestibular labyrinth and has intimate relationships with:

- petrous carotid artery
- internal auditory canal
- geniculate / facial nerve region
- middle ear

The cochlea can become the limiting structure in hearing-preservation approaches.

PRINCIPLE

The approach is only hearing-preserving while the cochlea and neural hearing pathway remain protected.

23.7 INTERNAL AUDITORY CANAL

The IAC transmits:

- facial nerve
- cochlear nerve
- superior vestibular nerve
- inferior vestibular nerve
- vascular structures

The nerve arrangement changes from medial to lateral.

At the fundus, bony partitions help separate neural compartments: the transverse (falciform) crest divides the canal into upper and lower halves, and the vertical crest (Bill's bar) separates the facial nerve anteriorly from the superior vestibular nerve posteriorly in the upper half.

Understanding this becomes important during:

- vestibular schwannoma surgery
- facial nerve surgery
- translabyrinthine approaches
- middle cranial fossa approaches

23.8 THE FUNDUS OF THE IAC

At the lateral IAC, the nerves approach the labyrinth and facial canal.

Important concepts include:

FACIAL NERVE

anterosuperior relationship at the fundal region.

COCHLEAR NERVE

anteroinferior relationship.

VESTIBULAR NERVES

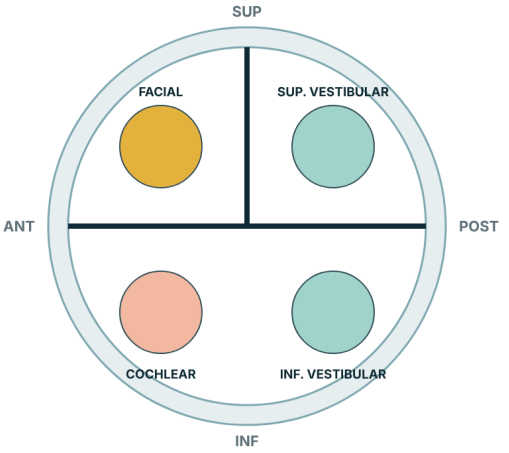
posterosuperior (superior vestibular) and posteroinferior (inferior vestibular) relationships.

The exact operative appearance changes with approach and tumour distortion.

> **PRINCIPLE**
>
> **Know the normal nerve geometry so you can recognise how the tumour has changed it.**

Figure 23.2 · The fundus of the internal auditory canal

Right IAC, viewed from medial (as from the cerebellopontine angle): superior at the top, anterior to the left



PARTITIONS

Transverse (falciform) crest
upper vs lower half

Vertical crest (Bill's bar)
facial (anterior) vs superior vestibular nerve (posterior)

"Seven-up, Coke down":
facial above, cochlear below, both anterior.

Tumour often rotates and displaces these.

23.9 FACIAL NERVE AT THE SKULL BASE

The facial nerve travels:

IAC

↓

LABYRINTHINE SEGMENT

↓

GENICULATE GANGLION

↓

TYMPANIC SEGMENT

↓

MASTOID SEGMENT

↓

STYLOMASTOID FORAMEN

Thus lateral skull-base surgery may encounter the same nerve repeatedly through different anatomical compartments.

A lesion can displace one segment while leaving another normal.

The surgeon should mentally trace the whole nerve.

23.10 SIGMOID SINUS

The sigmoid sinus is a major posterior skull-base boundary.

It descends toward the jugular bulb.

Surgically, its position influences:

- mastoid working space
- retrosigmoid access
- jugular foramen exposure
- presigmoid corridors

The sigmoid sinus is therefore both:

A VASCULAR STRUCTURE
and

A GEOMETRIC BOUNDARY.

23.11 THE JUGULAR BULB

The jugular bulb represents the superior dilated portion of the internal jugular venous system within the temporal bone.

Its position varies.

It may be:

- low
- high
- dehiscent
- dominant

It relates closely to:

- hypotympanum
- posterior fossa
- lower cranial nerves
- jugular foramen
- petrous carotid

A high jugular bulb can change the geometry of several skull-base corridors.

23.12 THE JUGULAR FORAMEN IS NOT ONE SIMPLE CANAL

The jugular foramen transmits a complex neurovascular bundle.

Important contents include:

- glossopharyngeal nerve
- vagus nerve
- accessory nerve
- venous structures
- arterial branches

Microsurgical studies describe a larger posterolateral venous (sigmoid) part receiving the sigmoid sinus, a smaller anteromedial venous (petrosal) part receiving the inferior petrosal sinus, and an intervening neural (intrajugular) part through which the glossopharyngeal nerve passes anteriorly and the vagus and accessory nerves posteriorly.

Anatomical partitions and relationships are variable.

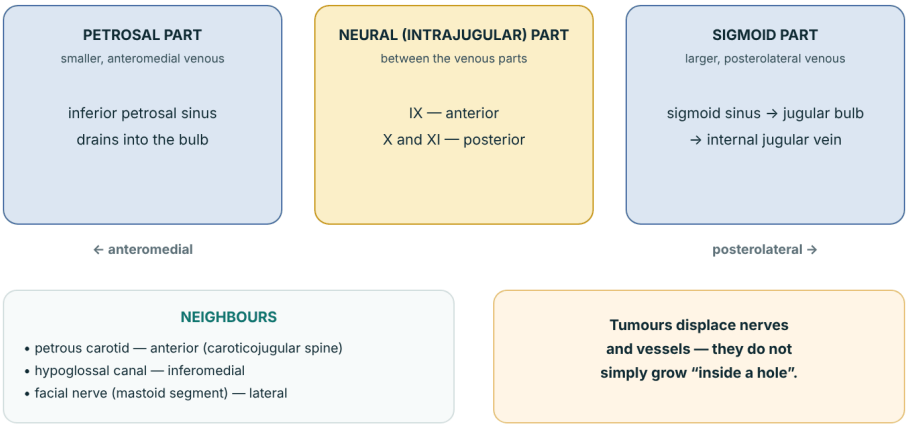
Tumours in this region can displace nerves and vessels rather than simply grow "inside a hole."

PRINCIPLE

The jugular foramen should be understood as a region — not merely an opening.

Figure 23.3 · The jugular foramen as a region

Conceptual compartments (after Rhoton and colleagues) — partitions and nerve positions vary



NEIGHBOURS

- petrous carotid — anterior (caroticojugular spine)
- hypoglossal canal — inferomedial
- facial nerve (mastoid segment) — lateral

Tumours displace nerves and vessels — they do not simply grow "inside a hole".

Document voice, swallowing, shoulder and tongue function before operating here.

23.13 LOWER CRANIAL NERVES

The major lower cranial nerves in this region include:

CN IX — GLOSSOPHARYNGEAL

Swallowing, sensation, taste-related functions.

CN X — VAGUS

Voice, swallowing, airway and autonomic functions.

CN XI — ACCESSORY

Shoulder function through sternocleidomastoid and trapezius pathways.

Their injury can create significant postoperative morbidity.

Therefore preoperative function should be documented.

23.14 FUNCTION BEFORE SKULL-BASE SURGERY

Document:

VOICE

Vocal fold mobility.

SWALLOWING

Aspiration risk and lower cranial nerve function.

SHOULDER

Accessory nerve function.

TONGUE

Hypoglossal function.

FACIAL MOVEMENT

HEARING

BALANCE

The operation may affect several systems simultaneously.

A baseline is essential.

23.15 HYPOGLOSSAL NERVE

The hypoglossal nerve exits through the hypoglossal canal, which lies inferomedial to the jugular foramen, above the occipital condyle.

Its relationship becomes important during:

- jugular foramen surgery
- upper neck dissection
- occipital condylar / far-lateral approaches

Injury can affect:

- tongue movement
- articulation
- swallowing

The lower cranial nerve examination should therefore include the tongue.

23.16 PETROUS INTERNAL CAROTID ARTERY

The internal carotid artery enters the skull base and travels through the petrous temporal bone.

Conceptually, its petrous course includes:

VERTICAL SEGMENT

↓

GENU (POSTERIOR BEND)

↓

HORIZONTAL PETROUS SEGMENT

before continuing over the foramen lacerum toward the cavernous sinus.

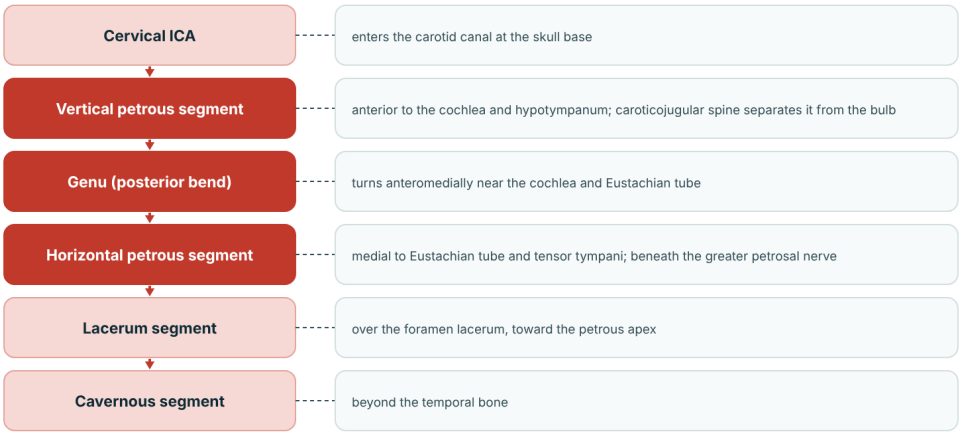
Its relationships include:

- cochlea
- Eustachian tube
- petrous apex
- middle ear
- jugular foramen region

The vertical segment lies anterior to the cochlea and is separated from the jugular bulb by the caroticojugular spine; the horizontal segment runs medial to the Eustachian tube and tensor tympani, beneath the greater petrosal nerve.

Figure 23.4 · The petrous internal carotid artery

Segments in the direction of blood flow and their key temporal-bone relationships (schematic)



Its surgical position — medial, anterior or deep — depends on the corridor, not only the textbook.

23.17 THE CAROTID IS A MOVING BOUNDARY THROUGH THE SKULL BASE

As the surgeon changes corridor, the carotid changes relative position.

In one approach it may be:

MEDIAL.

In another:

ANTERIOR.

In another:

DEEP.

Therefore memorising "the carotid lies medial" is insufficient.

> **PRINCIPLE**
>
> **A structure's surgical position is defined relative to the corridor, not only relative to the textbook.**

23.18 CAROTID CANAL ON CT

Review:

- bony covering
- vertical segment
- horizontal segment
- dehiscence
- asymmetry
- tumour relationship

For major skull-base lesions, vascular imaging may be required to assess:

- encasement
- narrowing
- displacement
- collateral circulation

Do not infer vascular resectability from routine CT alone.

23.19 MIDDLE CRANIAL FOSSA DURA

The middle cranial fossa lies superior to portions of:

- tegmen
- petrous apex
- IAC region
- geniculate region

Middle-fossa approaches use superior temporal-bone landmarks, such as the arcuate eminence, the greater petrosal nerve and the middle meningeal artery at the foramen spinosum, to reach:

- IAC
- facial nerve
- superior petrous structures

Temporal-lobe retraction and dural relationships become central considerations.

23.20 POSTERIOR FOSSA DURA

Posterior fossa dura relates to:

- sigmoid sinus
- posterior petrous surface
- IAC
- cerebellopontine angle
- jugular foramen

Approaches such as retrosigmoid and translabyrinthine surgery use different routes to the same deep neural region.

The anatomy is the same.

The view is different.

23.21 CEREBELLOPONTINE ANGLE

The CPA contains or relates to:

- facial nerve

- vestibulocochlear nerve complex
- lower cranial nerves
- cerebellum
- brainstem
- major vascular structures

Tumours can substantially distort normal nerve relationships.

PRINCIPLE

In skull-base tumour surgery, anatomy is often displaced rather than absent.

The task is to understand where it moved.

23.22 PETROUS APEX

The petrous apex lies medial to the otic capsule and anterior to parts of the posterior-fossa anatomy.

Its relationships include:

- internal carotid artery
- cochlea
- IAC
- dura
- Eustachian tube
- cranial nerves

No single approach gives universal access to the petrous apex.

The route is determined by what must be preserved.

23.23 WHAT CAN BE SACRIFICED DEFINES THE CORRIDOR

Approach planning often asks:

HEARING?

Must it be preserved?

LABYRINTH?

Can it be crossed?

FACIAL NERVE?

Must it remain in place or can it be mobilised?

SIGMOID SINUS?

Can it be mobilised or sacrificed in selected exceptional situations?

CAROTID?

Must remain protected or reconstructed?

LOWER CRANIAL NERVES?

What functional cost is acceptable?

This creates a fundamental skull-base principle:

> **The surgical corridor is built from the structures we must preserve and the structures we can safely traverse.**

Figure 23.5 · What each corridor preserves and what it crosses

Simplified comparison of classic lateral skull-base corridors

	Hearing	Labyrinth	Facial nerve	Sigmoid sinus	Petrous carotid
Retrosigmoid	can be kept	preserved	in place	preserved	not exposed
Translabyrinthine	sacrificed	removed	in place	skeletonised	not exposed
Middle cranial fossa	can be kept	preserved	in place	—	not routinely
Transcochlear	sacrificed	labyrinth + cochlea	rerouted posteriorly	skeletonised	exposed
Infratemporal fossa A	conductive loss	preserved	rerouted anteriorly	closed / packed	vertical ICA exposed

kept / not disturbed crossed, moved or sacrificed

The corridor is built from what must be preserved and what can safely be traversed.

23.24 MAJOR LATERAL SKULL-BASE CORRIDORS

Conceptually, major corridors include:

RETROSIGMOID

Posterior to the sigmoid sinus.

TRANSLABYRINTHINE

Through the labyrinth.

MIDDLE CRANIAL FOSSA

Superior route.

TRANSCOCHLEAR / EXTENDED PETROUS ROUTES

More extensive anterior-medial exposure with greater functional sacrifice.

JUGULAR FORAMEN / INFRATEMPORAL CORRIDORS

Inferior and anteroinferior access.

The detailed techniques follow in Chapter 25, Retrosigmoid Approach; Chapter 26, Translabyrinthine Approach; Chapter 27, Middle Cranial Fossa Approach; Chapter 28, Jugular Foramen & Paraganglioma Surgery; and Chapter 29, Petrous Apex & Petrosectomy Approaches.

23.25 THE SAME TARGET CAN BE REACHED FROM DIFFERENT DIRECTIONS

For example, the IAC/CPA region may be approached through:

- retrosigmoid route
- translabyrinthine route
- middle cranial fossa route

The target is similar.

The sacrificed or preserved structures differ.

Therefore approach selection depends upon:

HEARING

TUMOUR SIZE

LOCATION

EXTENSION

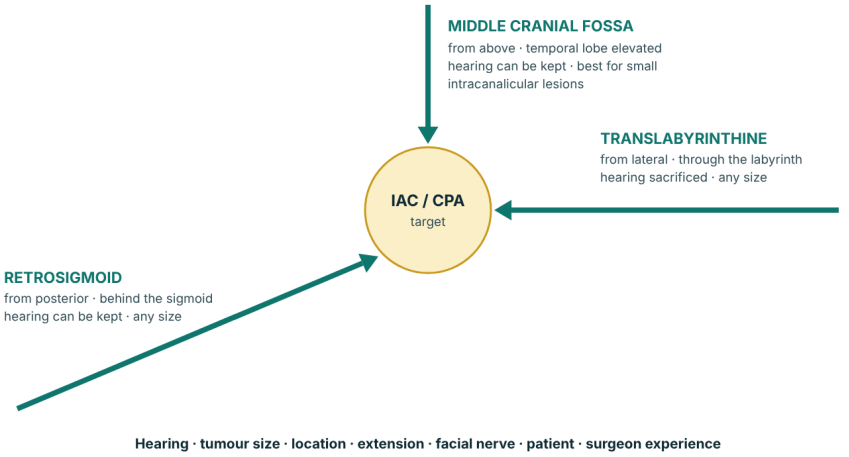
FACIAL NERVE

PATIENT FACTORS

SURGEON EXPERIENCE.

Figure 23.6 · One target, three directions

The IAC / cerebellopontine angle — the target is similar; what is crossed and preserved differs (conceptual)



23.26 VENOUS ANATOMY MATTERS

Important venous structures include:

- sigmoid sinus
- jugular bulb
- superior petrosal sinus
- inferior petrosal sinus
- emissary veins

Dominance and collateral drainage vary.

A venous structure should not be considered expendable simply because another sinus exists.

Preoperative vascular assessment may be required when sacrifice is contemplated.

23.27 SUPERIOR PETROSAL SINUS

The superior petrosal sinus runs along the superior petrous ridge, connecting the cavernous sinus with the transverse–sigmoid junction.

It becomes relevant in selected:

- middle fossa
- presigmoid
- petrosectomy approaches

Its management depends upon the surgical corridor and individual venous anatomy.

23.28 INFERIOR PETROSAL SINUS

The inferior petrosal sinus travels along the petroclival fissure from the cavernous sinus and drains into the jugular bulb through the anteromedial part of the jugular foramen, often by several channels.

It becomes relevant during:

- jugular foramen surgery
- petrous apex work
- petroclival approaches

Venous bleeding here can be significant despite the relatively small apparent vessel size.

23.29 THE STYLOID COMPLEX

The styloid region helps orient extracranial skull-base anatomy.

Relationships include:

- facial nerve
- parapharyngeal space

- internal carotid artery
- internal jugular vein
- lower cranial nerves

This becomes particularly important during infratemporal and jugular foramen approaches.

23.30 PARAPHARYNGEAL CONTINUITY

The skull base is not isolated from the neck.

Neurovascular structures descend from the skull base into:

- carotid space
- parapharyngeal region
- upper neck

Tumours can therefore extend:

INTRATEMPORAL

↓

SKULL BASE

↓

UPPER NECK.

Surgical planning must sometimes connect otologic and cervical approaches (Book 4 of this series, *Dura to Pleura*).

23.31 IMAGE THE SKULL BASE IN MULTIPLE PLANES

For skull-base lesions, review:

CT

Bone, foramina, erosion, carotid canal, labyrinth.

MRI

Nerves, tumour, dura, brainstem, vascular displacement.

VASCULAR IMAGING

When vessel involvement is significant.

Then reconstruct mentally:

AXIAL

+

CORONAL

+

SAGITTAL

+

3D RELATIONSHIP.

One plane rarely explains a skull-base lesion fully.

Imaging technique and interpretation are covered in Chapter 7, Temporal Bone Imaging for the Surgeon.

23.32 TUMOUR DISPLACEMENT PATTERNS

Different lesions may push:

- facial nerve
- cochlear nerve
- carotid
- jugular bulb
- lower cranial nerves
- dura

in predictable or semi-predictable directions.

Understanding the tumour's site of origin helps predict where critical structures may have moved.

PRINCIPLE

Find the origin of the lesion, then ask what it has displaced.

23.33 THE SKULL BASE HAS NO UNUSED SPACE

A growing lesion rarely expands without consequence.

It may:

- compress a nerve
- remodel bone
- displace vessel
- invade dura
- enter another compartment

Therefore even apparently benign lesions can create major functional effects through location alone.

23.34 LANDMARK NETWORKS AT THE LATERAL SKULL BASE

IAC NETWORK

Labyrinth
+ Petrous ridge
+ Posterior fossa dura
+ Facial nerve trajectory

JUGULAR FORAMEN NETWORK

Sigmoid sinus
+ Jugular bulb
+ Carotid artery
+ Lower cranial nerves

PETROUS APEX NETWORK

Cochlea
+ IAC
+ Carotid
+ Dura
+ Eustachian tube

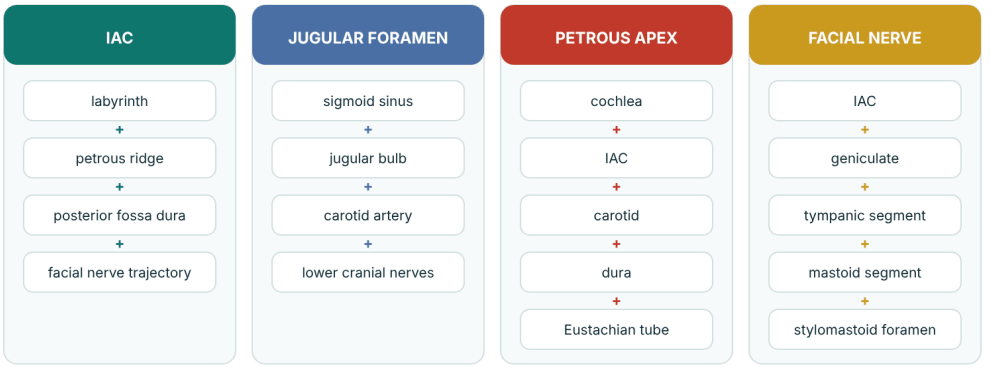
FACIAL NERVE NETWORK

IAC
+ Geniculate
+ Tympanic segment
+ Mastoid segment
+ Stylomastoid foramen

The deeper the surgery, the more valuable these networks become.

Figure 23.7 · Landmark networks at the lateral skull base

The deeper the surgery, the more each target should be predicted by several agreeing landmarks



If one landmark is missing or distorted, the others still agree on where the target must be.

23.35 APPROACH SELECTION IS AN ANATOMICAL EQUATION

Think:

TARGET

Where is the pathology?

+

FUNCTION TO PRESERVE

Hearing? Facial movement? Lower cranial nerves?

+

STRUCTURES THAT CAN BE TRAVERSED

Labyrinth? Mastoid? Temporal lobe corridor?

+

VASCULAR CONSTRAINTS

Carotid? Sinus? Jugular bulb?

+

RECONSTRUCTION

What defect will remain?

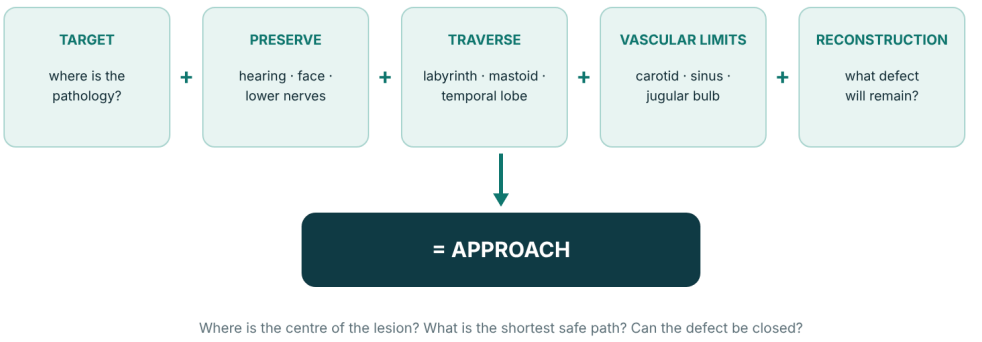
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APPROACH

The approach name should emerge from this equation.

Figure 23.8 · Approach selection as an anatomical equation

The approach name should emerge from the answers, not precede them



Where is the centre of the lesion? What is the shortest safe path? Can the defect be closed?

DECISION POINT

WHICH CORRIDOR SHOULD I USE?

Ask:

Where is the centre of the lesion?

Which direction provides the shortest safe working path?

Is useful hearing present?

Where is the facial nerve?

Which major vessel limits the corridor?

Which cranial nerves are already dysfunctional?

Will the approach provide vascular control?

Can the resulting defect be reconstructed?

Choose the corridor according to these answers.

FROM EXPERIENCE

The lateral skull base initially appears crowded.

Too many nerves.

Too many vessels.

Too many foramina.

But with repeated exposure, the anatomy begins to organise itself around a few central relationships.

The labyrinth tells us where hearing lies.

The IAC tells us where the facial and vestibulocochlear nerves travel.

The sigmoid becomes a posterior boundary.

The jugular bulb becomes the inferior venous centre.

The carotid becomes the anterior-medial vascular boundary.

The dura defines the cranial limits.

Once these relationships are understood, the named approaches become easier to understand.

Because an approach is simply:

> **a route between structures we must preserve to reach the structure we need to treat.**

TAKE IT TO THE OT

Before lateral skull-base surgery, define:

TARGET

HEARING STATUS

FACIAL NERVE FUNCTION

LOWER CRANIAL NERVE FUNCTION

LABYRINTH

IAC

SIGMOID SINUS

JUGULAR BULB

CAROTID

DURA

PETROUS APEX

NECK EXTENSION OF DISEASE

APPROACH OPTIONS

VASCULAR CONTROL

RECONSTRUCTION

CHAPTER SUMMARY

The lateral skull base is a three-dimensional neurovascular crossroad.

Do not learn it as isolated foramina.

Use the labyrinth, IAC, petrous carotid, jugular bulb, sigmoid sinus and dura as major orienting systems.

Trace the facial nerve through the whole temporal bone.

Understand the lower cranial nerves functionally before risking them.

Recognise the jugular foramen as a region rather than a single opening.

Use CT, MRI and vascular imaging together.

Predict how disease has displaced normal anatomy.

And choose the approach according to:

> **the target, the function that must be preserved, and the structures that can safely be crossed.**

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CHAPTER 24

Vestibular Schwannoma: Surgical Strategy

Tumour Control • Facial Nerve Preservation • Hearing Preservation

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the typical anatomical origin and growth pattern of vestibular schwannoma
- assess tumour size, IAC involvement and CPA extension
- integrate hearing status and facial nerve function into treatment planning
- understand the broad roles of observation, radiosurgery and microsurgery
- compare retrosigmoid, translabyrinthine and middle cranial fossa approaches conceptually
- anticipate facial nerve displacement
- understand the role of intraoperative neural monitoring
- balance extent of resection against neurological function
- recognise major postoperative complications and rehabilitation needs

24.1 THE TUMOUR IS BENIGN; THE LOCATION IS NOT

Vestibular schwannoma is typically a benign nerve-sheath tumour arising from the vestibular portion of the eighth cranial nerve.

Its biological behaviour may be relatively indolent.

But it grows within a region containing:

- facial nerve

- cochlear nerve
- brainstem
- cerebellum
- lower cranial nerves
- important vessels

Therefore morbidity is determined as much by **location and size** as by histology.

> **PRINCIPLE**
> **Benign pathology can still demand major skull-base surgery.**

24.2 THE TUMOUR JOURNEY

A typical tumour may begin within the internal auditory canal and enlarge toward the cerebellopontine angle.

Conceptually:

VESTIBULAR NERVE

↓

INTERNAL AUDITORY CANAL

↓

PORUS

↓

CEREBELLOPONTINE ANGLE

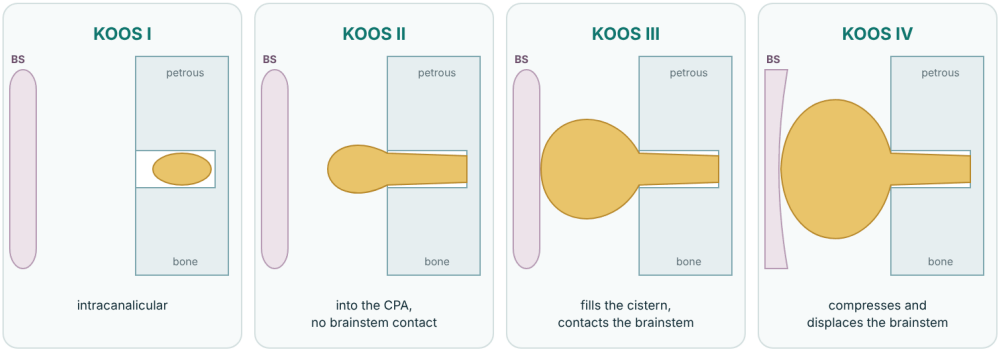
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BRAINSTEM / CEREBELLAR COMPRESSION IN LARGE LESIONS

The extent along this pathway helps determine both symptoms and surgical strategy.

Figure 24.1 · The tumour journey and Koos grade

Axial schematic, right side — the tumour grows from the IAC into the cerebellopontine angle (not to scale)



Vestibular nerve → IAC → porus → CPA → brainstem and cerebellar compression in large lesions

BS = brainstem (medial). The lateral IAC (fundus) lies to the right in each panel.

Extent along this path shapes symptoms, hearing prospects and the choice of corridor.

24.3 CLINICAL PRESENTATION

Patients may present with:

- unilateral sensorineural hearing loss
- asymmetric hearing
- tinnitus
- imbalance
- vertigo
- facial numbness (trigeminal involvement in larger tumours)
- headache
- gait disturbance
- cranial nerve dysfunction in larger lesions

Facial weakness is often relatively uncommon early despite close facial nerve relationship.

Its presence may indicate:

- large tumour
- altered nerve function
- previous treatment
- another pathology

24.4 HEARING ASSESSMENT

Before treatment planning, define:

PURE-TONE HEARING

SPEECH DISCRIMINATION / WORD RECOGNITION

FUNCTIONAL USEFULNESS

Do not describe hearing merely as:

present

or

absent.

The question is:

Is the hearing serviceable enough that preservation meaningfully affects approach selection?

Serviceable hearing is commonly defined by the "50/50 rule": pure-tone average 50 dB or better and word recognition 50% or better (AAO-HNS class A–B; Gardner–Robertson class I–II).

Figure 24.2 · Grading hearing before approach selection

Gardner–Robertson classes (pure-tone average and speech discrimination)

Class	Hearing	Pure-tone average	Speech discrimination
I	Good–excellent	0–30 dB	70–100%
II	Serviceable	31–50 dB	50–69%
III	Non-serviceable	51–90 dB	5–49%
IV	Poor	91 dB–max	1–4%
V	None	not testable	0%

"50/50 rule": PTA ≤ 50 dB and speech discrimination ≥ 50% = serviceable

(Gardner–Robertson I–II; AAO-HNS class A–B). Also ask whether the other ear is normal.

24.5 FACIAL NERVE FUNCTION

Document preoperative facial function.

This provides:

- baseline
- counselling information
- postoperative comparison

Even when facial function is normal, the nerve may be:

- stretched
- thinned
- displaced

by the tumour.

> **PRINCIPLE**
> **Normal function does not mean normal anatomy.**

24.6 MRI

MRI is central to diagnosis and surgical planning.

Assess:

TUMOUR SIZE

IAC COMPONENT

FUNDAL EXTENSION

CPA COMPONENT

BRAINSTEM CONTACT / COMPRESSION

CYSTIC CHANGE

RELATIONSHIP TO OTHER STRUCTURES

Contrast-enhanced T1-weighted and high-resolution T2-weighted sequences are complementary; the Koos grade (I intracanalicular; II into the CPA without brainstem

contact; III filling the cistern and contacting the brainstem without displacing it; IV compressing and displacing it) summarises CPA extension.

The scan should be read as a map of both:

TUMOUR
and

SURGICAL WORKING SPACE.

24.7 CT

Temporal-bone CT may provide additional information about:

- IAC anatomy
- petrous bone
- labyrinth
- high jugular bulb
- mastoid anatomy
- previous surgery

It becomes particularly relevant for temporal-bone approaches.

24.8 SIZE MATTERS — BUT SIZE IS NOT EVERYTHING

Tumour size influences:

- brainstem compression
- operative working space
- hearing-preservation probability
- facial nerve dissection difficulty
- extent of CPA involvement

But strategy also depends upon:

- age
- growth
- symptoms
- hearing
- comorbidity

- patient preference
- prior treatment

A small tumour may still require active treatment in one patient and observation in another.

24.9 TREATMENT OPTIONS

Broad management options include:

OBSERVATION

Selected tumours can be followed with serial imaging and clinical assessment.

STEREOTACTIC RADIOSURGERY / RADIATION

Provides tumour-control options in selected patients.

MICROSURGERY

Provides direct removal or decompression.

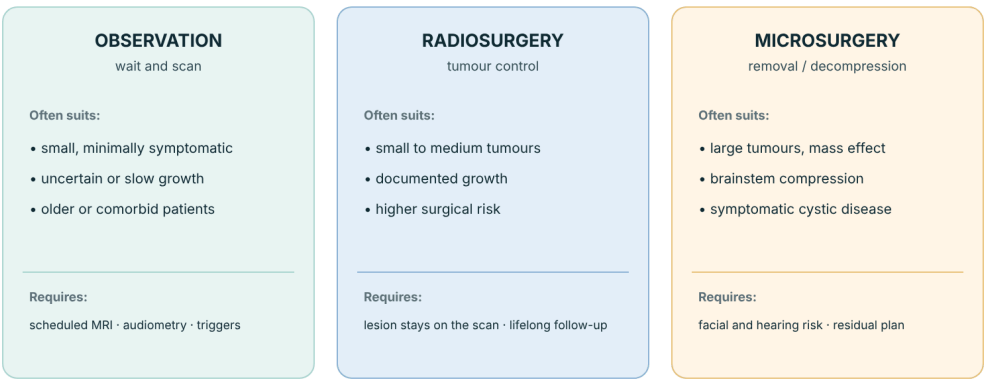
The decision should be individualised.

PRINCIPLE

Finding a tumour does not automatically create an indication to remove it.

Figure 24.3 · Observation, radiosurgery or microsurgery

Three active strategies — chosen by size, growth, hearing, age, comorbidity and preference



Finding a tumour does not automatically create an indication to remove it.

Indications overlap; this is a guide to discussion, not a rule.

24.10 OBSERVATION

Observation may be appropriate in selected:

- small
- minimally symptomatic
- slow-growing or uncertain-growth

tumours, especially when age or comorbidity influences treatment risk.

Observation is active management.

It requires:

- scheduled MRI
- hearing assessment
- symptom review
- predefined triggers for treatment

24.11 RADIOSURGERY

Stereotactic radiosurgery may provide high rates of tumour control in appropriately selected lesions.

Considerations include:

- tumour size
- age
- growth
- hearing
- cranial nerve function
- long-term surveillance

The goal is generally tumour control rather than immediate removal.

Patients should understand that the lesion remains radiologically present.

24.12 MICROSURGERY

Microsurgery may be considered when:

- tumour size or mass effect favours removal

- brainstem compression exists
- cystic or symptomatic disease requires decompression
- patient factors favour surgery
- other treatment strategies are less suitable

Surgical objectives can include:

TUMOUR CONTROL

BRAINSTEM DECOMPRESSION

FACIAL NERVE PRESERVATION

> **HEARING PRESERVATION WHERE REALISTIC**

These objectives may compete with each other.

24.13 THREE MAJOR SURGICAL CORRIDORS

The classic approaches are:

RETROSIGMOID
Posterior fossa route behind the sigmoid sinus.

TRANSLABYRINTHINE
Temporal-bone route through the labyrinth.

MIDDLE CRANIAL FOSSA
Superior route to the IAC.

Each approach reaches similar deep anatomy by sacrificing or preserving different structures.

24.14 APPROACH SELECTION BEGINS WITH HEARING

A useful first question is:

> **IS USEFUL HEARING PRESENT AND WORTH ATTEMPTING TO PRESERVE?**

If no useful hearing remains:

TRANSLABYRINTHINE
may become attractive because the labyrinth can be sacrificed to obtain direct IAC access.

If hearing preservation is a realistic objective:

RETROSIGMOID
or

MIDDLE CRANIAL FOSSA
may be considered depending upon tumour anatomy and surgeon strategy.

This is only the beginning of approach selection — not the entire decision.

24.15 RETROSIGMOID APPROACH

Potential advantages include:

- broad CPA access
- ability to treat tumours with significant posterior-fossa component
- potential hearing preservation

Limitations may include:

- cerebellar manipulation
- limited direct visualisation of the most lateral IAC fundus in some situations
- postoperative headache considerations
- need for IAC drilling from the posterior route

The approach is particularly useful when the CPA component is important.

The technique is described in Chapter 25, Retrosigmoid Approach.

24.16 TRANSLABYRINTHINE APPROACH

This approach passes through the labyrinth.

Therefore:

> **HEARING ON THAT SIDE IS SACRIFICED.**

Potential advantages include:

- direct access to the IAC

- early facial nerve identification in selected anatomy
- little or no cerebellar retraction
- broad temporal-bone route

It is particularly relevant when useful hearing is already absent.

The technique is described in Chapter 26, Translabyrinthine Approach.

PRINCIPLE

Do not preserve a nonfunctional labyrinth at the cost of a less appropriate corridor simply because anatomical preservation feels intuitively preferable.

24.17 MIDDLE CRANIAL FOSSA APPROACH

The middle fossa route provides superior access to the IAC and may be used for selected small intracanalicular or limited tumours when hearing preservation is a major objective.

Considerations include:

- tumour size
- fundal anatomy
- temporal lobe
- superior petrous landmarks
- facial nerve orientation

It is not designed primarily for large CPA tumours; most surgeons reserve it for tumours with little or no CPA extension.

The technique is described in Chapter 27, Middle Cranial Fossa Approach.

Figure 24.4 · Three corridors to the internal auditory canal

Simplified comparison — tumour geometry, hearing and experience refine the choice

	RETROSIGMOID behind the sigmoid	TRANSLABYRINTHINE through the labyrinth	MIDDLE FOSSA from above
Hearing	can be preserved	sacrificed	can be preserved
CPA access	wide	wide	limited
Lateral IAC / fundus	limited in some cases	direct	direct
Brain retraction	cerebellum	little or none	temporal lobe
Typical tumour	any size, CPA-dominant	any size, no useful hearing	small, intracanalicular

Choose the route toward where most of the tumour is — not merely where it began.

24.18 THE TUMOUR'S CENTRE MATTERS

Ask:

INTRACANALICULAR?

FUNDAL?

CPA DOMINANT?

LARGE WITH BRAINSTEM COMPRESSION?

The shortest safe corridor may differ according to the centre of disease.

APPROACH PRINCIPLE

Choose the route toward where most of the tumour is — not merely where the tumour began.

24.19 THE FACIAL NERVE IS OFTEN DISPLACED

The facial nerve may be stretched around the tumour capsule.

Its position may vary according to:

- tumour origin
- growth pattern

- size

Most often the nerve is displaced anteriorly over the capsule — anterosuperiorly, directly anteriorly or anteroinferiorly; a posterior position is uncommon but does occur.

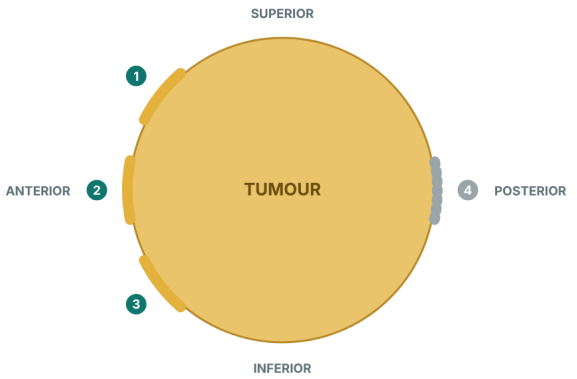
Although certain displacement patterns are common, no single position should be assumed.

PRINCIPLE

Predict the nerve — but confirm it before committing the dissection plane.

Figure 24.5 · Where the facial nerve usually lies

Schematic cross-section, right side, viewed from medial along the IAC axis — predict, then confirm by stimulation



FACIAL NERVE POSITION

1. anterosuperior
2. anterior (middle)
3. anteroinferior
4. posterior — uncommon

Most nerves lie on the anterior surface, often splayed thin. Never assume; stimulate before committing to a plane.

Positions shown are typical patterns, not fixed rules; the nerve may be fanned out across the capsule.

24.20 IDENTIFY THE FACIAL NERVE EARLY

Depending upon approach, the nerve may be identified:

- proximally
- distally
- through stimulation
- through known fundal or brainstem landmarks

The objective is to convert an unknown hidden nerve into a known boundary before aggressive tumour manipulation.

24.21 NERVE MONITORING

Monitoring may include:

- facial electromyography
- direct stimulation
- auditory monitoring in hearing-preservation surgery

These tools provide functional information.

They do not replace:

- anatomical identification
- tissue handling
- judgment

PRINCIPLE

The monitor can warn you that the nerve is unhappy. It cannot tell you why unless you understand what your hands just did.

24.22 AUDITORY MONITORING

When hearing preservation is attempted, intraoperative auditory monitoring, such as auditory brainstem responses or direct cochlear nerve action potentials, may provide information about cochlear or neural function.

A change may reflect:

- traction
- vascular compromise
- thermal injury
- direct neural injury

When meaningful deterioration occurs:

STOP

RELEASE MANIPULATION

REASSESS THE LAST STEP

Preserving hearing requires preservation of both:

NERVE
and

VASCULAR SUPPLY.

24.23 TUMOUR DEBULKING

For larger tumours, internal debulking may reduce tension on the surrounding capsule.

Conceptually:

DEBULK INTERNALLY
↓

ALLOW CAPSULE TO FALL INWARD
↓

DEVELOP ARACHNOID / NEURAL PLANES

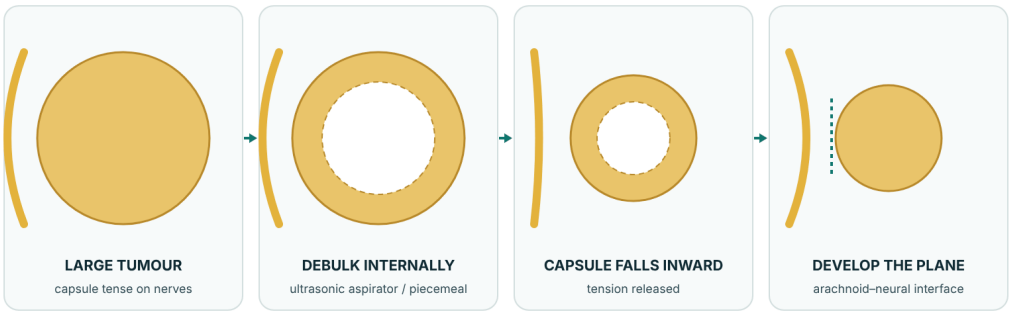
This can reduce the force required to mobilise the tumour from cranial nerves and brainstem.

PRINCIPLE

Make the tumour smaller before asking the nerves to move around it.

Figure 24.6 · Debulk first, then dissect the capsule

Schematic — make the tumour smaller before asking the nerves to move around it



Yellow line = facial nerve; dashed = debulked cavity or dissection plane.

Traction falls as the tumour shrinks — the plane is developed against a slack capsule.

24.24 CAPSULE DISSECTION

The capsule may be related to:

- facial nerve
- cochlear nerve
- brainstem
- cerebellum
- vessels

Dissection should proceed in a controlled plane.

Avoid:

- forceful traction
- blind stripping
- aggressive coagulation near neural structures

The correct plane may vary around different parts of the tumour.

24.25 BRAINSTEM INTERFACE

Large tumours may compress or adhere to the brainstem.

The objective is not to peel tumour away at any cost.

Assess:

- arachnoid plane
- vascular relationships
- cranial nerve attachments
- degree of adherence

PRINCIPLE

The final few millimetres may carry more functional risk than the first several centimetres.

24.26 EXTENT OF RESECTION

Potential surgical outcomes include:

GROSS TOTAL RESECTION

NEAR-TOTAL RESECTION

SUBTOTAL RESECTION

Historically, complete removal was often treated as the dominant objective.

Modern strategy increasingly recognises that intentionally leaving a small adherent remnant may be appropriate when complete removal would create disproportionate facial nerve or brainstem risk.

PRINCIPLE

Tumour control is the goal. Complete anatomical removal is one way — not the only way — to achieve it.

24.27 THE LAST FRAGMENT

When a thin tumour remnant is densely adherent to the facial nerve:

Ask:

What is the biological cost of leaving it?

versus

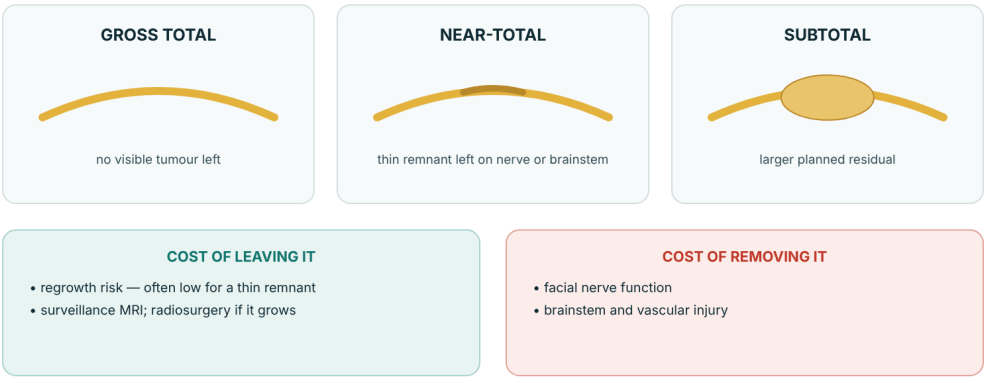
What is the functional cost of removing it?

In selected situations, preserving a functioning facial nerve with planned surveillance or later radiosurgical treatment may provide a better overall outcome than pursuing absolute gross total resection.

This is a judgment decision.

Figure 24.7 · Extent of resection: the cost of the last fragment

Tumour control is the goal; complete anatomical removal is one way to achieve it



Intentional residual tumour should be a strategy — documented, explained and followed.

24.28 FACIAL NERVE PRESERVATION

Preservation requires:

- early identification
- minimal traction
- controlled dissection
- careful coagulation
- preservation of vascularity
- interpretation of monitoring

Do not judge preservation only by whether the nerve remains anatomically intact.

Postoperative function is what matters.

24.29 COCHLEAR NERVE PRESERVATION

An anatomically preserved cochlear nerve may still lose function because of:

- traction
- vascular compromise
- thermal injury

Hearing preservation therefore requires more than avoiding direct transection.

PRINCIPLE

A nerve can survive anatomically and fail physiologically.

24.30 VASCULAR STRUCTURES

Small vessels supplying the nerves or brainstem can be functionally critical.

Preserve vessels when possible.

Do not assume that a vessel is expendable merely because it is small.

The consequence depends upon what it supplies.

24.31 LARGE TUMOUR STRATEGY

For large tumours:

DECOMPRESS FIRST

ESTABLISH PLANES

PRESERVE CRANIAL NERVES

RELEASE BRAINSTEM

DECIDE EXTENT OF FINAL CAPSULE REMOVAL BASED ON RISK

The operation should not be driven by the psychological urge to see an empty surgical field.

24.32 CYSTIC TUMOURS

Cystic tumours may behave differently surgically.

They may:

- decompress easily
- have thin adherent capsule
- distort neural relationships

A smaller volume after cyst drainage does not necessarily mean the capsule becomes easier to separate.

The interface still determines risk.

24.33 CSF LEAK

CSF leak is an important postoperative risk.

Prevention depends upon:

- careful dural closure
- sealing opened air cells
- appropriate fat / fascial or other reconstruction according to approach
- wound closure

Temporal-bone approaches particularly require attention to pneumatised pathways that may connect to the middle ear or Eustachian tube.

24.34 FAT GRAFT / CLOSURE PRINCIPLES

In selected approaches, abdominal fat or other autologous tissue may be used to obliterate the operative defect.

The objectives include:

- filling dead space
- supporting closure
- reducing CSF pathway

The material is part of the reconstruction — not a substitute for identifying and sealing the leak source.

24.35 POSTOPERATIVE FACIAL WEAKNESS

Facial weakness may be:

- immediate
- delayed

Evaluation should include:

- nerve continuity during surgery
- monitoring findings

- severity
- eye closure

Immediate priorities include:

EYE PROTECTION
and

FUNCTIONAL DOCUMENTATION.
Further management depends upon mechanism.

24.36 HEARING OUTCOME

After hearing-preservation surgery, hearing may be:

- preserved near baseline
- reduced
- lost

Outcome depends upon:

- tumour size
- preoperative hearing
- cochlear nerve handling
- vascular preservation
- approach

Patients should understand that a hearing-preservation approach is an attempt — not a guarantee.

24.37 VESTIBULAR COMPENSATION

After tumour removal, patients may experience imbalance because vestibular input has changed.

Rehabilitation may include:

- mobilisation
- vestibular therapy
- balance retraining

The brain must adapt to the altered vestibular system.

24.38 LOWER CRANIAL NERVE DYSFUNCTION

Large tumours may affect lower cranial nerves directly or through surgery.

Postoperative assessment should include:

- voice
- swallowing
- aspiration risk

Early rehabilitation and airway/nutrition planning may be necessary.

24.39 POSTOPERATIVE IMAGING

Follow-up MRI should assess:

- residual tumour
- recurrence / regrowth
- postoperative anatomy

The schedule depends upon:

- extent of resection
- pathology
- patient age
- institutional protocol

A subtotal or near-total resection is not complete without a surveillance strategy.

24.40 RESIDUAL TUMOUR

A small planned residual should be documented clearly:

- location
- reason it was left
- relationship to facial nerve or brainstem
- postoperative plan

Future management may include:

- observation
- radiosurgery
- further surgery in selected cases

PRINCIPLE

Intentional residual tumour should be a strategy — not an accident renamed afterward.

DECISION FRAMEWORK

WHICH APPROACH?

USEFUL HEARING?

No
→ Translabyrinthine may be considered.

Yes ↓

TUMOUR LOCATION?

Small / intracanalicular / selected fundal anatomy
→ Middle cranial fossa may be considered.

CPA component / wider posterior-fossa access required
→ Retrosigmoid may be considered.

Then refine using:

AGE

TUMOUR SIZE

IAC EXTENT

BRAINSTEM COMPRESSION

FACIAL NERVE

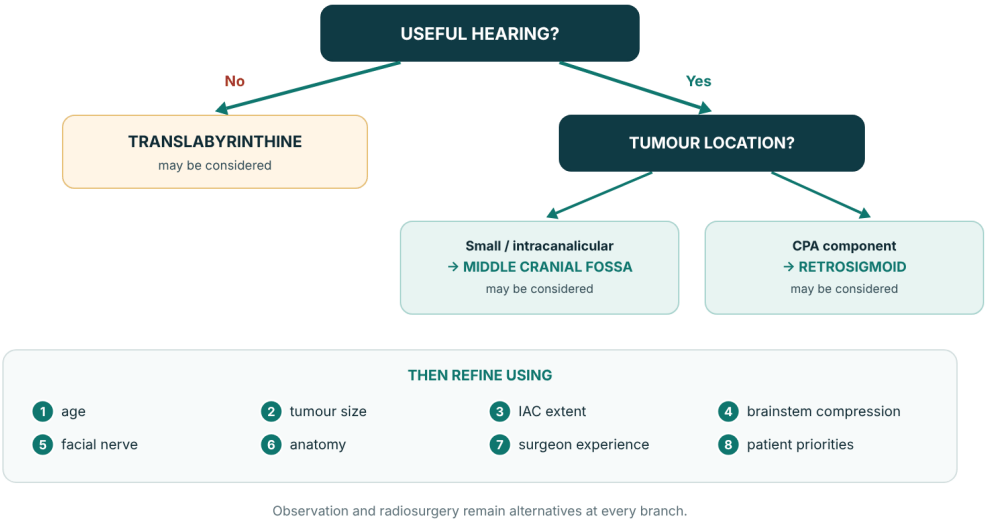
ANATOMY

SURGEON EXPERIENCE

PATIENT PRIORITIES

Figure 24.8 · Vestibular schwannoma approach-selection framework

Hearing first, then tumour geometry; refine with patient and surgeon factors



Observation and radiosurgery remain alternatives at every branch.

DECISION POINT

THE LAST CAPSULE IS ADHERENT TO THE FACIAL NERVE

Ask:

Can it be separated without significant traction or injury?

What is the current facial nerve stimulation response?

How much tumour actually remains?

What is the expected growth behaviour?

Can a small residual be followed or treated later?

The correct decision may be:

CONTINUE

or

LEAVE A PLANNED REMNANT.

The objective is the best long-term patient outcome.

FROM EXPERIENCE

Vestibular schwannoma surgery teaches a lesson that reaches far beyond this tumour.

At the beginning of an operation, removal appears to be the objective.

Near the end, preservation often becomes the more important objective.

A large central tumour can sometimes be removed quickly.

The thin capsule attached to a functioning facial nerve may take far longer.

That final fragment tests surgical maturity.

The question is no longer:

Can I remove it?

It becomes:

> **Should I remove it at this cost?**

TAKE IT TO THE OT

Before vestibular schwannoma surgery, define:

TUMOUR SIZE

IAC EXTENT

CPA EXTENT

BRAINSTEM EFFECT

HEARING

FACIAL NERVE FUNCTION

OTHER CRANIAL NERVES

APPROACH

HEARING-PRESERVATION GOAL

MONITORING

FACIAL NERVE IDENTIFICATION STRATEGY

EXTENT-OF-RESECTION GOAL

CSF-LEAK CLOSURE PLAN

REHABILITATION

SURVEILLANCE IF RESIDUAL REMAINS

CHAPTER SUMMARY

Vestibular schwannoma is a benign tumour in a high-consequence anatomical region.

Treatment is not automatically surgery.

Integrate tumour size, growth, symptoms, hearing, age and patient preference.

Choose the surgical approach according to hearing status and tumour geometry.

Predict facial nerve displacement but confirm it anatomically and electrophysiologically.

Debulk large tumours before applying traction to neural structures.

Protect the facial and cochlear nerves physiologically as well as anatomically.

Do not pursue complete resection when the final adherent fragment creates disproportionate functional risk.

Plan CSF-leak prevention and postoperative rehabilitation.

And remember:

> **The best operation is not necessarily the one that removes the most tumour.**

> **It is the one that achieves durable tumour control while preserving the most meaningful function.**

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CHAPTER 25

Retrosigmoid Approach

Posterior Corridor to the Cerebellopontine Angle

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the anatomical basis and indications of the retrosigmoid approach
- position the patient to create a natural posterior-fossa working corridor
- identify the transverse–sigmoid sinus junction and relevant bony landmarks
- perform a controlled retrosigmoid craniotomy or craniectomy
- understand dural opening and CSF release principles
- develop the cerebellopontine angle corridor with minimal cerebellar retraction
- identify cranial nerves and vascular structures within the CPA
- understand the principles of internal auditory canal drilling
- recognise the importance of air-cell closure and watertight reconstruction
- understand major complications including CSF leak, hearing loss, facial nerve injury and vascular injury

25.1 THE RETROSIGMOID APPROACH IS A CORRIDOR BEHIND THE SIGMOID SINUS

The retrosigmoid approach reaches the posterior fossa and cerebellopontine angle through a route:

POSTERIOR TO THE SIGMOID SINUS

and

INFERIOR TO THE TRANSVERSE SINUS.

It provides access to:

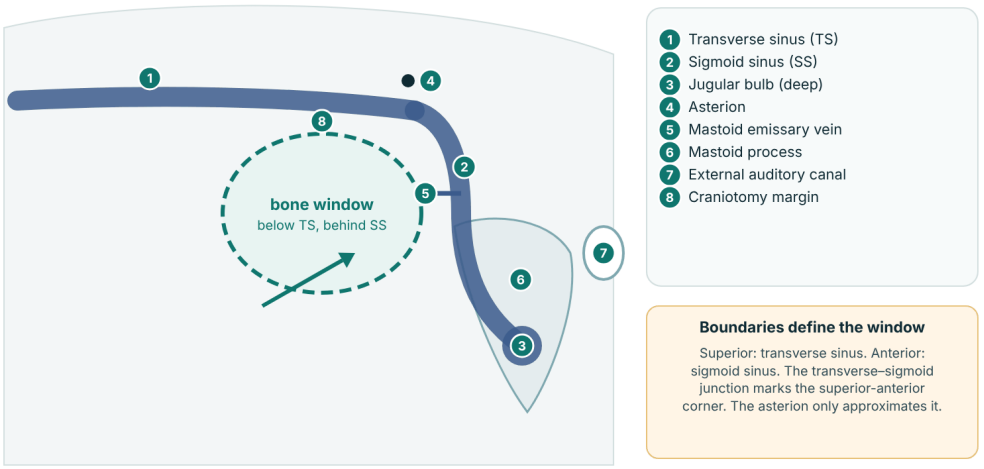
- cerebellopontine angle
- cranial nerves
- posterior surface of the petrous bone
- internal auditory canal
- selected posterior skull-base lesions

The fundamental advantage is that the labyrinth can remain intact.

Therefore useful hearing may potentially be preserved in selected operations.

Figure 25.1 · The retrosigmoid window

Right side, lateral surface projection, anterior to the right — schematic, not to scale



Teal arrow: the line of sight runs anteromedially along the posterior petrous surface into the cerebellopontine angle.

25.2 THE APPROACH IS NOT THE OPERATION

A retrosigmoid craniotomy merely creates access.

The actual operation may involve:

- vestibular schwannoma
- meningioma
- neurovascular compression
- selected epidermoid or other CPA lesions

- cranial nerve surgery

The size and geometry of exposure should therefore follow the target.

Tumour-specific strategy for vestibular schwannoma is discussed in Chapter 24, Vestibular Schwannoma: Surgical Strategy.

PRINCIPLE

Create enough corridor for the operation you need—not a standard hole because the approach has a standard name.

25.3 PREOPERATIVE IMAGING

Review:

MRI

- lesion size
- CPA extension
- brainstem relationship
- cranial nerve displacement
- vascular relationships
- IAC involvement

CT

Useful when significant IAC drilling or temporal-bone anatomy matters.

Assess:

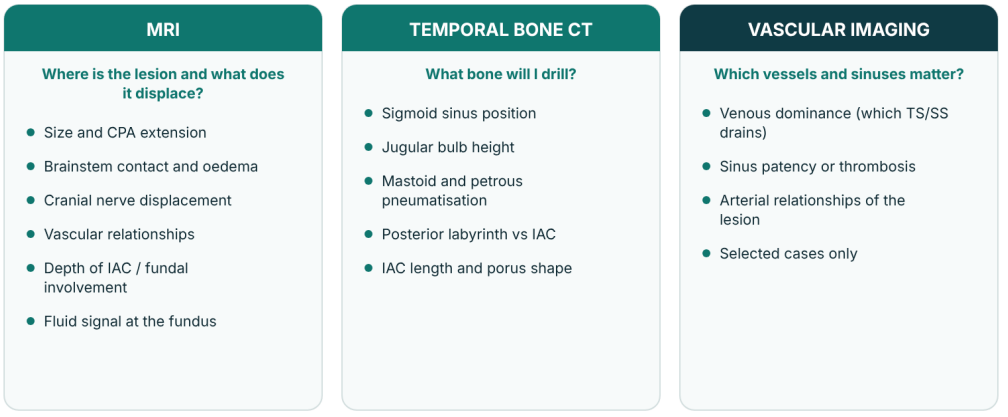
- sigmoid sinus
- jugular bulb
- mastoid pneumatisation
- petrous bone
- labyrinth
- IAC

VASCULAR IMAGING

When the lesion has important arterial or venous relationships.

Figure 25.2 · Imaging before a retrosigmoid approach

Each scan answers a different surgical question



Read the images in the direction of surgery: from the bone window, along the petrous surface, to the porus and fundus.

25.4 VENOUS ANATOMY

Understand:

TRANSVERSE SINUS

↓

SIGMOID SINUS

↓

JUGULAR BULB

The transverse–sigmoid junction helps define the superior-anterior limit of the retrosigmoid bony opening.

Venous dominance and anatomical variation should be considered.

PRINCIPLE

The sinus is not simply something to avoid. It is one of the landmarks that defines the approach.

25.5 POSITIONING

Positioning should create:

- comfortable posterior-fossa access

- gravity-assisted cerebellar relaxation where possible
- safe neck alignment
- stable head fixation
- anaesthetic access
- microscope mobility

Several positioning strategies are used: supine with the head turned, lateral (park-bench) and, in some centres, semi-sitting, which carries a recognised risk of venous air embolism.

The exact position is less important than the objectives.

Avoid excessive:

- neck flexion
- neck rotation
- venous obstruction
- pressure points

ERGONOMIC PRINCIPLE

Good positioning should make the corridor open before the surgeon begins retracting anything.

25.6 THE HEAD POSITION CHANGES THE CORRIDOR

Small changes in:

- flexion
- extension
- rotation

alter the relationship between:

- cerebellum
- petrous bone
- tentorium
- sigmoid sinus

Therefore positioning should be planned according to where the target lies.

UPPER CPA TARGET

may require a different visual trajectory from

LOWER CPA TARGET.

The anatomy is fixed.

The surgeon changes the line of sight.

25.7 INCISION

The incision should provide:

- adequate exposure
- healthy soft-tissue closure
- access to the retrosigmoid bone
- flexibility for extension if required

Soft-tissue handling matters because postoperative CSF-leak prevention depends partly upon reliable closure.

Do not treat the incision as separate from skull-base reconstruction.

25.8 EXPOSE THE BONE

The bony exposure should allow orientation to:

- mastoid region
- occipital bone
- expected sigmoid sinus
- transverse–sigmoid junction

Avoid excessive soft-tissue stripping beyond what the exposure requires.

The goal is a clear bony map.

25.9 LOCATING THE SIGMOID SINUS

The sinus position may be predicted by:

- surface anatomy, including the asterion (whose relationship to the transverse–sigmoid junction is variable)
- the mastoid emissary vein, which usually drains into the sigmoid sinus
- imaging

- mastoid contour
- navigation in selected cases

Do not assume identical sinus position between patients.

> **PRINCIPLE**
>
> **The retrosigmoid approach becomes safer when the sigmoid sinus is understood as a known boundary rather than an avoided unknown.**

25.10 CRANIOTOMY OR CRANIECTOMY

Either technique may be used depending upon:

- surgeon preference
- lesion
- reconstruction plan

The important principles are:

ADEQUATE EXPOSURE

CONTROLLED BONE REMOVAL

PROTECTION OF THE SINUSES

ABILITY TO ACHIEVE SECURE CLOSURE.

The technique should serve the corridor.

25.11 SIZE OF THE BONE OPENING

Larger is not automatically better.

Too small:

- restricts angle
- encourages fixed cerebellar retraction
- limits instrument movement

Too large:

- increases unnecessary tissue dissection
- may complicate reconstruction

PRINCIPLE

The smallest exposure is not the least invasive if it forces the brain to compensate for inadequate bone removal.

Bone can often be removed more safely than cerebellum can be retracted.

25.12 EXPOSE THE SINUS MARGIN DELIBERATELY

Appropriate bony exposure near the sinus can improve:

- surgical angle
- understanding of the corridor
- dural opening

But unnecessary sinus skeletonisation is not required.

Expose enough to know the boundary.

Do not turn landmark identification into vascular risk.

25.13 MASTOID AIR CELLS

Retrosigmoid drilling may open mastoid or petrous air cells.

These create a potential route:

POSTERIOR FOSSA

↓

AIR-CELL SYSTEM

↓

MIDDLE EAR / EUSTACHIAN TUBE

↓

CSF LEAK.

Whenever air cells are opened:

IDENTIFY THEM.

SEAL THEM DELIBERATELY.

This becomes particularly important during IAC drilling.

25.14 DURAL OPENING

Dural opening should provide:

- safe access
- protection of venous sinuses
- ability to close securely afterward

The incision pattern depends upon exposure.

Preserve usable dural margins for closure.

> **PRINCIPLE**
> **Open the dura while already thinking about how it will be closed.**

25.15 CSF RELEASE

Controlled CSF release from the cisternal spaces can allow the cerebellum to relax.

This may reduce the need for fixed retraction.

Conceptually:

RELEASE CSF

↓

CEREBELLUM RELAXES

↓

NATURAL CPA CORRIDOR OPENS

> **PRINCIPLE**
> **Relax the brain before retracting the brain.**

25.16 AVOID FORCEFUL CEREBELLAR RETRACTION

Excessive retraction can cause:

- cerebellar injury
- venous injury
- cranial nerve traction

- postoperative swelling

Use:

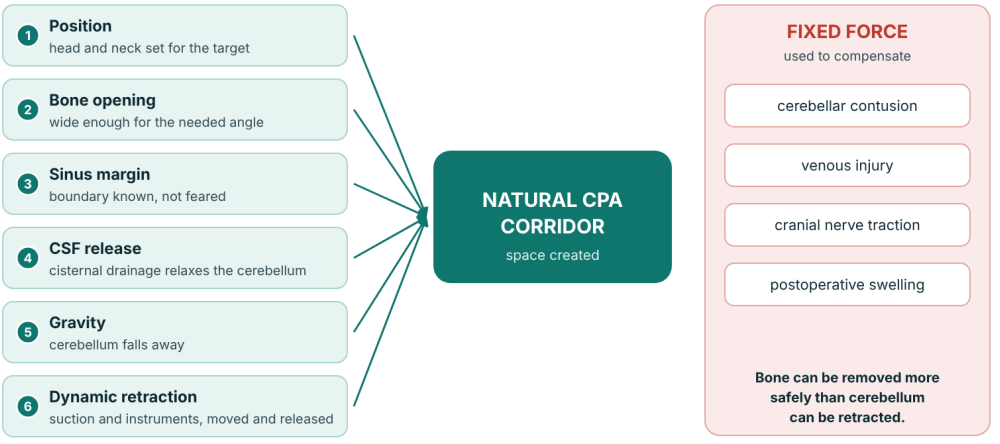
- positioning
- CSF release
- adequate bone opening
- dynamic instrument retraction

to reduce dependence on fixed pressure.

The corridor should be created by **space**, not force.

Figure 25.3 · Space, not force

The corridor is created by several factors acting together — not by a fixed retractor



Relax the brain before retracting the brain.

25.17 ENTERING THE CPA

As the cerebellum falls away, identify:

- petrous dura
- tumour or target
- cranial nerves
- vessels
- arachnoid planes

Do not begin manipulating a lesion before establishing the surrounding anatomy.

PRINCIPLE

See the neighbourhood before moving the lesion.

25.18 ARACHNOID PLANES

Arachnoid planes can help separate:

- tumour
- nerve
- vessel
- brainstem

Preserving these planes where possible can reduce injury.

But large or previously treated lesions may distort or obliterate them.

Do not assume a plane exists because a textbook says it should.

25.19 THE FACIAL–VESTIBULOCOCHLEAR COMPLEX

At the CPA and IAC, the facial and vestibulocochlear nerves may be displaced by tumour.

The exact relationship depends upon:

- site of origin
- size
- growth pattern

Use:

- anatomy
- stimulation
- operative context

to identify the facial nerve.

Do not assume a single displacement pattern.

25.20 LOWER CRANIAL NERVES

Inferiorly, identify:

- glossopharyngeal
- vagus
- accessory nerves

as relevant.

Large CPA tumours may compress or displace them.

Postoperative morbidity from lower cranial nerve injury can be substantial.

Therefore the inferior tumour pole deserves careful dissection.

25.21 TRIGEMINAL NERVE

Superior CPA lesions may approach or displace the trigeminal nerve.

This can be relevant in:

- vestibular schwannoma
- meningioma
- epidermoid
- neurovascular compression surgery

Symptoms may include facial numbness or pain.

The nerve should be identified as a functional structure—not merely an anatomical boundary.

25.22 VASCULAR STRUCTURES

Important vessels may include branches of:

- superior cerebellar artery (upper angle, with the trigeminal nerve)
- anterior inferior cerebellar artery (middle angle; usually the origin of the labyrinthine artery)
- posterior inferior cerebellar artery (lower angle, with the lower cranial nerves)
- other posterior circulation vessels

The superior petrosal vein complex (Dandy's vein) drains into the superior petrosal sinus near the trigeminal nerve and should be preserved where possible.

Small arterial branches may supply:

- brainstem
- cochlea
- cranial nerves

PRINCIPLE

Small vessel does not mean small consequence.

Avoid coagulating a vessel simply because its destination is not immediately visible.

Figure 25.4 · Three neurovascular complexes of the posterior fossa

After Rhoton — each artery travels with a group of nerves, a brainstem level and a cerebellar surface

Complex	Artery	Cranial nerves	Brainstem	Fissure	Cerebellar surface
UPPER	SCA	III, IV, V	Midbrain	Cerebellomesencephalic	Tentorial
MIDDLE	AICA	VI, VII, VIII	Pons	Cerebellopontine	Petrosal
LOWER	PICA	IX, X, XI, XII	Medulla	Cerebellomedullary	Suboccipital

Retrosigmoid view: the middle complex (VII/VIII with AICA) is the usual target; the upper and lower complexes frame it.

25.23 INTERNAL DEBULKING OF TUMOUR

For larger lesions:

OPEN CAPSULE WHERE APPROPRIATE

↓

DEBULK INTERNALLY

↓

REDUCE MASS

↓

ALLOW CAPSULE TO RELAX

↓

DEVELOP PERIPHERAL PLANES

The objective is to reduce traction on:

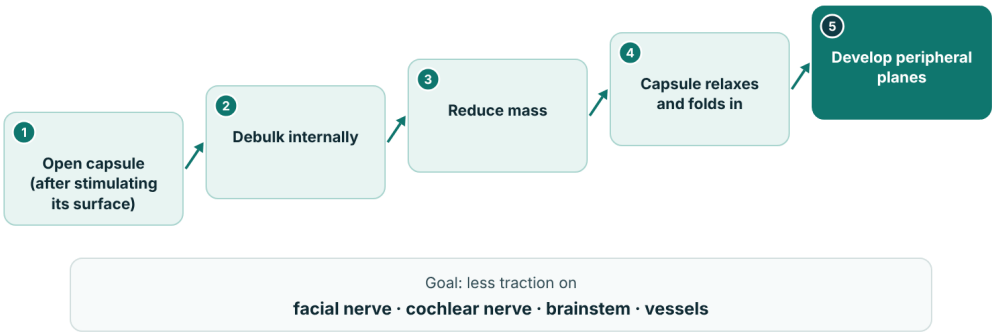
- facial nerve
- brainstem
- cochlear nerve
- vessels

PRINCIPLE

Remove tumour from inside before pulling the nervous system away from outside.

Figure 25.5 · Internal debulking before capsule dissection

Reduce the mass from inside so the capsule can be rolled away without pulling on nerves



25.24 IDENTIFY THE FACIAL NERVE BEFORE THE FINAL CAPSULE

Use:

- stimulation
- known brainstem relationship

- IAC anatomy
- distal fundal relationship where exposed

The nerve should become a defined structure before the most adherent capsule is addressed.

25.25 IAC DRILLING — WHY?

IAC drilling may be required to:

- expose intracanalicular tumour
- reach the fundus
- identify distal nerve anatomy

The extent should match:

- tumour extension
- hearing-preservation objective
- anatomy

Do not drill the full canal merely because the approach allows it.

25.26 KNOW WHAT SURROUNDS THE IAC

The IAC is related to:

SUPERIORLY

The petrous ridge and middle fossa dura; the superior semicircular canal lies above the lateral part of the canal.

POSTERIORLY — THE WALL BEING DRILLED

The posterior semicircular canal and common crus lie posterolateral to the canal; the vestibular aqueduct runs posteroinferiorly toward the endolymphatic sac.

LATERALLY

The fundus, with the vestibule immediately beyond it.

INFERIORLY

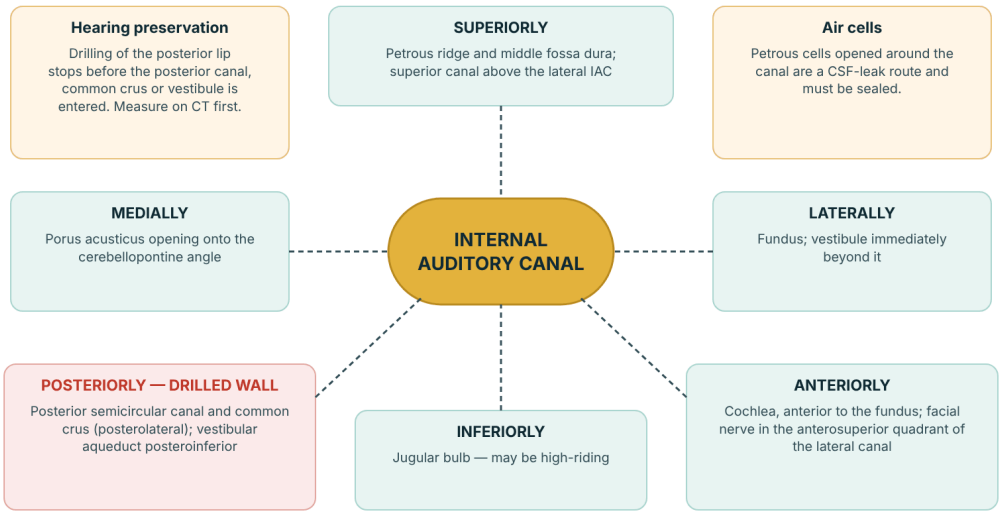
The jugular bulb, which may be high-riding and lie close beneath the canal.

ANTERIORLY

The cochlea, anterior to the fundus; within the lateral canal the facial nerve occupies the anterosuperior quadrant.

Figure 25.6 · What surrounds the internal auditory canal

Relational diagram, not a surgical view — from a retrosigmoid route the posterior wall is the one drilled



During drilling, the labyrinth is particularly important in hearing-preservation surgery.

25.27 LOCALISE THE LABYRINTH BEFORE IAC DRILLING

Understand:

- posterior semicircular canal
- superior semicircular canal
- vestibule
- common crus relationships

The exact exposure varies.

HEARING-PRESERVATION PRINCIPLE

The IAC can be opened only while the labyrinth remains protected.

Unplanned labyrinthine violation can eliminate the hearing-preservation objective.

25.28 DRILLING TECHNIQUE AROUND THE IAC

General principles include:

- controlled diamond drilling
- irrigation
- progressive thinning
- awareness of air cells
- protection of dura and labyrinth
- short, stable drill movements

The final shell can be removed delicately after adequate thinning.

PRINCIPLE

Reveal the canal progressively. Do not plunge toward the dura.

25.29 OPENED AIR CELLS

Any petrous air cells exposed during IAC drilling should be identified and sealed appropriately.

Failure can lead to postoperative CSF rhinorrhoea or otorrhoea.

This is one of the reasons that temporal-bone CT matters even in a posterior-fossa approach.

25.30 IAC DURA

After bony decompression, the IAC dura can be opened according to the operative objective.

The surgeon should understand:

- tumour location
- facial nerve
- cochlear nerve
- fundus

The canal is a neural corridor, not simply an extension of the tumour cavity.

25.31 HEARING-PRESERVATION SURGERY

If hearing preservation is an objective:

protect:

COCHLEAR NERVE

LABYRINTH

COCHLEAR BLOOD SUPPLY

INNER-EAR FLUID SYSTEM.

The nerve can remain anatomically intact yet functionally fail after:

- traction
- ischaemia
- heat
- labyrinthine violation

Preservation must therefore be physiological.

25.32 AUDITORY MONITORING CHANGES

If auditory monitoring deteriorates:

STOP MANIPULATION

↓

RELEASE TRACTION

↓

IRRIGATE / REASSESS AS APPROPRIATE

↓

REVIEW THE LAST STEP

↓

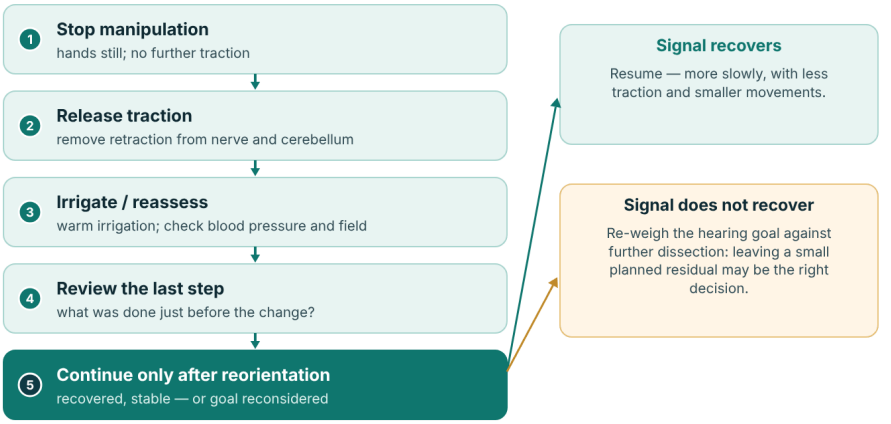
CONTINUE ONLY AFTER REORIENTATION

A signal change should influence behaviour.

Otherwise monitoring is merely decoration.

Figure 25.7 · Responding to a change in auditory monitoring

A signal change should alter behaviour — otherwise monitoring is merely decoration



25.33 THE FINAL TUMOUR CAPSULE

The final adherent capsule may lie against:

- facial nerve
- brainstem
- vessels
- cochlear nerve

At this stage, the risk-per-millimetre rises dramatically.

> **PRINCIPLE**
>
> **The operation becomes slower as the amount of tumour becomes smaller.**

That is appropriate.

25.34 PLANNED RESIDUAL

If complete removal threatens meaningful neurological function, a planned small residual may be appropriate in selected cases.

Document:

- location

- reason
- estimated amount
- postoperative imaging plan

Do not call uncontrolled residual disease a strategy.

A planned remnant requires a planned follow-up pathway.

25.35 HAEMOSTASIS

Haemostasis in the CPA should minimise:

- thermal spread
- nerve injury
- brainstem injury

Do not chase minor bleeding with aggressive coagulation near neural structures.

Use:

- pressure
- irrigation
- fine bipolar control where appropriate
- haemostatic adjuncts

according to source.

25.36 DURAL CLOSURE

A secure dural closure is central to preventing CSF leak.

Where primary watertight closure is difficult, additional reconstructive strategies may be required.

The closure plan should account for:

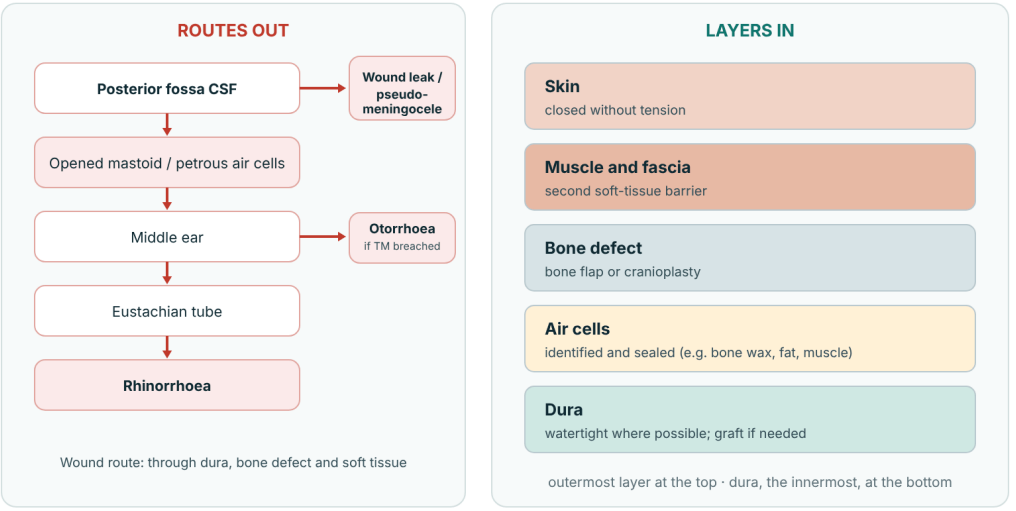
- dural defect
- opened air cells
- craniotomy defect
- soft-tissue layers

PRINCIPLE

CSF-leak prevention is layered reconstruction.

Figure 25.8 · The CSF-leak pathway and the layers that close it

Prevention is layered reconstruction — each layer closes a different route



25.37 BONE DEFECT RECONSTRUCTION

Cranioplasty or bone replacement may be performed depending upon technique.

Potential objectives include:

- contour
- protection
- reduction of soft-tissue depression
- possibly reduction of postoperative headache in selected strategies

Technique varies.

The central requirement remains secure closure.

25.38 SOFT-TISSUE CLOSURE

Close:

- muscle

- fascia
- subcutaneous tissue
- skin

without excessive tension.

Healthy soft tissue provides another layer protecting the intracranial closure.

Do not permit an excellent intradural operation to end with careless wound reconstruction.

25.39 POSTOPERATIVE CSF LEAK

Possible presentations include:

- wound leak
- pseudomeningocele
- rhinorrhoea
- otorrhoea

Evaluate the likely pathway.

Management depends upon:

- severity
- persistence
- route
- infection
- closure defect

Prevention remains easier than revision.

25.40 POSTOPERATIVE HEADACHE

Headache after retrosigmoid surgery may have multiple contributors, including:

- muscle dissection
- dural factors
- bone defect
- scar
- CSF dynamics

No single mechanism explains all cases.

Technique should therefore minimise unnecessary tissue trauma throughout the approach.

25.41 VENOUS COMPLICATIONS

Potential venous problems include:

- sinus injury
- thrombosis
- cerebellar venous injury

Avoid unnecessary injury to important venous structures.

The posterior fossa has limited tolerance for significant venous outflow disturbance.

25.42 LOWER CRANIAL NERVE ASSESSMENT

After large CPA surgery, assess:

- voice
- cough
- swallowing
- aspiration

before assuming routine oral intake is safe.

A patient can appear neurologically awake while still having important lower cranial nerve dysfunction.

25.43 EARLY MOBILISATION AND VESTIBULAR REHABILITATION

Patients may experience significant imbalance after vestibular nerve tumour surgery.

Early appropriate mobilisation and vestibular rehabilitation can support compensation.

The vestibular system is not repaired by removing the tumour.

The central nervous system must adapt afterward.

DECISION POINT

I CANNOT REACH THE LATERAL IAC SAFELY

Ask:

Is more IAC exposure actually required?

Where is the posterior labyrinth?

Would further drilling threaten hearing?

Can the residual fundal component be managed another way?

Would another approach have been better for this tumour geometry?

Do not convert a hearing-preservation approach into hearing loss merely to achieve a few additional millimetres of exposure.

FROM EXPERIENCE

The retrosigmoid approach is often described as an approach through a small opening behind the ear.

But its real geometry is created by several things working together:

the head position,

the bone opening,

the sigmoid boundary,

CSF release,

gravity,

the relaxed cerebellum,

and the angle toward the target.

When these are correct, the corridor can feel surprisingly open.

When they are poor, even a larger craniotomy can feel narrow.

That teaches a broader principle:

> **Surgical access is not created by incision size alone.**

IT IS CREATED BY GEOMETRY.

TAKE IT TO THE OT

Before retrosigmoid surgery, define:

TARGET

MRI GEOMETRY

HEARING GOAL

FACIAL NERVE FUNCTION

LOWER CRANIAL NERVES

SIGMOID / TRANSVERSE SINUS

TUMOUR EXTENT IN THE IAC

LABYRINTH

AIR-CELL PNEUMATISATION

POSITION

CSF-RELEASE PLAN

MONITORING

IAC DRILLING EXTENT

CLOSURE / CSF-LEAK PLAN

BAILOUT IF FUNCTIONAL RISK RISES

CHAPTER SUMMARY

The retrosigmoid approach creates a posterior corridor to the CPA while potentially preserving the labyrinth.

Use imaging to understand tumour and venous anatomy.

Position the patient to allow gravity and CSF release to create space.

Remove enough bone to reduce the need for cerebellar retraction.

Identify the CPA anatomy before manipulating the lesion.

Debulk large tumours internally.

Protect cranial nerves and their blood supply.

Drill the IAC only to the extent required.

Seal opened air cells.

Close the dura and wound as a layered reconstruction.

And remember:

> **The retrosigmoid corridor is not created by pushing the cerebellum away.**

> **It is created by giving the cerebellum somewhere to go.**

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CHAPTER 26

Translabyrinthine Approach

Sacrifice Hearing • Gain Direct Access to the IAC

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the indications and anatomical logic of the translabyrinthine approach
- recognise that useful hearing on the operated side is sacrificed
- perform the approach as an extension of mastoid and labyrinthine anatomy
- skeletonise the sigmoid sinus, tegmen and semicircular canals in a controlled sequence
- understand the relationship of the facial nerve to the labyrinth and IAC
- expose the internal auditory canal from the temporal-bone route
- identify the jugular bulb and petrous dura as deep boundaries
- understand tumour dissection principles around the facial nerve and brainstem
- plan obliteration and layered closure to reduce postoperative CSF leak

26.1 THE TRANSLABYRINTHINE APPROACH USES A FUNCTION THAT IS ALREADY LOST

The translabyrinthine approach reaches the internal auditory canal and cerebellopontine angle by removing the labyrinth.

Therefore:

> **RESIDUAL HEARING ON THAT SIDE IS SACRIFICED.**

This is not a complication of the approach.

It is part of its design.

The approach is most useful when hearing preservation is not a meaningful objective and direct IAC access is advantageous.

26.2 THE LOGIC OF THE APPROACH

The route can be understood as:

MASTOID

↓

SEMICIRCULAR CANALS

↓

LABYRINTH

↓

POSTERIOR PETROUS BONE

↓

INTERNAL AUDITORY CANAL

↓

CEREBELLOPONTINE ANGLE

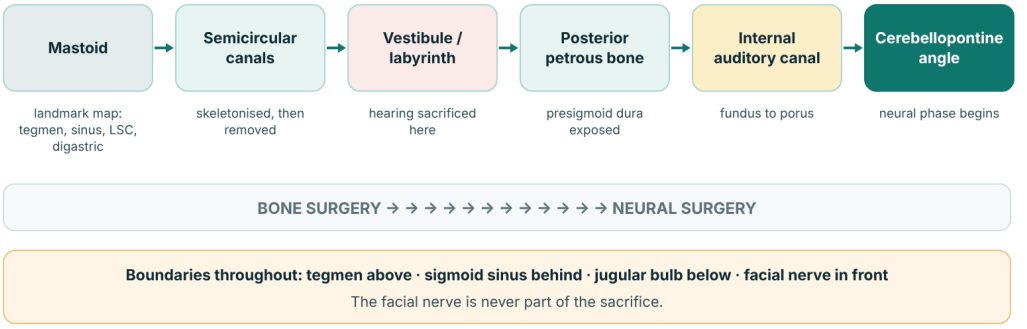
The approach converts the labyrinth from a structure that limits access into the corridor itself.

PRINCIPLE

A structure can become part of the approach only when its functional sacrifice is acceptable.

Figure 26.1 · The translabyrinthine route

The labyrinth stops being a barrier and becomes the corridor — once its function is given up



26.3 COMMON INDICATIONS

The approach may be considered for selected lesions such as:

- vestibular schwannoma in an ear without useful hearing
- selected facial nerve or IAC lesions
- selected CPA pathology requiring temporal-bone access

The exact indication depends upon:

- hearing
- tumour size
- anatomy
- patient factors
- surgeon experience

The procedure should not be selected solely because the tumour involves the IAC.

26.4 ADVANTAGES

Potential advantages include:

- direct exposure of the IAC
- wide fundal access
- early identification of the facial nerve in selected circumstances
- little or no cerebellar retraction

- direct temporal-bone route to the lesion

The cost is deliberate destruction of the labyrinth.

26.5 PREOPERATIVE ASSESSMENT

Review:

HEARING

Is useful hearing truly absent or not worth preserving?

MRI

Tumour size, IAC extension, CPA component, brainstem relation.

CT

Mastoid pneumatisation, sigmoid sinus, jugular bulb, labyrinth, IAC, petrous bone.

FACIAL NERVE FUNCTION

Baseline.

LOWER CRANIAL NERVES

Especially in large lesions.

VASCULAR ANATOMY

Where clinically relevant.

26.6 THE DECISION ABOUT HEARING MUST BE MADE BEFORE THE LABYRINTH IS OPENED

Before surgery, the patient should understand clearly:

> **THIS APPROACH WILL ELIMINATE RESIDUAL HEARING ON THE OPERATED SIDE.**

The surgeon should be equally clear.

There should be no intraoperative uncertainty about whether hearing is being preserved once the labyrinthine phase begins.

26.7 POSITIONING

Positioning should permit:

- broad mastoid access
- microscope mobility
- comfortable drilling angle
- later access to the CPA

The head should be stable.

The surgeon should be able to transition from:

LATERAL TEMPORAL-BONE DRILLING

to

DEEP IAC / CPA WORK

without awkward ergonomics.

26.8 EXPOSURE

A postauricular incision generally provides broad access.

The soft-tissue exposure should reveal enough temporal bone to define:

- mastoid cortex
- temporal line / tegmen region
- sigmoid sinus region
- mastoid tip

The exposure is usually wider than a routine cortical mastoidectomy because the operation continues substantially deeper.

26.9 THE FIRST PHASE IS A COMPLETE MASTOID MAP

Perform a generous landmark-based mastoidectomy.

Define:

TEGMEN

SIGMOID SINUS

POSTERIOR CANAL WALL

MASTOID TIP

LATERAL SEMICIRCULAR CANAL

INCUS REGION

DIGASTRIC RIDGE

The deeper skull-base portion should begin only after the mastoid anatomy is fully oriented.

26.10 SKELETONISE THE SIGMOID SINUS

The sigmoid sinus forms a major posterior boundary.

Progressive thinning of bone over the sinus can:

- define the posterior limit
- improve working space
- orient the surgeon toward the presigmoid petrous bone

The sinus need not be aggressively exposed everywhere.

PRINCIPLE

Define the boundary sufficiently to use it.

Do not create vascular risk merely for visual completeness.

26.11 DEFINE THE TEGMEN

Superiorly, identify the tegmen and middle-fossa dural boundary.

This defines the superior limit of the approach.

The space between:

TEGMEN

and

SIGMOID SINUS

becomes an important working region.

26.12 THE SINODURAL REGION

The sinodural angle should be fully understood.

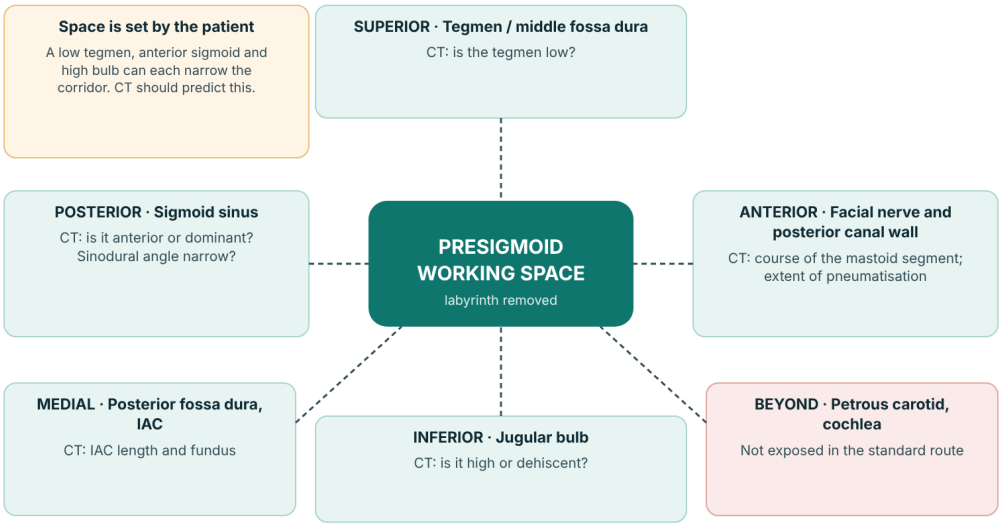
This region helps orient the upper posterior mastoid and petrous exposure.

A narrow sinodural corridor may affect working space.

Again, CT should have predicted this.

Figure 26.2 · Boundaries of the translabyrinthine corridor

Relational diagram — each boundary has a CT question that should be answered before surgery



26.13 THE LABYRINTH

The three semicircular canals are progressively identified:

LATERAL

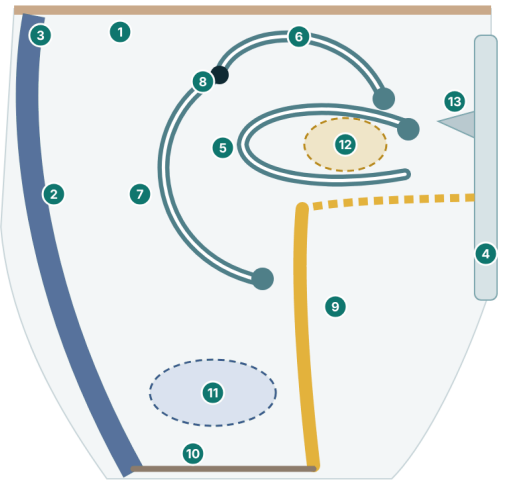
SUPERIOR

POSTERIOR

Before labyrinthectomy, understand them as a three-dimensional system around the vestibule.

Figure 26.3 · The skeletonised labyrinth

Right ear, lateral (surgical) view, superior up, anterior to the right — schematic; dashed = deeper structures projected



1. Tegmen (middle fossa dura)
2. Sigmoid sinus
3. Sinodural angle
4. Posterior canal wall
5. Lateral semicircular canal
6. Superior semicircular canal
7. Posterior semicircular canal
8. Common crus
9. Facial nerve (tympanic seg. dashed)
10. Digastric ridge
11. Jugular bulb (deep)
12. IAC (deep, medial to vestibule)
13. Incus, short process

Read the relations

Second genu just below the lateral canal; posterior canal ampulla medial to the mastoid segment; bulb below the labyrinth.

Filled circles: ampullated ends. Vestibule deep, at the centre of the canals. Tympanic segment hidden medial to the canal wall.

26.14 SKELETONISE BEFORE ENTERING

As with other critical structures:

DEFINE FIRST.

The canals should be exposed enough to understand:

- their arcs
- common crus
- vestibular relationships

Then the labyrinthectomy proceeds in a controlled sequence.

PRINCIPLE

Do not enter the labyrinth before you understand the labyrinth.

26.15 THE FACIAL NERVE REMAINS THE CRITICAL STRUCTURE

Although hearing is sacrificed, facial function is not.

The facial nerve lies in close relation to:

- lateral semicircular canal
- second genu
- mastoid segment
- vestibule
- IAC fundus

Use the complete landmark network.

The labyrinthectomy should improve facial nerve orientation, not threaten it.

26.16 LABYRINTHECTOMY

Conceptually, the semicircular canals are opened and removed progressively to expose the vestibular region and deepen the petrous corridor.

The sequence should maintain:

- orientation
- facial nerve protection
- controlled drilling
- awareness of IAC direction

As the otic capsule is entered:

DRILLING BECOMES FINER,
not more aggressive.

26.17 THE COMMON CRUS

The superior and posterior semicircular canal relationship at the common crus helps orient the deeper labyrinth.

Its identification contributes to understanding:

- vestibule
- posterior IAC relationship

Avoid random removal of dense otic-capsule bone.

Follow the geometry.

26.18 THE VESTIBULE

The vestibule lies at the centre of the labyrinthine system.

After labyrinthectomy, it becomes an important landmark for the lateral IAC and nerve relationships.

The facial nerve lies close by: its labyrinthine segment anterosuperiorly, and its tympanic segment lateral to the vestibule, just below the lateral semicircular canal.

PRINCIPLE

The vestibule leads toward the IAC, but the facial nerve guards the route.

26.19 THE IAC

The IAC should be conceptualised as a cylinder extending from:

FUNDUS

laterally

to

PORUS

medially.

The translabyrinthine route provides excellent lateral access to the fundus.

This is one of its principal advantages.

26.20 EXPOSE THE IAC PROGRESSIVELY

The bone around the IAC should be thinned in a controlled fashion.

Define:

SUPERIOR IAC

POSTERIOR IAC

INFERIOR IAC

FUNDUS

The amount of circumferential exposure depends upon the operative objective.

Avoid premature dural opening before the bony anatomy is sufficiently defined.

26.21 FUNDAL ANATOMY

At the IAC fundus, key neural relationships include:

FACIAL NERVE
anterosuperior.

COCHLEAR NERVE
anteroinferior.

SUPERIOR VESTIBULAR NERVE
posterosuperior.

INFERIOR VESTIBULAR NERVE
posteroinferior.

Tumour can distort these relationships.

The normal map tells the surgeon what to expect before distortion is interpreted.

26.22 BILL'S BAR AND FUNDAL PARTITIONS

Bony partitions at the lateral IAC may help define neural compartments.

The transverse (falciform) crest divides the fundus into superior and inferior compartments.

Bill's bar, the vertical crest, divides the superior compartment: the facial nerve lies anterior to it and the superior vestibular nerve posterior to it.

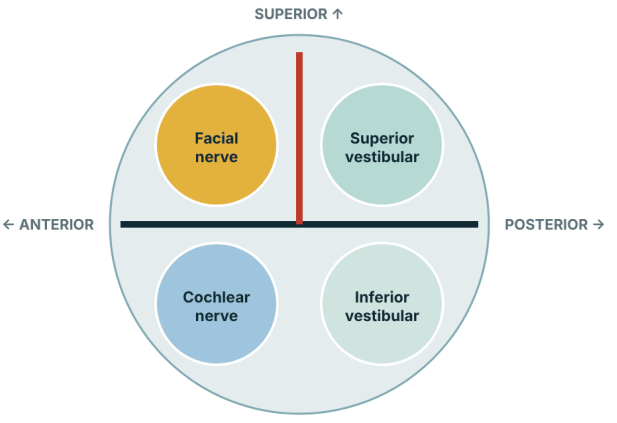
These landmarks can assist in locating the facial nerve near the fundus.

However, they should be treated as part of a network, not relied upon in isolation.

Tumour and anatomy may alter their appearance.

Figure 26.4 · The fundus of the internal auditory canal

Right IAC fundus viewed from medial (as in Figure 23.2), superior up, anterior to the left — mirror it for the translabyrinthine view



Transverse (falciform) crest

Black line: divides superior from inferior compartments.

Bill's bar (vertical crest)

Red line: in the superior compartment, facial nerve anterior, superior vestibular nerve posterior.

"Seven-up, Coke down"

Facial (VII) anterosuperior; cochlear anteroinferior. Vestibular nerves posterior.

26.23 FACIAL NERVE IDENTIFICATION

One advantage of the translabyrinthine route is the ability to identify the distal facial nerve in the lateral IAC/fundal region in selected cases.

This can establish a known neural boundary before tumour dissection proceeds medially.

Use:

DIRECT ANATOMY

+

NERVE STIMULATION

+

> **EXPECTED FUNDAL RELATIONSHIPS.**

26.24 JUGULAR BULB

The jugular bulb forms an important inferior boundary.

A high bulb can reduce the space available below the IAC.

This should be anticipated on CT.

Do not attempt to create a standard inferior IAC exposure when the patient's venous anatomy does not permit it.

26.25 PETROUS CAROTID

The carotid lies anterior to the operative corridor.

In routine translabyrinthine vestibular schwannoma surgery it is not typically exposed, but the surgeon must remain aware of its deeper petrous relationship.

Extended drilling beyond the standard corridor changes the vascular risk substantially.

26.26 POSTERIOR FOSSA DURA

After sufficient IAC and posterior petrous bone exposure, the posterior fossa dura is opened according to the operative plan.

The target becomes:

- IAC contents
- tumour
- CPA

The operation transitions from:

BONE SURGERY

to

NEURAL SURGERY.

The surgeon must consciously change speed and instrument behaviour.

26.27 OPEN THE DURA WITH THE NERVE MAP ALREADY IN MIND

Before dural opening, know:

- facial nerve
- tumour location
- porus

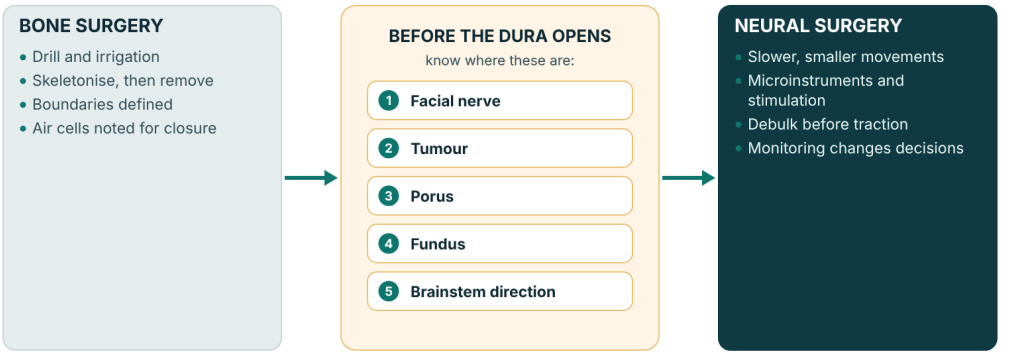
- fundus
- brainstem direction

Do not begin intradural tumour dissection while still uncertain about the bony orientation.

The bone work should have prepared the neural operation.

Figure 26.5 · From bone surgery to neural surgery

A deliberate checkpoint before the dura is opened — speed and instrument behaviour change here



The bone work should have prepared the neural operation.

26.28 TUMOUR DEBULKING

For larger tumours:

INTERNAL DEBULKING

reduces:

- capsule tension
- brainstem pressure
- traction on the facial nerve

As before:

> **MAKE THE TUMOUR SMALLER BEFORE ASKING THE NERVE TO MOVE.**

26.29 THE FACIAL NERVE PLANE

The nerve may be:

- thin
- stretched
- displaced around the capsule

Dissection should use:

- visual identification
- stimulation
- fine traction-countertraction
- preservation of vascularity

Avoid treating monitoring as a substitute for seeing the nerve.

26.30 DISTAL-TO-PROXIMAL AND PROXIMAL-TO-DISTAL THINKING

Because the translabyrinthine approach provides access to the fundus and IAC, the surgeon may have options for identifying the facial nerve at different points.

The best direction depends upon:

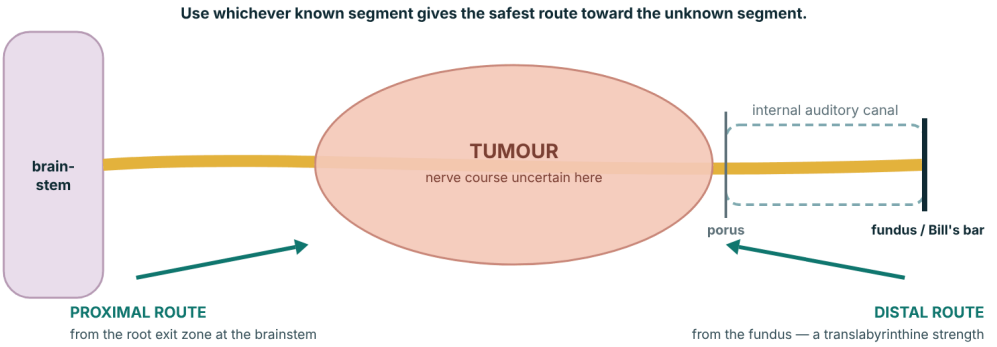
- tumour size
- nerve position
- operative anatomy

PRINCIPLE

Use whichever known segment gives the safest route toward the unknown segment.

Figure 26.6 · Finding the facial nerve from either known end

Schematic course of the nerve from brainstem to fundus with a tumour obscuring the middle



26.31 THE COCHLEAR NERVE

Because hearing is already sacrificed by the approach, cochlear nerve preservation may not carry the same functional goal as in hearing-preservation surgery.

However, neural anatomy should still be respected.

The cochlear nerve may help define:

- tumour origin
- facial nerve relationship
- fundal anatomy

Do not create unnecessary neural injury simply because hearing is already absent.

26.32 CPA DISSECTION

At the CPA, tumour may contact:

- brainstem
- cerebellum
- lower cranial nerves
- vessels

The same general principles apply:

DEBULK

DEVELOP ARACHNOID PLANES

IDENTIFY NERVES

PRESERVE VESSELS

> **REMOVE CAPSULE ONLY WHERE THE PLANE IS SAFE.**

26.33 EXTENT OF RESECTION

As with other vestibular schwannoma approaches, the goal is not blindly defined by "total."

If the last capsule is densely adherent to a functioning facial nerve or brainstem:

STOP AND REASSESS.
A planned residual with surveillance may be preferable to a preventable major neurological deficit in selected circumstances.

26.34 FACIAL NERVE MONITORING

Monitoring should be active throughout the neural phase.

Changes should influence behaviour.

If stimulation threshold or response worsens:

STOP
↓

RELEASE TRACTION
↓

> **REASSESS THE DISSECTION PLANE**

↓

> **CONSIDER LEAVING ADHERENT CAPSULE IF FUNCTIONAL RISK IS HIGH**

Monitoring is valuable only if it changes decisions.

26.35 LOWER CRANIAL NERVES

Large tumours may extend inferiorly.

Identify and protect:

- glossopharyngeal
- vagus
- accessory nerves

as appropriate.

Preoperative dysfunction should influence counselling and postoperative airway/swallow planning.

26.36 CLOSURE IS A MAJOR PART OF THE APPROACH

The translabyrinthine approach opens:

- mastoid air-cell system
- labyrinth
- petrous air cells
- posterior fossa

This creates several potential CSF pathways.

Closure must therefore be planned as carefully as the exposure.

26.37 EUSTACHIAN-TUBE AND MIDDLE-EAR ROUTES

Potential CSF pathways may communicate through:

PETROUS / MASTOID AIR CELLS

↓

MIDDLE EAR

↓

EUSTACHIAN TUBE

↓

NASOPHARYNX.

Sealing relevant pathways is essential.

In many techniques the incus is removed and the aditus, middle ear and Eustachian tube orifice are packed with soft tissue such as muscle or fascia.

The exact method depends upon the operative technique and air-cell anatomy.

26.38 FAT OBLITERATION

Autologous abdominal fat is commonly used in many translabyrinthine closures to:

- obliterate dead space
- support closure
- reduce CSF pathway

But fat alone is not the closure.

The surgeon must also address:

- opened air cells
- dural defect
- middle-ear pathways
- soft-tissue layers

PRINCIPLE

Obliteration supports closure. It does not replace closure.

Figure 26.7 · Translabyrinthine closure

Each pathway opened during the approach needs its own seal — fat supports closure but does not replace it

OPENED PATHWAY	SEAL
Middle ear and Eustachian tube	Incus removed; aditus, middle ear and tube orifice packed with soft tissue
Mastoid and petrous air cells	Every opened cell identified and sealed
Dural defect	Edges approximated where possible; graft or fascia as needed
Dead space	Autologous abdominal fat obliterates the cavity
Soft tissues	Muscle, fascia and skin closed in layers without tension

Prevention begins during drilling: recognise every air cell as it is opened.

26.39 TEMPORALIS FASCIA / MUSCLE AND OTHER LAYERS

Vascularised local tissue may provide additional closure layers.

The objective is a multilayer barrier between:

INTRACRANIAL CSF

and

> **EXTERNAL / MIDDLE-EAR AIR SPACES.**

Layered reconstruction reduces dependence upon any one closure method.

26.40 POSTOPERATIVE CSF LEAK

Potential presentations include:

- wound leak
- rhinorrhoea
- middle-ear fluid
- pseudomeningocele

The likely pathway should be identified.

Management depends upon:

- persistence
- severity
- route
- infection
- closure defect

Again, prevention begins during drilling by recognising every air cell that is opened.

26.41 FACIAL WEAKNESS

Postoperative facial weakness should be graded and documented.

Immediate priorities include:

- eye protection
- correlation with intraoperative monitoring
- assessment of nerve continuity

Delayed weakness may occur even after apparently intact nerve preservation.

The management depends upon clinical context.

26.42 VESTIBULAR CONSEQUENCES

The labyrinth has been intentionally sacrificed.

Postoperative imbalance is therefore expected.

The patient must undergo central vestibular compensation.

Early appropriate mobilisation and vestibular rehabilitation can be important.

COUNSELLING PRINCIPLE

Hearing loss is intentional. Imbalance is expected. Compensation is part of recovery.

26.43 POSTOPERATIVE HEARING REHABILITATION

Because hearing on the operated side is lost, rehabilitation options may include, depending upon contralateral hearing and patient factors:

- CROS/BiCROS strategies

- bone-conduction systems
- other hearing rehabilitation pathways

Single-sided hearing loss has consequences for:

- localisation
- hearing in noise
- spatial awareness

Device options are discussed in Chapter 18, Implantable Hearing Devices.

The postoperative plan should not end with tumour removal.

DECISION POINT

USEFUL HEARING EXISTS — SHOULD I STILL USE A TRANSLABYRINTHINE APPROACH?

Ask:

How useful is the hearing?

What is the probability of preserving it with another approach?

What is the tumour size and geometry?

What are the patient's priorities?

What additional risk does another corridor create?

The hearing-preservation alternatives are described in Chapter 25, Retrosigmoid Approach, and Chapter 27, Middle Cranial Fossa Approach.

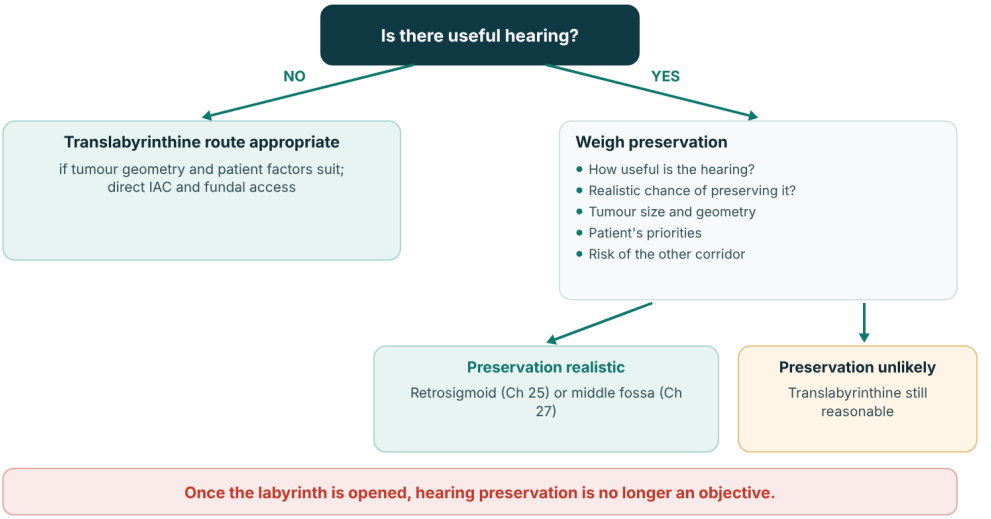
If the labyrinth is opened:

> **hearing preservation is no longer an objective.**

That decision should therefore be made before surgery, not discovered during it.

Figure 26.8 · Useful hearing exists — translabyrinthine or not?

The hearing decision is made before surgery, not discovered during it



FROM EXPERIENCE

The translabyrinthine approach demonstrates a central principle of skull-base surgery.

Sometimes the safest route to a deep structure requires sacrificing a function that has already been lost.

The labyrinth normally blocks direct access to the IAC.

If useful hearing is absent, that same labyrinth can become the corridor.

This is not “more aggressive surgery.”

It is anatomy used differently because the functional equation has changed.

> **What we preserve defines the operation.**

> **What we can afford to sacrifice defines the corridor.**

TAKE IT TO THE OT

Before a translabyrinthine approach, define:

HEARING

Is sacrifice acceptable?

TUMOUR

IAC + CPA geometry.

FACIAL NERVE

Baseline function and monitoring.

MASTOID

Pneumatisation.

SIGMOID SINUS

Position.

TEGMEN

Height.

JUGULAR BULB

High / dominant?

LABYRINTH

Normal anatomy?

IAC

Length, fundus, tumour extent.

AIR CELLS

Where are CSF pathways likely?

CLOSURE

How will the defect be sealed and obliterated?

HEARING REHABILITATION

What happens afterward?

CHAPTER SUMMARY

The translabyrinthine approach reaches the IAC and CPA through deliberate sacrifice of the labyrinth.

Use it when hearing preservation is not a meaningful objective and the temporal-bone corridor offers appropriate access.

Map the mastoid completely before entering the labyrinth.

Skeletonise and understand the three semicircular canals before removing them.

Protect the facial nerve throughout the approach.

Expose the IAC progressively.

Use the fundus to establish distal neural orientation.

Debulk tumour before applying traction to the facial nerve and brainstem.

Do not pursue adherent capsule at disproportionate neurological cost.

Treat closure as a major reconstructive phase.

And remember:

> **The translabyrinthine approach sacrifices hearing deliberately.**

> **That sacrifice is justified only when it buys a safer and more useful surgical corridor.**

FURTHER READING & REFERENCES

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CHAPTER 27

Middle Cranial Fossa Approach

Superior Access to the Internal Auditory Canal

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the anatomical logic and principal indications of the middle cranial fossa approach
- recognise its role in selected hearing-preservation surgery
- identify the superior surface landmarks of the petrous temporal bone
- understand different strategies for locating the internal auditory canal from above
- protect the temporal lobe, labyrinth and facial nerve during exposure
- understand the relationship of the greater superficial petrosal nerve, arcuate eminence and petrous ridge to the IAC
- expose the IAC progressively from a superior route
- understand tumour dissection principles for small intracanalicular lesions
- recognise major complications including hearing loss, facial nerve injury, temporal-lobe injury and CSF leak
- perform layered closure with attention to opened petrous air cells

27.1 THE MIDDLE FOSSA APPROACH REACHES THE IAC FROM ABOVE

The middle cranial fossa approach reaches the superior surface of the petrous temporal bone by elevating the temporal lobe and identifying the internal auditory canal from above.

Conceptually:

TEMPORAL BONE

↓

MIDDLE FOSSA DURA

↓

SUPERIOR PETROUS SURFACE

↓

INTERNAL AUDITORY CANAL

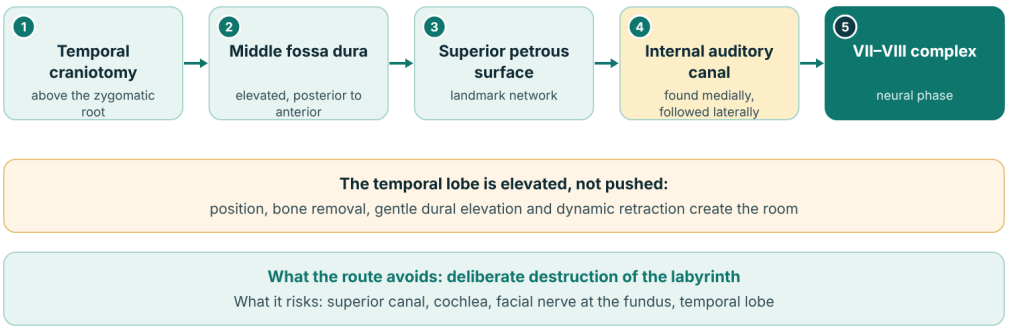
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FACIAL–VESTIBULOCOCHLEAR NERVE COMPLEX

It provides a hearing-preservation route that avoids deliberate destruction of the labyrinth.

Figure 27.1 · The middle fossa route

Reaching the IAC from above while the labyrinth stays intact



27.2 WHY USE THIS APPROACH?

The approach may be considered for selected lesions such as:

- small intracanalicular vestibular schwannoma
- selected lesions near the lateral IAC / fundus
- selected facial nerve pathology
- superior semicircular canal dehiscence repair

- tegmen defects, encephalocele and CSF leak repair
- other superior petrous lesions

Its use depends upon:

- hearing status
- tumour size
- tumour location
- anatomy
- age and patient factors
- surgeon experience

It is generally not the preferred corridor for tumours with a significant CPA component.

27.3 HEARING PRESERVATION IS CENTRAL TO THE LOGIC

The middle fossa route allows access to the IAC while preserving the labyrinth.

Therefore it is particularly relevant when:

USEFUL HEARING EXISTS

and

> **THE LESION'S ANATOMY MAKES HEARING PRESERVATION REALISTIC.**

PRINCIPLE

The approach exists because there is function worth preserving.

If hearing is already non-serviceable, another corridor may offer more direct access with less temporal-lobe manipulation.

The retrosigmoid and translabyrinthine alternatives are described in Chapter 25, Retrosigmoid Approach, and Chapter 26, Translabyrinthine Approach.

Figure 27.2 · Three routes to the internal auditory canal

A simplified comparison — tumour geometry, hearing and patient factors decide in each case

	Retrosigmoid	Translabyrinthine	Middle fossa
Hearing	can be preserved	sacrificed	can be preserved
Typical tumour	any size, incl. large CPA	any size	small, mainly intracanalicular
Lateral IAC / fundus	limited by the labyrinth	full access	full access
Brain handled	cerebellum	minimal retraction	temporal lobe
Facial nerve	often anterior, deep to tumour	found early at the fundus	superior — between surgeon and tumour
Chapter	25	26	27

27.4 PREOPERATIVE IMAGING

Review:

MRI

- intracanalicular tumour length
- fundal extension
- CPA component
- facial and cochlear nerve relationships where inferable
- other pathology

CT

- superior semicircular canal
- petrous ridge
- IAC
- tegmen
- pneumatisation
- geniculate region
- carotid canal
- anatomical variation

The superior petrous surface should be mentally mapped before surgery.

27.5 THE SUPERIOR PETROUS SURFACE

Important landmarks may include:

GREATER SUPERFICIAL PETROSAL NERVE

ARCUATE EMINENCE

PETROUS RIDGE

MIDDLE MENINGEAL ARTERY / FORAMEN SPINOSUM REGION (ANTERIOR LIMIT OF ELEVATION)

GENICULATE REGION

SUPERIOR SEMICIRCULAR CANAL

INTERNAL AUDITORY CANAL

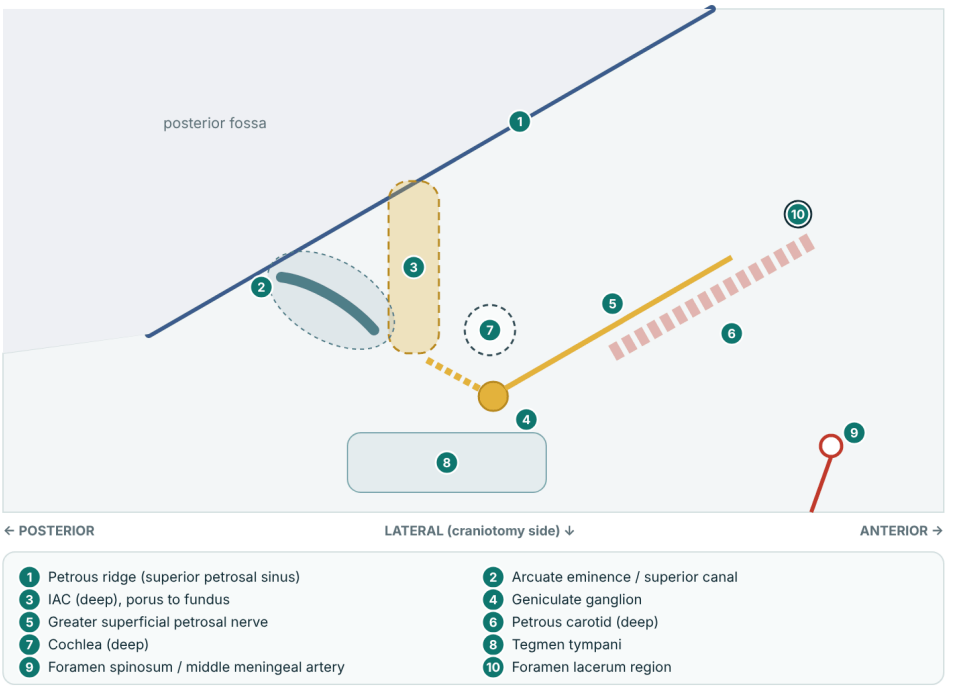
These landmarks are not equally visible in every patient.

PRINCIPLE

Use a network of relationships rather than depending on one surface landmark.

Figure 27.3 · The superior petrous surface

Right side, view from above: medial at the top, anterior to the right. Schematic; the IAC bisects the GSPN–arcuate eminence angle



27.6 POSITIONING

Position should allow:

- comfortable temporal craniotomy
- gravity-assisted temporal-lobe relaxation where possible
- stable head fixation
- direct microscope trajectory toward the superior petrous bone
- anaesthetic access

Avoid excessive neck rotation or extension.

The goal is to create a natural working angle toward the middle fossa floor.

27.7 TEMPORAL CRANIOTOMY

The craniotomy should provide sufficient access to:

- middle fossa floor

- petrous ridge
- superior petrous landmarks

A very small opening may force excessive temporal-lobe retraction.

Again:

> **BONE REMOVAL CAN BE SAFER THAN BRAIN RETRACTION.**

The exposure should match the target.

27.8 DURAL ELEVATION

The middle fossa dura is progressively elevated from the temporal bone.

Dissection should be controlled because important structures may remain attached to or immediately beneath the dura.

The surgeon should expect:

- dural adherence
- petrosal nerve anatomy
- vascular structures

Avoid forceful stripping.

Elevation is usually carried from posterior to anterior, because the geniculate ganglion may be dehiscent on the middle fossa floor and the GSPN can be lifted with the dura.

> **PRINCIPLE**
>
> **Elevate the dura as an anatomical layer—not as something merely blocking the bone.**

27.9 TEMPORAL LOBE PROTECTION

The temporal lobe should be handled with minimal pressure.

Use:

- appropriate positioning
- adequate craniotomy
- controlled dural elevation

- dynamic rather than excessive fixed retraction where possible

Potential injury can include:

- contusion
- oedema
- venous injury
- seizures

The approach should create room around the temporal lobe rather than asking the temporal lobe to tolerate the exposure.

27.10 GREATER SUPERFICIAL PETROSAL NERVE

The greater superficial petrosal nerve is an important superior petrous landmark.

It leaves the geniculate ganglion through the facial hiatus and runs anteromedially, roughly parallel to the petrous ridge, toward the foramen lacerum. The horizontal petrous carotid lies deep to it.

Its relationship may help orient:

- geniculate ganglion
- facial nerve
- petrous carotid
- IAC

However, unnecessary traction may produce facial nerve consequences through the geniculate region.

PRINCIPLE

A landmark is useful because it points somewhere. It does not need to be aggressively mobilised to prove its identity.

27.11 ARCUATE EMINENCE

The arcuate eminence may correspond approximately to the superior semicircular canal.

But its surface expression is variable and does not always perfectly represent the canal.

Therefore:

> **ARCUATE EMINENCE ≠ GUARANTEED EXACT CANAL LOCATION.**

Use:

- CT
- petrous ridge
- GSPN
- expected IAC geometry

together.

27.12 SUPERIOR SEMICIRCULAR CANAL

The superior semicircular canal is one of the critical structures limiting hearing-preservation drilling.

Before exposing the IAC, understand:

- canal axis
- ampullated end
- relationship to arcuate eminence
- relationship to IAC

PRINCIPLE

The IAC can be approached from above only while the labyrinth remains protected.

27.13 LOCATING THE IAC

Several landmark strategies have been described, for example:

- **House:** follow the GSPN back to the geniculate ganglion, then the labyrinthine segment to the IAC
- **Fisch:** blue-line the superior semicircular canal; the IAC lies at an angle of about 60° to its axis
- **García-Ibáñez:** the IAC lies along the bisector of the angle between the GSPN and the arcuate eminence, and is opened first medially near the porus

Conceptually, the IAC can be predicted using relationships between:

GSPN

SUPERIOR SEMICIRCULAR CANAL

PETROUS RIDGE

GENICULATE REGION

The exact technique varies.

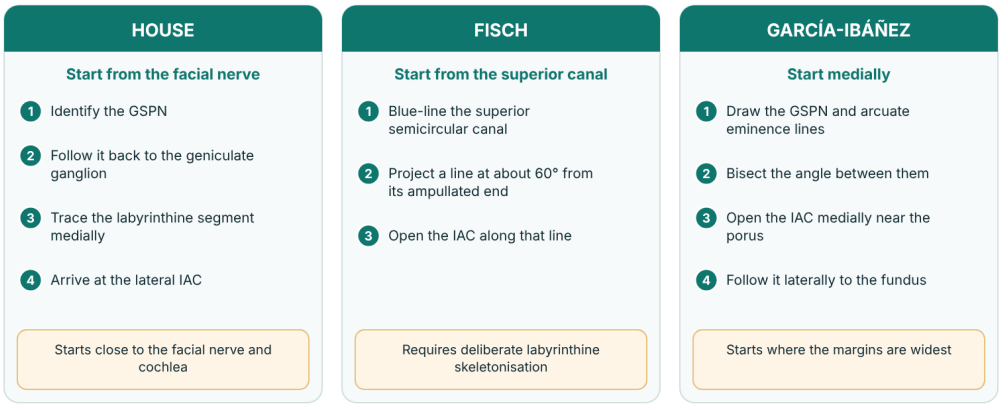
The important principle is:

> **DO NOT DRILL RANDOMLY INTO THE PETROUS APEX SEARCHING FOR THE CANAL.**

Predict the IAC trajectory first.

Figure 27.4 · Three ways of finding the IAC from above

Different starting points, one aim: predict the canal before drilling for it



Whatever the method: confirm with CT (and navigation where available); several landmarks agreeing beats any one.

27.14 THE IAC IS A LINE, NOT A POINT

The IAC extends from:

PORUS

medially

to

FUNDUS
laterally.

From above, understand:

- its long axis
- lateral relationship to labyrinth
- medial opening into posterior fossa
- anterior facial nerve / geniculate relationships

The drilling strategy should follow that line.

27.15 BEGIN WITH A SAFE REFERENCE REGION

Where appropriate, expose a region of IAC whose location is reliable from the chosen landmark system.

Then progressively follow:

MEDIAL ↔ LATERAL
according to operative objective.

Do not attempt to expose the fundus first if the lateral anatomy is uncertain.

PRINCIPLE

Find the canal where you are most certain, then follow it toward where you are less certain.

27.16 DRILLING THE IAC

General principles include:

- use controlled diamond drilling
- maintain irrigation
- thin bone progressively
- keep the labyrinth mentally mapped
- avoid heat transmission
- recognise petrous air cells
- reduce force near the fundus

The operation moves from broad superior petrous drilling toward increasingly fine neural exposure.

27.17 THE FUNDUS IS THE HIGH-RISK LATERAL END

The fundus lies close to:

- labyrinth
- facial nerve
- cochlear nerve
- geniculate region

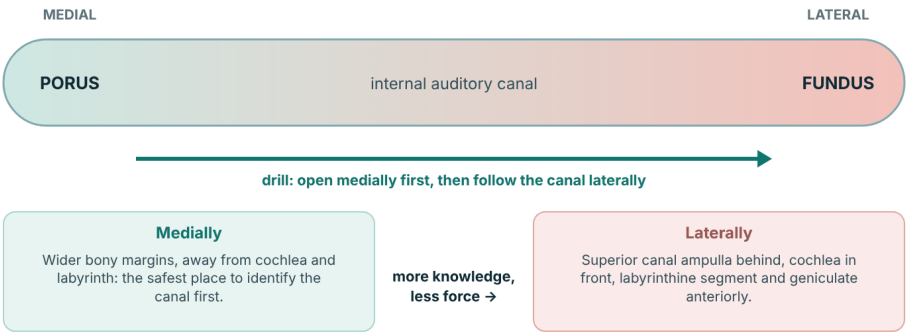
This is where hearing-preservation anatomy becomes least forgiving.

PRINCIPLE

The final millimetres toward the fundus require more knowledge and less force than the first millimetres over the IAC.

Figure 27.5 · From porus to fundus

Find the canal where you are most certain, then follow it toward where you are less certain



27.18 FACIAL NERVE RELATIONSHIP

From the superior perspective, the facial nerve occupies an important anterior-superior relationship within the IAC and continues toward the labyrinthine segment and geniculate ganglion.

Because it lies in the superior compartment, the facial nerve is usually the first nerve met from above. It often lies between the surgeon and a tumour arising from the inferior vestibular nerve.

The tumour may displace it.

Therefore:

EXPECT

but

CONFIRM

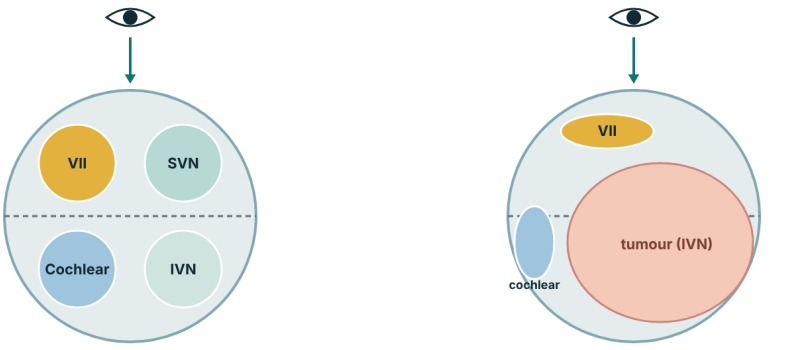
with:

- anatomy
- stimulation
- operative findings

before manipulating tumour near the nerve.

Figure 27.6 · The facial nerve from above

Schematic cross-section of the lateral IAC — superior up, anterior to the left



Normal: VII anterosuperior
the first nerve seen from above

Tumour from the inferior vestibular nerve
pushes VII up — into the surgeon's path

27.19 COCHLEAR NERVE

Hearing preservation depends upon protecting:

- cochlear nerve
- cochlear vascular supply
- labyrinth

- inner-ear fluids

The nerve may appear anatomically intact while hearing is lost through physiological injury.

Therefore minimise:

- traction
- heat
- vascular compromise
- manipulation near the cochlear division

27.20 DURAL OPENING OVER THE IAC

After adequate bony exposure, the IAC dura can be opened according to the lesion.

Before opening, know:

WHERE IS THE FACIAL NERVE LIKELY TO BE?

WHERE IS THE TUMOUR?

WHERE IS THE FUNDUS?

WHERE IS THE PORUS?

The bony phase should have created a complete neural map.

27.21 SMALL INTRACANALICULAR TUMOUR

For selected small vestibular schwannomas, the tumour may occupy predominantly the IAC.

The surgical objectives are:

IDENTIFY FACIAL NERVE

IDENTIFY COCHLEAR NERVE

DEFINE TUMOUR ORIGIN

REMOVE TUMOUR WITH MINIMAL NERVE TRACTION

The small tumour does not mean the operation is low risk.

The working space is also small.

27.22 THE TUMOUR AT THE FUNDUS

Fundal tumour requires particular care because of proximity to:

- facial nerve
- cochlear nerve
- labyrinthine structures

The advantage of the middle fossa approach is direct superior access to this region.

The price is that drilling occurs close to hearing-critical anatomy.

27.23 INTERNAL DEBULKING

Even relatively small tumours may benefit from controlled internal debulking if this reduces capsule tension.

The principle remains:

REDUCE THE TUMOUR
before

MOVING THE NERVES.
Avoid excessive capsule traction within the confined IAC.

27.24 FACIAL NERVE MONITORING

Continuous or intermittent facial nerve monitoring may help:

- identify the nerve
- map tumour–nerve relationship
- detect changes during manipulation

Use it in combination with anatomy.

PRINCIPLE

Monitoring gives functional information. It does not make a poor dissection plane safe.

27.25 AUDITORY MONITORING

When hearing preservation is attempted, auditory monitoring may provide information about neural function during surgery.

If meaningful deterioration occurs:

STOP

↓

RELEASE TRACTION

↓

REASSESS

↓

REVIEW THE LAST MANOEUVRE

The surgeon should be willing to alter behaviour in response to the signal.

27.26 VASCULAR PRESERVATION

Small vessels can be essential to:

- cochlear nerve
- inner ear
- facial nerve

Avoid unnecessary coagulation.

A vessel may look insignificant while supplying a function the operation is specifically trying to preserve.

27.27 AIR CELLS

Drilling the superior petrous bone may open air cells.

Potential pathways can communicate with:

- middle ear
- mastoid
- petrous apex

If opened:

IDENTIFY

SEAL

DOCUMENT

Unsealed air cells can contribute to postoperative CSF leak.

27.28 CSF LEAK

Potential pathways include:

IAC / INTRACRANIAL CSF

↓

PETROUS AIR CELLS

↓

MIDDLE EAR / MASTOID

↓

EUSTACHIAN TUBE OR WOUND.

Prevention requires:

- sealing cells
- secure dural closure where possible
- layered reconstruction

Again, closure begins during drilling.

27.29 TEMPORAL LOBE COMPLICATIONS

Potential complications include:

- contusion
- oedema
- venous infarction
- seizure
- neurological deficit

Prevention depends upon:

- adequate exposure
- gentle retraction
- preservation of veins
- minimising operative pressure and duration where possible

The brain should not pay the price for an exposure that was too small.

27.30 HEARING LOSS DESPITE ANATOMIC PRESERVATION

Hearing may be lost despite intact:

- cochlea
- cochlear nerve

because of:

- vascular injury
- nerve traction
- thermal damage
- labyrinthine injury
- inner-ear fluid disturbance

PRINCIPLE

Hearing preservation is physiological preservation, not merely structural preservation.

27.31 FACIAL WEAKNESS

Postoperative weakness may result from:

- direct injury
- traction
- thermal insult
- vascular compromise
- delayed neuropathy

Document:

- intraoperative nerve status

- monitoring
- postoperative grade

Protect the eye immediately when closure is inadequate.

27.32 CLOSURE

Closure should address:

IAC / DURAL DEFECT

OPENED AIR CELLS

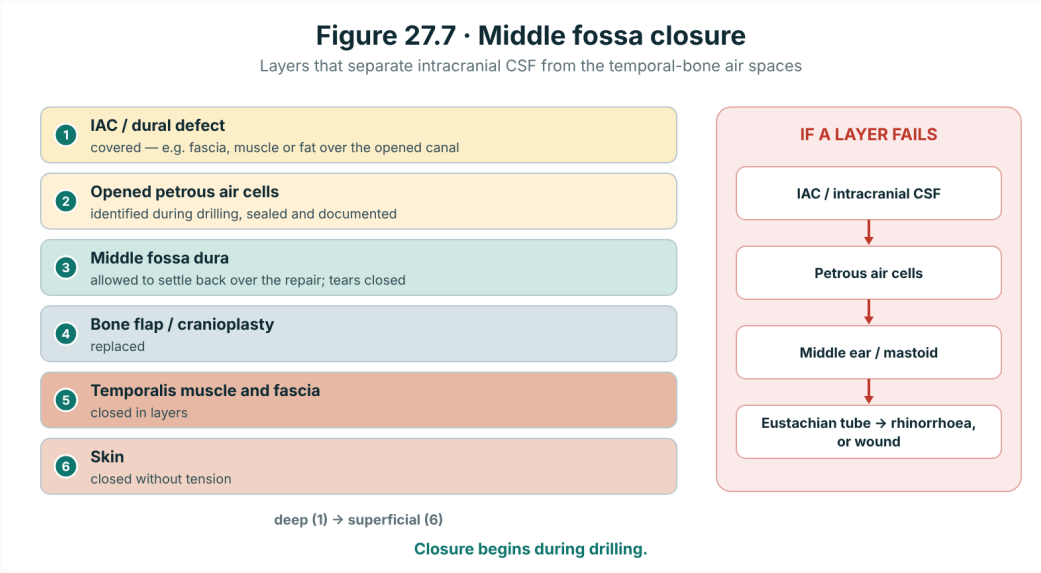
MIDDLE FOSSA DURA

BONE FLAP / CRANIOPLASTY

TEMPORALIS / FASCIA

SKIN

The reconstructed layers should separate intracranial CSF from temporal-bone air spaces.



27.33 HEARING OUTCOME

Postoperative hearing should be assessed functionally and reported with a standard system, such as the AAO-HNS hearing classes or the Gardner–Robertson scale.

Possible outcomes include:

- useful hearing preserved
- threshold deterioration
- speech discrimination decline
- complete hearing loss

Patients should understand that a hearing-preservation approach is an attempt to preserve hearing—not a guarantee.

DECISION POINT

I CANNOT LOCALISE THE IAC WITH CONFIDENCE

Do not drill deeper.

Ask:

Is the arcuate eminence reliable in this patient?

Can I identify the GSPN?

Where is the petrous ridge?

What does the preoperative CT show?

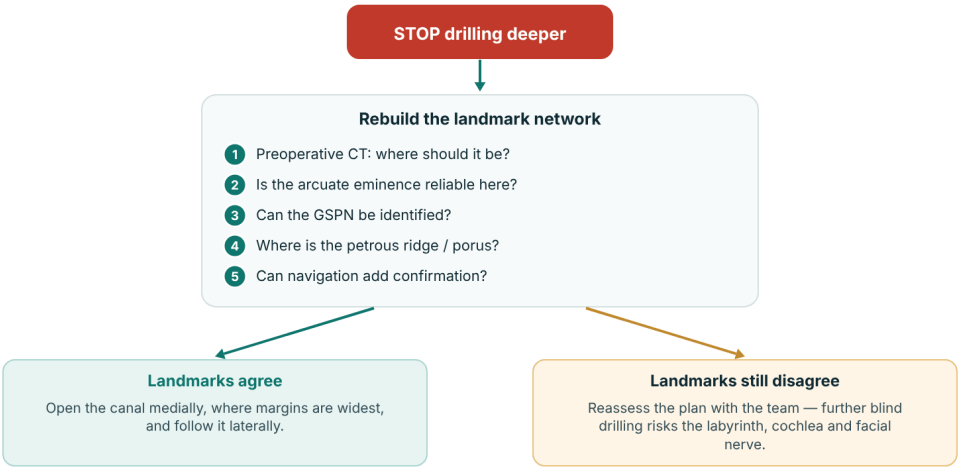
Can navigation add useful confirmation?

Then reconstruct the landmark network.

DO NOT TURN UNCERTAINTY INTO PETROUS BONE REMOVAL.

Figure 27.8 · When the IAC cannot be localised with confidence

Do not turn uncertainty into petrous bone removal



DECISION POINT

THE TUMOUR IS ADHERENT TO A FUNCTIONING COCHLEAR OR FACIAL NERVE

Ask:

How much tumour remains?

Can the plane be improved by further internal debulking?

What is monitoring showing?

What functional loss may result from complete removal?

Would a small residual be manageable with surveillance or other treatment?

The objective is not to prove complete excision at the cost of the function the approach was chosen to preserve.

FROM EXPERIENCE

The middle cranial fossa approach is a good example of why surgical anatomy must be learned in more than one direction.

From the mastoid, we learn the temporal bone from lateral to medial.

Here, we look down upon the same structures from above.

The facial nerve looks different.

The labyrinth looks different.

The IAC has a different axis.

Yet none of the anatomy has changed.

Only our viewpoint has.

That is important because mastery of anatomy is not recognising one familiar picture.

> **It is recognising the same structure from every direction from which surgery may approach it.**

TAKE IT TO THE OT

Before a middle cranial fossa approach, define:

INDICATION

HEARING STATUS

TUMOUR SIZE & FUNDAL EXTENT

SUPERIOR SEMICIRCULAR CANAL

GSPN

PETROUS RIDGE

IAC AXIS

FACIAL NERVE

COCHLEAR NERVE

TEMPORAL LOBE / VENOUS ANATOMY

AIR-CELL PNEUMATISATION

FACIAL & AUDITORY MONITORING

HEARING-PRESERVATION GOAL

CLOSURE / CSF-LEAK PLAN

CHAPTER SUMMARY

The middle cranial fossa approach reaches the IAC from above while preserving the labyrinth.

Use it selectively when hearing preservation matters and tumour geometry is appropriate.

Study the superior petrous surface on CT before surgery.

Use multiple landmarks to predict the IAC.

Do not rely exclusively on the arcuate eminence.

Protect the temporal lobe through positioning, adequate bone exposure and gentle dural elevation.

Drill the IAC progressively.

Treat the fundus as a high-risk hearing-preservation region.

Identify and monitor the facial and cochlear nerves.

Preserve small vascular structures.

Seal opened air cells.

And remember:

> **The temporal bone does not have one surgical view.**

> **True anatomical understanding begins when the same structure remains recognisable from another direction.**

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CHAPTER 28

Jugular Foramen & Paraganglioma Surgery

Vascular Control • Lower Cranial Nerves • Functional Preservation

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the surgical anatomy of the jugular bulb and jugular foramen
- recognise the clinical presentation and anatomical behaviour of temporal-bone paragangliomas
- distinguish limited middle-ear disease from extensive jugular-foramen/skull-base disease
- integrate CT, MRI and vascular imaging into operative planning
- understand the principles and limitations of preoperative embolisation
- plan proximal and distal vascular control before tumour manipulation
- understand the relationship of tumour to the facial nerve, internal carotid artery and lower cranial nerves
- balance extent of resection against neurological morbidity
- recognise when observation or radiotherapy may be preferable to surgery
- anticipate postoperative voice, swallowing, airway and shoulder rehabilitation needs

28.1 THE JUGULAR FORAMEN IS A FUNCTIONAL CROSSROAD

Within and around the jugular foramen lie:

JUGULAR BULB / VENOUS OUTFLOW

GLOSSOPHARYNGEAL NERVE

VAGUS NERVE

ACCESSORY NERVE

INTERNAL CAROTID ARTERY NEARBY

FACIAL NERVE LATERALLY

HYPOGLOSSAL NERVE MEDIALLY / INFERIORLY

Classically the foramen is described in two parts: an anteromedial pars nervosa (glossopharyngeal nerve, inferior petrosal sinus) and a posterolateral pars vascularis (jugular bulb, vagus and accessory nerves).

The lower cranial nerves run along the medial wall of the jugular bulb.

Disease in this region can therefore affect:

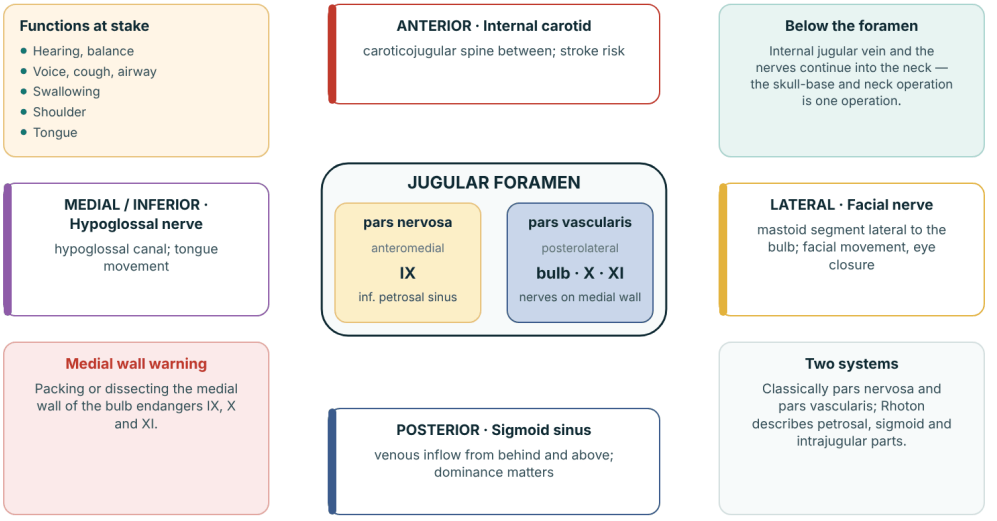
- hearing
- tinnitus
- voice
- swallowing
- airway protection
- shoulder function
- tongue function

PRINCIPLE

The surgical morbidity of a jugular-foramen lesion is determined by the functions packed around it.

Figure 28.1 · The jugular foramen as a functional crossroad

Relational diagram, not to scale: anterior up, medial to the left — morbidity is set by the functions around the foramen



28.2 PARAGANGLIOMA

Head and neck paragangliomas are highly vascular neuroendocrine tumours arising from paraganglionic tissue.

Within the temporal-bone region, clinically important patterns include lesions centred around:

MIDDLE EAR / PROMONTORY REGION

and

JUGULAR BULB / JUGULAR FORAMEN.

The tumour's centre of origin helps predict:

- vascular supply
- direction of spread
- cranial nerve involvement
- required surgical corridor

28.3 GLOMUS TYMPANICUM AND JUGULARE — THINK CENTRE OF ORIGIN

Traditional terminology remains clinically useful, but the surgeon should ask:

WHERE IS THE CENTRE OF THE LESION?

A small lesion centred on the promontory behaves very differently from a large tumour centred at the jugular bulb with:

- mastoid
- carotid
- intracranial
- neck extension.

PRINCIPLE

Name the tumour—but operate on its actual anatomy.

Figure 28.2 · Think centre of origin

The same tumour type, two very different operations

	TYMPANIC	JUGULAR
Centre	Promontory (tympanic plexus)	Jugular bulb / foramen
Early symptoms	Pulsatile tinnitus, conductive loss	Pulsatile tinnitus; later IX–XII deficits
Spread	Middle ear, mastoid	Infralabyrinthine bone, carotid, neck, intracranial
Key structures	Ossicles, facial nerve (tympanic)	Carotid, sigmoid–jugular system, lower nerves
Usual operation	Transcanal or retroauricular	Skull-base approach, e.g. infratemporal fossa type A

Name the tumour — but operate on its actual anatomy.

28.4 CLINICAL PRESENTATION

Possible symptoms include:

- pulsatile tinnitus
- conductive hearing loss

- ear fullness
- visible vascular middle-ear mass
- otorrhoea or bleeding in advanced disease
- hoarseness
- dysphagia
- aspiration
- shoulder weakness
- tongue weakness
- facial weakness in advanced disease

Pulsatile tinnitus should trigger consideration of a vascular process before biopsy or instrumentation.

28.5 DO NOT BIOPSY A VASCULAR MIDDLE-EAR MASS CASUALLY

A red or pulsatile middle-ear lesion may represent a highly vascular tumour.

Before biopsy:

DEFINE THE LESION.

Use appropriate imaging.

SAFETY PRINCIPLE

Do not create haemorrhage simply to obtain tissue from a lesion whose imaging diagnosis and vascular nature can be established first.

28.6 PREOPERATIVE CRANIAL NERVE EXAMINATION

Document:

CN VII

Facial movement.

CN VIII

Hearing and balance.

CN IX / X

Voice, palate, swallowing and aspiration symptoms.

CN XI

Shoulder elevation.

CN XII

Tongue movement.

Consider formal:

- laryngoscopy
- swallowing assessment
- audiology

where appropriate.

A pre-existing deficit changes both operative risk and postoperative adaptation.

28.7 A PRE-EXISTING PALSY CAN CHANGE THE FUNCTIONAL EQUATION

A patient with longstanding vagal dysfunction may already have partially compensated.

A patient with completely normal lower cranial nerve function may experience major new morbidity if those nerves are sacrificed.

Therefore the same tumour anatomy may produce a different treatment decision in two different patients.

> **PRINCIPLE**
>
> **What the tumour has already taken influences what surgery can afford to risk.**

28.8 CT

High-resolution CT helps define:

- temporal-bone erosion
- jugular foramen enlargement
- hypotympanic involvement
- mastoid extension
- carotid canal relationship

- facial canal
- inner ear
- skull-base destruction

Bone erosion patterns can help distinguish different skull-base lesions: irregular, "moth-eaten" erosion of the jugular foramen, including the caroticojugular spine, favours paraganglioma, whereas smooth, scalloped enlargement favours schwannoma.

28.9 MRI

MRI defines:

- soft-tissue extent
- intracranial extension
- neck extension
- dural relationship
- carotid relationship
- neural involvement

Flow-related features may reflect the vascular nature of the tumour, such as the "salt-and-pepper" pattern of flow voids seen in larger lesions.

CT and MRI should be interpreted together.

28.10 VASCULAR IMAGING

For larger vascular tumours, vascular imaging may help define:

- feeding vessels
- carotid involvement
- venous anatomy
- intracranial circulation
- collateral pathways

Angiography may also form part of embolisation planning where appropriate.

PRINCIPLE

Do not enter a major vascular skull-base tumour without understanding how it is supplied and how it drains.

28.11 CLASSIFICATION SYSTEMS

Several classification systems are used to describe temporal-bone paraganglioma extent, notably the Fisch classification (in its modified form) and the Glasscock–Jackson classification.

In broad terms, the modified Fisch classification describes:

- **Class A:** tumour confined to the middle ear cleft
- **Class B:** tympanomastoid tumour without erosion of the infralabyrinthine compartment
- **Class C:** erosion of the infralabyrinthine compartment and jugular foramen, subdivided C1–C4 by increasing involvement of the carotid canal
- **Class D:** intracranial extension, extradural (De) or intradural (Di)

They can help communicate:

- middle-ear disease
- mastoid involvement
- carotid canal involvement
- intracranial extension

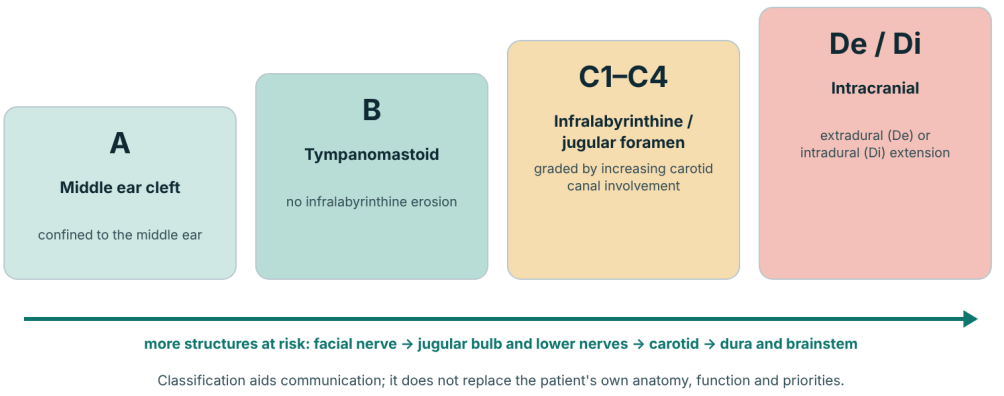
But classification should not replace direct anatomical planning.

Two lesions in the same category may still differ in:

- cranial nerve function
- vascular anatomy
- hearing
- age
- growth
- patient priorities

Figure 28.3 · The modified Fisch classification

Simplified — each step outward adds structures at risk and widens the operation



Classification aids communication; it does not replace the patient's own anatomy, function and priorities.

28.12 TREATMENT IS NOT AUTOMATICALLY SURGERY

Management options may include:

OBSERVATION

RADIOTHERAPY / STEREOTACTIC TREATMENT

SURGERY

COMBINED / STAGED STRATEGIES

Selection depends upon:

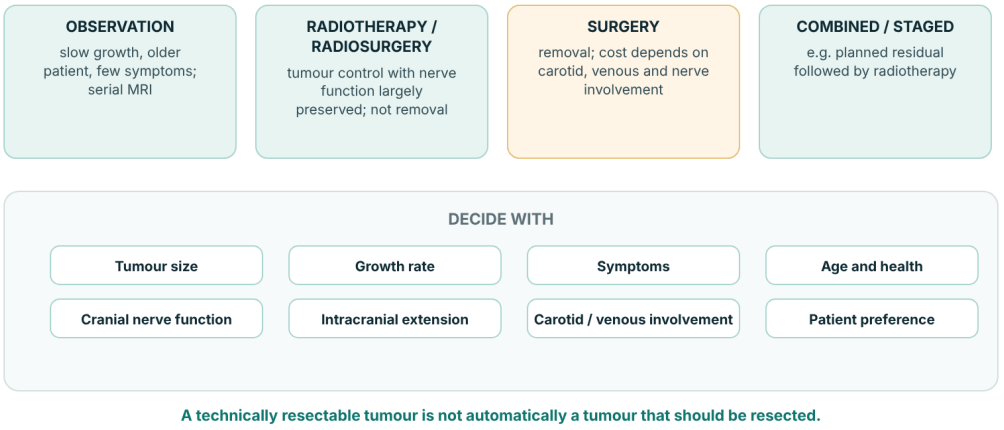
- tumour size
- growth
- symptoms
- age
- cranial nerve function
- intracranial extension
- vascular involvement
- patient preference

PRINCIPLE

A technically resectable tumour is not automatically a tumour that should be resected.

Figure 28.4 · Treatment is not automatically surgery

Options weighed against the patient's age, growth, function and priorities



A technically resectable tumour is not automatically a tumour that should be resected.

28.13 THE ELDERLY PATIENT WITH A SLOW-GROWING TUMOUR

For selected patients, the morbidity of major skull-base surgery may exceed the likely morbidity from the natural history of the tumour.

Observation or radiation may therefore provide a better balance.

Treatment should consider the patient's lifetime—not merely the tumour's existence.

28.14 PREOPERATIVE EMBOLISATION

Selected vascular paragangliomas may undergo preoperative embolisation to reduce tumour blood flow.

Potential benefits may include:

- reduced intraoperative bleeding
- improved visualisation
- easier dissection

But embolisation also carries risks, including:

- cranial nerve ischaemia
- stroke
- non-target embolisation
- vascular injury

It should be performed by experienced teams after detailed vascular assessment.

28.15 EMBOLISATION DOES NOT MAKE THE TUMOUR AVASCULAR

Even after embolisation:

EXPECT BLEEDING.

The surgeon still requires:

- exposure
- vascular control
- haemostatic strategy
- blood availability
- appropriate team support

PRINCIPLE

Embolisation reduces a vascular problem. It does not abolish the vascular anatomy.

28.16 OPERATIVE PLANNING BEGINS WITH CONTROL

Before tumour manipulation, ask:

WHERE IS PROXIMAL ARTERIAL CONTROL?

WHERE IS DISTAL / ALTERNATIVE CONTROL?

HOW WILL THE SIGMOID–JUGULAR SYSTEM BE MANAGED?

WHERE IS THE INTERNAL CAROTID?

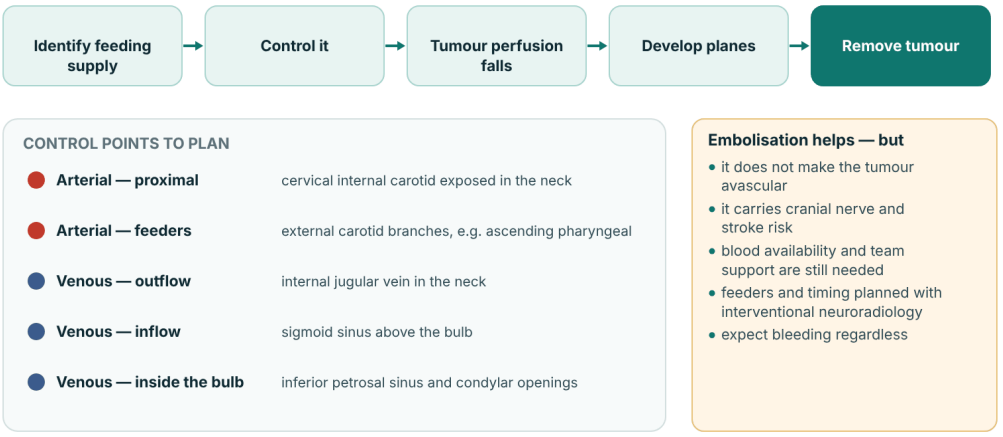
WHAT BLOOD LOSS CAN THE PATIENT TOLERATE?

The operation should not begin with tumour removal.

It should begin with the ability to control what may bleed.

Figure 28.5 · Control before tumour

Plan where each vessel can be controlled before the most vascular part of the lesion is entered



Chasing bleeding from the tumour surface is the alternative — and the worse one.

28.17 NECK EXPOSURE

For extensive jugular-foramen tumours, cervical exposure may provide access to:

- internal jugular vein
- internal carotid artery
- external carotid artery and branches
- lower cranial nerves
- tumour extension into the neck

This connects the temporal-bone operation with upper-neck anatomy.

28.18 IDENTIFY THE LOWER CRANIAL NERVES

Where possible, identify:

- glossopharyngeal
- vagus
- accessory
- hypoglossal

nerves in relatively less distorted anatomy before following them toward the tumour.

REVISION-LIKE PRINCIPLE

Move from known nerve toward tumour-distorted nerve—not from tumour into an unknown nerve.

28.19 INTERNAL JUGULAR VEIN

The internal jugular vein may be:

- compressed
- invaded
- incorporated into tumour
- part of the operative venous-control strategy

Before sacrifice, understand:

- contralateral venous drainage
- sigmoid sinus dominance
- intracranial venous anatomy

A large vein should not be sacrificed merely because it can be ligated technically.

28.20 SIGMOID SINUS

The sigmoid sinus descends into the jugular bulb and may be intimately related to tumour.

Management depends upon:

- tumour extent
- venous dominance

- collateral drainage
- intracranial extension

If planned occlusion or sacrifice is contemplated, preoperative venous assessment becomes important.

28.21 JUGULAR BULB

The jugular bulb is often central to the operative field.

Control of venous bleeding requires understanding of:

- sigmoid inflow
- jugular outflow
- inferior petrosal sinus
- emissary channels

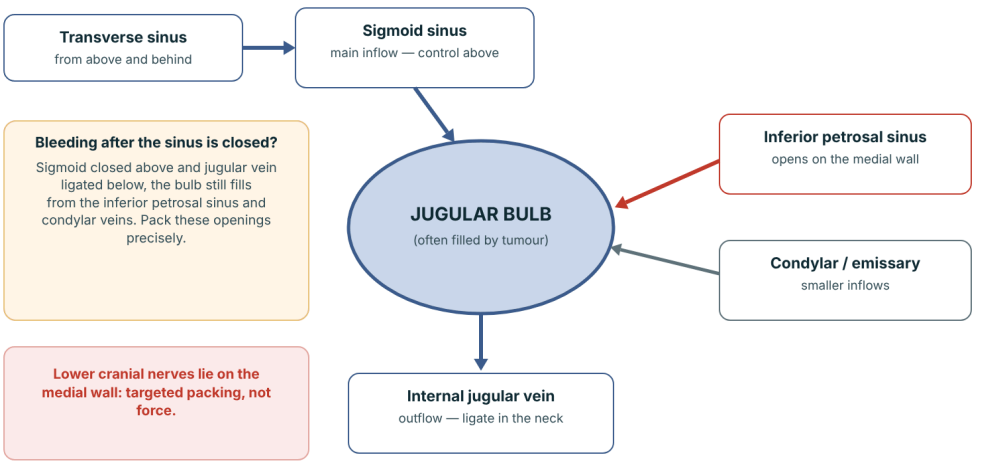
PRINCIPLE

Venous bleeding is controlled by understanding where blood is coming from—not by packing blindly into the skull base.

Aggressive packing or dissection on the medial wall of the bulb, where the inferior petrosal sinus opens and the lower cranial nerves lie, risks those nerves.

Figure 28.6 · Venous inflow and outflow at the jugular bulb

Flow diagram, not anatomy — know where blood comes from before packing



28.22 INFERIOR PETROSAL SINUS

Bleeding from the inferior petrosal sinus region can be persistent.

Control may require:

- targeted packing
- haemostatic material
- patience
- avoidance of unnecessary deep blind instrumentation

This region lies close to important neural and vascular structures.

28.23 INTERNAL CAROTID ARTERY

Advanced tumours may:

- contact
- displace
- encase
- invade

the petrous or cervical carotid.

The distinction is critical.

Assess with appropriate imaging before surgery.

QUESTION:

Can the tumour be separated safely from the carotid?

If not:

Can the artery be reconstructed or sacrificed safely?

These decisions require specialised vascular/skull-base planning.

28.24 CAROTID SACRIFICE IS NOT AN INTRAOPERATIVE IMPROVISATION

If arterial sacrifice is a possibility, planning may require:

- collateral circulation assessment

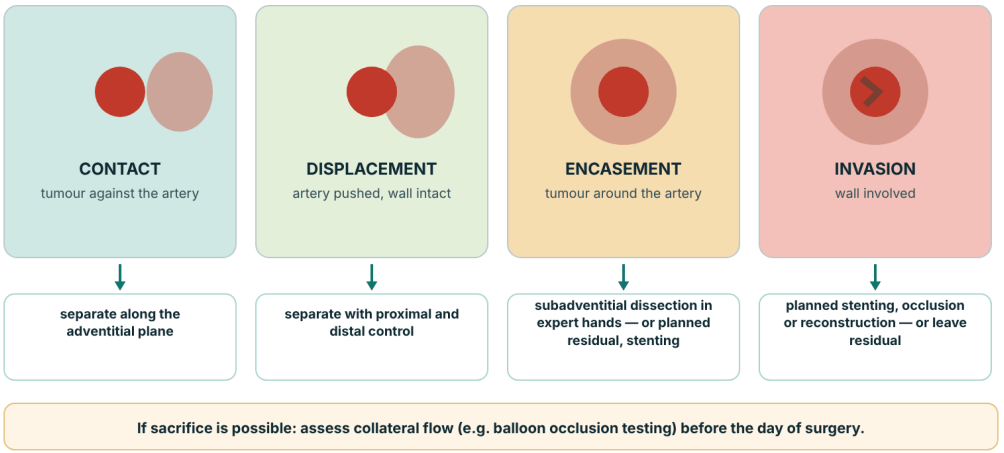
- balloon occlusion testing in selected settings
- endovascular stenting, or permanent balloon occlusion, in selected centres
- bypass/reconstruction considerations
- vascular or neurosurgical expertise

PRINCIPLE

The time to discover that the carotid cannot be sacrificed is before the carotid is injured.

Figure 28.7 · The tumour and the carotid

The distinction between contact and invasion is made on imaging — before surgery



28.25 FACIAL NERVE

The facial nerve may obstruct access to portions of extensive jugular-foramen disease.

Depending upon tumour extent and surgical approach, strategies may involve:

- preservation in situ
- skeletonisation
- mobilisation / rerouting in selected approaches
- sacrifice and reconstruction when directly invaded

Every additional manipulation has functional cost.

Facial nerve repair and reanimation are covered in Chapter 21, Facial Nerve Surgery in the Temporal Bone, and Chapter 22, Facial Reanimation & Functional Rehabilitation.

28.26 FACIAL NERVE REROUTING

Facial nerve rerouting can increase surgical access, for example permanent anterior rerouting in the Fisch infratemporal fossa type A approach.

But it may cause:

- neuropraxia
- ischaemic injury
- postoperative weakness

Therefore it should be performed only when the increased exposure meaningfully serves the operation.

> **PRINCIPLE**
>
> **Do not move a functioning nerve merely because moving it makes the anatomy look easier.**

28.27 PRESERVE THE NERVE'S BLOOD SUPPLY

During skeletonisation or mobilisation:

- minimise stripping
- avoid excessive traction
- preserve vascular supply where possible
- limit thermal injury

A nerve may remain continuous yet lose function because its biological support has been compromised.

28.28 TEMPORAL-BONE EXPOSURE

Depending upon disease extent, the operation may involve:

- mastoidectomy
- hypotympanic exposure
- infralabyrinthine / retrofacial corridors
- facial nerve exposure
- jugular bulb exposure

- carotid exposure

The exact bone removal should follow the tumour map.

Not every paraganglioma requires the same skull-base exposure.

For extensive class C tumours, the infratemporal fossa type A approach remains the classical route.

28.29 SMALL TYMPANIC PARAGANGLIOMA

A limited middle-ear lesion may require a far smaller operation.

The goals are:

- complete exposure
- early vascular control where possible
- careful separation from ossicles and middle-ear structures
- preservation of hearing when feasible

Do not apply a major jugular-foramen operation to disease that remains confined to the middle ear.

28.30 CONTROL THE FEEDER BEFORE THE TUMOUR WHEN POSSIBLE

A vascular tumour becomes easier to manipulate after its blood supply has been progressively controlled.

Conceptually:

IDENTIFY FEEDING SUPPLY

↓

CONTROL

↓

DECREASE TUMOUR PERFUSION

↓

DEVELOP PLANES

↓

REMOVE TUMOUR

This is preferable to repeatedly chasing bleeding from the tumour surface.

28.31 DEBULKING VERSUS EN BLOC REMOVAL

The surgical strategy depends upon:

- tumour extent
- vascularity
- neural relationships
- approach

In some situations, controlled debulking can improve visualisation.

In others, maintaining a tumour plane facilitates removal.

The technique should not violate major vessels or nerves merely to satisfy an en bloc concept.

28.32 LOWER CRANIAL NERVE INVOLVEMENT

The tumour may:

- displace
- stretch
- encase
- invade

CN IX, X and XI.

Attempting to peel tumour completely from functioning nerves can create significant morbidity.

The decision regarding extent of resection must consider:

CURRENT FUNCTION

DEGREE OF INVOLVEMENT

TUMOUR BIOLOGY

ALTERNATIVE TREATMENT.

28.33 THE COST OF VAGAL INJURY

Vagal dysfunction may produce:

- vocal fold paralysis
- dysphonia
- weak cough
- aspiration
- swallowing difficulty

These can affect:

- nutrition
- pulmonary health
- quality of life

Therefore “cranial nerve preserved” should be assessed functionally.

28.34 GLOSSOPHARYNGEAL DYSFUNCTION

CN IX dysfunction may contribute to:

- swallowing impairment
- sensory loss
- altered pharyngeal function

Combined IX and X deficits can produce substantial dysphagia.

The rehabilitation plan should be anticipated before surgery.

28.35 ACCESSORY NERVE

CN XI injury may cause:

- shoulder droop
- pain
- impaired abduction
- reduced quality of life

Preserve the nerve where oncologically and technically possible.

Postoperative physiotherapy may be important when function is affected.

28.36 HYPOGLOSSAL NERVE

Large inferior tumours may involve or approach CN XII.

Injury may produce:

- tongue weakness
- dysarthria
- swallowing difficulty

Document tongue function before and after surgery.

28.37 INTRACRANIAL EXTENSION

Tumours extending intracranially may require:

- combined otologic–neurosurgical exposure
- dural management
- posterior-fossa tumour dissection
- brainstem / cranial nerve protection

The extracranial and intracranial components should be understood as one continuous lesion.

28.38 DURAL INVOLVEMENT

Define:

DURAL CONTACT

DURAL ADHERENCE

DURAL INVASION

INTRADURAL EXTENSION

The reconstructive requirement changes as these boundaries are crossed.

A large skull-base defect may require vascularised tissue and layered CSF-leak prevention.

28.39 EXTENT OF RESECTION

Possible strategies include:

GROSS TOTAL

NEAR-TOTAL

SUBTOTAL

In selected patients, leaving tumour densely adherent to functioning lower cranial nerves or major vessels may provide a better functional outcome, with surveillance or radiotherapy used for residual disease.

PRINCIPLE

Complete removal is valuable only while the cost of completeness remains acceptable.

28.40 PLANNED RESIDUAL DISEASE

If residual tumour is intentionally left:

Document:

- location
- structure involved
- reason for preservation
- expected surveillance
- possible future radiotherapy

As in vestibular schwannoma:

> **INTENTIONAL RESIDUAL IS A STRATEGY ONLY WHEN THE NEXT STEP IS ALSO PLANNED.**

28.41 RECONSTRUCTION

Large jugular-foramen resections may leave:

- temporal-bone cavity
- dural defect
- exposed carotid
- exposed lower cranial nerves
- dead space
- communication with middle ear

Reconstruction may require:

- fat
- muscle
- fascial tissue
- regional flap
- free tissue transfer

depending upon defect magnitude (see Chapter 31, Skull Base Reconstruction after Temporal Bone Resection).

The reconstruction should:

SEPARATE

COVER

OBLITERATE DEAD SPACE

PROTECT VESSELS

PREVENT CSF LEAK.

28.42 POSTOPERATIVE AIRWAY

Lower cranial nerve dysfunction can create:

- aspiration
- weak cough

- airway protection problems

Selected patients may require:

- prolonged airway monitoring
- temporary tracheostomy
- intensive care

This should be anticipated preoperatively in high-risk cases.

28.43 SWALLOWING

Before oral feeding after major lower cranial nerve surgery:

ASSESS SWALLOWING.

Do not assume the absence of obvious choking means swallowing is safe.

Formal evaluation may be required.

Nutrition planning should be proactive.

28.44 VOICE REHABILITATION

Vagal injury causing vocal fold paralysis may require:

- voice therapy
- injection augmentation
- framework surgery
- other rehabilitative strategies

Timing depends upon:

- expected nerve recovery
- aspiration
- voice needs

Voice rehabilitation is part of the skull-base treatment pathway. Laryngeal procedures are covered in Book 4 of this series, *Dura to Pleura*.

28.45 SHOULDER REHABILITATION

Accessory nerve dysfunction may require:

- physiotherapy
- pain management
- shoulder stabilisation strategies

A tumour successfully removed from the skull base can still leave major disability if functional rehabilitation is ignored.

Figure 28.8 · The functional cost of each lower cranial nerve

Deficits to document before surgery — and the rehabilitation to plan for afterwards

Nerve	Deficit	Rehabilitation to plan
IX	Pharyngeal sensation and swallowing impairment	Swallowing therapy; nutrition plan
X	Vocal fold paralysis, weak cough, aspiration, dysphagia	Airway monitoring, swallow assessment, voice therapy, injection or framework surgery
IX + X	Combined: substantial dysphagia, silent aspiration	Formal swallow study before oral intake; temporary non-oral feeding; tracheostomy in selected cases
XI	Shoulder droop, pain, weak abduction	Physiotherapy, pain management, shoulder stabilisation
XII	Tongue weakness, dysarthria, bolus control	Speech and swallowing therapy

A patient with a longstanding palsy may have compensated; a patient with normal nerves has everything to lose.

DECISION POINT

SHOULD THIS PARAGANGLIOMA BE REMOVED COMPLETELY?

Ask:

How old is the patient?

How fast is the tumour growing?

What symptoms is it causing?

What cranial nerve function is still intact?

Is the carotid safely separable?

Is venous sacrifice acceptable?

What neurological deficit would complete removal create?

Could residual tumour be observed or treated with radiotherapy?

Then compare:

BIOLOGICAL COST OF LEAVING TUMOUR

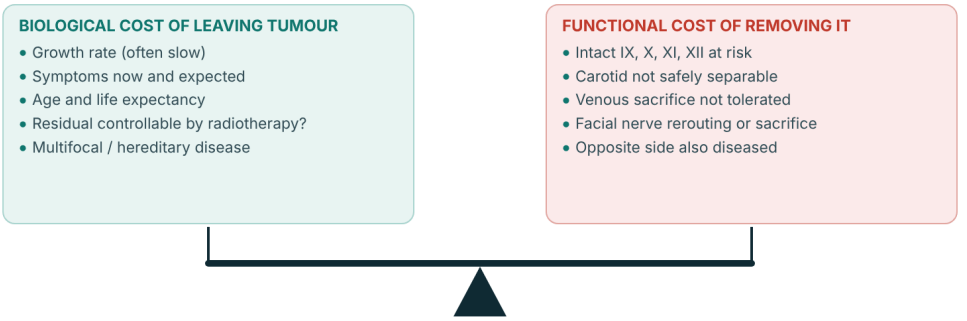
with

FUNCTIONAL COST OF REMOVING IT.

The technically most complete operation is not automatically the most appropriate treatment.

Figure 28.9 · Should this paraganglioma be removed completely?

Compare the biological cost of leaving tumour with the functional cost of removing it



When the functional cost outweighs the gain, the operation becomes function-preserving rather than tumour-pursuing.

28.46 WHEN SURGERY SHOULD BECOME FUNCTION-PRESERVING RATHER THAN TUMOUR-PURSUING

The operative goal may need to change when:

- the final tumour plane is inseparable from a functioning lower cranial nerve
- carotid manipulation creates unacceptable vascular risk
- venous sacrifice would create disproportionate neurological risk
- brainstem or dural adherence increases morbidity
- the remaining tumour can be controlled safely through another modality

At this point, the question changes from:

CAN I REMOVE MORE?

to:

WHAT WILL THE PATIENT LOSE IF I DO?

That shift is not retreat.

It is surgical judgment.

28.47 POSTOPERATIVE CRANIAL NERVE MAP

After surgery, assess deliberately:

VII

Facial movement.

VIII

Hearing and balance as relevant.

IX / X

Voice, cough and swallowing.

XI

Shoulder movement.

XII

Tongue movement.

Do not wait for symptoms to reveal a deficit that should have been examined directly.

28.48 ASPIRATION RISK

A patient with lower cranial nerve dysfunction may aspirate silently.

Warning signs may include:

- wet voice
- weak cough
- recurrent chest symptoms
- prolonged swallowing
- weight loss

Formal swallowing assessment should be used when clinically indicated.

28.49 NUTRITIONAL STRATEGY

If swallowing is unsafe:

> **DO NOT FORCE EARLY ORAL FEEDING.**

Consider appropriate temporary or longer-term nutritional support according to:

- expected recovery
- aspiration risk
- nutritional status
- rehabilitation plan

The feeding route should protect recovery rather than simply shorten hospital stay.

28.50 FUNCTIONAL REHABILITATION IS PART OF THE OPERATION

A major jugular-foramen procedure may require coordinated input from:

- speech and swallowing therapy
- laryngology
- physiotherapy
- nutrition
- audiology
- facial rehabilitation
- rehabilitation medicine

The operation may end in the theatre.

The functional treatment does not.

28.51 SURVEILLANCE

Postoperative surveillance may involve:

- clinical cranial nerve assessment
- MRI

- audiology where relevant
- endocrine/genetic review where appropriate for specific paraganglioma syndromes
- assessment of residual tumour

The follow-up plan should reflect:

- extent of resection
- tumour biology
- residual disease
- age
- hereditary considerations where relevant

28.52 BILATERAL OR MULTIFOCAL PARAGANGLIOMA

Some patients may have:

- bilateral disease
- multicentric head and neck paragangliomas
- hereditary predisposition

This changes treatment philosophy substantially.

Sacrificing lower cranial nerve function on one side may have very different consequences if the opposite side is also diseased.

> **PRINCIPLE**
>
> **Treat the patient's entire neurovascular system—not one tumour in isolation.**

28.53 GENETIC CONSIDERATIONS

Selected paragangliomas may be associated with hereditary syndromes.

Depending upon:

- age
- family history
- multifocal disease
- tumour characteristics

genetic evaluation may be appropriate.

This can influence:

- surveillance
- family counselling
- screening for additional tumours
- long-term treatment strategy

Contemporary guidance, such as the Endocrine Society guideline, recommends considering genetic testing in all patients with paraganglioma, including testing for succinate dehydrogenase (SDHx) gene mutations.

28.54 FUNCTIONAL PARAGANGLIOMA

Some paragangliomas may demonstrate catecholamine secretion.

Secretory activity is uncommon in head and neck paragangliomas but should be excluded, typically with plasma free or urinary fractionated metanephrines (including 3-methoxytyramine, as head and neck paragangliomas may secrete dopamine), before invasive treatment.

A functional tumour requires preoperative alpha-adrenergic blockade, with beta-blockade added only after adequate alpha-blockade.

An unrecognised functional tumour can create substantial perioperative haemodynamic risk.

PRINCIPLE

Before treating a paraganglioma as only an anatomical tumour, know whether it is also a physiological tumour.

28.55 MULTIDISCIPLINARY PLANNING

Major jugular-foramen surgery may require collaboration among:

- neurotology
- skull-base surgery
- neurosurgery
- head and neck surgery
- interventional neuroradiology
- vascular surgery

- anaesthesia
- speech/swallow rehabilitation
- radiation oncology

The larger the tumour, the less useful the idea of a single-surgeon operation becomes.

FROM EXPERIENCE

Jugular-foramen surgery initially appears to be a problem of bleeding.

And bleeding is important.

But with experience, the more difficult question often becomes function.

The vessel can sometimes be controlled.

The tumour can sometimes be separated.

But the vagus nerve may be working perfectly before surgery.

The patient may swallow normally.

The voice may be normal.

The shoulder may be strong.

At that point, every additional millimetre of tumour removal carries a functional price.

That changes the meaning of complete resection.

A CLEAN SCAN IS VALUABLE.

> **A functioning patient is more valuable.**

The best operation tries to preserve both.

When it cannot, the trade-off should be understood before the nerve is sacrificed—not after.

TAKE IT TO THE OT

Before jugular-foramen or paraganglioma surgery, define:

CENTRE OF TUMOUR

Middle ear? Jugular bulb? Skull base? Neck?

CRANIAL NERVE FUNCTION

VII / VIII / IX / X / XI / XII.

HEARING

Useful?

VOICE

Vocal fold mobility?

SWALLOWING

Safe?

CT

Bone and carotid canal.

MRI

Soft tissue and intracranial extension.

VASCULAR IMAGING

Feeders, carotid, sigmoid–jugular anatomy.

EMBOLISATION

Useful and appropriate?

PROXIMAL / DISTAL VASCULAR CONTROL

Where?

FACIAL NERVE

Preserve in situ, mobilise or reconstruct?

CAROTID

Displaced, encased or invaded?

LOWER CRANIAL NERVES

Displaced, encased or already non-functional?

RESECTION GOAL

Total, near-total or planned residual?

RECONSTRUCTION

How will vessels, dura and dead space be protected?

AIRWAY / SWALLOWING / VOICE

What is the postoperative rehabilitation plan?

CHAPTER SUMMARY

Jugular-foramen and temporal-bone paraganglioma surgery combines vascular, neural and skull-base surgery.

Define the tumour's centre of origin and actual anatomical extent.

Do not biopsy a vascular middle-ear mass casually.

Document lower cranial nerve function before treatment.

Use CT, MRI and vascular imaging together.

Understand arterial supply and venous drainage before tumour manipulation.

Use embolisation selectively and recognise its limitations.

Obtain vascular control before entering the most vascular portion of the lesion.

Preserve facial and lower cranial nerves when safely possible.

Do not sacrifice carotid or major venous outflow without preoperative planning.

Balance complete tumour removal against the functional cost of cranial nerve injury.

Plan voice, swallowing, airway and shoulder rehabilitation before surgery.

And remember:

> **At the jugular foramen, the tumour is only one part of the problem.**

> **The function surrounding it is the other.**

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CHAPTER 29

Petrous Apex & Petrosectomy Approaches

Choose the Corridor Around the Cochlea, Labyrinth, IAC & Carotid

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand the three-dimensional anatomy of the petrous apex
- classify petrous-apex lesions according to their relationship to the cochlea, labyrinth, IAC, carotid and dura
- distinguish drainage procedures from ablative skull-base resections
- understand the principles of infralabyrinthine, infracochlear and anterior petrosectomy corridors
- understand the functional cost of transcochlear and extended petrous approaches
- recognise the petrous internal carotid artery as a major limiting structure
- select hearing-preserving versus hearing-sacrificing corridors appropriately
- plan reconstruction and CSF-leak prevention
- avoid choosing an approach by name before defining the lesion geometry

29.1 THE PETROUS APEX IS DEEP BECAUSE IMPORTANT STRUCTURES SURROUND IT

The petrous apex lies anteromedial to the otic capsule.

Its neighbours include:

COCHLEA

LABYRINTH

INTERNAL AUDITORY CANAL

PETROUS INTERNAL CAROTID ARTERY

MIDDLE & POSTERIOR FOSSA DURA

EUSTACHIAN-TUBE REGION

CRANIAL NERVES

The difficulty of petrous-apex surgery is therefore not simply depth.

It is that nearly every possible route is limited by a function or major vessel.

> PRINCIPLE
> **Petrous-apex surgery is corridor selection more than bone removal.**

29.2 DO NOT BEGIN WITH THE APPROACH NAME

Do not start with:

Infracochlear?

Infralabyrinthine?

Kawase?

Transcochlear?

Start with:

WHERE IS THE LESION?

WHAT FUNCTION MUST BE PRESERVED?

WHICH STRUCTURE BLOCKS THE SHORTEST ROUTE?

Then the approach becomes obvious more often than expected.

29.3 THE FOUR-STRUCTURE MAP

A useful way to conceptualise the petrous apex is by four major structures:

COCHLEA — LATERAL / ANTEROLATERAL FUNCTIONAL LIMIT

LABYRINTH — POSTEROLATERAL FUNCTIONAL LIMIT

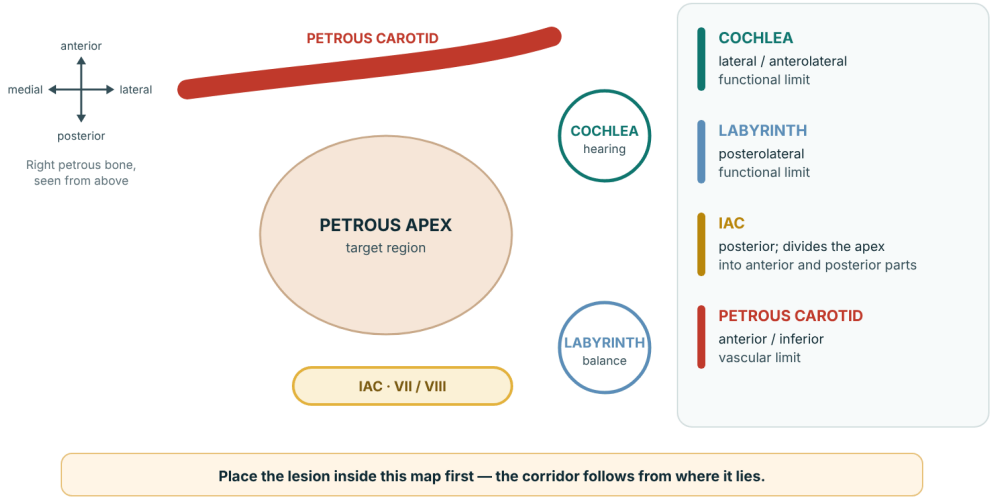
IAC — POSTERIOR NEURAL LIMIT, DIVIDING THE APEX INTO ANTERIOR AND POSTERIOR PARTS

CAROTID — ANTERIOR / INFERIOR VASCULAR LIMIT

The lesion lies somewhere within or around this framework.

Figure 29.1 · The four-structure map of the petrous apex

Conceptual map, not to scale — every corridor to the apex passes between these four structures



Place the lesion inside this map first — the corridor follows from where it lies.

29.4 DIAGNOSIS CHANGES THE OPERATION

Petrous-apex pathology may include:

- cholesterol granuloma
- cholesteatoma
- infection
- mucoceles
- cystic lesions
- benign tumours
- malignant tumours
- skull-base extension from adjacent disease

The objective may therefore be:

DRAIN

EXTERIORISE

BIOPSY

DECOMPRESS

RESECT

OBSERVE

Do not perform an ablative petrosectomy for a lesion that only requires durable drainage.

29.5 CHOLESTEROL GRANULOMA — DRAINAGE PRINCIPLE

A cholesterol granuloma often represents a trapped expansile cystic process.

In selected cases, the objective may be:

> **CREATE A DURABLE DRAINAGE PATHWAY**

rather than

> **REMOVE EVERY MILLIMETRE OF CYST WALL.**

The best corridor is one that reaches the lesion safely and remains functionally useful over time.

29.6 CHOLESTEATOMA — DIFFERENT BIOLOGY

Petrous-apex cholesteatoma is epithelial disease.

Unlike simple cyst drainage, management generally requires attention to:

- matrix
- hidden extensions
- facial nerve
- labyrinth
- IAC
- carotid

- dura

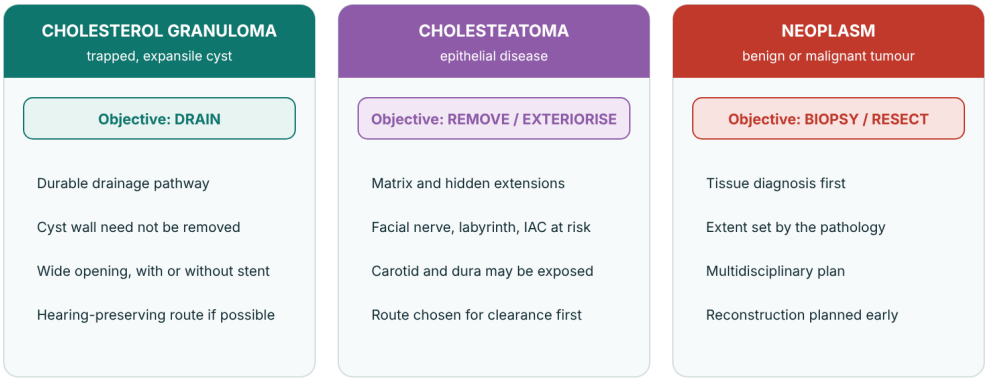
The surgical objective is disease control rather than simple decompression.

PRINCIPLE

Two lesions in the same location may require completely different operations because their biology is different.

Figure 29.2 · Same location, different biology, different operation

The diagnosis sets the objective; the objective sets the extent of surgery



Do not perform an ablative petrosectomy for a lesion that only needs durable drainage.

29.7 PREOPERATIVE IMAGING

Use:

HIGH-RESOLUTION CT

for:

- bone anatomy
- petrous pneumatisation
- cochlea
- labyrinth
- carotid canal
- IAC
- bony erosion

MRI

for:

- lesion characterisation
- soft tissue
- neural relationships
- dura
- diffusion characteristics where appropriate

VASCULAR IMAGING

when carotid involvement or major vascular displacement is suspected.

29.8 READ THE LESION RELATIVE TO THE CORRIDORS

Ask:

BELOW THE LABYRINTH?

Could an infralabyrinthine route reach it?

BELOW THE COCHLEA?

Could an infracochlear route reach it?

ABOVE / ANTERIOR TO THE IAC?

Could a middle-fossa/anterior petrosectomy route be appropriate?

BEHIND THE COCHLEA WITH NON-SERVICEABLE HEARING?

Would a hearing-sacrificing corridor provide safer access?

This is more useful than memorising approach indications in isolation.

29.9 HEARING STATUS

Before selecting a route, define:

SERVICEABLE HEARING?

If yes:

- cochlea
- labyrinth
- cochlear nerve

become structures to preserve.

If no:

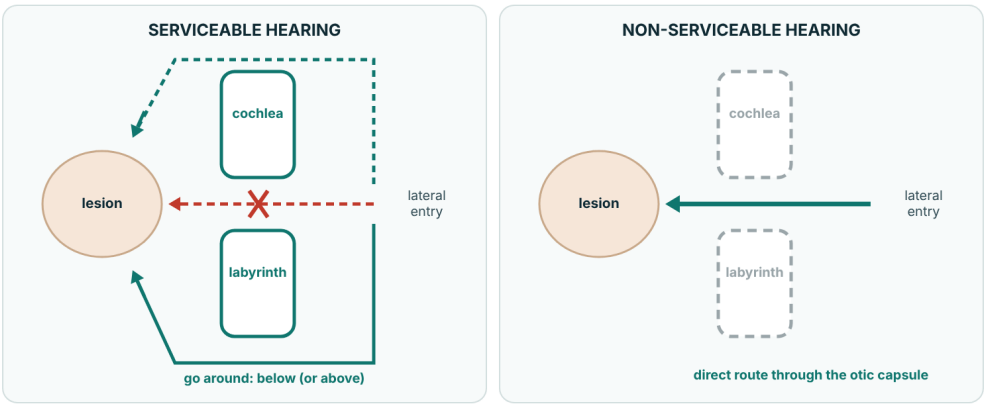
some corridors that were previously unacceptable may become available.

PRINCIPLE

Hearing status changes the geometry of the operation because it changes what structures can be traversed.

Figure 29.3 · Hearing status changes which structures are walls

Conceptual — the same lesion behind the otic capsule, with and without serviceable hearing



cochlea, labyrinth and cochlear nerve are walls the corridor must go around

the otic capsule may be traversed — translabyrinthine / transotic / transcochlear

The facial nerve and carotid remain walls in both situations.

29.10 FACIAL NERVE FUNCTION

Document preoperative facial function.

Petrous-apex disease may involve:

- labyrinthine facial nerve
- geniculate ganglion
- tympanic segment
- IAC

Facial nerve preservation or reconstruction may become central to the operation.

29.11 INFRALABYRINTHINE CORRIDOR

The infralabyrinthine route passes:

BELOW THE LABYRINTH

and

ABOVE / AROUND THE JUGULAR BULB REGION

toward the petrous apex.

Its feasibility depends heavily upon:

- jugular bulb height
- labyrinth position
- petrous pneumatisation
- lesion location

A high jugular bulb can make this corridor very narrow or unavailable.

29.12 THE INFRALABYRINTHINE WINDOW

Conceptually, the corridor is bounded by:

LABYRINTH (POSTERIOR SEMICIRCULAR CANAL) SUPERIORLY

JUGULAR BULB INFERIORLY

MASTOID SEGMENT OF THE FACIAL NERVE ANTERIORLY

POSTERIOR FOSSA DURA POSTERIORLY

PETROUS APEX MEDIALLY

This is a classic example of a route defined by structures that cannot be injured.

PRINCIPLE

If the anatomical window is too narrow, do not enlarge it by sacrificing structures unintentionally. Choose another route.

29.13 INFRACOCHLEAR CORRIDOR

The infracochlear route reaches the petrous apex below the cochlea through the hypotympanic region.

Major limits include:

BASAL TURN OF THE COCHLEA SUPERIORLY

JUGULAR BULB POSTERIORLY / INFERIORLY

PETROUS CAROTID ANTERIORLY

This corridor can be useful for selected lesions when the anatomy provides sufficient space.

29.14 THE INFRACOCHLEAR TRIANGLE IS SMALL

The surgeon must know precisely:

- basal turn of cochlea
- carotid canal
- jugular bulb
- hypotympanum

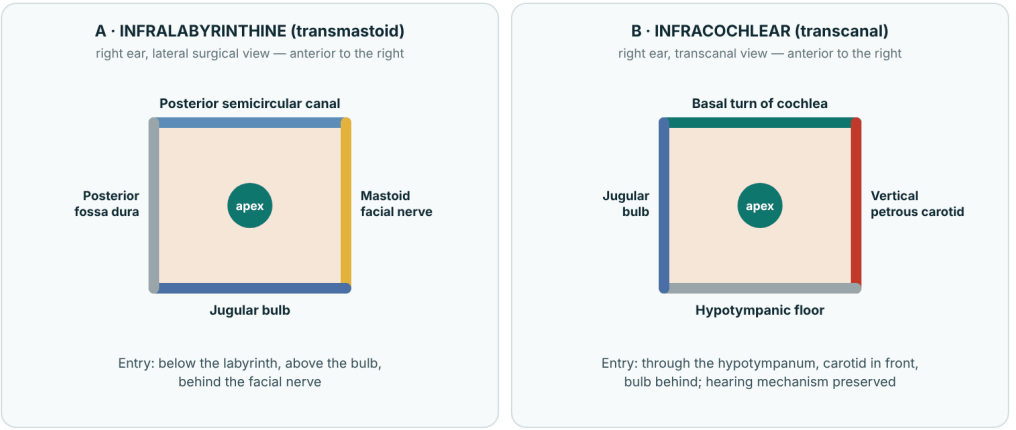
CT is critical.

> **PRINCIPLE**
>
> **The infracochlear route is not a place to discover the carotid by drilling.**

The carotid must already be mapped before the burr enters the corridor.

Figure 29.4 · The infralabyrinthine and infracochlear windows

Schematic boundaries, not to scale — each window is defined by structures that must not be injured



A high jugular bulb narrows both windows — this should be seen on CT before surgery.
If the window is too small, change the approach; do not enlarge it by drilling into a wall.

29.15 HIGH JUGULAR BULB

A high jugular bulb can reduce both:

- infralabyrinthine
- infracochlear

working spaces.

This should be visible preoperatively.

If the window is inadequate:

CHANGE THE APPROACH.
Do not force the corridor.

29.16 PETROUS CAROTID

The petrous carotid is one of the most important structures in petrous-apex surgery.

Its course should be traced on imaging.

Assess:

- dehiscence

- tumour displacement
- encasement
- narrowing
- previous surgery

The artery may be only a thin bony shell away from the working corridor.

29.17 ANTERIOR PETROSECTOMY

The anterior petrosectomy / Kawase-type concept approaches the petrous apex from the middle cranial fossa.

It may provide access to:

- anterior petrous apex
- petroclival region
- selected posterior-fossa structures

while preserving the labyrinth when performed within safe boundaries.

The approach requires detailed knowledge of:

- GSPN
- petrous carotid
- arcuate eminence / superior semicircular canal
- IAC
- petrous ridge

29.18 KAWASE-REGION GEOMETRY

The safe bony working region is defined conceptually by relationships among:

GSPN — WITH THE HORIZONTAL PETROUS CAROTID BENEATH IT — LATERALLY

MANDIBULAR NERVE (V3) AND TRIGEMINAL GANGLION ANTERIORLY

ARCUATE EMINENCE / SUPERIOR SEMICIRCULAR CANAL POSTERIORLY

PETROUS RIDGE MEDIALLY

Beneath the bone, the IAC limits drilling posteriorly, and the cochlea lies in the angle between the GSPN and the IAC, close to the geniculate ganglion.

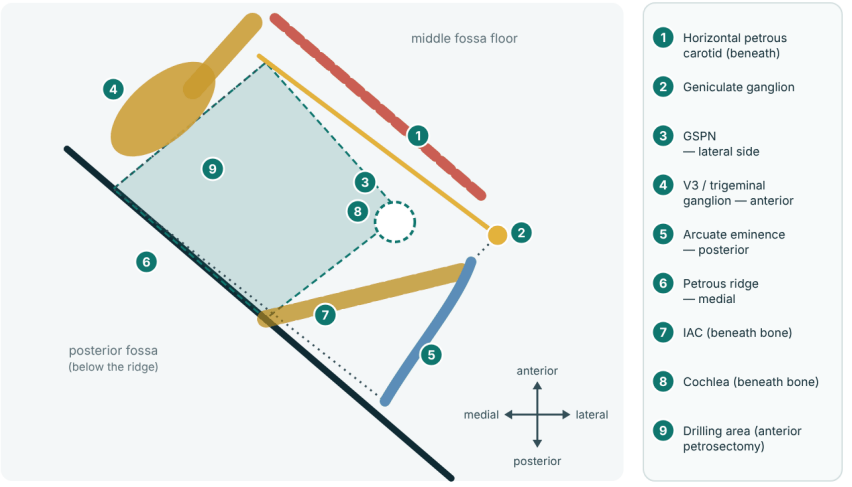
The exact exposure varies.

PRINCIPLE

The "triangle" is only useful when the surgeon understands what each side represents beneath the bone.

Figure 29.5 · Kawase-region geometry seen from the middle fossa

Right side, schematic view from above after temporal lobe elevation — anterior at top, medial to the left



Dashed structures lie beneath the bone. Drilling stays anteromedial to the IAC and medial to the cochlea and carotid.

29.19 THE GSPN

The greater superficial petrosal nerve can help orient the:

- geniculate ganglion
- petrous carotid

Excessive manipulation may transmit traction to the facial nerve.

Use it as a guide.

Not as a handle.

29.20 THE SUPERIOR SEMICIRCULAR CANAL

The superior canal limits posterior-lateral drilling in a hearing-preservation anterior petrosectomy.

Violation can produce:

- hearing loss
- vestibular dysfunction

Therefore CT and surface landmark interpretation are essential.

29.21 PETROUS RIDGE

The petrous ridge forms an important boundary between middle and posterior fossa.

Bone removal along this region can create access to deeper petroclival anatomy.

But drilling progressively closer to:

- IAC
- cochlea
- carotid

requires increasingly controlled technique.

29.22 TRANSCOCHLEAR APPROACH

A transcochlear approach removes the cochlea to create a more direct route toward deeper petrous and petroclival anatomy.

This carries major functional consequences:

HEARING IS SACRIFICED.

The classic transcochlear approach also includes posterior rerouting of the facial nerve; the transotic variant leaves the nerve in its bony canal, at the cost of a narrower field.

Therefore it is reserved for selected advanced pathology where the gain in access justifies the functional cost.

29.23 TRANSCOCHLEAR IS NOT JUST A BIGGER TRANSLABYRINTHINE APPROACH

The functional sacrifice increases.

The surgeon moves closer to:

- petrous carotid
- brainstem
- clivus
- cranial nerves

The approach should therefore be selected only when the target demands the additional medial exposure.

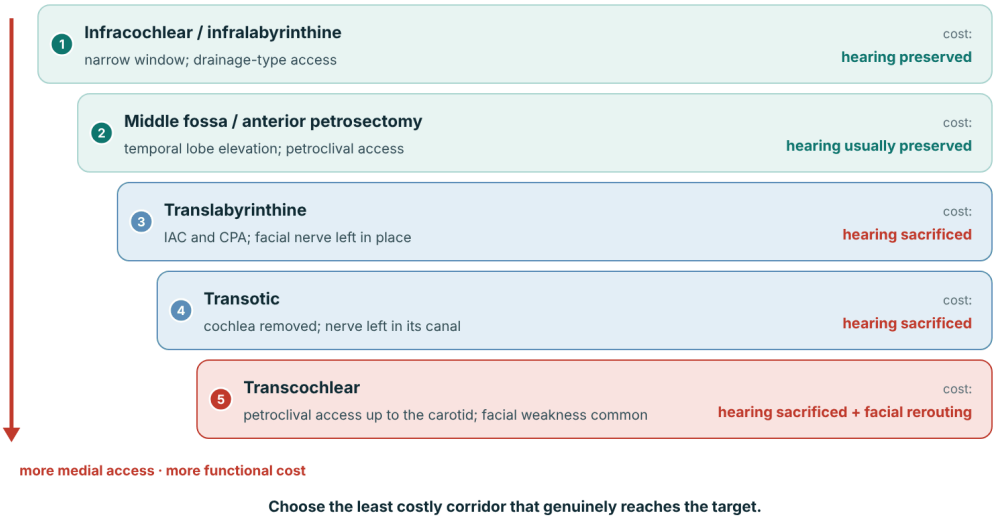
PRINCIPLE

Every additional structure sacrificed should buy meaningful additional access.

If it does not, the sacrifice is unjustified.

Figure 29.6 · What each extension of the petrous corridor costs

Every additional structure sacrificed should buy meaningful additional access



Choose the least costly corridor that genuinely reaches the target.

29.24 FACIAL NERVE MOBILISATION

Extended petrosectomy may require facial nerve mobilisation.

This can improve exposure but carries risk of:

- neuropraxia
- vascular compromise
- long-term weakness

The amount of mobilisation should be minimised.

A functioning facial nerve should not be moved simply because it obstructs a comfortable view.

29.25 COCHLEAR SACRIFICE

If the cochlea is removed:

- hearing preservation is no longer possible
- the cochlear nerve may still remain anatomically present
- CSF pathways may be created depending upon deeper exposure

The decision should be explicit preoperatively.

The patient should understand the functional consequence.

29.26 COMBINED PETROSECTOMY

Some large lesions require combined anterior and posterior petrous bone removal.

The principle is to expand access while reducing excessive brain retraction.

However, combined approaches increase:

- operative complexity
- cranial nerve risk
- vascular exposure
- reconstruction requirements

They should be target-driven.

29.27 SUBTOTAL PETROSECTOMY

Subtotal petrosectomy is a different concept.

It may be used to create a closed, obliterated temporal-bone environment in selected situations such as:

- chronically infected ears
- complex revision ears
- cochlear implant preparation
- CSF leak or other specific indications

Conceptually, it involves:

- extensive removal of temporal-bone air-cell tracts
- closure of external auditory canal
- management of Eustachian-tube pathway
- cavity obliteration

It is reconstructive/ablative ear surgery rather than simply an approach to one deep lesion.

29.28 EXTERNAL AUDITORY CANAL CLOSURE

When blind-sac closure is performed, it must be:

- well vascularised
- free of trapped epithelium
- tension-free
- durable

Any residual epithelial pocket can create future disease.

PRINCIPLE

When you close access permanently, the tissue left behind must be safe permanently.

29.29 EUSTACHIAN-TUBE CLOSURE

Selected petrosectomy / obliterative procedures require management of the Eustachian-tube pathway to reduce:

- contamination
- CSF communication

The method depends upon the procedure.

The aim is durable separation between:

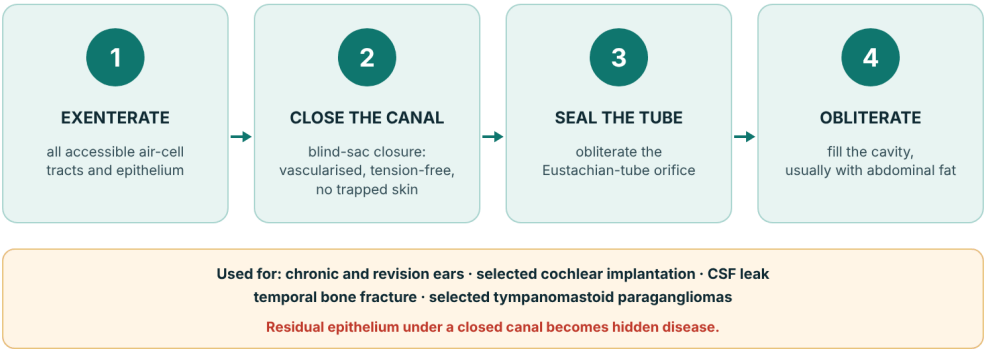
NASOPHARYNGEAL / MIDDLE-EAR PATHWAY

and

OBLITERATED SKULL-BASE SPACE.

Figure 29.7 · Subtotal petrosectomy: a closed, obliterated temporal bone

Four components — the result must stay safe permanently



29.30 DRAINAGE VERSUS COMPLETE RESECTION

For cystic lesions, durable drainage may be safer and more effective than complete wall removal.

For epithelial or neoplastic lesions, complete disease control may require a more extensive operation.

DECISION PRINCIPLE

Choose the objective before choosing the corridor.

The same corridor can be used for different operations.

The same lesion may be accessible through several corridors.

29.31 ENDOSCOPIC ENDONASAL ROUTES

Selected petrous-apex lesions may be approached endonasally, depending upon their relationship to:

- sphenoid sinus
- carotid artery
- clivus

- lesion medialisation

This can be advantageous for lesions medial to the petrous carotid in selected anatomy.

The lateral skull-base surgeon should understand these corridors even when not performing them personally.

> **PRINCIPLE**
> **The best route may come from another specialty's side of the skull base.**

29.32 MULTIDISCIPLINARY CORRIDOR SELECTION

A petrous-apex lesion may be reachable through:

- otologic lateral route
- middle cranial fossa route
- posterior fossa route
- endoscopic endonasal route
- combined approach

The best option may require collaboration among:

- neurotology
- neurosurgery
- rhinology / skull-base surgery
- interventional neuroradiology

Choose the shortest safe functional route—not the route owned by one specialty.

29.33 AIR CELLS & CSF PATHWAYS

Petrosectomy opens numerous air-cell systems.

If dura or CSF spaces are entered, opened cells can create pathways toward:

- middle ear
- mastoid
- Eustachian tube
- external canal

Identify and seal them.

> **PRINCIPLE**
>
> **The deeper the petrous drilling, the more seriously every air cell should be treated as a potential CSF pathway.**

29.34 RECONSTRUCTION

Depending upon the operation, reconstruction may require:

- fat
- fascia
- muscle
- vascularised flap
- bone/cartilage
- dural substitute
- free tissue transfer in larger defects

The objectives include:

SEPARATE COMPARTMENTS

OBLITERATE DEAD SPACE

PROTECT CAROTID / DURA / NERVES

PREVENT CSF LEAK

PROVIDE DURABLE COVER.

29.35 POSTOPERATIVE FUNCTION

Assess according to structures placed at risk:

HEARING

FACIAL NERVE

VESTIBULAR FUNCTION

LOWER CRANIAL NERVES

CSF LEAK

VASCULAR STATUS

The approach determines which deficits are expected versus unexpected.

This distinction should be established before surgery.

DECISION FRAMEWORK

CHOOSING A PETROUS-APEX CORRIDOR

STEP 1 — WHAT IS THE OBJECTIVE?

Drain / biopsy / remove / decompress?

↓

STEP 2 — WHERE IS THE LESION?

Relative to:

Cochlea

Labyrinth

IAC

Carotid

↓

STEP 3 — IS USEFUL HEARING PRESENT?

Yes → prioritise hearing-preservation corridors.

No → hearing-sacrificing routes may become acceptable.

↓

STEP 4 — WHICH NATURAL WINDOW EXISTS?

Below labyrinth → infralabyrinthine concept.

Below cochlea → infracochlear concept.

Superior/anterior petrous apex → anterior petrosectomy concept.

Medial lesion with non-serviceable hearing and need for extensive access → extended transpetrous/transcochlear strategies may be considered.

↓

STEP 5 — WHAT STRUCTURE LIMITS THE CORRIDOR?

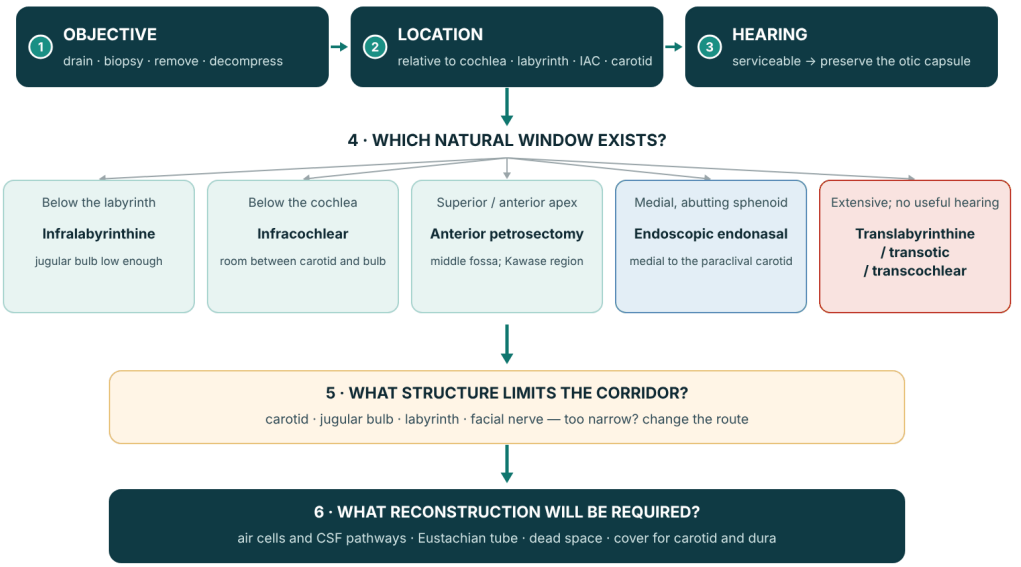
Carotid? Jugular bulb? Labyrinth? Facial nerve?

↓

STEP 6 — WHAT RECONSTRUCTION WILL BE REQUIRED?

Figure 29.8 · Petrous-apex approach-selection algorithm

Objective → location → hearing → natural window → limiting structure → reconstruction



Combined routes are considered when no single corridor reaches the whole lesion safely.

DECISION POINT

THE LESION IS ACCESSIBLE THROUGH TWO DIFFERENT ROUTES

Compare:

Which route is shorter?

Which preserves hearing?

Which avoids facial nerve mobilisation?

Which gives better carotid control?

Which provides enough working angle—not merely enough visualisation?

Which creates the smaller reconstructive problem?

Which route matches the lesion's biological objective?

The most direct route anatomically is not always the least morbid route functionally.

FROM EXPERIENCE

The petrous apex is a useful place to understand what skull-base surgery really means.

There is rarely a straight empty road to the lesion.

There is a cochlea.

A labyrinth.

An IAC.

A carotid.

A jugular bulb.

A facial nerve.

So the surgeon does not ask:

How do I reach the petrous apex?

The better question is:

> **Between which structures can I reach this particular part of the petrous apex without sacrificing function I still need?**

That is the essence of corridor surgery.

TAKE IT TO THE OT

Before petrous-apex surgery, define:

DIAGNOSIS

OBJECTIVE

Drain / biopsy / resection?

HEARING

Serviceable?

COCHLEA

Relation to lesion.

LABYRINTH

Relation to lesion.

IAC

Relation to lesion.

CAROTID

Course, dehiscence, displacement.

JUGULAR BULB

High / limiting corridor?

FACIAL NERVE

Expected course and function.

DURA / INTRACRANIAL EXTENSION

AVAILABLE CORRIDORS

Infracochlear
Infralabyrinthine
Middle fossa / anterior petrosectomy

Extended transpetrous
Endonasal / combined

FUNCTIONAL SACRIFICE

What does each route cost?

RECONSTRUCTION

How will CSF pathways and dead space be managed?

CHAPTER SUMMARY

Petrous-apex surgery is defined by the structures surrounding the target.

Do not begin with an approach name.

Define the lesion's biology and operative objective first.

Map it relative to the cochlea, labyrinth, IAC and petrous carotid.

Use infralabyrinthine and infracochlear corridors only when the anatomical window truly exists.

Use anterior petrosectomy for selected superior/anterior petrous targets while respecting the labyrinth and carotid.

Reserve transcochlear and extended petrosectomy strategies for lesions that genuinely require the added exposure and justify the functional sacrifice.

Consider endonasal and combined corridors where they reduce morbidity.

Plan reconstruction as part of the approach.

And remember:

> **The petrous apex is not difficult because it is deep.**

> **It is difficult because every route to it passes beside something worth preserving.**

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CHAPTER 30

Temporal Bone Resection for Malignancy

Oncological Boundaries • Neurovascular Risk • Reconstruction

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- understand temporal bone resection as an oncological operation rather than a larger mastoidectomy
- define the disease extent before selecting the resection type
- distinguish lateral, subtotal and more extended temporal bone resections conceptually
- understand the role of parotid, temporomandibular joint and neck management
- assess facial nerve, dura and carotid involvement
- plan specimen orientation and margin assessment
- coordinate resection and reconstruction
- recognise when complete resection carries disproportionate functional or vascular cost
- integrate surgery with adjuvant oncological treatment

30.1 TEMPORAL BONE MALIGNANCY IS A BOUNDARY PROBLEM

Temporal bone cancer may begin in:

- external auditory canal
- middle ear
- skin
- parotid-related structures

- adjacent skull base

But the operation is determined by the boundaries crossed.

A relatively small tumour may become complex if it reaches:

FACIAL NERVE

TEMPOROMANDIBULAR JOINT

PAROTID

DURA

PETROUS CAROTID

JUGULAR FORAMEN

INTRACRANIAL SPACE

PRINCIPLE

The size of the tumour matters.

> **The structures it has crossed matter more.**

30.2 THE OBJECTIVE IS NOT "REMOVE THE TEMPORAL BONE"

The objective is:

> **REMOVE THE MALIGNANCY WITH APPROPRIATE ONCOLOGICAL MARGINS**

while balancing:

- neurological function
- vascular safety
- reconstructability
- expected oncological benefit

Temporal bone removal is simply the anatomical means by which that objective is achieved.

30.3 BEGIN WITH DISEASE MAPPING

Before surgery, define:

SITE OF ORIGIN

HISTOLOGY

EXTERNAL AUDITORY CANAL EXTENT

MIDDLE EAR

MASTOID

PAROTID

TMJ

FACIAL NERVE

DURA

CAROTID

JUGULAR BULB / FORAMEN

NECK NODES

DISTANT DISEASE

The resection plan should emerge from this map.

30.4 CLINICAL EXAMINATION

Assess:

- pinna
- canal
- tympanic membrane where visible
- parotid
- skin
- TMJ symptoms
- facial nerve
- other cranial nerves
- neck nodes

- swallowing and voice in advanced disease

Preoperative functional documentation becomes essential when major nerve sacrifice is possible.

30.5 IMAGING

CT

Useful for:

- canal erosion
- temporal bone destruction
- middle ear
- mastoid
- TMJ
- carotid canal
- skull-base bone

MRI

Useful for:

- soft-tissue extent
- parotid
- facial nerve / perineural spread
- dura
- intracranial extension
- marrow

VASCULAR IMAGING

When:

- carotid involvement
- jugular / sigmoid involvement
- major vascular displacement

is suspected.

The scan should define the operative boundaries.

30.6 HISTOLOGY CHANGES THE OPERATION

Not all temporal bone malignancies behave the same way.

Squamous cell carcinoma is common in this region, but other histologies occur.

Tumour biology affects:

- margin strategy
- perineural risk
- nodal risk
- adjuvant treatment
- prognosis

PRINCIPLE

Do not perform the same temporal bone operation for every tumour that occupies the same space.

30.7 THE RESECTION SPECTRUM

Conceptually:

LIMITED / SLEEVE-TYPE RESECTION

for highly selected superficial disease.

↓

LATERAL TEMPORAL BONE RESECTION

for disease requiring en bloc removal of the external canal and lateral middle-ear structures.

↓

SUBTOTAL TEMPORAL BONE RESECTION

for more medially extensive disease.

↓

EXTENDED / COMBINED SKULL-BASE RESECTION

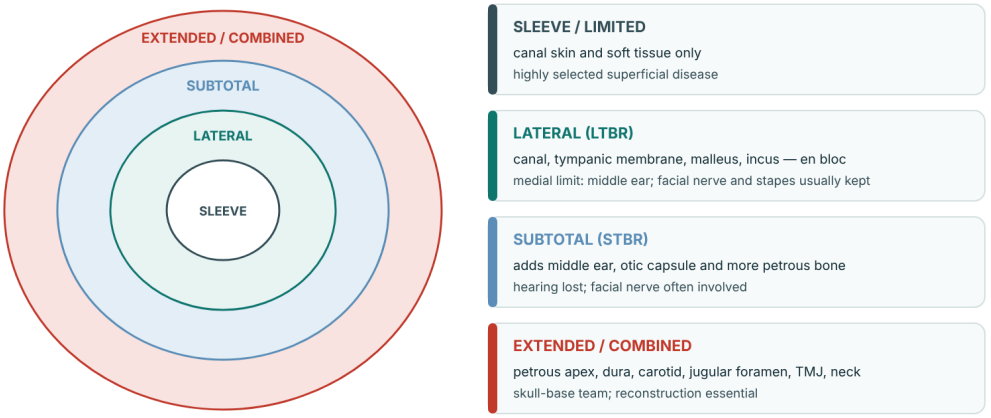
when adjacent skull-base compartments are involved.

These terms describe anatomical extent.

They should not become rigid templates.

Figure 30.1 · The resection spectrum

Conceptual — each step outward removes more anatomy and costs more function



These are descriptions of extent, not templates — the margins required decide the operation.

30.8 LATERAL TEMPORAL BONE RESECTION — CONCEPT

The resection generally removes the lateral temporal bone containing:

- external auditory canal
- tympanic membrane
- malleus and incus

with the stapes, medial wall of the middle ear and facial nerve normally left in place, according to the oncological boundaries.

The objective is an intact specimen with planned margins rather than piecemeal canal tumour removal.

ONCOLOGICAL PRINCIPLE

Do not chase the tumour from inside outward.

> **Define the outer resection boundaries first and remove the tumour with them.**

30.9 THE SPECIMEN SHOULD HAVE GEOMETRY

Before cutting bone, know:

SUPERIOR BOUNDARY

POSTERIOR BOUNDARY

INFERIOR BOUNDARY

ANTERIOR BOUNDARY

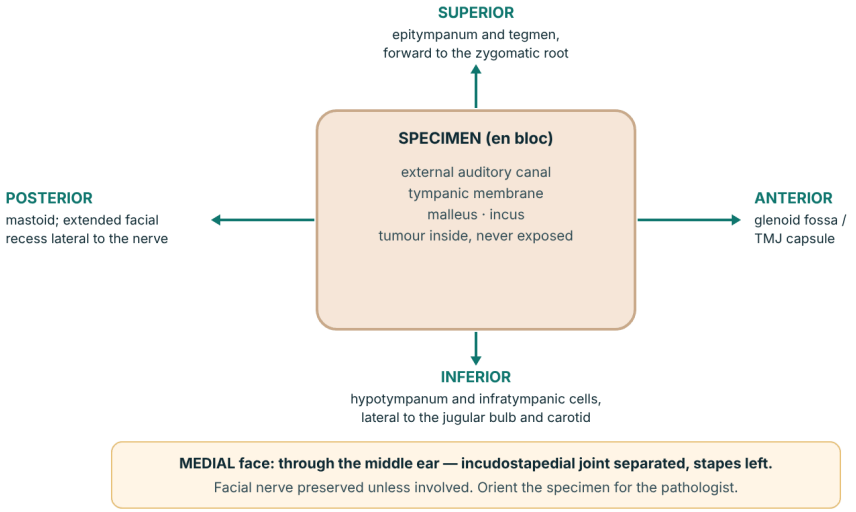
MEDIAL BOUNDARY

Then determine:

- where bone cuts will be made
- which soft-tissue structures remain attached
- where the specimen will be delivered

Figure 30.2 · The lateral temporal bone specimen and its planned boundaries

Conceptual, right ear, lateral view — anterior to the right; define every face of the block before cutting



30.10 EN BLOC THINKING

Where appropriate, en bloc resection helps:

- avoid tumour violation
- preserve specimen orientation
- improve pathological margin assessment

This does not mean forcefully removing all surrounding anatomy in one piece if doing so creates avoidable major risk.

The oncological objective matters more than ritual adherence to one technique.

30.11 EXTERNAL AUDITORY CANAL BOUNDARIES

Disease may cross:

ANTERIOR WALL

toward the TMJ and parotid.

POSTERIOR WALL

toward mastoid.

SUPERIOR WALL

toward the tegmen and dura.

INFERIOR WALL

toward the parotid, infratemporal soft tissue and jugular-related anatomy.

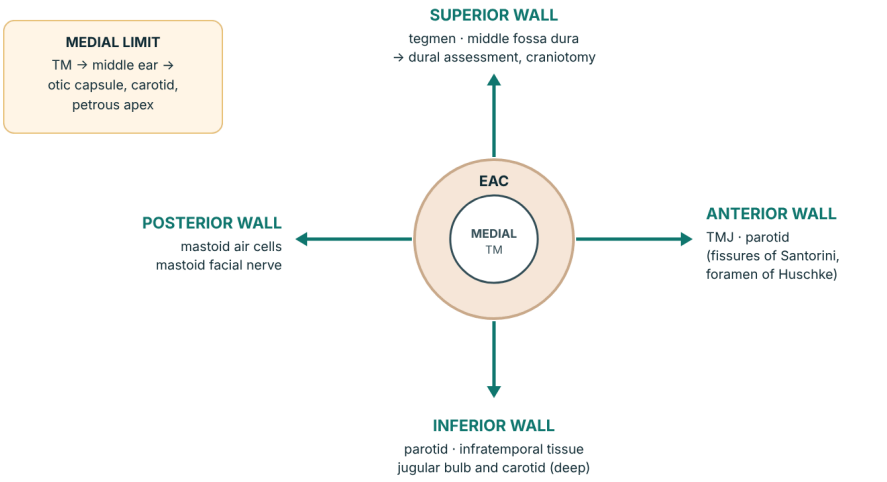
MEDIAL LIMIT

toward tympanic membrane and middle ear.

Each direction changes the operation.

Figure 30.3 · Each canal wall leads to a different structure

Conceptual, right ear, lateral view — anterior to the right; the direction of spread decides the extension



30.12 THE TMJ

Anterior canal-wall or preauricular extension may involve:

- capsule
- condyle
- mandibular fossa
- adjacent soft tissue

Assess:

ABUTMENT

BONE EROSION

TRUE JOINT INVASION

The required resection may range from:

- periarticular soft tissue
- partial condylar / joint resection
- more extensive composite resection

depending upon disease.

Do not remove the TMJ automatically simply because the tumour approaches it.

30.13 PAROTID MANAGEMENT

The parotid may be involved through:

- direct extension
- lymphatic disease
- natural pathways through the anterior canal wall (fissures of Santorini, foramen of Huschke)
- intraparotid nodes

The role of parotidectomy depends upon:

- stage
- histology
- anterior / inferior extension
- nodal risk
- current evidence

PRINCIPLE

Parotidectomy should have an oncological reason—not simply accompany temporal bone resection by habit.

30.14 THE FACIAL NERVE

The nerve may be:

- uninvolved
- displaced
- surrounded by disease
- invaded
- involved by perineural spread

Preoperative facial weakness raises concern but does not alone define the exact segment involved.

Use:

- clinical function
- MRI
- operative findings

to determine strategy.

30.15 PRESERVE OR SACRIFICE?

Preserve a functioning nerve when:

- oncologically uninvolved
- adequate margin remains achievable

Consider sacrifice when:

- gross invasion exists
- meaningful oncological clearance otherwise cannot be achieved

PRINCIPLE

A large operation does not justify sacrificing a normal nerve.

And:

> **A functioning nerve does not justify preserving gross tumour around it.**

30.16 PLAN FACIAL REANIMATION BEFORE DIVISION

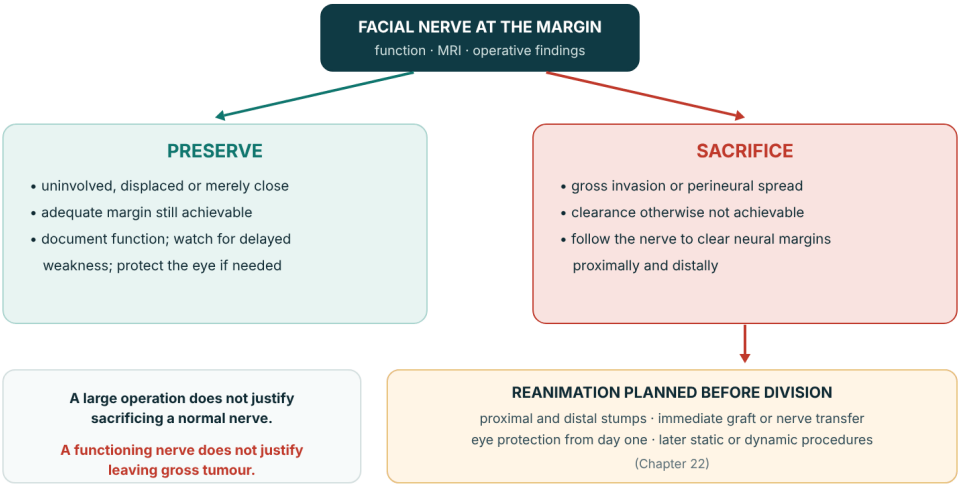
If nerve sacrifice is likely, plan:

- proximal segment
- distal segment
- immediate graft
- nerve transfer
- eye protection
- later static or dynamic reanimation

The reanimation plan should exist before the nerve is cut (see Chapter 22, Facial Reanimation & Functional Rehabilitation).

Figure 30.4 · The facial nerve: preserve, sacrifice and plan reanimation

Decide on involvement, not on the size of the operation



30.17 PERINEURAL SPREAD

Perineural tumour may extend beyond the visible primary.

Relevant pathways may include:

- facial nerve
- auriculotemporal pathways
- other cranial nerve branches depending upon tumour biology

MRI can be important.

The surgical margin may need to follow the involved nerve proximally or distally.

PRINCIPLE

A clean soft-tissue margin does not guarantee a clean neural margin.

30.18 MIDDLE-EAR EXTENSION

Once disease enters the middle ear, assess:

- ossicles
- facial nerve

- hypotympanum
- epitympanum
- mastoid
- Eustachian-tube region

The medial extent determines whether a lateral resection remains oncologically adequate.

30.19 SUBTOTAL TEMPORAL BONE RESECTION — CONCEPT

More medially advanced disease may require removal of additional:

- middle ear
- otic capsule-related bone
- petrous temporal bone

while preserving or sacrificing specific structures according to disease.

This is not merely a "bigger lateral resection."

The operation enters a different neurovascular risk level.

30.20 HEARING

Major temporal bone resection may sacrifice hearing.

Before surgery, document:

- ipsilateral hearing
- contralateral hearing

This matters for:

- counselling
- approach
- postoperative rehabilitation

When the operated ear already has little useful hearing, the functional cost of a more medial route may be different.

30.21 LABYRINTH

If disease reaches:

- otic capsule
- labyrinth

the resection strategy may require intentional inner-ear sacrifice.

This should be anticipated.

A labyrinth should never be entered accidentally during an operation in which hearing was expected to be preserved.

30.22 DURA

Superior or medial disease may involve, in increasing depth:

TEGMEN BONE

EXTRADURAL SPACE

DURA

INTRADURAL COMPARTMENT

Distinguish these carefully.

Dural contact is not the same as dural invasion.

If dura is involved, resection may require:

- dural removal
- intracranial control
- neurosurgical collaboration
- multilayer reconstruction

30.23 INTRACRANIAL EXTENSION

Intracranial disease changes:

- resectability
- morbidity
- reconstruction

- prognosis

The operation may require a combined otologic–neurosurgical approach.

The question becomes:

> **Can meaningful oncological clearance be achieved without unacceptable neurological cost?**

Technical access alone does not answer this.

30.24 INTERNAL CAROTID ARTERY

Advanced temporal bone malignancy may:

- abut
- encase
- narrow
- invade

the petrous carotid.

This is one of the major limits of resectability.

Preoperative planning may require:

- CT angiography / MR angiography / catheter angiography
- balloon occlusion testing in selected cases
- bypass / reconstruction discussion
- vascular / neurosurgical collaboration

PRINCIPLE

A carotid problem must be solved on the plan before it becomes a bleeding problem in the field.

30.25 CAROTID PRESERVATION VERSUS RESECTION

If tumour can be separated with an oncologically acceptable margin:

PRESERVE.

If true arterial invasion exists:

the decision becomes much larger.

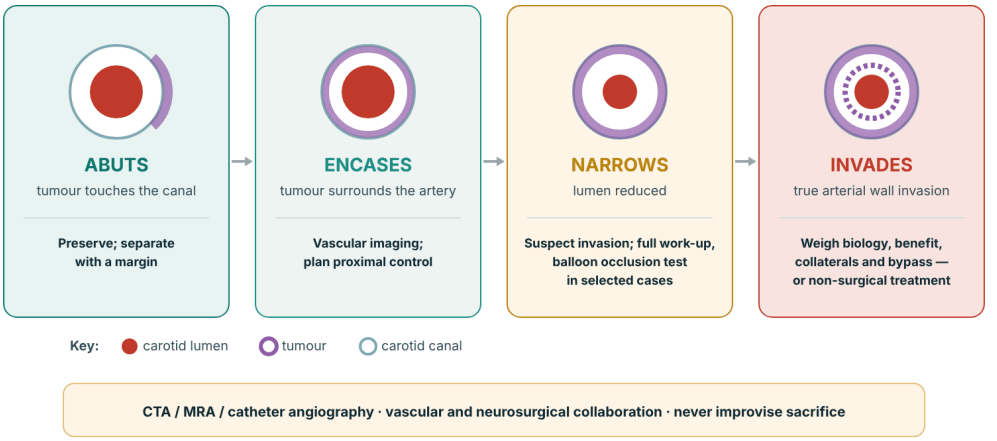
Consider:

- tumour biology
- expected survival benefit
- collateral circulation
- reconstruction feasibility
- neurological risk

Carotid sacrifice should never be improvised.

Figure 30.5 · Carotid involvement: from abutment to invasion

The carotid problem is solved on the plan, before it becomes a bleeding problem in the field



30.26 JUGULAR BULB & SIGMOID SINUS

Inferior / posterior extension may involve:

- jugular bulb
- sigmoid sinus
- jugular foramen

Venous sacrifice requires understanding of:

- dominance
- collateral outflow
- intracranial venous anatomy

A sinus that appears surgically ligatable may still be physiologically important.

30.27 LOWER CRANIAL NERVES

Once disease reaches the jugular foramen, assess:

- IX
- X
- XI
- XII

function.

The operation transitions from temporal bone oncology toward major skull-base neurovascular surgery.

Voice and swallowing consequences may become more important than hearing loss.

30.28 NECK MANAGEMENT

Regional nodal treatment depends upon:

- histology
- T stage
- clinically involved nodes
- parotid involvement
- institutional evidence-based practice

Potential options include:

- therapeutic neck dissection
- elective neck management
- radiation

The neck should be planned as part of the oncological operation, not as an afterthought.

30.29 THE ORDER OF THE OPERATION

For major resections, sequencing matters.

Conceptually:

EXPOSURE

↓

VASCULAR CONTROL

↓

NEURAL IDENTIFICATION

↓

BONE CUTS / SOFT-TISSUE MARGINS

↓

SPECIMEN DELIVERY

↓

MARGIN ASSESSMENT

↓

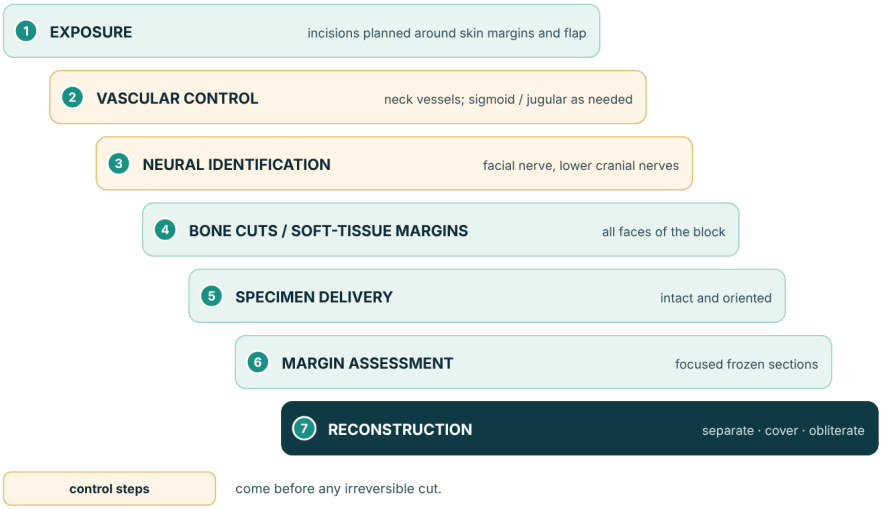
RECONSTRUCTION

The exact order changes by disease.

But control should precede irreversible deep dissection.

Figure 30.6 · The order of a major temporal bone resection

Control precedes irreversible deep dissection — the exact order changes with the disease



30.30 SOFT-TISSUE MARGINS

A temporal bone specimen is not only bone.

Soft-tissue margins may involve:

- skin
- parotid
- TMJ region
- temporalis
- upper neck
- skull-base musculature

These should be defined preoperatively.

> **PRINCIPLE**
>
> **The bone cut may be perfect while the soft-tissue margin remains inadequate.**

Treat the tumour as a three-dimensional composite.

30.31 BONE MARGINS

Bone margins can be difficult to interpret.

Plan:

- where cuts should occur relative to radiological disease
- which margins require pathological evaluation
- how the specimen will be oriented

The surgeon and pathologist should discuss the specimen geometry.

30.32 SPECIMEN ORIENTATION

Mark:

SUPERIOR

INFERIOR

ANTERIOR

POSTERIOR

MEDIAL

CRITICAL SOFT-TISSUE MARGINS

Use:

- sutures
- clips
- diagrams
- direct communication

The pathologist should not have to reconstruct the operation from an unmarked block of bone.

30.33 FROZEN SECTION

Frozen section may help answer specific questions such as:

- suspicious soft-tissue margin
- neural margin
- selected deep margin

But it has limitations in:

- complex bone
- sampling
- large composite specimens

> **PRINCIPLE**
>
> **Frozen section should answer a focused intraoperative question.**

It does not replace the planned resection geometry.

30.34 THE DEFECT AFTER RESECTION

Potential defect components include:

SKIN LOSS

PAROTID / PREAURICULAR SOFT-TISSUE LOSS

TEMPORAL BONE CAVITY

DURAL DEFECT

EXPOSED CAROTID

EXPOSED BRAIN / DURA

TMJ DEFECT

NECK DEAD SPACE

The reconstruction must address each component.

30.35 RECONSTRUCTION OBJECTIVES

The reconstructive plan may need to:

SEPARATE INTRACRANIAL AND EXTRACRANIAL SPACES

COVER MAJOR VESSELS

OBLITERATE DEAD SPACE

PROVIDE SKIN COVER

RESTORE CONTOUR

SUPPORT HEALING BEFORE RADIOTHERAPY

This is why reconstruction must be planned before the ablative surgery begins (see Chapter 31, Skull Base Reconstruction after Temporal Bone Resection).

Figure 30.7 · From defect components to reconstructive objectives

Name each component of the defect; the reconstruction must answer every one

DEFECT COMPONENT	WHAT THE RECONSTRUCTION MUST DO
Skin loss	skin paddle or local / regional skin cover
Parotid / preauricular loss	volume and contour
Temporal bone cavity	obliterate dead space; seal air-cell pathways
Dural defect	watertight, multilayer repair
Exposed carotid	durable vascularised soft-tissue cover
Exposed brain / dura	separate intracranial from extracranial spaces
TMJ defect	mouth opening, occlusion, chewing
Neck dead space	fill and drain

And all of it must survive postoperative radiotherapy — choose vascularised tissue the wound can rely on.

30.36 REGIONAL FLAPS

Selected defects may be reconstructed with robust regional tissue.

Potential options depend upon:

- defect size
- skin requirement
- prior treatment
- vessel availability

Regional tissue may be particularly valuable where:

- operation duration must be controlled
- microsurgical resources are limited
- defect geometry is suitable

The correct flap is the one that solves the defect reliably.

30.37 FREE TISSUE TRANSFER

Large composite or irradiated skull-base defects may benefit from free tissue transfer.

Advantages can include:

- large vascularised volume
- skin paddle
- flexible geometry
- protection of carotid and dura
- filling deep skull-base dead space

Free flap choice should follow:

DEFECT NEED
not

FLAP FAMILIARITY.

30.38 RECONSTRUCTION AND RADIOTHERAPY

If postoperative radiotherapy is likely, reconstruction should provide:

- durable vascularised coverage
- stable wound healing
- protection of vessels
- minimal chronic fistula risk

A marginal wound may deteriorate substantially under adjuvant treatment.

PRINCIPLE

Reconstruct not only for healing today, but for the treatment the wound must survive tomorrow.

30.39 CSF-LEAK PREVENTION

If dura is opened or violated, closure may require:

- dural repair
- fascial layer
- fat
- vascularised flap
- obliteration of air-cell pathways

The strategy depends upon defect size and location.

A single layer should not be expected to solve a complex skull-base communication.

30.40 CAROTID COVERAGE

An exposed carotid after oncological resection requires durable vascularised soft-tissue protection.

This is especially important in:

- irradiated fields
- contaminated cavities
- salivary communication
- skin loss

Catastrophic carotid exposure or blowout is a reconstructive failure as much as a vascular complication.

30.41 POSTOPERATIVE FACIAL FUNCTION

If the facial nerve was:

PRESERVED
document function and monitor for delayed weakness.

SACRIFICED
begin the planned reanimation pathway.

Eye protection is immediate.

Do not wait for later rehabilitation discussions after the cornea is already exposed.

30.42 HEARING REHABILITATION

Depending upon contralateral hearing and operative extent, postoperative options may include:

- CROS/BiCROS
- bone-conduction devices
- implantable hearing strategies in selected cases

Cancer treatment comes first.

But rehabilitation should still be discussed.

30.43 TMJ FUNCTION

After TMJ or condylar resection, assess:

- mouth opening
- occlusion
- pain
- chewing

Rehabilitation may require:

- physiotherapy
- dental / maxillofacial input
- reconstructive procedures

A successful cancer operation should still consider mandibular function.

30.44 ADJUVANT THERAPY

Postoperative treatment may include:

- radiotherapy
- chemoradiotherapy in selected high-risk settings
- systemic treatment depending upon histology and stage

The decision is based upon:

- final pathology
- margins
- nodal disease
- perineural invasion
- lymphovascular invasion
- stage
- tumour biology

The operation is one component of the oncological pathway.

30.45 POSITIVE OR CLOSE MARGIN

If final pathology shows a problematic margin, reassess:

WHERE IS IT?

Bone? Soft tissue? Nerve? Dura?

CAN IT BE RE-RESECTED?

> **WHAT FUNCTIONAL COST WOULD RE-RESECTION CREATE?**

> **WOULD ADJUVANT THERAPY PROVIDE BETTER BALANCE?**

Management should be multidisciplinary.

30.46 SALVAGE TEMPORAL BONE RESECTION

Prior radiotherapy or surgery changes:

- tissue planes
- vascularity
- wound healing
- reconstructive options
- carotid vulnerability

Salvage surgery is not the same operation performed later.

Expect:

- fibrosis
- scar
- exposed structures
- increased reconstructive need

30.47 WHEN NOT TO OPERATE

Surgery may not provide meaningful benefit when:

- disease is unresectable
- carotid or brainstem involvement creates unacceptable risk
- distant disease dominates prognosis

- functional cost exceeds expected oncological benefit
- patient factors make morbidity disproportionate

PRINCIPLE

Resectability is not defined by whether tissue can be removed.

> **It is defined by whether meaningful treatment can be achieved at an acceptable cost.**

DECISION FRAMEWORK

HOW MUCH TEMPORAL BONE SHOULD BE REMOVED?

> **STEP 1 — WHERE DID THE TUMOUR START?**

↓

> **STEP 2 — WHICH BOUNDARIES HAS IT CROSSED?**

Canal?
Middle ear?
Mastoid?
TMJ?
Parotid?
Facial nerve?
Dura?
Carotid?
Jugular foramen?

↓

> **STEP 3 — WHAT MARGIN IS REQUIRED?**

↓

> **STEP 4 — WHICH FUNCTIONAL STRUCTURES MUST BE SACRIFICED TO ACHIEVE IT?**

↓

STEP 5 — IS THAT FUNCTIONAL COST JUSTIFIED BY EXPECTED ONCOLOGICAL BENEFIT?

↓

STEP 6 — CAN THE DEFECT BE RECONSTRUCTED RELIABLY?

↓

SELECT RESECTION EXTENT

Limited

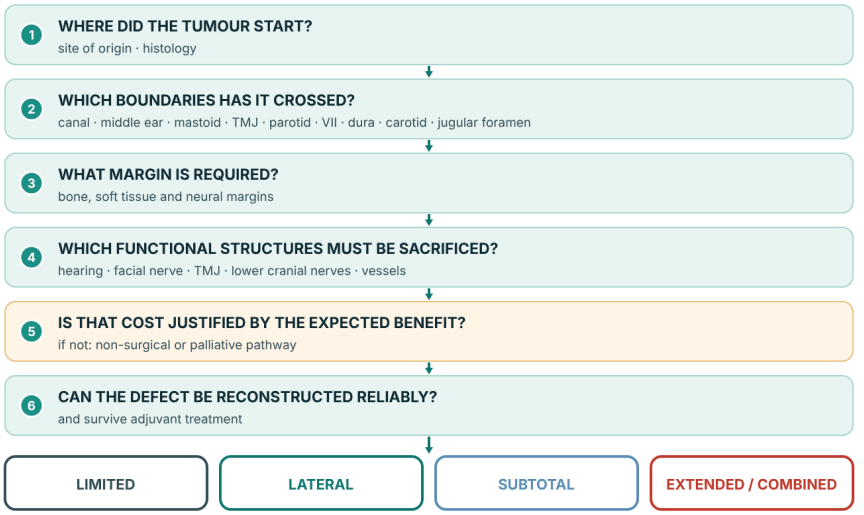
Lateral

Subtotal

Extended / Combined

Figure 30.8 · How much temporal bone should be removed?

Resection extent is the output of the decision, not its starting point



The resection should be large enough for the disease — no larger.

DECISION POINT

THE FINAL MARGIN LIES AGAINST A FUNCTIONING CRITICAL STRUCTURE

Ask:

Is the structure truly invaded?

What does imaging show?

Can another plane provide clearance?

What function will sacrifice remove?

What is the expected oncological gain?

Can adjuvant treatment address microscopic risk?

The correct answer may be:

SACRIFICE

or

PRESERVE

or

> **LEAVE PLANNED RESIDUAL / DECLARE UNRESECTABLE**

depending upon tumour biology and patient benefit.

FROM EXPERIENCE

Temporal bone malignancy surgery can easily become defined by the size of the operation.

Lateral.

Subtotal.

Extended.

But the procedure name is not the achievement.

The real work happens before that:

Where does the disease actually end?

Is the facial nerve invaded or merely close?

Is the TMJ truly involved?

Can the carotid be separated?

Is the dura touched or invaded?

What margin matters?

What function are we sacrificing?

And can we reconstruct the defect well enough for the patient to complete the rest of cancer treatment?

Once those questions are answered, the operation becomes clearer.

> **The resection should be large enough for the disease.**

> **Not large enough for the surgeon's reputation.**

TAKE IT TO THE OT

Before temporal bone resection, define:

HISTOLOGY

PRIMARY SITE

STAGE

CANAL

MIDDLE EAR

MASTOID

PAROTID

TMJ

FACIAL NERVE

DURA

CAROTID

JUGULAR / SIGMOID

LOWER CRANIAL NERVES

NECK NODES

PLANNED MARGINS

FACIAL REANIMATION PLAN

VASCULAR CONTROL

RECONSTRUCTION

CSF-LEAK CLOSURE

ADJUVANT TREATMENT PATHWAY

CHAPTER SUMMARY

Temporal bone resection is an oncological operation built around anatomical boundaries.

Map disease before naming the procedure.

Distinguish limited, lateral, subtotal and extended resections by the margins required.

Treat parotid and neck only when oncologically indicated.

Preserve a functioning facial nerve when safe, and plan reanimation before intentional sacrifice.

Define dura and carotid involvement precisely.

Do not improvise vascular sacrifice.

Orient the specimen clearly for pathology.

Plan reconstruction before creating the defect.

Build the wound to withstand adjuvant treatment.

And remember:

> **The objective is not to remove the most temporal bone.**

> **It is to remove the right disease with the right boundary at a functional cost the patient can justify.**

FURTHER READING & REFERENCES

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CHAPTER 31

Skull Base Reconstruction after Temporal Bone Resection

Separate • Cover • Obliterate • Restore

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- analyse a post-resection skull-base defect by compartments and functional requirements
- distinguish defects requiring simple soft-tissue coverage from those requiring dural, vascular or composite reconstruction
- understand the principles of CSF-leak prevention
- provide durable vascularised coverage for exposed carotid or other major vessels
- obliterate dead space without compromising surveillance or adjacent structures
- choose regional versus free tissue transfer according to defect geometry and tissue quality
- reconstruct irradiated or previously operated fields
- understand how reconstruction influences postoperative radiotherapy, wound healing and long-term surveillance
- plan facial contour and soft-tissue restoration in major lateral skull-base defects

31.1 RECONSTRUCTION BEGINS BEFORE THE RESECTION

Before the tumour is removed (Chapter 30, Temporal Bone Resection for Malignancy), the surgeon should already know:

Will dura be removed?

Will the carotid be exposed?

Will parotid or facial skin be lost?

Will the external auditory canal be closed?

Will a large temporal-bone cavity remain?

Will the patient need postoperative radiotherapy?

These questions determine reconstructive need.

PRINCIPLE

Do not wait for the defect to appear before deciding how to reconstruct it.

31.2 ANALYSE THE DEFECT BY FUNCTION

A skull-base defect may require one or more of the following:

SEPARATION

Between intracranial and extracranial spaces.

VASCULAR COVER

For carotid, jugular or other critical structures.

DEAD-SPACE OBLITERATION

To reduce fluid collection and infection.

SOFT-TISSUE COVER

For skin or mucosal loss.

STRUCTURAL SUPPORT

For selected bony or facial defects.

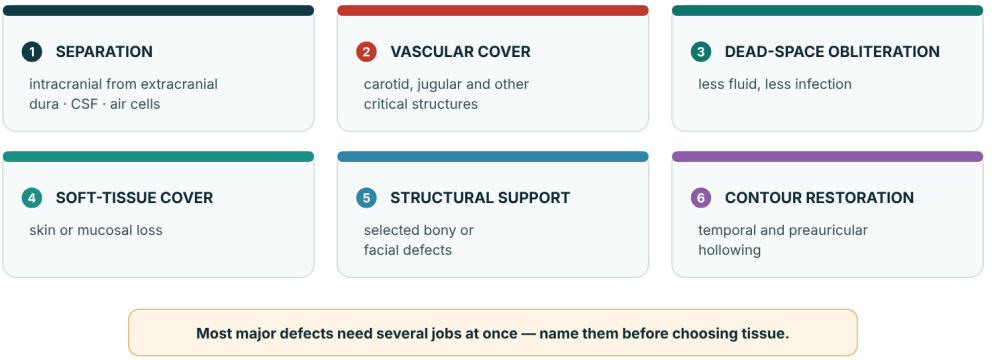
CONTOUR RESTORATION

To reduce visible temporal or preauricular hollowing.

The reconstruction should match these functions.

Figure 31.1 · Analyse the defect by function

A skull-base defect is a list of jobs; the reconstruction must do each one



Most major defects need several jobs at once — name them before choosing tissue.

31.3 THE FOUR-QUESTION RECONSTRUCTIVE MAP

Ask:

WHAT IS OPEN?

Dura? Middle ear? Neck? Skin?

WHAT IS EXPOSED?

Carotid? Brain? Cranial nerve? Bone?

WHAT SPACE IS LEFT?

Small cavity or large three-dimensional dead space?

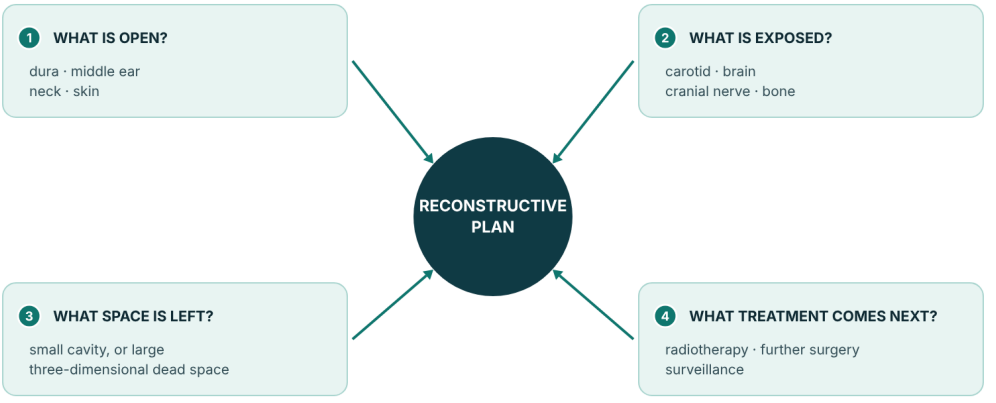
WHAT TREATMENT COMES NEXT?

Radiotherapy? Further surgery? Surveillance?

This converts a complex defect into a reconstructive plan.

Figure 31.2 · The four-question reconstructive map

Four questions turn a complex defect into a reconstructive plan



31.4 DURAL DEFECT

If dura has been resected or violated, the objectives are:

WATERTIGHT OR FUNCTIONALLY SECURE CLOSURE

SEPARATION OF CSF FROM AIR-CELL SYSTEMS

PROTECTION OF UNDERLYING BRAIN

Possible reconstructive layers may include:

- primary dural closure where feasible
- fascial graft
- dural substitute
- fat
- vascularised tissue

The exact strategy depends upon:

- size
- location
- contamination
- available tissue

31.5 MULTILAYER CSF CLOSURE

A useful conceptual reconstruction is:

INTRADURAL / DURAL LAYER

↓

FASCIAL OR SUBSTITUTE LAYER

↓

DEAD-SPACE FILL

↓

VASCULARISED SOFT TISSUE

↓

SKIN / EXTERNAL CLOSURE

The larger the defect, the less reasonable it is to depend upon a single closure layer.

> PRINCIPLE
>
> **Complex CSF leaks deserve layered solutions.**

31.6 AIR CELLS ARE PART OF THE DEFECT

Opened temporal-bone air cells may communicate with:

- mastoid
- middle ear
- Eustachian tube

If CSF is also present, these become potential leak pathways.

Therefore reconstruction should include:

IDENTIFY

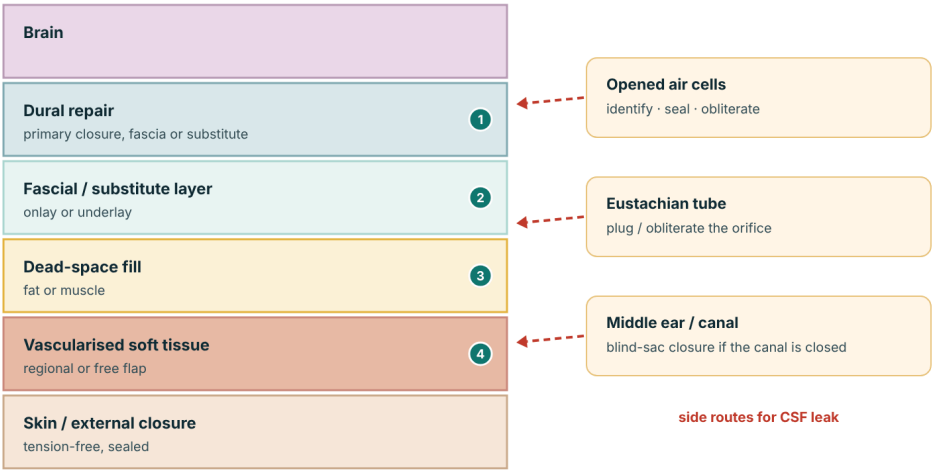
SEAL

OBLITERATE WHERE APPROPRIATE.

A watertight dural repair can still fail clinically if an adjacent air-cell pathway remains open.

Figure 31.3 · Multilayer closure and the side pathways around it

Conceptual stack, not anatomy — a watertight dural layer can still fail through an open air-cell route



The larger the defect, the less reasonable it is to rely on a single layer.

31.7 THE EUSTACHIAN-TUBE PATHWAY

In selected extensive skull-base resections, the Eustachian-tube pathway may need to be managed to prevent:

- nasopharyngeal contamination
- CSF rhinorrhoea

The exact method depends upon:

- operation
- extent of middle-ear sacrifice
- reconstruction

The objective is durable separation between the reconstructed skull base and the nasopharyngeal route.

31.8 EXPOSED CAROTID ARTERY

An exposed carotid requires:

VASCULARISED TISSUE COVERAGE.

This is especially important in:

- irradiated fields
- infected or contaminated wounds
- salivary communication
- large skin defects

The objective is not simply to put tissue over the artery.

It is to create a durable biological barrier.

PRINCIPLE

A major vessel should not be left one wound breakdown away from exposure.

31.9 CAROTID BLOWOUT IS OFTEN A RECONSTRUCTIVE PROBLEM BEFORE IT BECOMES A VASCULAR CATASTROPHE

Risk increases with:

- radiation
- infection
- fistula
- exposed vessel
- recurrent tumour

Therefore reconstruction should aim to separate the carotid from:

- saliva
- skin breakdown
- infected cavity
- exposed hardware

Prevention is far more effective than rescue.

31.10 DEAD SPACE

Large temporal-bone resections may leave irregular cavities.

Dead space can accumulate:

- blood
- seroma
- infected material
- CSF

Management may require:

- fat
- muscle
- vascularised flap
- free tissue

PRINCIPLE

Do not merely fill the cavity.

> **Fill the cavity with tissue that improves the biology of the wound.**

31.11 FAT

Autologous fat can provide:

- volume
- conformability
- dead-space obliteration

It is useful in selected clean skull-base reconstructions.

Limitations include:

- resorption
- limited vascularity
- less suitability where robust vascularised cover is required

Fat is a volume solution.

It is not always a vascular solution.

31.12 MUSCLE

Muscle provides:

- vascularised bulk
- dead-space filling
- coverage of exposed structures

Regional muscle may be particularly useful when:

- defect is moderate
- local vascularity remains good
- fast reliable reconstruction is required

However, muscle may atrophy over time.

Plan for the final contour, not only the immediate postoperative bulk.

31.13 REGIONAL FLAPS

Regional options may include selected:

- temporalis-based tissue
- pectoralis major
- supraclavicular
- other regional flaps

depending upon defect location and reach.

Potential advantages:

- relatively rapid
- reliable
- no microvascular anastomosis required

Limitations:

- arc of rotation
- bulk
- donor-site effect
- limited skin design in some defects

The flap should be chosen according to what the defect needs.

31.14 TEMPORALIS-BASED RECONSTRUCTION

Temporalis muscle or fascial tissue can be useful for selected lateral skull-base defects.

Potential uses include:

- local coverage
- cavity obliteration
- dural support

But prior:

- surgery
- radiation
- tumour involvement

may reduce availability or reliability.

Local tissue is only useful when it is still healthy tissue.

31.15 FREE TISSUE TRANSFER

Free flaps become particularly valuable for:

- large composite defects
- irradiated fields
- exposed carotid
- major skin loss
- deep dead space
- combined dural and soft-tissue reconstruction

Potential tissue characteristics can be selected according to need:

BULK

SKIN

FASCIA

BONE

LONG PEDICLE.
This flexibility is one of the major advantages of microsurgical reconstruction.

Figure 31.4 · What each reconstructive tissue provides

Fill the cavity with tissue that improves the biology of the wound

TISSUE	VOLUME	OWN BLOOD SUPPLY	SKIN	REACH / FLEXIBILITY	WATCH FOR
Fat	●	○	○	○	resorption poor in irradiated or infected fields
Local muscle (e.g. temporalis)	●	●	○	◐	atrophy unusable if operated or irradiated
Regional pedicled flap	●	●	◐	◐	arc of rotation, bulk, donor site
Free tissue transfer	●	●	●	●	recipient vessels, time, monitoring

● provides ◐ partly / depends on flap ○ does not provide

31.16 CHOOSE THE FREE FLAP BY DEFECT CHARACTERISTICS

Ask:

Do I need bulk?

Do I need thin pliable skin?

Do I need a large skin paddle?

Do I need bone?

Do I need long vascular reach?

Then select the flap.

PRINCIPLE

Do not reconstruct every skull base with the same flap simply because it is familiar.

Figure 31.5 · Choose the free flap by what the defect needs

Ask the defect's questions first; the flap is the answer, not the starting point



Examples only — choose by defect, donor site, recipient vessels and the team's experience.

31.17 RECIPIENT VESSELS

Recipient-vessel planning is essential in previously:

- dissected
- irradiated
- operated

necks.

Assess:

- available arterial inflow
- venous outflow
- prior ligation
- previous flap pedicles
- radiation field

The vascular plan should exist before the flap is harvested.

31.18 PREVIOUS RADIOTHERAPY

Radiated tissue is often:

- fibrotic
- less vascular
- less mobile
- more prone to breakdown

This increases the value of importing healthy vascularised tissue from outside the treated field.

PRINCIPLE

In a hostile wound, reconstruction often needs to bring new biology—not merely new volume.

31.19 PREVIOUS SURGERY

Prior temporal-bone or neck surgery may alter:

- soft-tissue availability
- vascular pedicles
- skin mobility
- recipient vessels
- flap options

Review the previous operative history before choosing reconstruction.

The old reconstruction has become part of the new anatomy.

31.20 SKIN LOSS

When skin is resected, the reconstruction must consider:

- surface area
- contour
- hair-bearing versus non-hair-bearing tissue
- colour and texture
- radiotherapy

In major oncological defects, durable vascularised cover may take priority over perfect aesthetic match.

Function and reliability come first.

31.21 FACIAL CONTOUR

Temporal-bone and parotid resections can create:

- preauricular hollowing
- temporal depression
- mastoid contour loss

While tumour clearance and wound safety are primary, contour restoration can meaningfully affect:

- appearance
- glasses fit
- psychosocial recovery

Volume should be restored where doing so does not compromise surveillance or function.

31.22 RECONSTRUCTION AROUND THE TMJ

If the TMJ or condyle has been resected, reconstruction may need to consider:

- joint space
- mandibular movement
- soft-tissue interposition
- contour
- postoperative physiotherapy

The aim is not always to recreate a native joint anatomically.

It is to preserve useful jaw function.

31.23 FACIAL NERVE RECONSTRUCTION

If the facial nerve was sacrificed, immediate reconstructive options may be integrated into the same operation (see Chapter 22, Facial Reanimation & Functional Rehabilitation).

Possible strategies include:

- nerve grafting

- nerve transfer
- static suspension
- eye protection procedures

The soft-tissue reconstruction should not obstruct future facial reanimation.

> **PRINCIPLE**
> **One reconstruction should not make the next necessary reconstruction impossible.**

31.24 HEARING REHABILITATION AND THE DEFECT

When the ear is sacrificed, future hearing rehabilitation may require:

- bone-conduction device
- CROS hearing aid
- other device options

Reconstruction should consider whether implant placement may be needed later.

Do not occupy every useful temporal or postauricular surface without considering future rehabilitation.

31.25 DRAINS

Drains may be used to:

- reduce fluid accumulation
- monitor output
- protect large dead-space reconstructions

But they should not:

- lie against exposed carotid
- compress a flap pedicle
- cross delicate dural repair

Drain position is part of reconstructive design.

31.26 FLAP INSET

The inset should:

- fill required space
- cover critical structures
- avoid excessive tension
- avoid pedicle kinking
- avoid compressing the airway or neck

Do not overfill the defect.

Excessive bulk can create:

- pressure
- contour problems
- difficulty with surveillance

> **PRINCIPLE**
> **Replace enough volume to solve the defect—not enough to create a new one.**

31.27 PEDICLE PROTECTION

Before closure, follow the pedicle from:

RECIPIENT VESSEL
to

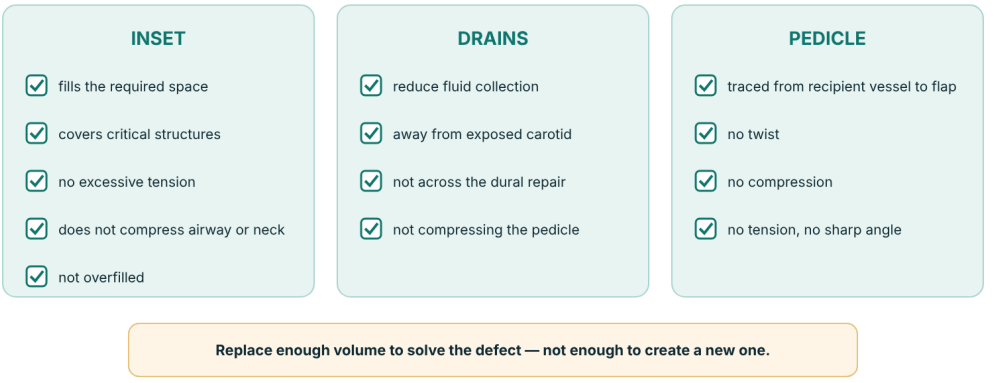
FLAP.
Confirm:

- no twist
- no compression
- no excessive tension
- no sharp angle

This is particularly important in deep skull-base insets where the pedicle may be hidden after closure.

Figure 31.6 · Inset, drains and pedicle: checks before closure

In a deep skull-base inset the pedicle disappears once the skin is closed



31.28 POSTOPERATIVE FLAP MONITORING

Monitoring may include:

- clinical skin paddle assessment
- Doppler
- implantable monitoring techniques where appropriate

The exact strategy depends upon flap type and institutional protocol.

Early vascular compromise requires urgent assessment.

PRINCIPLE

A flap that cannot be monitored still requires a monitoring strategy.

31.29 CSF LEAK AFTER RECONSTRUCTION

If postoperative CSF leak occurs, determine:

WHERE IS THE PATHWAY?

Dural closure?
Air cells?
Eustachian tube?
Wound edge?

Then manage according to the source.

Do not assume every leak originates from the same layer.

31.30 WOUND INFECTION

Infection can threaten:

- flap
- carotid
- dura
- hardware
- adjuvant therapy schedule

Management should include:

- source control
- drainage where needed
- culture-guided treatment
- assessment of vascular exposure

In a reconstructed skull base, wound infection is never a superficial problem until proven otherwise.

31.31 TIMING OF RADIOTHERAPY

The reconstruction should heal sufficiently to permit timely adjuvant treatment.

Factors that delay radiotherapy include:

- wound breakdown
- infection
- flap necrosis
- fistula

Therefore reconstructive reliability has oncological consequences.

> **PRINCIPLE**
>
> **A reconstruction that delays essential cancer treatment has failed part of its oncological purpose.**

31.32 SURVEILLANCE AFTER LARGE FLAP RECONSTRUCTION

Large flaps can alter imaging appearance.

Therefore:

- document flap type
- orientation
- expected anatomy
- baseline postoperative imaging when appropriate

Radiologists and oncologists should know what tissue has been transferred.

Tumour surveillance should be planned around the reconstruction.

31.33 BULK CAN HIDE RECURRENCE CLINICALLY

A large soft-tissue flap may make clinical examination more difficult.

This does not mean the flap should be inadequate.

It means imaging surveillance becomes more important.

> **PRINCIPLE**
>
> **Reconstruction changes how recurrence is detected.**

It should not reduce the commitment to detecting it.

31.34 DONOR-SITE FUNCTION

Major skull-base reconstruction should not create disproportionate donor-site morbidity.

Assess:

- shoulder
- upper limb
- chest wall
- thigh
- gait
- abdominal wall

depending upon flap choice.

The best recipient-site reconstruction should still respect the rest of the patient.

31.35 FAILED RECONSTRUCTION

Failure may involve:

CSF LEAK

WOUND BREAKDOWN

FLAP NECROSIS

CAROTID EXPOSURE

INFECTION

DEAD-SPACE COLLECTION

CONTOUR PROBLEM

Revision should identify which function of the reconstruction failed.

Do not simply “add another flap” without understanding the mechanism.

Figure 31.7 · Failed reconstruction: which function failed?

Revision starts with the mechanism, not with another flap

FAILURE	FUNCTION THAT FAILED	FIRST RESPONSE
CSF leak	separation	find the pathway: dura, air cells, tube or wound edge
Wound breakdown	soft-tissue cover	debride; bring healthy vascularised tissue
Flap necrosis	blood supply	urgent assessment; salvage or replace
Carotid exposure	vascular cover	emergency cover; vascular team
Infection	biology of the wound	source control, drainage, cultures; check vessels
Dead-space collection	obliteration	drain; refill with better tissue
Contour problem	volume / contour	revise after healing and treatment

DECISION FRAMEWORK

WHAT DOES THIS SKULL-BASE DEFECT NEED?

DURA OPEN?

→ Secure dural / CSF separation.

CAROTID EXPOSED?

→ Durable vascularised cover.

LARGE DEAD SPACE?

→ Volume replacement / obliteration.

SKIN MISSING?

→ Skin-bearing reconstruction.

IRRADIATED FIELD?

→ Import healthy vascularised tissue.

MAJOR COMPOSITE DEFECT?

→ Consider free tissue transfer.

SMALLER CLEAN LOCAL DEFECT?

→ Local or regional options may suffice.

↓

THEN ASK:

Will the reconstruction tolerate radiotherapy?

Can it be monitored?

Will it preserve future rehabilitation options?

Figure 31.8 · Skull-base defect-to-reconstruction algorithm

Each finding adds a requirement; the reconstruction must meet all of them



DECISION POINT

REGIONAL FLAP OR FREE FLAP?

Consider:

Defect size

Required bulk

Skin requirement

Vessel exposure

Radiation

Previous surgery

Recipient vessels

Operating time

Patient physiology

Local microsurgical resources

Choose the least complex reconstruction that reliably solves the complete defect.

FROM EXPERIENCE

A temporal bone resection can be impressive when viewed from the ablative side.

The specimen is large.

The margins are complex.

The carotid may be exposed.

The dura may be resected.

But the patient does not live with the specimen.

The patient lives with the defect.

That is why reconstruction is not the final chapter of the operation.

It is half of the operation.

The resection determines what must be removed.

The reconstruction determines whether the patient can safely heal, receive radiotherapy, protect the brain and vessels, and return to life afterward.

ABLATION REMOVES DISEASE.

> **Reconstruction makes the result survivable.**

TAKE IT TO THE OT

Before skull-base reconstruction, define:

DURAL DEFECT

CSF PATHWAY

AIR-CELL COMMUNICATION

CAROTID / MAJOR VESSEL EXPOSURE

DEAD SPACE

SKIN LOSS

TMJ / FACIAL CONTOUR DEFECT

PREVIOUS RADIATION

PREVIOUS FLAPS

RECIPIENT VESSELS

REGIONAL VERSUS FREE FLAP

PEDICLE ROUTE

DRAIN POSITION

RADIOTHERAPY TIMELINE

SURVEILLANCE PLAN

CHAPTER SUMMARY

Skull-base reconstruction should be planned before temporal bone resection begins.

Analyse the defect according to separation, vascular cover, dead space, surface loss and contour.

Use multilayer closure for complex CSF pathways.

Cover exposed carotid with durable vascularised tissue.

Correct dead space with biologically useful tissue.

Use regional flaps when they reliably solve the defect.

Use free tissue transfer when the defect requires greater volume, surface or vascularised tissue.

Import healthy tissue into irradiated fields.

Protect flap pedicles.

Plan reconstruction to withstand adjuvant treatment and allow long-term surveillance.

And remember:

> **The resection decides what must disappear.**

> **The reconstruction decides what the patient is left with.**

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CHAPTER 32

Complications & Bailout Strategies in Lateral Skull Base Surgery

Control First • Preserve Function • Reconstruct • Then Complete

CHAPTER OBJECTIVES

By the end of this chapter, the reader should be able to:

- recognise the major intraoperative and postoperative complications of lateral skull-base surgery
- distinguish immediate life-threatening events from function-threatening events
- apply a structured bailout sequence during major vascular or neural complications
- understand the principles of carotid, sigmoid and jugular bleeding control
- recognise facial and lower cranial nerve injury early
- manage CSF leak as a pathway problem rather than only a wound problem
- understand when temporary control, staging or abandonment is safer than continued dissection
- plan airway, swallowing and rehabilitation after lower cranial nerve injury
- recognise that complication management may redefine the objective of the operation

32.1 COMPLICATIONS CHANGE THE OPERATION

In skull-base surgery, a complication may alter:

- the surgical objective
- the available corridor
- the acceptable extent of resection

- the reconstructive plan
- postoperative destination

The surgeon must therefore be prepared not only for:

PLAN A

but also for:

> **THE OPERATION THAT EXISTS AFTER PLAN A FAILS.**

PRINCIPLE

A bailout is not a backup operation memorised separately.

> **It is the ability to redesign the operation after the anatomy changes.**

32.2 THE FIRST PRIORITY IS NOT COMPLETION

When a major complication occurs, use the sequence:

CONTROL

↓

STABILISE

↓

DEFINE

↓

PROTECT

↓

RECONSTRUCT

↓

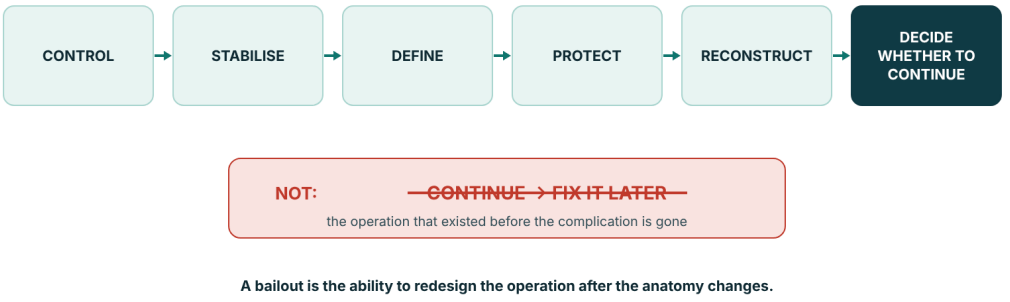
DECIDE WHETHER TO CONTINUE

Not:

CONTINUE → FIX IT LATER.

Figure 32.1 · The sequence after a major complication

The first priority is control, not completion



A bailout is the ability to redesign the operation after the anatomy changes.

32.3 THE THREE LEVELS OF PRIORITY

LEVEL 1 — LIFE

Major haemorrhage
Airway failure
Haemodynamic collapse
Major vascular compromise

LEVEL 2 — NEUROLOGICAL FUNCTION

Brainstem
Facial nerve
Lower cranial nerves
Cochlear / vestibular function
Venous outflow

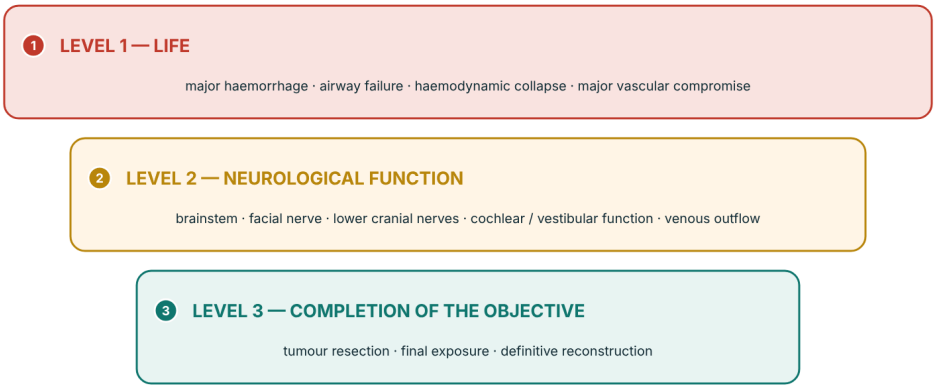
LEVEL 3 — COMPLETION OF THE ORIGINAL SURGICAL OBJECTIVE

Tumour resection
Final exposure
Definitive reconstruction

The third level should never overtake the first two.

Figure 32.2 · Three levels of priority

The third level should never overtake the first two



Work from the top down; return to level 3 only when levels 1 and 2 are secure.

32.4 MAJOR ARTERIAL BLEEDING

Potential arterial injuries may involve:

- petrous internal carotid artery
- cervical internal carotid artery
- external carotid branches
- posterior circulation branches

The initial response is universal:

STOP THE INJURING MANOEUVRE

OBTAIN TEMPORARY CONTROL

COMMUNICATE WITH ANAESTHESIA

MAINTAIN VISUALISATION

DEFINE THE VESSEL AND DEFECT

Do not continue dissecting around uncontrolled arterial bleeding.

32.5 CAROTID INJURY

Carotid injury may be:

- small wall defect
- laceration
- transection
- tumour-related rupture

Immediate priorities include:

CONTROL BLEEDING

PRESERVE CEREBRAL PERFUSION

AVOID EXTENDING THE INJURY

MOBILISE VASCULAR / ENDOVASCULAR SUPPORT

The specific definitive repair depends upon:

- segment
- defect size
- tumour involvement
- collateral circulation
- available expertise

32.6 DO NOT PACK THE CAROTID BLINDLY

Blind forceful packing can:

- enlarge the defect
- obscure anatomy
- compress adjacent cranial nerves
- create delayed vessel injury

Temporary packing may be lifesaving.

But it should be deliberate and followed by definitive planning.

PRINCIPLE

Temporary haemostasis is a bridge to control—not permission to forget the vessel.

32.7 OPTIONS AFTER CAROTID INJURY

Depending upon the situation, definitive management may involve:

- direct repair
- patch repair
- interposition graft
- bypass
- endovascular stenting
- vessel sacrifice in carefully selected circumstances

These are not interchangeable.

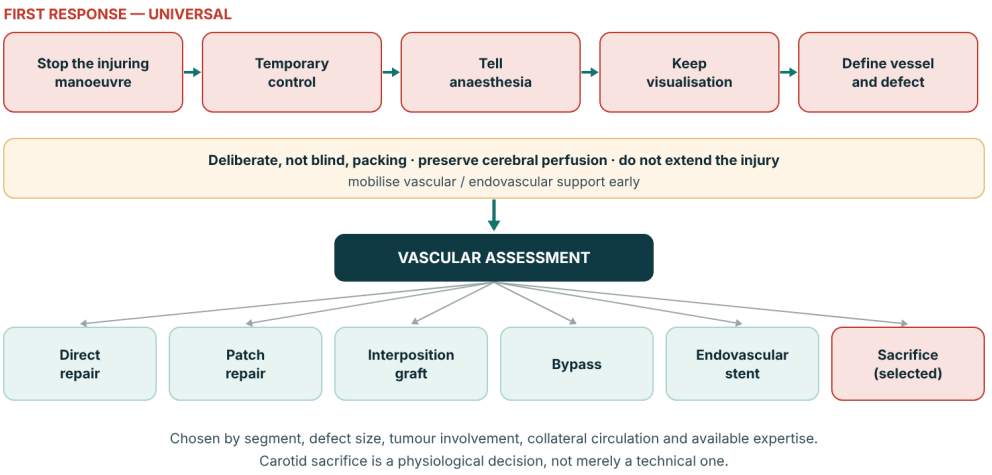
The correct choice requires vascular assessment.

PRINCIPLE

Carotid sacrifice should be a physiological decision, not merely a technical one.

Figure 32.3 · Major arterial bleeding: first response and definitive options

Temporary haemostasis is a bridge to control — not permission to forget the vessel



Chosen by segment, defect size, tumour involvement, collateral circulation and available expertise.
Carotid sacrifice is a physiological decision, not merely a technical one.

32.8 SIGMOID SINUS BLEEDING

Sigmoid bleeding may result from:

- drilling injury

- tumour dissection
- venous wall avulsion

Initial management may include:

- pressure
- appropriate haemostatic material
- controlled packing
- repair where feasible

Avoid repeatedly enlarging the defect while attempting to improve visualisation.

The first objective is controlled venous haemostasis.

32.9 JUGULAR BULB BLEEDING

Jugular bulb injury can produce substantial low-pressure but high-volume bleeding.

Control requires understanding:

SIGMOID INFLOW

JUGULAR OUTFLOW

INFERIOR PETROSAL / COLLATERAL VENOUS CHANNELS

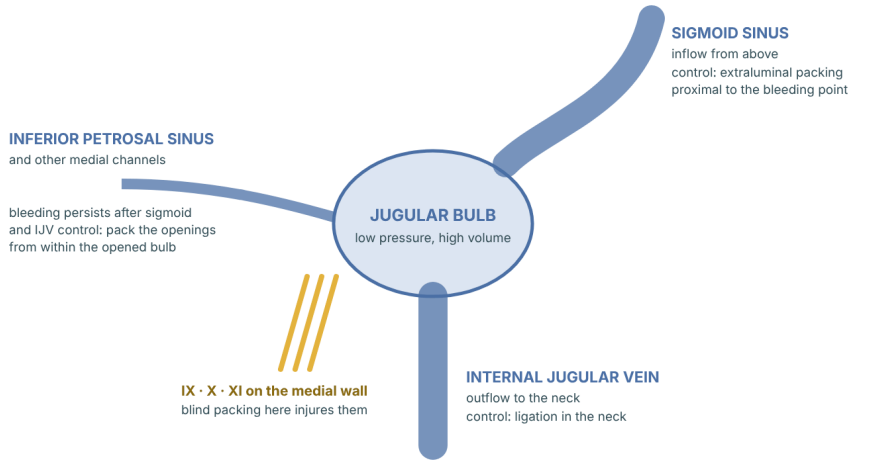
Packing blindly into the bulb region can injure nearby lower cranial nerves or carotid artery.

PRINCIPLE

Venous bleeding becomes manageable when the venous map is understood.

Figure 32.4 · The venous map around the jugular bulb

Conceptual flow diagram, not to scale — know every inflow before packing



Packing blindly into the bulb region can injure the lower cranial nerves or the carotid.

32.10 VENOUS SACRIFICE

Before intentional sinus or jugular sacrifice, consider:

- dominance
- contralateral drainage
- intracranial venous anatomy
- collateral pathways

Venous complications may present later as:

- thrombosis
- venous infarction
- raised intracranial pressure
- neurological deterioration

A technically controlled vein can still have major physiological importance.

32.11 SMALL VESSEL — LARGE CONSEQUENCE

Branches supplying:

- brainstem

- facial nerve
- cochlea
- lower cranial nerves

may appear small.

Injury can produce disproportionate functional loss.

> **PRINCIPLE**
>
> **Never coagulate an unfamiliar skull-base vessel merely because it is small enough to coagulate.**

Identify what it supplies first.

32.12 FACIAL NERVE INJURY

Mechanisms include:

- transection
- drill injury
- heat
- traction
- ischaemia
- tumour dissection
- rerouting injury

If injury is suspected:

STOP MANIPULATION

IDENTIFY THE SEGMENT

CHECK MONITORING

ASSESS CONTINUITY

DEFINE THE MECHANISM

Then decide:

- observation
- decompression
- repair

- grafting
- reanimation pathway

32.13 ANATOMIC CONTINUITY DOES NOT END THE ASSESSMENT

A nerve may look intact yet be:

- thermally injured
- devascularised
- severely stretched

If monitoring deteriorates significantly:

do not continue aggressive manipulation simply because continuity remains visible.

> **PRINCIPLE**
> **Function can fail before anatomy breaks.**

32.14 TRANSECTED FACIAL NERVE

If recognised and oncologically appropriate:

IDENTIFY HEALTHY PROXIMAL AND DISTAL SEGMENTS

↓

DIRECT TENSION-FREE REPAIR IF POSSIBLE

or

INTERPOSITION GRAFT

If the proximal facial nerve is unavailable:

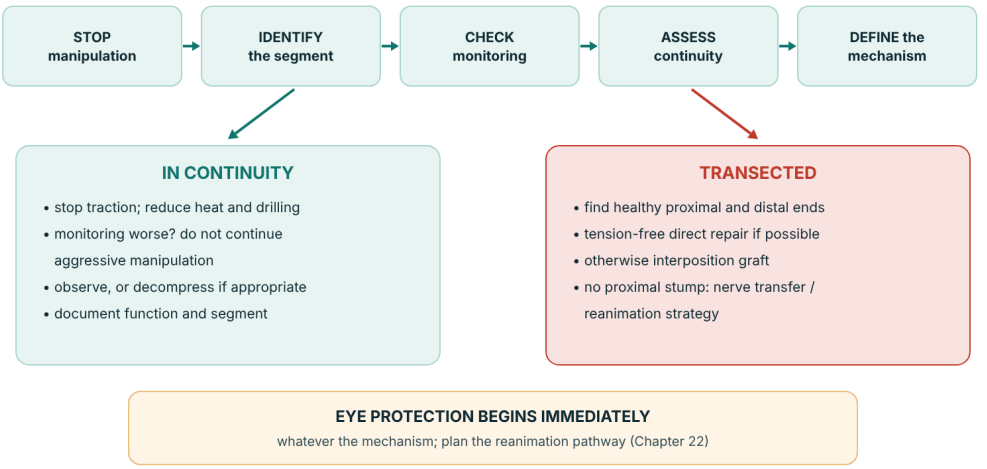
NERVE TRANSFER / REANIMATION STRATEGY

should be considered.

Eye protection begins immediately.

Figure 32.5 · Suspected facial nerve injury

Function can fail before anatomy breaks



32.15 LOWER CRANIAL NERVE INJURY

Injury to CN IX, X, XI or XII may affect:

- swallowing
- voice
- cough
- airway protection
- shoulder
- tongue

Unlike a pure sensory deficit, these injuries can threaten:

NUTRITION

RESPIRATORY SAFETY

QUALITY OF LIFE.

The postoperative plan must change immediately when injury occurs.

32.16 VAGAL INJURY

If the vagus nerve is injured or sacrificed, anticipate:

- vocal fold paralysis
- aspiration
- dysphonia
- weak cough

Plan:

AIRWAY OBSERVATION

SWALLOW ASSESSMENT

NUTRITION

EARLY LARYNGOLOGY INPUT

VOICE / ASPIRATION REHABILITATION

The patient should not simply be sent to the ward with "lower cranial nerve weakness."

32.17 BILATERAL LOWER CRANIAL NERVE RISK

When contralateral lower cranial nerve function is already impaired, additional ipsilateral injury may produce severe swallowing or airway consequences.

This should influence:

- extent of resection
- decision to leave adherent tumour
- airway planning

PRINCIPLE

Functional reserve matters more than the deficit on the operative side alone.

Figure 32.6 · Lower cranial nerve injury: deficit and plan

These deficits threaten nutrition and respiratory safety — the plan changes the moment injury occurs

NERVE	DEFICIT	PLAN
IX glossopharyngeal	pharyngeal sensation, swallow trigger	swallow assessment
X vagus	vocal fold palsy, aspiration, weak cough	airway watch · laryngology · nutrition
XI accessory	shoulder drop and pain	early physiotherapy, range of motion
XII hypoglossal	articulation, bolus control	speech and swallow therapy

X + XII together, or a weak contralateral side, can be disabling

nil by mouth until swallowing is shown to be safe · low threshold for monitored care
tracheostomy when airway protection is inadequate · nasogastric or gastrostomy feeding as needed

32.18 BRAINSTEM INJURY

Brainstem injury may occur through:

- direct dissection
- vascular injury
- excessive traction
- thermal damage

Any suspected injury should prompt:

STOP

RELEASE TRACTION

CONTROL BLEEDING

REASSESS NEUROPHYSIOLOGY

STABILISE PHYSIOLOGY

The operative objective may need to be reduced or abandoned.

32.19 CEREBELLAR INJURY

Potential mechanisms include:

- fixed retraction
- venous injury
- arterial injury
- direct trauma

Prevention includes:

- adequate bone exposure
- CSF release
- positioning
- dynamic retraction

If swelling occurs, the surgical team must consider:

- decompression
- haemostasis
- venous outflow
- postoperative imaging / ICU care

32.20 HEARING LOSS DURING HEARING-PRESERVATION SURGERY

Monitoring deterioration may indicate:

- cochlear nerve traction
- labyrinthine violation
- vascular compromise
- thermal injury

The correct response is not:

finish quickly.

It is:

STOP

RELEASE

REASSESS

MODIFY THE DISSECTION.

Once hearing is clearly lost, the functional equation may change—but do not assume that this justifies more aggressive neural dissection automatically.

32.21 LABYRINTHINE VIOLATION

If a hearing-preservation approach unintentionally enters the labyrinth:

- stop
- define the injury
- avoid unnecessary suction
- protect the opening
- reassess whether hearing preservation remains realistic

The surgical corridor may need to change.

PRINCIPLE

Once a structure that defined the approach has been lost, the approach itself may need to be reconsidered.

32.22 CSF LEAK

CSF leak is not merely fluid escaping from a wound.

It is a communication:

INTRACRANIAL CSF

↓

DEFECT

↓

AIR CELL / MIDDLE EAR / WOUND / NOSE

The treatment should target the pathway.

32.23 INTRAOPERATIVE CSF CLOSURE FAILURE

If closure does not appear reliable:

> **DO NOT CLOSE THE SKIN AND HOPE.**

Reassess:

- dural defect
- air cells
- Eustachian tube
- obliteration
- vascularised tissue

Add layers where needed.

PRINCIPLE

An uncertain skull-base closure should become a more secure closure before the patient leaves the theatre.

32.24 POSTOPERATIVE CSF RHINORRHOEA OR OTORRHOEA

Potential pathways may involve:

- petrous air cells
- mastoid
- middle ear
- Eustachian tube

Management depends upon:

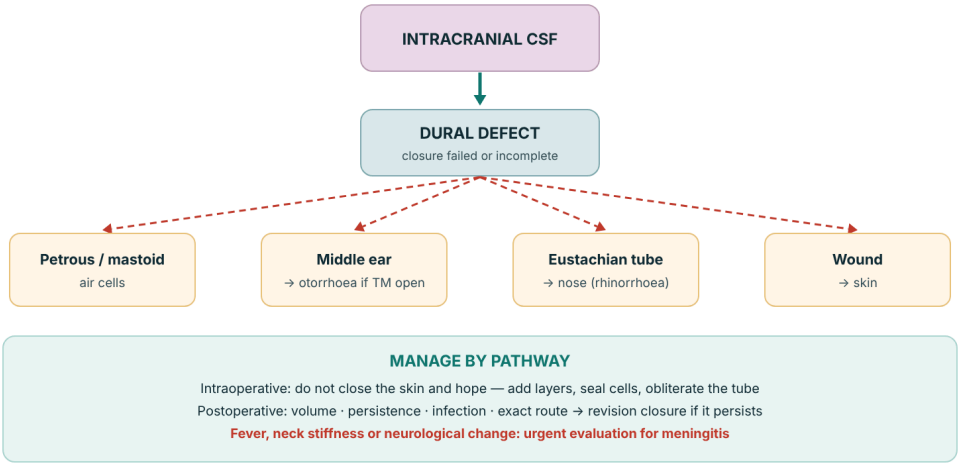
- volume
- persistence
- infection
- exact pathway

Some cases may require revision closure.

Do not manage persistent leak indefinitely without understanding its route.

Figure 32.7 · CSF leak is a pathway, not a wound

Conceptual — treat the route, not only the place where fluid appears



32.25 MENINGITIS

A postoperative CSF communication increases infection risk.

Clinical deterioration, fever, neck stiffness or neurological symptoms require urgent evaluation.

Management may include:

- antimicrobial treatment
- imaging
- source control
- CSF leak repair

A leak is not only a wound complication.

It can become an intracranial infection problem.

32.26 FLAP FAILURE

In skull-base reconstruction, flap failure may expose:

- carotid
- dura

- brain
- hardware

Therefore compromised flap perfusion is an urgent problem.

If vascular compromise is suspected:

EARLY RE-EXPLORATION
may offer the best chance of salvage.

Do not wait for obvious necrosis if monitoring suggests vascular failure.

32.27 CAROTID EXPOSURE AFTER WOUND BREAKDOWN

This is a high-risk situation.

Priorities include:

- protect the vessel
- control infection
- obtain vascularised coverage
- involve vascular / endovascular support where appropriate

A dry dressing over an exposed carotid is not definitive management.

32.28 AIRWAY FAILURE

After major skull-base surgery, airway problems may arise from:

- lower cranial nerve dysfunction
- aspiration
- oedema
- haematoma
- reduced consciousness

The threshold for monitored care should be low when:

- bilateral cranial nerve reserve is poor
- prolonged surgery occurred
- major tongue / pharyngeal dysfunction is expected

32.29 TRACHEOSTOMY AS A BAILOUT

Tracheostomy may be required when:

- airway protection is inadequate
- prolonged ventilatory support is expected
- aspiration risk is high
- extubation is unsafe

This is not a failure of skull-base surgery.

It is airway protection.

> **PRINCIPLE**
>
> **Protect the airway before testing whether the patient can manage without protection.**

32.30 SWALLOWING FAILURE

If lower cranial nerve function is impaired:

> **NOTHING BY MOUTH UNTIL SWALLOWING IS SHOWN TO BE SAFE.**

Assess:

- cough
- voice
- secretion handling
- formal swallow function

Nutrition may require:

- nasogastric
- gastrostomy
- other enteral support

depending upon duration and severity.

32.31 SHOULDER DYSFUNCTION

Accessory nerve injury may produce severe shoulder morbidity.

Early:

- physiotherapy
- pain control
- range-of-motion work

can reduce secondary disability.

The complication should not be dismissed as “only CN XI.”

32.32 TONGUE DYSFUNCTION

Hypoglossal injury may affect:

- articulation
- swallowing
- bolus control

Combined X and XII injury can be particularly disabling.

Rehabilitation should therefore be coordinated rather than treating each nerve in isolation.

32.33 WHEN TO LEAVE TUMOUR

One of the most important bailout strategies is:

STOPPING RESECTION.

Consider leaving adherent tumour when further dissection risks:

- functioning facial nerve
- brainstem
- carotid
- critical perforating vessel
- lower cranial nerve with meaningful function

This is particularly reasonable when:

- tumour biology is indolent
- surveillance is possible
- radiotherapy is available

PRINCIPLE

A planned remnant is often safer than a preventable deficit.

32.34 WHEN TO STAGE

Stage the operation when:

- physiological burden becomes excessive
- bleeding control is temporary but stable
- definitive vascular reconstruction requires another team
- swelling limits safe continuation
- reconstruction must precede further resection
- more imaging is needed

Completing everything in one sitting is not inherently superior.

32.35 WHEN TO ABANDON

Stopping may be appropriate when:

- orientation is lost
- major vascular control cannot be achieved safely
- neurological injury risk becomes unacceptable
- pathology is more extensive than anticipated
- definitive reconstruction is unavailable
- patient physiology deteriorates

The decision should be made before catastrophe.

32.36 THE BAILOUT HIERARCHY

When the original plan becomes unsafe:

MODIFY EXPOSURE

↓

CHANGE CORRIDOR

↓

CALL ADDITIONAL EXPERTISE

↓

LEAVE PLANNED RESIDUAL

↓

STAGE

↓

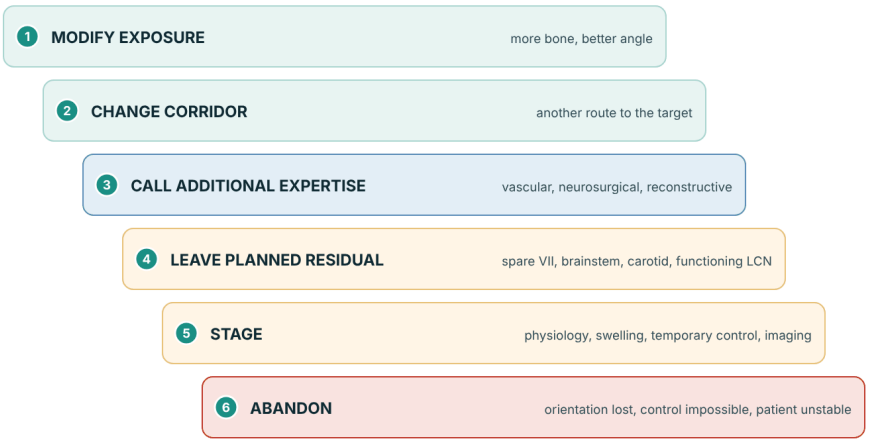
ABANDON

The hierarchy is not rigid.

The correct choice depends upon the event.

Figure 32.8 · The bailout hierarchy

When the original plan becomes unsafe — not rigid; the event decides the step



A planned remnant is often safer than a preventable deficit. Decide before catastrophe.

32.37 COMMUNICATION DURING CRISIS

During major bleeding or neural injury, team communication should become simpler.

State clearly:

WHAT HAPPENED

WHAT IS NEEDED

WHO IS DOING WHAT

Avoid multiple simultaneous instructions.

The operating room should become more organised as the complication becomes more serious—not less.

32.38 DOCUMENTATION

After a major complication, record:

- structure involved
- mechanism
- timing
- repair
- monitoring changes
- residual tumour if left
- postoperative risk
- consultations
- rehabilitation plan

Documentation should be factual and clinically useful.

32.39 DISCLOSURE

Patients and families should receive clear communication regarding:

- what occurred
- current functional effect
- what was done
- what remains uncertain
- next steps

Avoid premature certainty when outcome is still evolving.

Honest communication is part of complication management.

32.40 REVIEW THE EVENT

After recovery from the immediate crisis, review:

WHAT WAS THE FIRST WARNING?

WHAT ACTION CREATED THE INJURY?

WAS THE RISK PREDICTABLE ON IMAGING?

WAS THE EXPOSURE ADEQUATE?

SHOULD ANOTHER TEAM HAVE BEEN INVOLVED EARLIER?

WHAT WILL CHANGE NEXT TIME?

The purpose is not blame.

It is preventing recurrence.

DECISION FRAMEWORK

MAJOR SKULL-BASE COMPLICATION

1. STOP

↓

2. CONTROL THE IMMEDIATE THREAT

Bleeding / airway / pressure / neural traction

↓

3. STABILISE PATIENT & FIELD

↓

4. DEFINE WHAT HAS HAPPENED

↓

5. CALL REQUIRED EXPERTISE

↓

6. REPAIR / RECONSTRUCT

↓

7. REASSESS ORIGINAL OPERATIVE GOAL

↓

CONTINUE

MODIFY

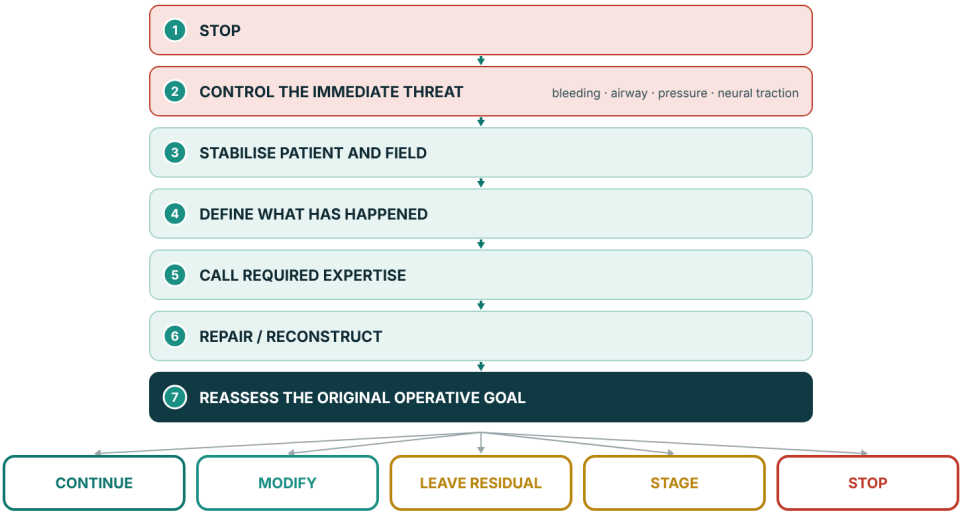
LEAVE RESIDUAL

STAGE

STOP

Figure 32.9 · Lateral skull-base bailout algorithm

Control first · preserve function · reconstruct · then decide whether to complete



FROM EXPERIENCE

The most dangerous moment in skull-base surgery is sometimes not when the complication begins.

It is the minute afterward.

Because the surgeon may still be psychologically attached to the operation that existed before the complication.

But that operation is gone.

A carotid injury creates a vascular operation.

A vagal injury creates an airway and swallowing problem.

A major CSF defect creates a reconstructive operation.

Loss of hearing can change the logic of the corridor.

The surgeon must therefore be able to release the original plan quickly.

> **The complication changes the anatomy.**

> **The anatomy changes the objective.**

> **The objective changes the operation.**

That adaptability is part of skull-base surgery.

TAKE IT TO THE OT

Before major lateral skull-base surgery, know:

CAROTID BAILOUT

Who can repair / stent / bypass?

VENOUS BAILOUT

What if sigmoid or jugular bleeding occurs?

FACIAL NERVE

Repair / graft plan?

LOWER CRANIAL NERVES

Airway and swallowing plan?

CSF LEAK

What tissue is available for closure?

FLAP FAILURE

Can the reconstruction be revised?

HEARING LOSS

Does it change the corridor?

RESIDUAL TUMOUR

Can it be observed or irradiated?

STAGING

What would make you stop today and return later?

POSTOPERATIVE DESTINATION

ICU / monitored unit?

CHAPTER SUMMARY

Major skull-base complications should change the operation immediately.

Control life-threatening problems first.

Stabilise before attempting definitive repair.

Understand arterial and venous anatomy before treating vascular injury.

Recognise that neural function can deteriorate despite anatomical continuity.

Plan airway and swallowing management after lower cranial nerve injury.

Treat CSF leak as a pathway problem.

Use vascularised tissue to protect exposed critical structures.

Leave planned residual tumour when the functional price of complete removal becomes excessive.

Stage or abandon surgery when continuing no longer serves the patient.

And remember:

CONTROL FIRST.

PRESERVE FUNCTION SECOND.

RECONSTRUCT THIRD.

> **Only then decide whether the original operation should continue.**

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From Pinna to Petrous

We began at the surface.

PINNA
Skin.

Cartilage.

Contour.

↓

EXTERNAL AUDITORY CANAL
A narrow epithelial corridor surrounded by bone and critical anatomy.

↓

TYMPANIC MEMBRANE
A thin membrane converting sound into mechanical movement.

↓

MIDDLE EAR
Three ossicles.

A few millimetres of space.

A complete mechanical system.

↓

MASTOID
Bone that initially appears without direction until landmarks begin to emerge.

↓

LABYRINTH
Hearing and balance contained within dense otic capsule.

↓

FACIAL NERVE
A nerve whose position should be predicted before it is exposed.

↓

INTERNAL AUDITORY CANAL

Several neural functions travelling through one small corridor.

↓

JUGULAR FORAMEN

Nerves, vessels, voice, swallowing and shoulder function meeting within the skull base.

↓

PETROUS APEX

Where almost every possible route is defined by something that must be preserved.

THE OPERATIONS CHANGED.

At the beginning we discussed:

- myringotomy
- myringoplasty
- canal surgery

Then:

- tympanoplasty
- ossiculoplasty
- mastoidectomy
- cholesteatoma

Then:

- stapes surgery
- cochlear implantation
- facial nerve surgery

And finally:

- vestibular schwannoma
- jugular-foramen surgery
- petrosectomy

- temporal-bone malignancy
- skull-base reconstruction

The procedures became larger.

But the fundamental method did not change.

THE SAME QUESTIONS REMAINED

WHERE AM I?

WHAT IS MY LANDMARK?

WHAT SHOULD APPEAR NEXT?

WHAT LIES BEYOND THE BONE I AM REMOVING?

WHAT FUNCTION AM I TRYING TO PRESERVE?

WHAT CAN I SAFELY SACRIFICE?

WHAT IS MY BAILOUT?

These questions belong equally to cortical mastoidectomy and skull-base surgery.

Only the consequences change.

THE TEMPORAL BONE TEACHES RELATIONSHIPS

The lateral semicircular canal is important partly because it predicts the facial nerve.

The digastric ridge matters because it predicts another segment of the same nerve.

The sigmoid sinus defines a boundary.

The jugular bulb changes the corridor.

The cochlea determines whether hearing-preservation remains possible.

The carotid defines how far some operations can safely proceed.

Anatomy becomes useful when one structure predicts another.

LANDMARK → RELATIONSHIP → ORIENTATION → SAFE MOVEMENT

FROM SEEING TO PREDICTING

At first, surgical anatomy is recognition.

> **There is the lateral semicircular canal.**

Later it becomes prediction.

> **The facial nerve should be here because the lateral canal, incus and digastric ridge are here.**

Eventually it becomes anticipation.

> **If I continue in this direction, the facial nerve will become vulnerable before I reach my target.**

That progression is important.

SEEING → RECOGNIZING → RELATING → PREDICTING → ANTICIPATING → OPERATING

COMPLEXITY DID NOT BEGIN AT THE SKULL BASE

A ventilation tube placed in the wrong direction can injure.

A poorly reconstructed tympanic membrane can fail.

An unstable ossicular prosthesis can transmit no sound.

A badly designed mastoid cavity can discharge for years.

A cochlear electrode forced against resistance can injure the inner ear.

A final tumour fragment pulled from a facial nerve can permanently change a patient's face.

The scale differs.

The principle does not.

There are no operations in which observation and judgment become unnecessary.

FUNCTION CHANGED THE CORRIDOR

Throughout this book, one principle repeatedly determined the operation:

WHAT FUNCTION STILL EXISTS?

If useful hearing exists:

protect the labyrinth where possible.

If hearing has already been lost:

the labyrinth may become a surgical corridor.

If the facial nerve functions:

preservation carries enormous value.

If the nerve must be sacrificed for oncological clearance:

reanimation becomes part of the original operation.

If lower cranial nerves remain functional:

complete tumour removal may carry a different cost than when those nerves are already paralysed.

Therefore:

ANATOMY TELLS US WHAT IS POSSIBLE.

FUNCTION HELPS TELL US WHAT IS WORTH DOING.

THE LAST MILLIMETRE

Many temporal-bone operations become most dangerous near their apparent completion.

The final matrix over a labyrinthine fistula.

The final shell over the facial nerve.

The final millimetre toward the IAC fundus.

The last tumour capsule attached to the facial nerve.

The last margin beside the carotid.

This creates an important surgical paradox:

AS THE AMOUNT LEFT TO DO DECREASES,

THE CONSEQUENCE OF EACH MOVEMENT MAY INCREASE.

Therefore the operation should often become slower as it approaches completion.

STOPPING IS ALSO A SURGICAL ACT

Throughout this book we repeatedly encountered the same decision:

continue

or

stop.

Sometimes the correct operation requires:

- changing the approach
- leaving a planned tumour remnant
- staging reconstruction
- asking for another surgeon
- abandoning an unsafe corridor

Stopping is not the absence of surgery.

It can be the result of surgical judgment.

THE SURGEON DOES NOT CONTROL EVERYTHING

We can:

- expose
- dissect
- drill
- reconstruct
- graft

- implant
- repair

But eventually biology continues the operation.

The tympanic graft must heal.

The mastoid cavity must epithelialize.

The nerve must regenerate.

The brain must compensate for vestibular loss.

The cochlear implant recipient must learn to interpret electrical hearing.

The flap must vascularize and withstand radiotherapy.

Therefore technical completion is only one stage of treatment.

From Pinna to Petrous

The distance is only a few centimetres.

But within those centimetres we travel from:

SKIN → CARTILAGE → BONE → OSSICLES → LABYRINTH → NERVE → DURA → BRAIN → MAJOR VESSELS.

That is what makes temporal-bone surgery extraordinary.

Not because the operations are called basic or advanced.

But because each additional millimetre reveals another relationship.

TAKEAWAY

Before every ear and temporal-bone operation:

SEE THE PATIENT.

READ THE IMAGING.

MAP THE ANATOMY.

DEFINE THE FUNCTION.

CHOOSE THE CORRIDOR.

ESTABLISH LANDMARKS.

PREDICT WHAT COMES NEXT.

KNOW WHAT MUST BE PRESERVED.

KNOW WHAT CAN BE SACRIFICED.

KNOW WHEN TO STOP.

KNOW THE BAILOUT BEFORE YOU NEED IT.

Then operate.

BOOK 2 · PINNA TO PETROUS — COMPLETE.

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MASTERING PRECISION IN OTORHINOLARYNGOLOGY

SURGICAL PERSPECTIVE · BOOK 2

Pinna to Petrous

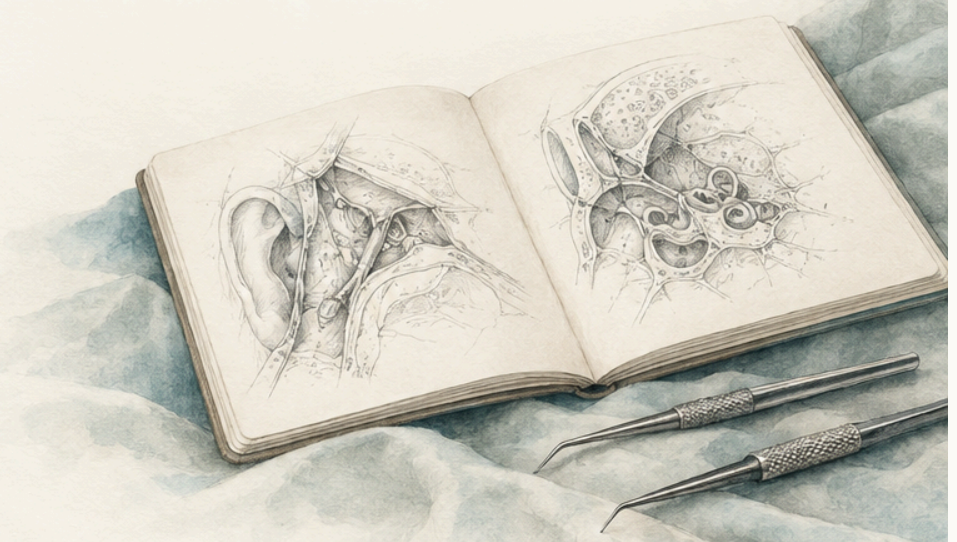
The ear, temporal bone and lateral skull base

Knowing the steps is only part of learning an operation. Understanding what guides each decision is another.

Pinna to Petrous brings operative technique into conversation with surgical reasoning: choosing an approach, developing exposure, recognising danger, preserving structures and reconsidering the plan when the expected anatomy does not appear.

Written for students, residents and surgeons who continue to learn, this volume encourages careful observation, deliberate practice and honest reflection on difficulty and complications.

Why this approach? What should appear next? What would make me stop?



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