Henning Hildmann
Holger Sudhoff

Middle Ear Surgery

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H. Hildmann, H. Sudhoff · Middle Ear Surgery

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Middle Ear Surgery

With contributions by
Manuel Bernal-Sprekelsen
Stefan Dazert
Orlando Guntinas-Lichius
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With 165 Figures in 182 Parts and 9 Tables

Springer

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Foreword

During the past 20 years, the ENT Department of the Ruhr University, Bochum, has been, under the leadership of Professor Henning Hildmann, an important centre for the teaching of otosurgery. Furthermore, during this time Bochum Clinic has become, mainly due to the efforts of Holger Sudhoff, a major focal point for otological research. A combination of two such eminent ear surgeons and their colleagues is a guarantee for an informative and inspiring book on ear surgery.

In Bochum Clinic, 17 Ear and Temporal Bone Surgery Courses have taken place over the years, each course with an attendance of 60–80 pupils from over the world. I had the privilege to be one of the teachers on these courses and was able to follow the outstanding surgery of the course leaders, Henning Hildmann and Jan Helms, both pupils of Dietrich Plester. It is therefore fitting that the book is mainly based on the ideas and techniques of this pioneering ear surgeon.

The book is divided into 34 chapters, most of which are written by Henning Hildmann or Holger Sudhoff. The remaining chapters are written by the teachers of the course at Bochum – all experts in their specialist topics: Alexander Rauchfuss, Jürgen Lautermann, Martin Scholz, Sergije Jovanovic, Matthew Yung and, finally, Stefan Dazert, who is the new chairman of Bochum Clinic and the new Director of the Bochum Ear and Temporal Bone Surgery Courses.

The many chapters on surgical methods are well written and easy to understand, even for beginners in otosurgery. These chapters are illustrated with many beautiful, clear and realistic colour illustrations. Most of them do not need a special explanation in the text. The surgical chapters are enhanced by chapters on preoperative evaluation, on „when not to do surgery" and on postoperative treatment.

Even though the title of the book is *Middle Ear Surgery*, several topics outside the middle ear are included, making this book even more complete.

One cannot but admire Henning Hildmann and Holger Sudhoff who, besides their clinical and administrative work, surgery and teaching, research and international obligations, have produced this well-written and well-illustrated work during the course of one year. I believe that both young and established otosurgeons all over the world will enjoy and benefit from this book.

Mirko Tos, Professor Emeritus of Otolaryngology
University of Copenhagen, Denmark

Preface

This book aims to give the young surgeon a step-by-step introduction to middle ear surgery, and we hope that the experienced surgeon will also find ideas and suggestions which may improve routine surgery and serve as a basis for discussion. A systematic approach is provided to frequent otological operations. Procedures in surgery of the ear canal, acute and chronic middle ear diseases, otosclerosis, cochlear implantation and vertigo are explained step-by-step to acquaint the beginner with the surgical techniques which have proven to give good results.

The book is mainly based on the ideas and techniques developed by Dietrich Plester, who had a major impact on the development of middle ear surgery. His secret of time efficient and successful surgery was based on a thorough preoperative assessment of the case, counselling of the patient to set realistic expectations, economic use of a few instruments, tender treatment of the tissue and the use of standardized procedures without being too rigid. This approach to surgery is not an unrealistic ideal, but it is teachable and learnable for a normally gifted surgeon. The principles were published in the German literature (by Plester, Hildmann, and Steinbach) 15 years ago. In the meantime our experience has grown. Jan Helms must especially be mentioned for the numerous courses and otologic events we have conducted together. Indeed many of his ideas have contributed to this book. We thank our national and international friends and colleagues, as well as participants of workshops, roundtables and conferences for valuable ideas, hints and criticism. We thank the teachers of our workshops and hosts in centres in many parts of the world. Therefore the principles presented here are the fruits of acquired surgical and clinical knowledge over time. This is a surgical textbook; nevertheless it should be remembered that a basic knowledge of clinical pathology and pathophysiology is necessary to understand the causes of failures. We thank Steinbach, Tos, Michaels, Behrend and many others for their teachings. Two chapters do not directly follow the concept of this book. A chapter on laser surgery by an experienced specialist and a chapter on cartilage tympanoplasty were included because these techniques are under discussion at the present time and may be of importance in the future.

Successful middle ear surgery, regardless of technique, requires intensive training on temporal bones, surgical training under the observation of an experienced surgeon, and permanent continuous education until retirement.

Conferences, workshops and visits to other centres are necessary. Surgical manuals provide additional ideas. Especially we want to mention the excellent compilation of otosurgical techniques by Mirko Tos.

We are very grateful to Harald Konopatzki, who provided us with the excellent illustrations in this book. We wish also to express our sincere gratitude to Dr. Andre Gurr for his excellent help with the assembly of the DVD. We also thank the publishers for their substantial help, support and patience.

We hope that our book will serve as an aid to learning the techniques of middle ear surgery and will provide a systematic and comprehensive approach to the subject for all surgeons involved in otologic surgery.

Henning Hildmann, Holger Sudhoff
Bochum, Germany

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1 Surgical Anatomy

Alexander Rauchfuss

The temporal bone presents a very complex anatomy. Therefore this overview is restricted to some major points from the viewpoint of surgical anatomy. For more detailed information see "Suggested Reading".

The temporal bone according to its developmental anatomy is divisible into four parts: the squamous, mastoid, petrous, and tympanic portions. Points of topographical reference on the lateral surface are the external acoustic meatus with its suprameatal spine, the temporal line, and the mastoid process.

The base of the zygoma extends as a crest posteriorly and slightly upward, forming the supramastoid crest or temporal line. The temporal line as a landmark corresponds to the base of the medial cranial fossa/tegmen tympani, which in most cases of surgery can easily be identified. In combination with the radiological anatomy in a Schüller view it allows adequate planning of the surgical approach to the antrum via the mastoid.

All figures show the anatomy of a left ear.

Figs. 1.1–1.5. Temporal bone and sigmoid sinus

Fig. 1.1. Temporal bone. The degree of pneumatization is inconstant. The extent and arrangement of air cells varies considerably from a minimal air cell system in the surroundings of the antrum to involvement of most of the temporal bone. Pneumatization usually begins in late fetal life, progressing until the end of childhood. The pneumatization process starts from the antrum. In most cases one can describe the topography of the cells as follows: periantral, sinodural, perisinual, perifacial and mastoid tip cells. According to the extension of the cells, there is only one rule: the further from the antrum, the bigger the cells

Fig. 1.2. Schüller view of the left ear. The bony shell of the sigmoid sinus, the base of the middle cranial fossa/tegmen tympani, and the external auditory canal can easily be identified

Fig. 1.3. The temporal line, the position of the sigmoid sinus as identified in the Schüller view, and the margin of the posterior wall of the external auditory canal form a triangle which represents a safe approach to the antrum via the mastoid (......). The sigmoid sulcus housing the sigmoid sinus is a deep groove on the medial surface of the mastoid. Following the ancient Greek anatomical terminology, the sigmoid sulcus describes an S-shaped figure, curving from the transverse sinus downward, terminating in the bulb of the internal jugular vein

Fig. 1.4. A prominent suprameatal spine is an indicator of normal topography of the sigmoid sinus in most cases. The superior petrosal sulcus is a dual venous channel along the superior angle of the pyramid ending in the transverse sinus. The inferior petrosal sulcus follows the posterior angle and ends in the jugular bulb. The jugular fossa is situated on the inferior surface of the temporal bone posteromedial to the carotid foramen. During surgery one should always be aware that the fossa jugularis sometimes is separated from the posterior cranial fossa by only a thin plate of bone. When the roof of the fossa is dehiscent, the bulbous vein protrudes into the tympanic cavity covered with nothing more substantial than the middle ear mucosa

Fig. 1.5. In the case of a narrow or absent suprameatal spine one should be aware of a protruding sigmoid sinus

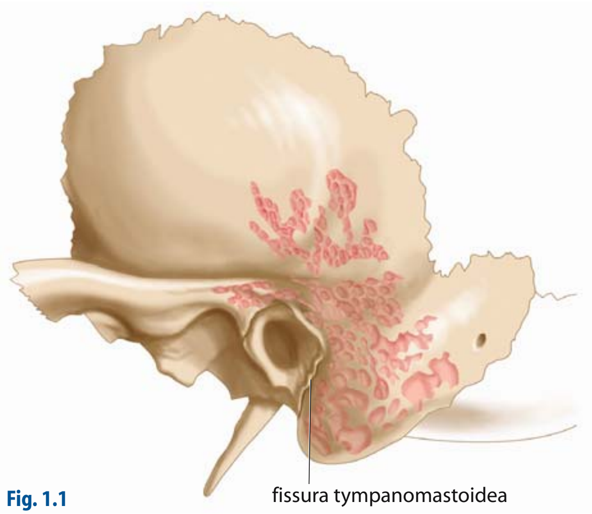
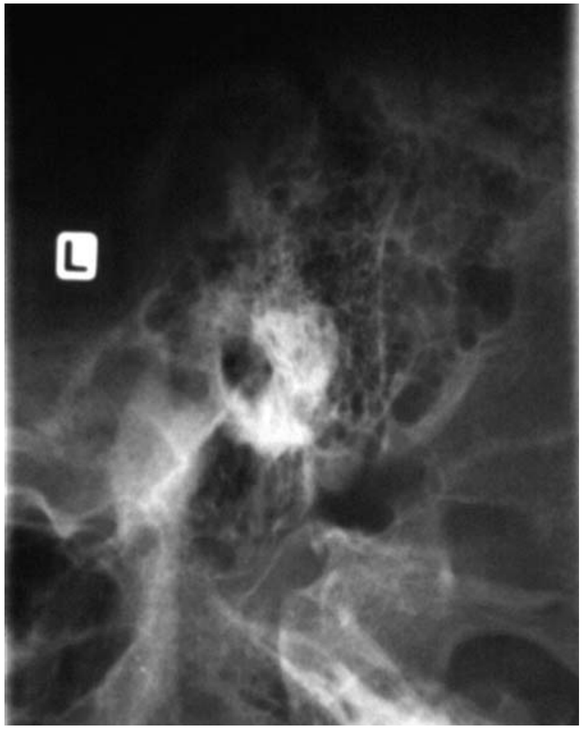


Fig. 1.1



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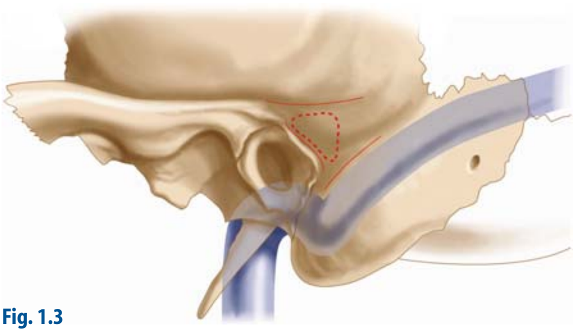

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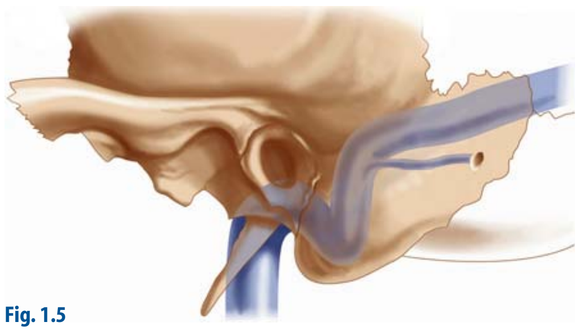

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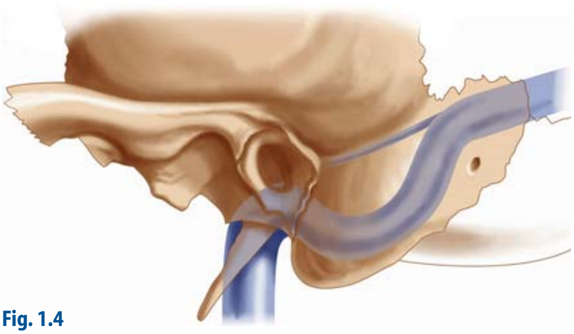
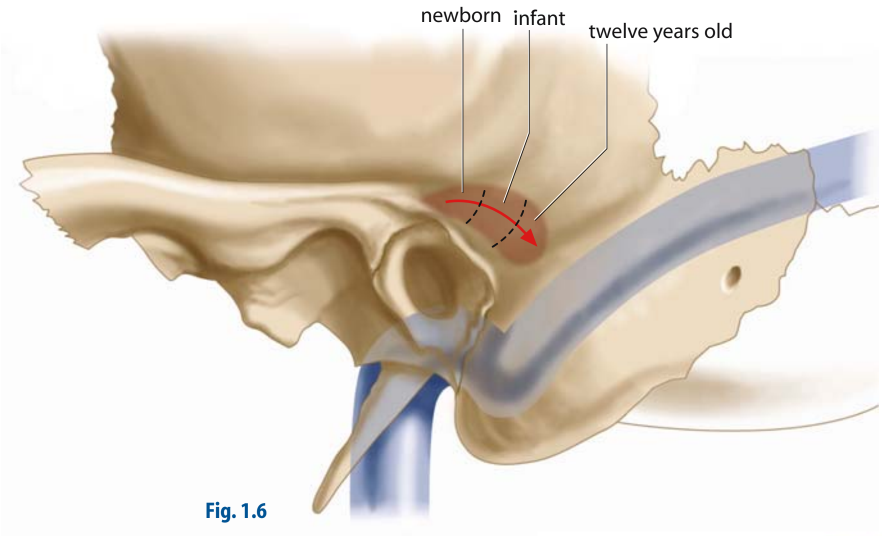


Fig. 1.4

Figs. 1.6 – 1.7. The antrum and the topography of the posterior approach to the middle ear

Fig. 1.6. The antrum is an aperture in the upper part of the posterior wall of the epitympanic recess, positioned above, behind, and lateral to the tympanic cavity. It varies exceedingly in size. The lumen and the extent of the antrum into the mastoid depend on the individual's age. In the newborn it is almost cranial to the external auditory canal. During the process of aging and pneumatization it exfoliates stepwise into the mastoid

Fig. 1.7. Sketch of the mastoid topography



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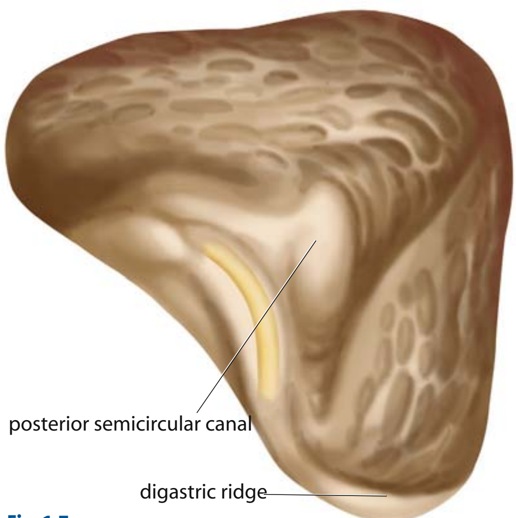


Fig. 1.7

Figs. 1.8 – 1.10. Stepwise exposure of the middle ear via the posterior approach

Fig. 1.8. Identification of the short process of the incus in the antrum just over the bony coverage of the lateral semicircular canal. The digastric ridge can be helpful as a landmark and a guideline for identification of the facial nerve in cases of difficult topography

Fig. 1.9. Posterior approach to the middle ear. The buttress ("*Brücke*" *in the German surgical literature) is still intact*

Fig. 1.10. The buttress is removed and part of the bony coverage of the facial canal is taken away. The posterior tympanic artery, which lies in close contact with the nerval sheath, is a reliable landmark with which to identify the facial nerve

Fig. 1.8

Fig. 1.9

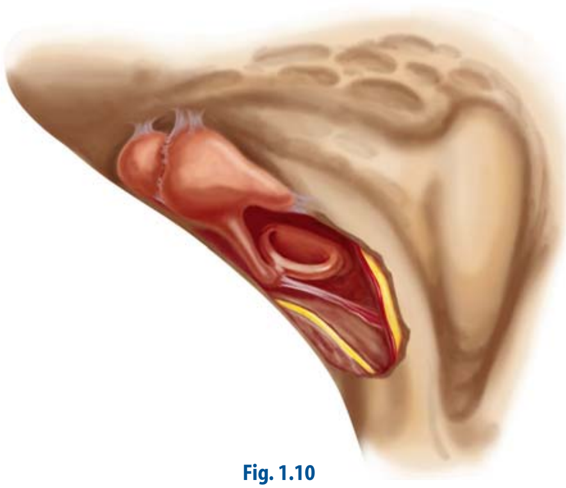


Fig. 1.10

Figs. 1.11 – 1.14. The middle ear

The boundaries of the middle ear/tympanic cavity are the tegmental wall, a thin bony plate which separates the middle ear from the middle cranial fossa, the jugular wall, which is part of the floor of the middle ear, the posterior mastoid wall, which contains the facial nerve, the labyrinthine wall with the promontory and the tympanic plexus, the oval and the round window, and the cochleariform process with the tensor tympani tendon. The anterior wall protects the internal carotid artery and contains the orifice of the auditory tube

Fig. 1.11. The tympanic membrane, which forms the lateral wall of the middle ear, stretches out into the tympanic sulcus, a groove in the concavity of the tympanic ring. In this sketch the tympanic membrane is removed. The tympanic ring is an incomplete circle. Between its anterior and posterior horn there is the tympanic incisura, also called the incisura Rivini. The chorda tympani arises from the facial nerve in the facial canal. It ascends at an acute angle into the tympanic cavity. The chorda crosses the tympanum, passing between the long crus of the incus and the manubrium of the malleus. Entering the aperture of the petrotympanic fissure (fissura Glaseri), it descends to the inferior surface of the tympanic part of the temporal bone

Fig. 1.12. Incus and malleus. The short leg of the incus is directed horizontally backward and lies in the fossa incudis. The long leg lies parallel to the manubrium of the malleus and articulates via a small process with the stapes. The head of the malleus occupies the recessus epitympanicus. The head is separated by the neck from the handle of the malleus. The tendon of the tensor tympani muscle after emerging from the cochleariform process inserts in the malleus neck

Fig. 1.13. Topography of the oval window region. The sinus tympani appears as a deep fossa on the medial wall of the tympanic cavity, just in front of and below the pyramidal eminence. Te base of the stapes is the footplate, which fills the oval window. The stapes possesses two legs and a head. The average length of the footplate is 2.99 mm; the average width is 1.41 mm [1]. The stapedius muscle arises from a sulcus in the wall of the facial canal. Its tendon escapes through the apex of the pyramidal eminence and inserts on the posterior surface of the stapedial neck

Fig. 1.14. The relationship between the stapedial footplate and the structures of the inner ear, utricle and saccule is of considerable surgical importance. During surgery one should be aware of the critical distances in the vestibule

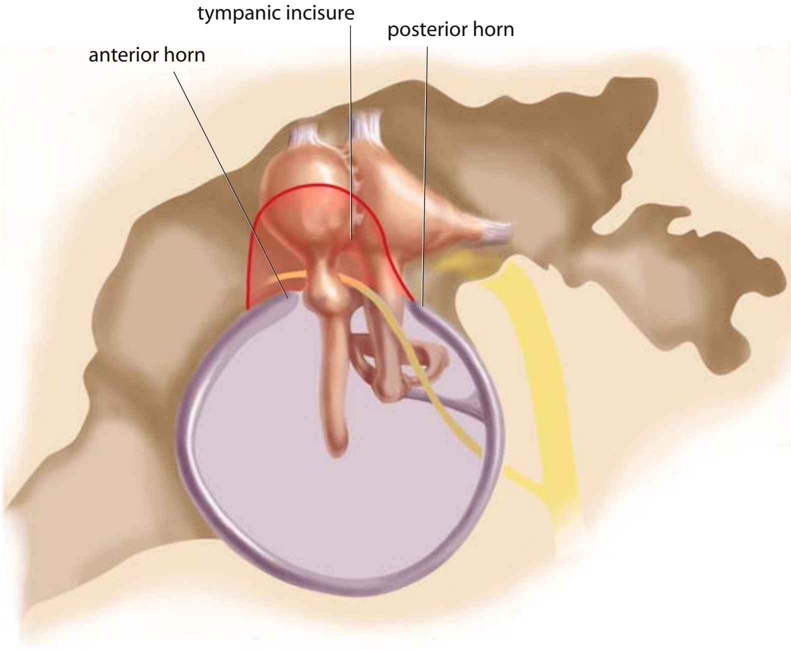
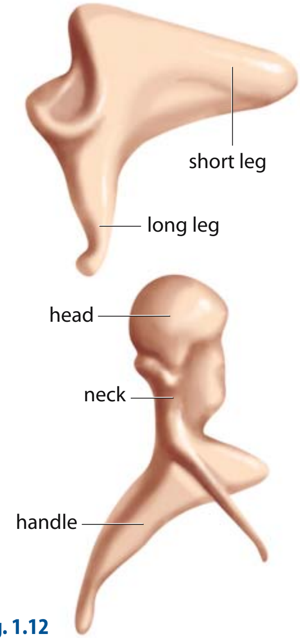


Fig. 1.11



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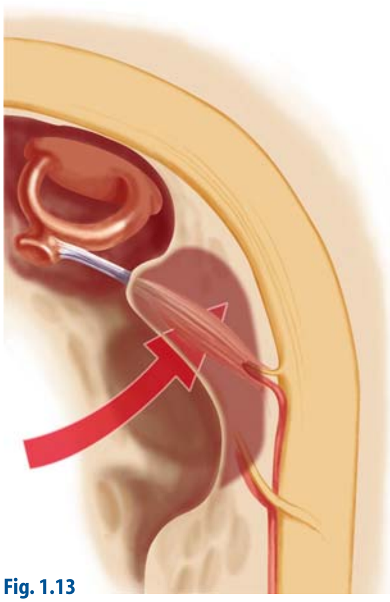

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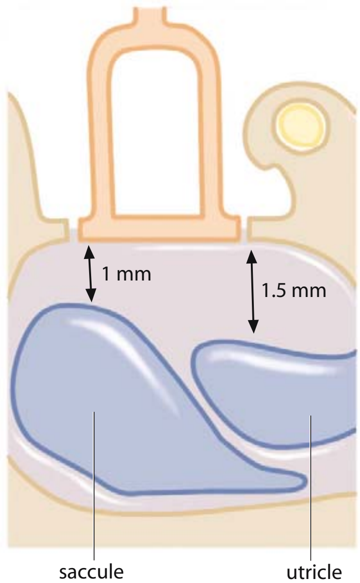


Fig. 1.14

Fig. 1.15a. The facial nerve

The facial nerve runs a tortuous course in the temporal bone. The first horizontal part of the facial nerve goes from the internal auditory canal to the geniculate ganglion and is called the "labyrinthine segment". Its length varies from 3 to 5 mm. It approaches the geniculate fossa, which is the crossroads of four nerve canals: the central and peripheral portion of the facial canal, and the canals for the major superficial petrosal nerve and the minor superficial petrosal nerve.

The second portion of the facial canal is called the "tympanic segment". It extends from the geniculate fossa, where the nerve forms its first turn, has a length of 10 – 12 mm, and lies at its beginning above and medial to the cochleariform process. Its middle portion runs over the oval window, forming the roof of the posterior tympanic sinus.

The third or "vertical portion" emerges from the second turn of the canal, which lies beneath the posterior part of the horizontal canal and extends to the stylomastoid foramen with a length of 10 – 14 mm.

All portions of the facial canal are subject to variations and anomalies. The facial canal may display bony dehiscences and variations in its course.

b The congenital bony dehiscences may involve any part of the canal as it traverses the temporal bone, and most often they are found in the surroundings of the oval window. There they are almost frequently located above and posterior to the oval window. During surgery they should always be anticipated. "As a rule they are less numerous and smaller in a well-pneumatized temporal bone" [2].

The numerous anomalies of the route of the facial nerve may involve each segment and may be conveniently classified under topographical aspects. They are frequently observed in cases of malformation and are often associated with other abnormalities of the external, middle, and inner ear.

The tiny shell of the facial canal can adhere to the jugular dome, especially when the jugular bulb rises into the tympanic cavity. The facial canal may even be dehiscent on its further route to the stylomastoid foramen.

The chorda tympani nerve arises from the facial nerve, on average, 5 mm above the stylomastoid foramen. Its origin may vary from 1 to 11 mm from the foramen, and in some cases the origin is extratemporal

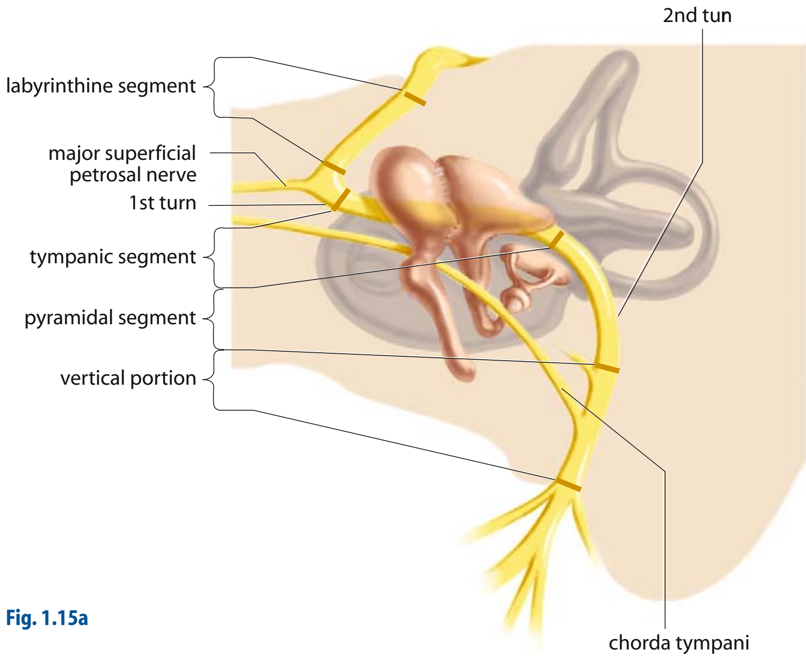


Fig. 1.15a

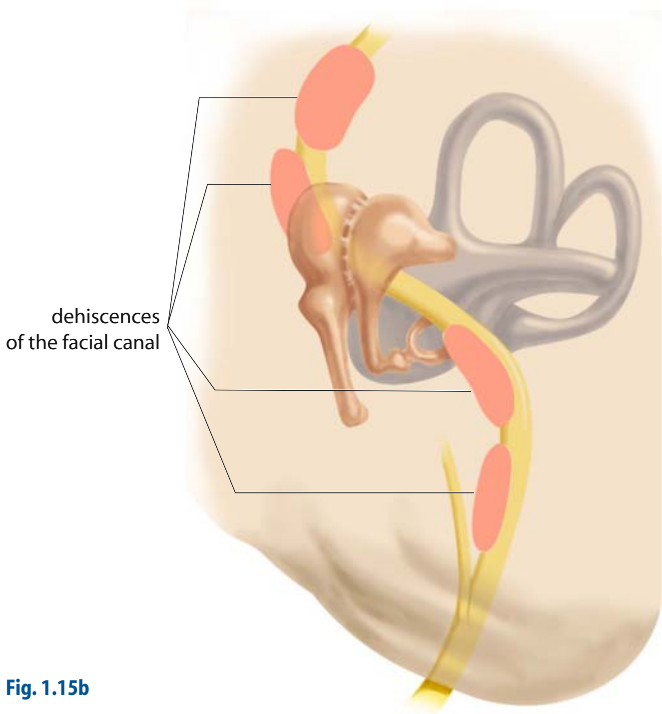


Fig. 1.15b

2 Preoperative Evaluation

Jürgen Lautermann, Holger Sudhoff, Henning Hildmann

The patient's past medical condition should be taken preoperatively. The patient should be asked about any pre-existing diseases, what medication they are on and whether they have any drug allergies. Aspirin, for example, should be discontinued for 1 week prior to surgery, warfarin should be substituted with heparin and metformin should be discontinued 48 h before general anaesthesia. A thorough examination of the head and neck including otomicroscopy should be performed. If cleaning of the external auditory canal becomes necessary, care must be taken because suctioning in rare cases can cause an acoustic trauma. Weber and Rinne tuning fork tests should be performed on each patient. These tests are simple and reliable and serve as a cross-check to audiometric tests. In otosclerosis, for example, the handle of the malleus readily moves when applying air pressure to the external canal whereas these movements cannot be detected in fixation of the head of the malleus. If Valsalva's manoeuvre is negative, special attention should be given to the nose and the nasopharynx in order to exclude special conditions leading to obstruction of the eustachian tube. However, current tests are not reliable or exact. In selected cases a septoplasty or surgical reduction of the turbinates may become necessary before tympanoplasty or even revision tympanoplasty. The patency of the eustachian tube is of great importance for the success of the operation, so that patients should learn to perform Valsalva's manoeuvre not only preoperatively but also in the early postoperative period. In children ventilation of the eustachian tube can be performed by inflating special balloons through the nose.

Perforations of the eardrum preoperatively can be covered with a non-ototoxic antibiotic ointment. Improvement of hearing indicates that the ossicular chain is probably intact. In patients with a cholesteatoma, erosions of the semicircular canal should be tested for with the help of a Politzer balloon. However, even in cholesteatoma with proven erosion of the semicircular canal the fistula sign is positive only in about 60 % of cases.

Audiology

Preoperative audiologic testing should include at a minimum pure tone audiometry and tympanometry with the measurement of acoustic reflexes. Proper masking of the contralateral ear is important in order not to miss preoperative unilateral deafness and to prevent a shadow curve. In doubtful cases it is recommended to test understanding of speech while masking the contralateral ear with a Barany masker. Audiologic testing should include tuning fork tests. In general if the test according to Rinne is negative, conductive hearing loss is more than 20 dB and surgical improvement of hearing is worthwhile. If the patient reports vertigo or if a nystagmus is detected using Frenzel's glasses, thermic responses in vestibular testing should be tested either with water or with air in perforated eardrums. In unilateral loss of vestibular response or pre-existing unilateral sensorineural hearing loss, a retrocochlear pathology must be excluded.

Imaging

The pneumatization of the mastoid and a protruding lateral sinus can be seen on the conventional X-ray according to Schüller. This is important if a mastoidectomy has to be performed. In cholesteatoma surgery for example the surgeon would "follow the pathology" in a badly pneumatized mastoid and remove the pathology by an atticotomy, whereas in a well pneumatized mastoid a mastoidectomy with or without a posterior tympanotomy would be performed. A high-resolution CT scan is not needed routinely for every ear operation, not even for cholesteatoma surgery. A CT scan should be performed for example in congenital cholesteatoma, malformations, before cochlear implant surgery and if complications are suspected such as erosion of the semicircular canal. Magnetic resonance imaging plays an important role for intracranial complications, visualization of the cerebellopontine angle and the petrous apex. Moreover, before cochlear implant surgery the patency of the cochlear ducts can be evaluated.

Patient Information

The patient will be satisfied with an operation if the disease is eradicated and hearing is improved. However, improvement of hearing is not certain, recurrent disease is possible and complications may occur. Ensuring the patient has sufficient preoperative information without making any exaggerated optimistic promises will avoid a disappointed patient and medicolegal problems.

In cholesteatoma cases, surgery is necessary to prevent life-threatening complications. The patient must know that the primary aim of surgery is a safe ear. Hearing improvement is secondary and cannot always be achieved. Hearing might be normal before surgery. Nevertheless the chain has to be dissembled to remove the epithelium and reconstruction may fail. The patient must know that hearing might be worse after the operation. Revisions are possible but are also not always successful.

In chronic suppurative otitis media, complications are rare. Consequently the patient's subjective wishes are more important, i.e. protection against infections through the perforated drum, the cessation of draining and hearing improvement.

Stapes surgery for otosclerosis is a procedure which has good hearing results. However, according to the meta-analysis of Häusler, a considerable number of patients do not show complete closure of the air-bone gap [1]. Therefore borderline cases should not be operated on. The Rinne test should be clearly negative. Since serious inner ear damage may be possible in 0.5 % – 1 % of cases, a hearing aid should be discussed as an alternative. Stapes surgery generally should not be performed if the contralateral ear is completely deaf. Subjectively, patients will have a significant benefit from hearing improvement only if surgery results in an air conduction threshold of 30 dB in the impaired ear or if the level of hearing is within 15 dB of the contralateral ear (the Belfast Rule of Thumb).

Signed Consent

The patient should give his or her informed consent at least the night before the operation. Potential risks include intra- and postoperative bleeding, infection, scar formation, hearing loss, vertigo, tinnitus, facial nerve paralysis, taste deterioration due to chorda tympani injury, abnormal shape of the auricle and revision surgery. Particularly before stapes surgery the patient should be informed about the risk of postoperative deafness and possible alternatives for hearing rehabilitation such as a hearing aid. It must be discussed whether the operation should be performed using general or local anaesthesia. When operating using local anaesthesia the patient can immediately inform the surgeon about vertigo or improvement of hearing after reconstruction of the ossicular chain. If a cholesteatoma is operated on using a closed technique, the need for a second look operation should be discussed with the patient before the operation. Indications for hearing improvement have to be very restrictive if surgery is intended on the only hearing ear with complete deafness on the contralateral side. In these cases the alternative of a hearing aid should be discussed with the patient.

Medical Treatment

The best way to dry a draining ear is by way of a tympanoplasty. In general we do not give antibiotics preoperatively or intraoperatively unless severe inflammation of the ear canal or the middle ear is noticed or complications are likely. In these cases the patient is treated before surgery based on the antibiogram-resistogram or receives a one-shot prophylaxis according to the severity of the inflammation. Antibiotics are given during surgery when the inner ear is inadvertently opened or other structures such as the cochlea, the facial nerve, the dura or sinus seem affected. If we expect inner ear trauma during surgery, 1 g of prednisolone is administered in addition to the antibiotic treatment. High doses of steroids seem to have a protective effect on the inner ear as shown.

In chronic suppurative otitis media it is desirable to operate on a dry and non-infected ear. However, if preoperative therapy cannot stop secretion, surgery is the treatment of choice for the draining ear. Cultures should be taken because chronically draining ears are often infected with *Pseudomonas aeruginosa*. In these cases ciprofloxacin-containing eardrops can be administered. If the meatal skin is infected and swollen, a gauze soaked in a corticoid and antibiotic-containing ointment should be applied to the external ear canal.

Nerve Monitoring and Computer-Assisted Surgery

Facial nerve monitoring is not routinely recommended, but is certainly helpful and is recommended for inner ear (e.g. vestibular neurectomy, facial nerve exploration) and malformation surgery. At the moment computer-assisted surgery in the lateral skull base is not precise enough and is too time consuming. It may become useful in the future for surgery of tumours and malformations and for difficult revisions.

3 When Not To Do Surgery

Henning Hildmann, Holger Sudhoff

A central perforation of the tympanic membrane with and more so without suppuration is hardly a threat to the patient. In contrast to cholesteatoma surgery, surgery for suppurative otitis media is not obligatory and therefore should be individualized according to the general medical status, the age and the wishes of the patient. When there is a normally hearing contralateral ear, there is a requirement for a greater level of care and counselling with the patient for the affected side. Besides hearing loss, chronic draining or the desire to swim are additional arguments for surgery.

Microscopic inspection, audiometry and possibly imaging enable the prognosis to be estimated. Ears with combined hearing loss, extensive tympanosclerosis or complete adhesive otitis have less chance of hearing improvement. Sometimes fitting a hearing aid after successful closure of a perforation might be the better alternative to revision surgery. Even a type I tympanoplasty may cause serious inner ear damage. If the contralateral ear is deaf, surgery may cause complete deafness. The patient must be aware of this risk, though it is small.

Tubal dysfunction is one of the causes of chronic middle ear disease. A reliable and reproducible test for tubal function does not exist. To estimate the prognosis we need to rely on indicators such as cleft palates, cranial deformities, and hypomobility of the orofacial neuromuscular system causing dysfunction. Complete adhesive otitis also indicates tubal insufficiency. In these situations an open cavity in cholesteatoma cases is often preferable to techniques with reconstruction of the posterior wall.

In completely adhesive otitis the tympanic membrane should be reconstructed. This gives more resistance to the negative pressure in the middle ear.

In cases of recurrence the surgeon must consider the limits. A hearing aid might be better for a recurrent adhesive otitis than revision surgery. A reluctant patient should not be urged to have surgery unless it is unavoidable.

A less experienced surgeon might encounter situations, for instance, extensive cholesteatomas, intracranial extension of the disease, brain hernias, and facial nerve abnormalities or tumours, which he or she is not trained to handle. In this case the surgeon should close the ear and refer the patient to an experienced centre.

4 Postoperative Treatment

Holger Sudhoff, Henning Hildmann

The packing material is completely removed from the external canal 2–3 weeks after surgery for a chronic ear and in cases of tympanoscopy or stapes surgery, within 1 week after the operation. Some patients, especially children, may sometimes require general anaesthesia or sedation for the removal of the ear packing and local treatment with antibiotic and steroid-containing drops for an additional 2 weeks to clear the ear of residual Gelfoam and debris. Granulations which do not respond to eardrops are removed by cupped forceps or by chemical cauterization. In the region of the facial nerve chemical cautery should not be used. Necrotic parts of a flap can be removed with microscissors. Often the remnants of the flap are still viable and attention has to be paid that the intervention is not impaired by extraction of the total flap. Postoperative stenosis may develop when the skin of the ear canal has been injured in its whole circumference. Sometimes a wick can be used to bougie the stenosis.

Mastoid cavities need a longer postoperative treatment. The patient should be informed of this prior to surgery. Keeping the cavity dry and clean is the most important factor of treatment. Sometimes an electric hairdryer used several times daily is helpful. It is recommended that Valsalva's manoeuvre be performed three times a day beginning 2–3 weeks after the surgery. A postoperative audiogram is obtained 6–8 weeks later, and the tympanic membrane is examined. If the hearing result is good and the tympanic membrane is clear, the ear is examined at 6 months and again at 1 year from the date of surgery. If effusion is present, nasal steroids are added, and Valsalva's manoeuvre is encouraged. The tympanic membrane may be punctured, the fluid aspirated and a mixture of cortisone and antibiotic solution administered directly into the middle ear.

Unless the clinical or personal situation of the patient requires it, second stage surgery or recurrent perforations should not be done earlier than 1 year after the first intervention. As animal experiments have shown, the middle ear mucosa needs a long time to normalize. Residual cholesteatoma generally develops slowly in a non-inflamed ear. Staged surgery for residual cholesteatoma should be done after 2 years unless the microscopic examination indicates epithelial growth.

Even though some authors do not object to the patient flying 2 days after surgery and no adverse effects are mentioned in the literature, we suggest waiting for 4 weeks especially when infections of the upper respiratory airways are present.

There is no objection to the patient diving if the ear is dry, the outer ear canal is normal and the pressure equilibration is sufficient. Patients with infected ears and radical cavities should refrain from diving.

5 Local Anaesthesia

Holger Sudhoff, Henning Hildmann

Local and general anaesthesia can be used for middle ear surgery. However, both forms require the use of local injection to reduce intraoperative bleeding and intra- and postoperative pain. Local anaesthesia is achieved by the subcutaneous injection of 1% or 2% local anaesthetic with 1:100,000 adrenaline using a 2-ml syringe. It can be applied in combination with sedation in local or in general anaesthesia. For this the auricle is pulled forward and a depot is placed in the postauricular fold (**Fig. 5.1**). The needle is then advanced further under permanent application of local anaesthetic towards the posterior canal skin, then pulled back and advanced superiorly and inferiorly to the prior injection site (**Fig. 5.2**). Subsequently the ear canal is opened with a nasal speculum, allowing subperiostal injection at the 3, 6, 9 and 12 o'clock positions (**Fig. 5.3**). The bevelling of the needle is placed against the bone and the anaesthetic is injected until the ear canal skin turns white and becomes prominent. The ear canal is sealed with a cotton ball prior to disinfection to avoid the penetration of potentially ototoxic substances into the middle ear cavity if a perforation is present. In some cases the local anaesthesia is insufficient for the promontorial region innervated by the tympanic nerve. This can be overcome by the topical application of lidocaine solution.

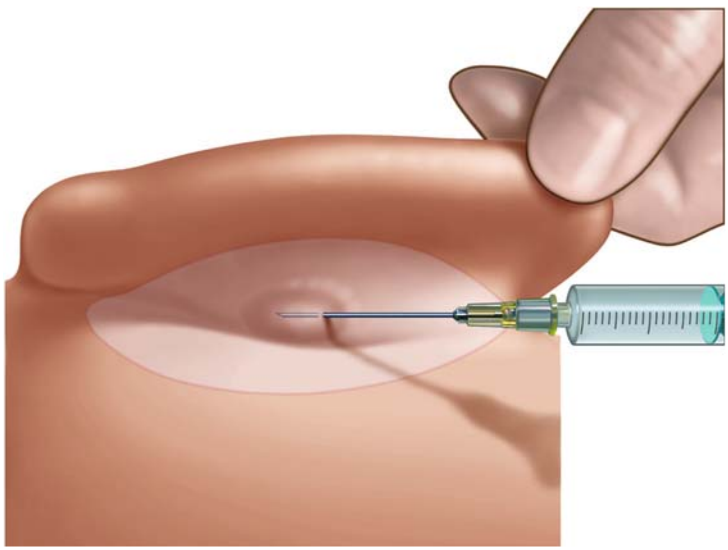


Fig. 5.1

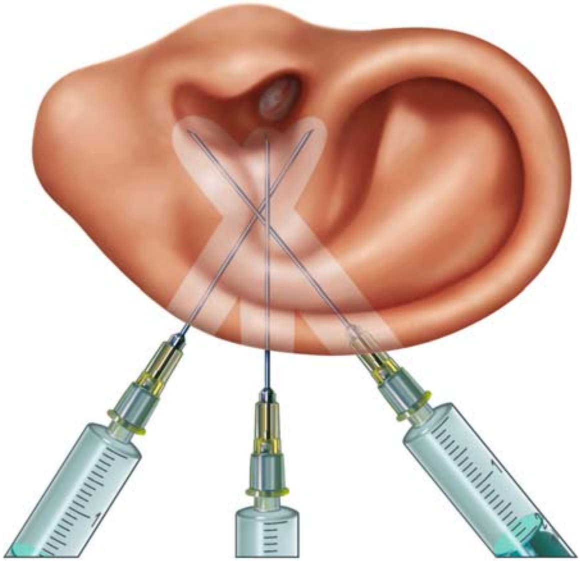


Fig. 5.2

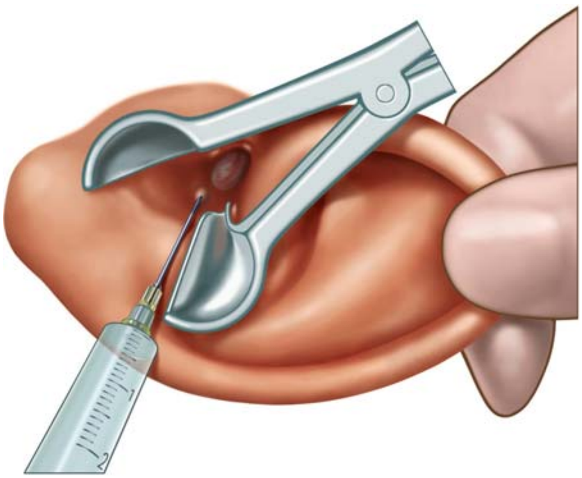


Fig. 5.3

General Anaesthesia

General anaesthesia is used for extended and long-lasting procedures, generally in children and non-cooperative patients (handicapped or language-deficient). Routine preoperative examinations are performed.

6 Approaches to the Middle Ear

Andre Gurr, Holger Sudhoff, Henning Hildmann

The decision as to perform transcanal, endaural or a retroauricular approach should be based on the preoperative evaluation. The expected extent of surgery, the necessity of opening the mastoid, the given anatomical findings, e.g. a narrow or angled external ear canal and a bulging anterior external ear canal wall, all have to be considered. The position of the sigmoid sinus and the depth of the dura are further aspects to be taken into account. Smaller central perforations and fresh traumatic perforations can be closed through a transcanal approach using a speculum.

The transcanal approach is the least traumatic approach and can be used for office procedures and small perforations. The endaural approach is generally used for surgery within the middle ear. It mainly comprises the region which can be seen by examining the patient preoperatively with the speculum, i.e. before stapes surgery and tympanoplasties without work in the mastoid.

Transcanal Approach

This approach can be used for small central and small residual central perforations, but a good overall view is essential. The use of self-retaining specula allows bimanual manipulations. Local anaesthesia should be restricted to avoid bulging and to ensure good access to the tympanic membrane. Essentially the transcanal approach is considered as an office procedure. We do not use this approach for stapes surgery.

Endaural Approach

Most central perforations in chronic otitis media can be treated using an endaural approach. Enlargement of the ear canal and the partial reduction of a prominent anterior canal wall to expose the anterior part of the drum may be necessary. Additionally, tragal cartilage or perichondrium can easily be harvested by extending the incision to the anterior portion of the external meatus. However, the amount of perichondrium accessible from that approach may not be sufficient for the closure of subtotal perforations. The endaural approach – as shown by the dashed yellow line – is faster and less traumatic compared to the retroauricular approach (**Fig. 6.1**). It is facilitated by the assistance of the nurse retracting the auricle posterior-superiorly without bending the helix cartilage (**Fig. 6.2**). The lateral portion of the ear canal is expanded by an ear speculum using the left hand. The surgeon now has a good view over the superior entrance of the external ear canal between the helical and the tragal cartilage.

The intercartilaginous incision starts with a No. 10 scalpel with permanent contact to the bony external ear canal. The incision is extended parallel to the anterior portion of the helix upwards in a smoothly curved line with reduced pressure. This procedure reduces the risk to the superficial temporal vein and avoids bleeding (**Fig. 6.1**).

A second skin medial circumferential incision is placed 4–5 mm medial to the introitus of the external ear between the 6 and 12 o'clock positions and is extended to the intercartilaginous incision. The underlying soft tissue and periosteum are pushed laterally using a raspatory, exposing the suprameatal spine and tympanomastoid fissure. A small portion of the mastoid cortex will be exposed as well. A self-retaining retractor with sharp edges elevates the laterally based skin flap. A second self-retaining retractor is placed at a 90° angle to the first retractor with its blunt edge against the anterior portion of the external ear canal and the tragus (**Fig. 6.3**). The view may be obstructed by a prominent suprameatal spine or by a bulging bony anterior external meatus, which have to be drilled away. In the case of a perforation the middle ear should be protected against bone dust by gelatine balls. Irrigation may dislocate the elevated tympanomeatal flap by winding or tearing it. Therefore the use of diamond burrs is preferable adjacent to the tympanomeatal flap.

Retroauricular Approach

Even though mastoid surgery can be done from an endaural incision, e.g. with an extended Heermann's incision, we prefer a retroauricular approach for most situations when surgery in the mastoid is expected. We feel the overview is easier especially for cavity reduction techniques, such as removal of the tip of the mastoid or harvesting flaps for obliteration.

The retroauricular approach is preferable for assessment of the sinus-dura angle, air cells behind the sigmoid sinus and the potentially pneumatized posterior portion of the zygomatic arch. The exposure of the internal tabula of the middle and posterior cranial fossa is easily achieved by the retroauricular approach. A meatoplasty to enlarge the entrance of the external ear canal requires sufficient resection of conchal cartilage in selected cases. Large fascia and cartilage-perichondrium transplants are collectable from the concha. If soft tissue flaps are needed, the postauricular skin incision has to be 1.5 cm distant to the retroauricular fold.

The skin incision is performed by pulling the auricle anteriorly as illustrated by the red dashed line in **Fig. 6.4**. If a muscle-soft tissue flap is not necessary, the auricle is pulled forward and the skin and subcutis are incised from upwards down. Afterwards the scalpel should be used with permanent contact to the bony mastoid. Putting the left middle finger into the entrance of the external ear canal and bending the auricle forwards with the thumb and index

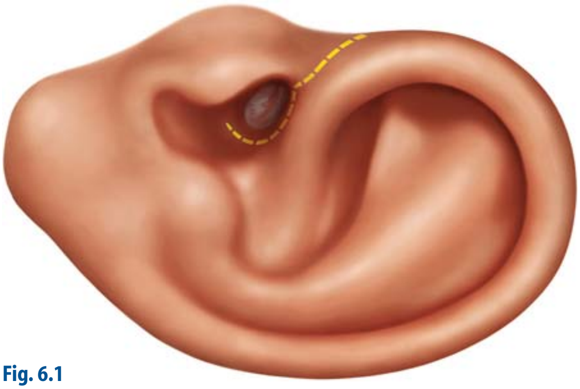


Fig. 6.1

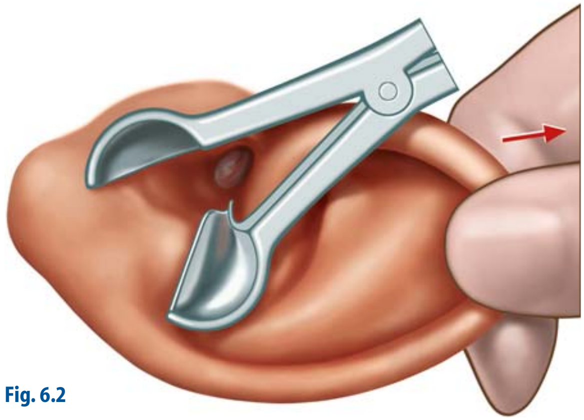


Fig. 6.2

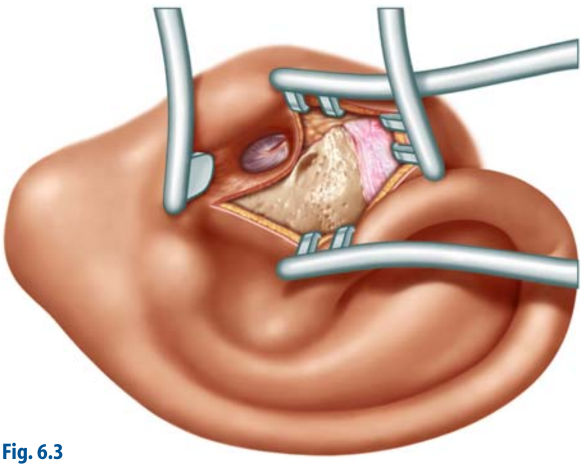


Fig. 6.3

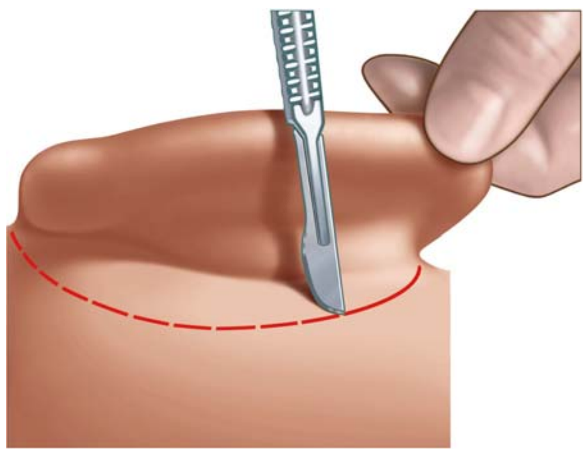


Fig. 6.4

finger, an incision is made to open the access to the external ear canal. The mastoid plane is exposed with a subcutaneous unloading incision angled at 90° as marked by the dashed red line in **Fig. 6.5**.

If fascia is needed, retractors are placed into the superior part of the incision, the covering soft tissue is pushed away and the necessary amount is removed.

The ear canal is opened from its posterior portion (**Fig. 6.6**). The retroauricular skin, the suprameatal spine and the entrance of the bony external ear canal are exposed. The meatal skin is incised from 12 to 6 o'clock 4–5 mm medial to the entrance of the ear canal to avoid injuring the anterior ear canal skin (red line).

By a second incision the canal is opened and the retractors are placed according to **Fig. 6.6**.

Tympanomeatal Flap

The tympanomeatal flap must be shaped according to the specific pathological findings of the tympanic membrane. Generally a No. 15 scalpel is used to incise the posterior skin of the external meatus between a 6 and a 12 o'clock position. The incision will be reinforced with the Plester's knife (**Fig. 6.7**).

The elevation of the tympanomeatal flap is created using the Plester's knife until the ligamental portion of the annulus tympanicus can be posteriorly and circumferentially seen close to the annulus; the angled knife is used, the blade drops into the sulcus and lifts it out of its position in its posterior portion (**Fig. 6.8**). The not-transected skin adjacent to the annulus can be cut with the Bellucci scissors to avoid disruptions of the tympanomeatal flap. Separating the soft tissue from the bone, the surgeon must work immediately on the bone, especially separating the fibres along the tympanomastoidal fissure line, which avoids tearing the flap. The suction is applied behind the knife. Otherwise the tissue is constantly pulled into the suction and slows down the procedure considerably.

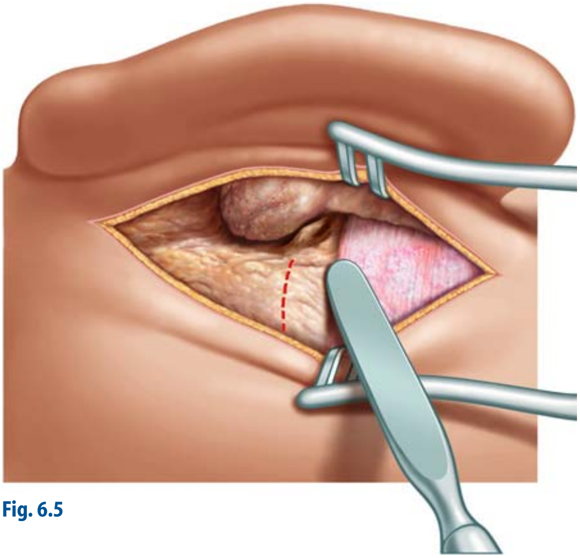


Fig. 6.5

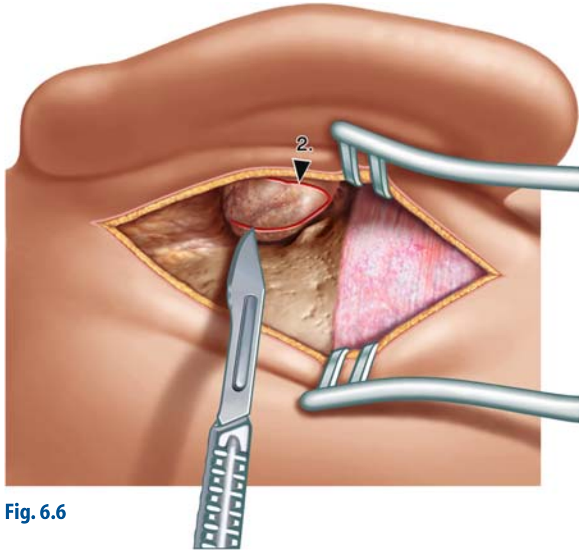


Fig. 6.6

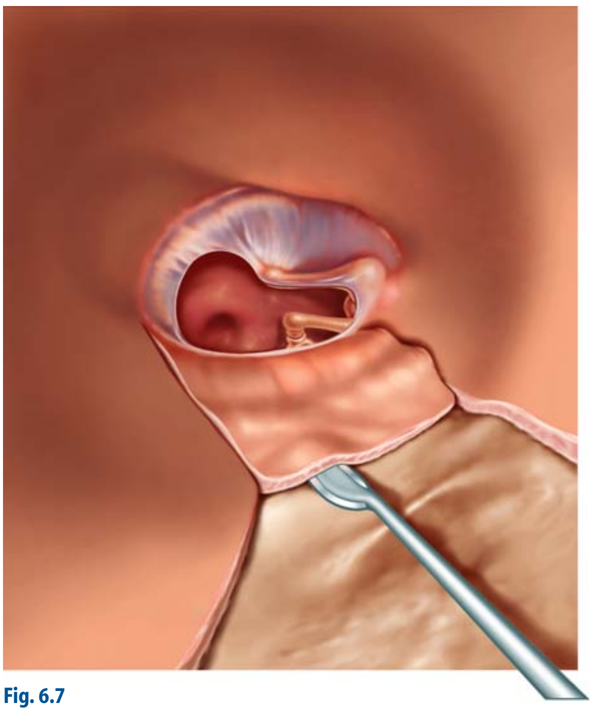


Fig. 6.7

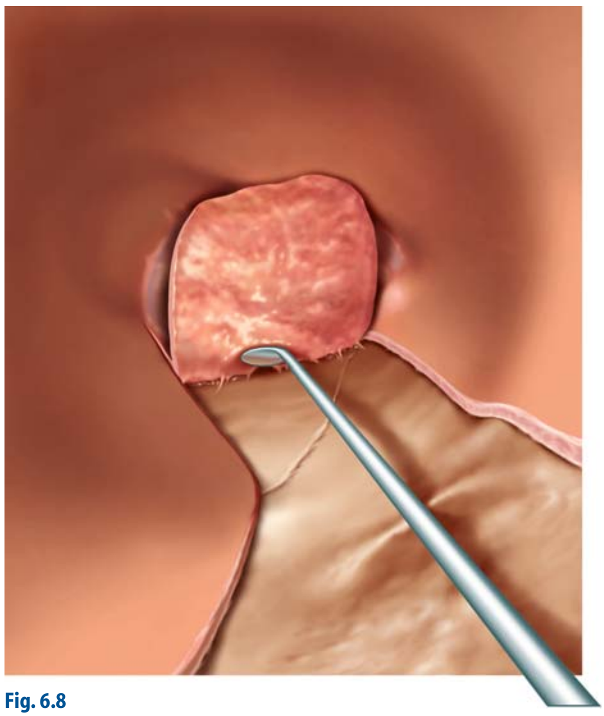


Fig. 6.8

7 Harvesting and Processing of Soft Tissues

Holger Sudhoff, Henning Hildmann

The temporalis fascia can be harvested using an endaural, retroauricular approach or by an additional superior laterally based skin incision. After having inserted the self-retaining retractors during the endaural approach, it is preferable to harvest the temporalis fascia to avoid readjustment of the retractors. The retractor is placed into the upper part of the incision. The overlying soft tissue is pushed aside by a raspatory (**Fig. 7.1**). The soft tissue overlying the solid fascia should not be used for tympanic membrane closure. The density of fibres is too low. Atrophic scars result after healing.

The fascia is exposed. The temporalis fascia is incised parallel to the linea temporalis, taking care not to injure the muscle (**Fig. 7.2**). A hook is inserted into the upper edge of the incision. The undersurface of the temporalis fascia is separated from the underlying muscle with a raspatory and the fascia is removed with dissecting scissors (**Fig. 7.3**). Attention should be paid not to injure the adjacent vessels. If the preparation is restricted to the fascia, no bleeding will occur as marked by the red dashed line in **Fig. 7.4**. Bleeders from the muscle or the margins of the fascia need to be coagulated or even ligated at this stage.

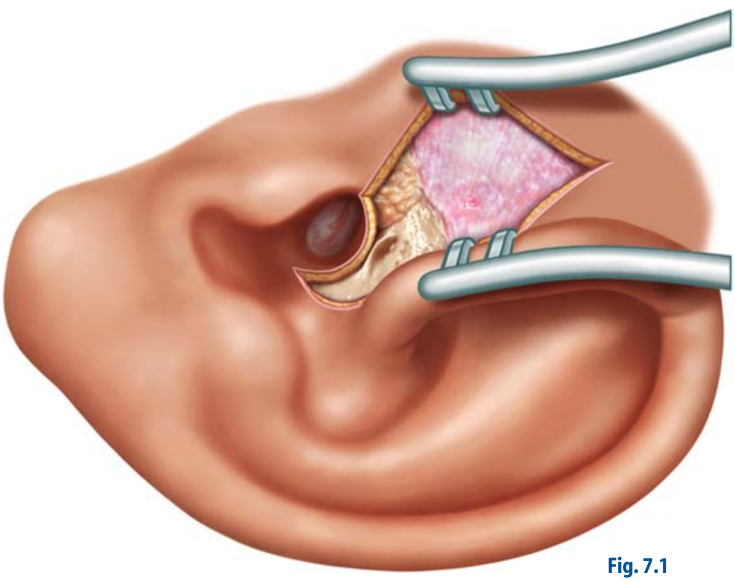


Fig. 7.1

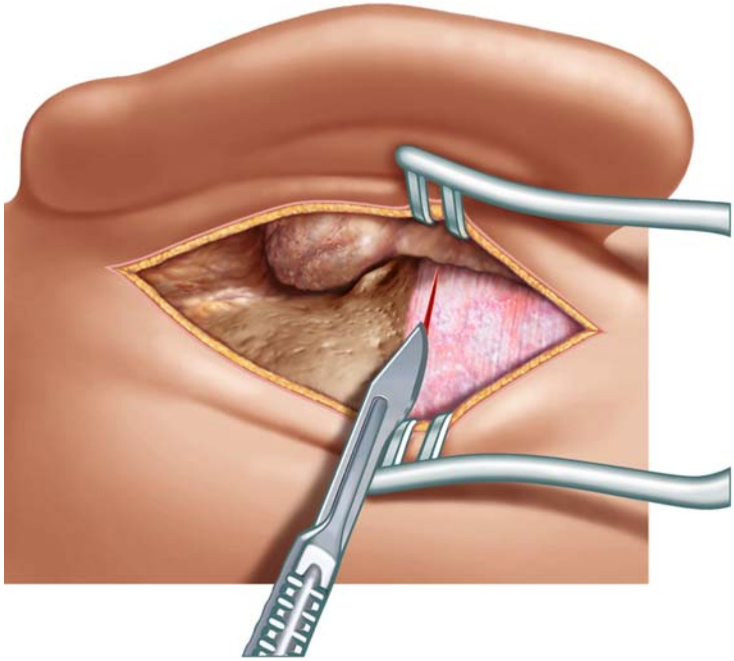


Fig. 7.2

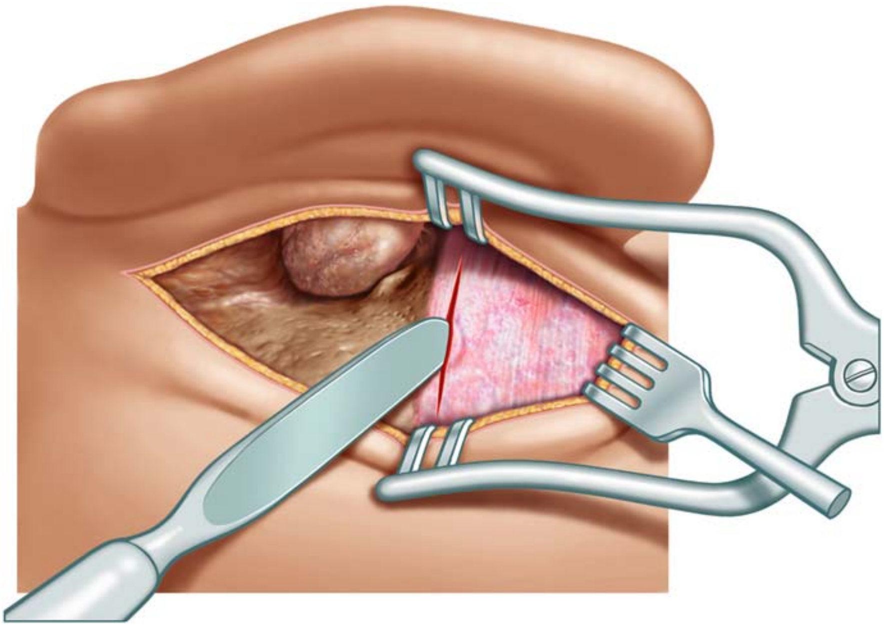


Fig. 7.3

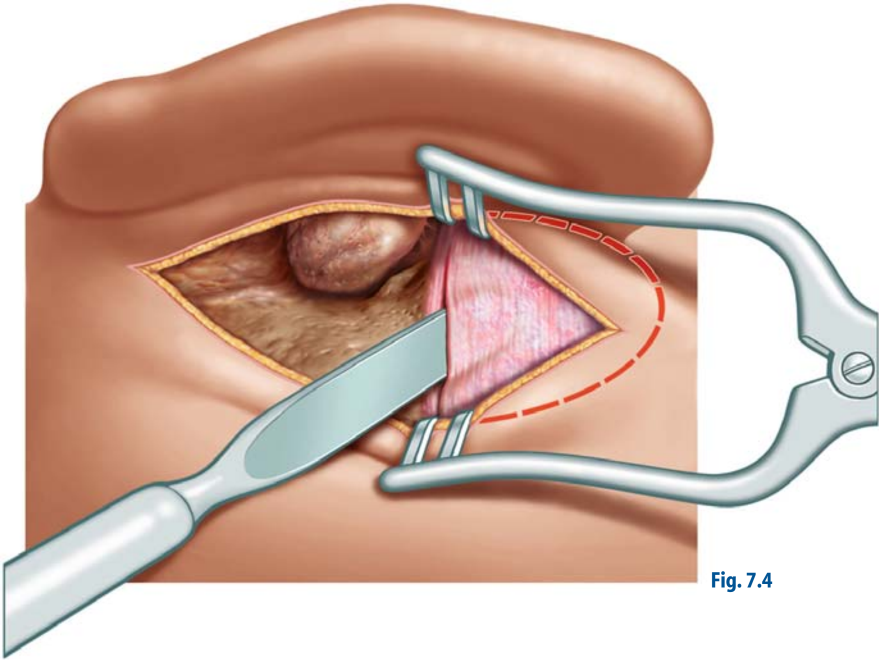


Fig. 7.4

Different ways of storing the fascia until reimplantation have been tried. We prefer not to dry the fascia because we believe that vital cells improve the integration of the graft, prevent resorption of intercellular collagen fibres and later reduce the frequency of atrophic scars.

Harvesting of the temporalis fascia can be achieved by superior extension of the retroauricular approach incision. The exposure is slightly better. Larger pieces can be removed. Even vascularized flaps for reducing large cavities can be harvested when the excision is extended cranially.

Harvesting Cartilage

Cartilage can be harvested from: (1) the tragus, (2) the anterior crus of the helix, (3) the cavum, (4) the cymba and (5) the triangular fossa (**Fig. 7.5**). Mainly tragal, conchal and cymba cartilaginous grafts are used as autologous transplants in middle ear surgery. Cartilage, even in larger amounts, is more easily collected by a postauricular approach. Thick grafts may be split.

1. Tragal cartilage is mainly used when an endaural approach has been chosen. It can be exposed from the endaural incision between the tragus and the anterior crus of the helix or by a separate incision (**Fig. 7.6**). Generally it appears to be almost plane and even in thickness and is removed using curved scissors (**Fig. 7.7**). The covering perichondrium can be left attached for an island graft, used separately or exclusively.

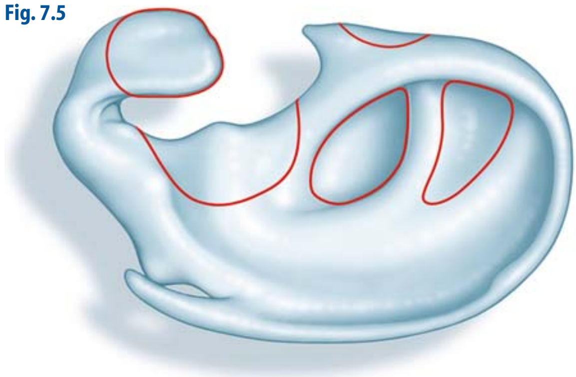


Fig. 7.5

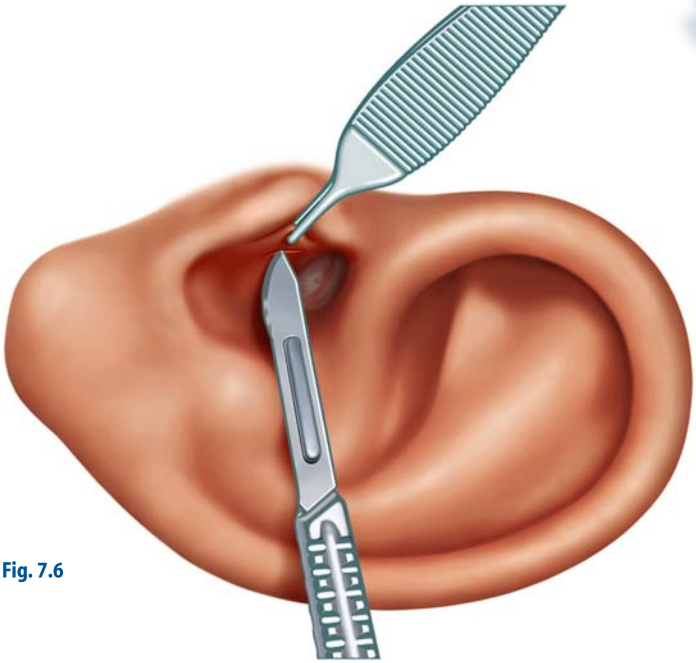


Fig. 7.6

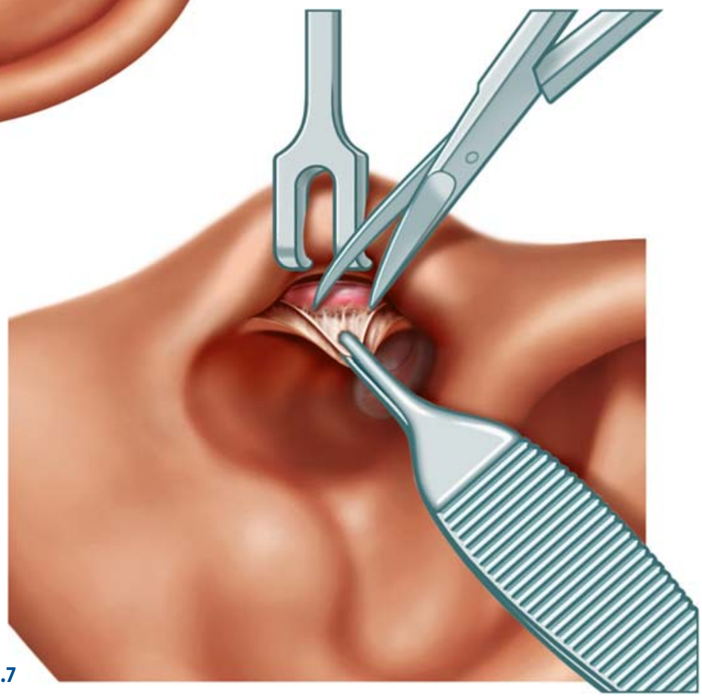


Fig. 7.7

2. Grafts from the anterior crus of the helix provide small and thin cartilage grafts with perichondrium which is useful for small posterior attic defects, when an endaural incision has been chosen.
3. Large quantities of cartilage can be gathered from the concha. The conchal cartilage varies in thickness. Therefore splitting is often necessary to avoid a bulky graft. The perichondrium is harder to remove (**Fig. 7.8**).
4. The cymba supplies medium sized slightly rounded grafts. The shape is favourable for the closure of larger defects in the posterior meatal wall. The covering perichondrium is easy to remove and can also be used separately as a soft tissue graft.
5. Triangular fossa: This site is seldom used. The anterior and posterior crus of the anthelix must be respected.

Preparation of Cartilage

The cartilage grafts in our opinion are easier to place as a cover of the middle ear, when applied as strips (palisades) if total or subtotal reconstruction of the tympanic membrane is intended. They adapt better to the variable anatomy of the middle ear. The grafts must be thin enough to allow air flow in the middle ear cavity and leave a sufficient distance from the promontory. To facilitate car-

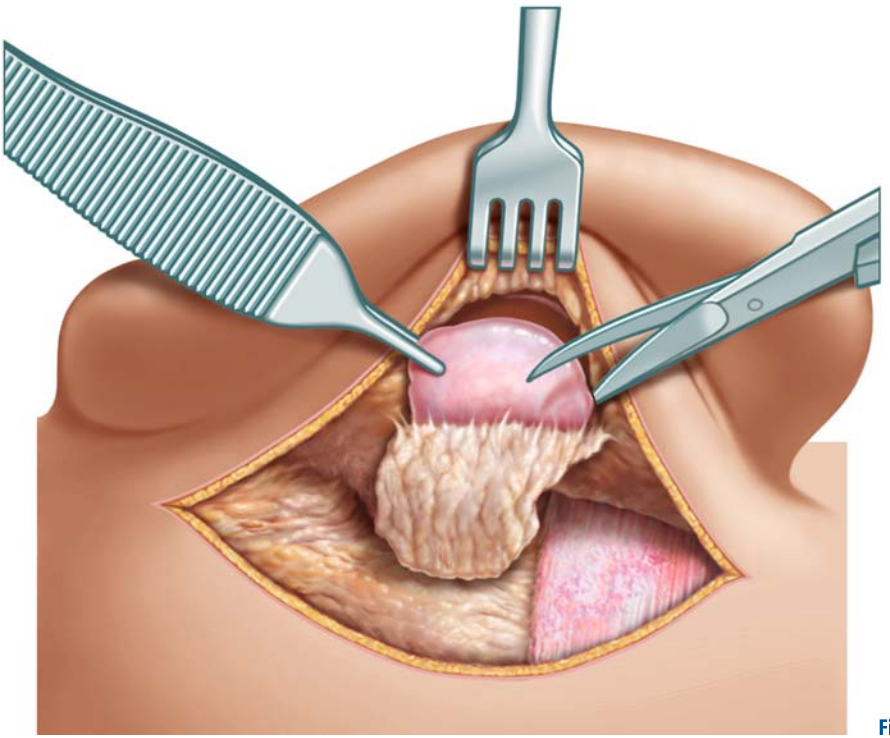


Fig. 7.8

tilage slicing, a special clamp can be used to fix a No. 15 scalpel for this procedure as illustrated (**Fig. 7.9**). If the distance is short, the perichondrium should be removed on the middle ear side to reduce the possibility of adhesions.

For reconstruction of the posterior wall total pieces are generally used. Sometimes, however, strips are easier to position.

Harvesting Perichondrium

Perichondrium can be taken from both sides of the cartilage for a larger graft. The cartilage must not be removed from its original site to collect perichondrium. Essentially the same procedures apply to gathering perichondrium as for cartilage (**Fig. 7.10**).

Fig. 7.9

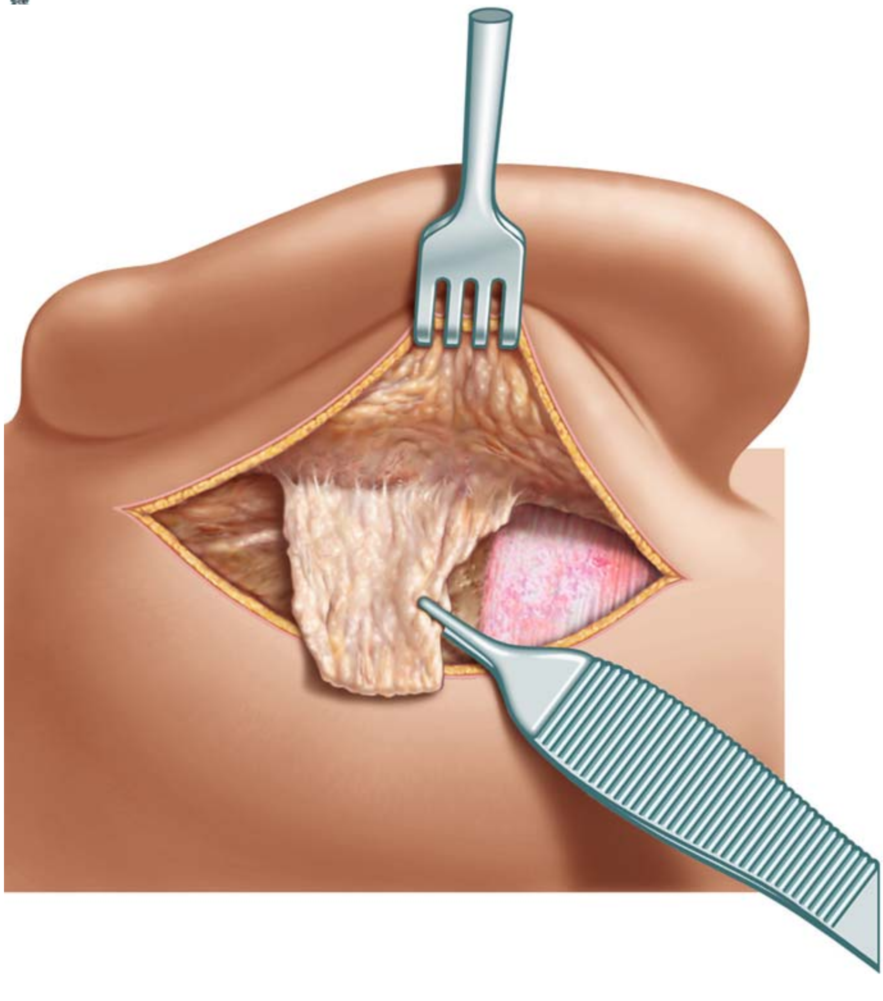


Fig. 7.10

8 External Ear Canal Surgery

Henning Hildmann, Holger Sudhoff

Surgery in the external auditory canal without surgery in the middle ear may be necessary:

1. After surgery
2. After trauma
3. Postinflammatory
4. Due to idiopathic changes

All procedures postoperatively need a wide and well aerated outer ear canal. An endaural incision is generally used. The remaining meatal skin may be removed and reimplanted as a free graft if necessary. However, the skin of the anterior tympanomeatal angle should be left untouched whenever possible to prevent blunting after surgery. If skin is missing, this area should be carefully reconstructed.

If widening of the ear canal anteriorly is necessary, the anterior bony meatal wall should be left intact. Small defects generally do not cause any problems, but larger defects cause hernias of the perimandibular tissue into the ear canal that are hard to treat.

Postoperative Changes

Postoperative Stenosis

Entrance of the Ear Canal

The entrance often becomes stenotic due to scar contraction after endaural, but especially after retroauricular, incision. The remaining ear canal is sufficiently wide.

The skin in the cavum is incised as indicated, forming a superiorly based flap that later covers the gap remaining superiorly after pulling the meatal skin outward (**Fig. 8.1a, b**). Suturing of this flap in the ear canal is difficult. Therefore we only use careful packing at the end of the surgery. The underlying cartilage and scar tissue must be resected until the bone is exposed. Removing bone from the posterior circumference of the ear canal gives additional space. Henle's spine and the outer part of the tympanosquamous fissure may be prominent and should be removed.

If this does not appear to be sufficient, a pretragal pedicled flap is inserted into the endaural incision area (**Fig. 8.2a, b**).

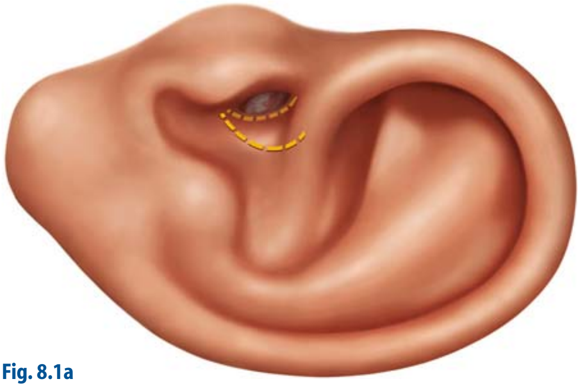
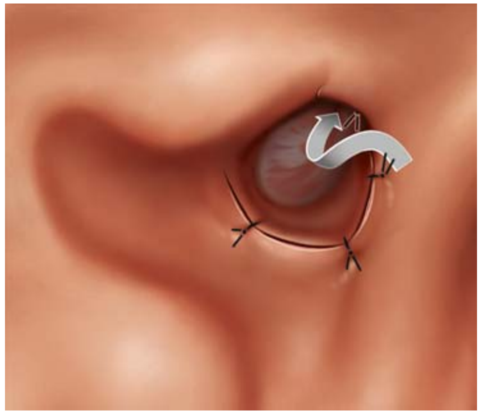


Fig. 8.1a



b

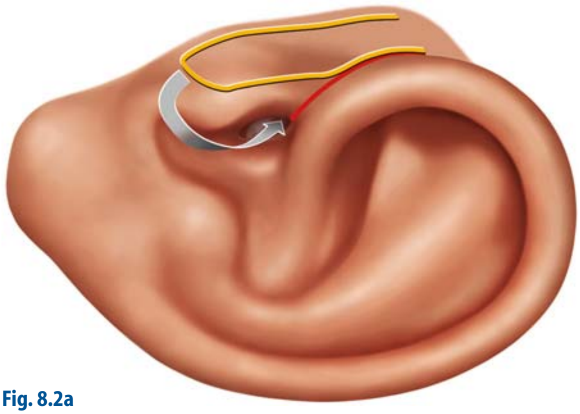
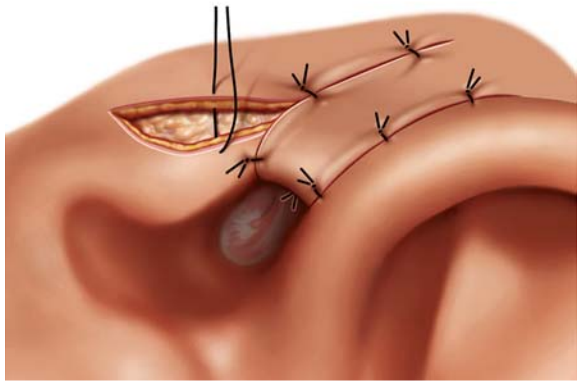


Fig. 8.2a



b

Postoperative Stenosis of the Canal

Weblike stenosis may be observed and may be widened with a wick. Some stenoses become so thin that they may be resected with a sickle knife after some months.

More substantial stenosis and synechia should be reoperated on. The complete scar is resected and replaced by split-thickness skin grafts. The quantity needed may be harvested from the posterior side of the auricle with a No. 10 blade.

If the anterior tympanomeatal angle is affected, it should be carefully reconstructed. A good result is dependent, as in surgery for major malformations, on the precision of the graft placement. Overlapping and folding must be strictly avoided.

Other Postoperative Changes

Annulus Cholesteatoma

This usually develops after tympanoplasty using an onlay technique for tympanic membrane closure (**Fig. 8.3**). The outer part of the cholesteatoma should be removed while the epithelium covering the tympanic membrane and the anterior tympanomeatal angle often forms a perfect lining and can be preserved.

Cholesteatoma of the Ear Canal

This usually develops postoperatively. Small cysts can be removed with incisions as an office procedure. Larger cysts should be removed by an endaural or postauricular approach. The underlying bone should be flattened with a diamond burr.

Lateralization

The graft may lateralize after tympanoplasty due to epithelial migration. It is more frequent after onlay techniques, but seldomly may develop spontaneously. It will result in a conductive hearing loss. An underlay tympanoplasty placing the graft under the handle of the malleus prevents recurrences. The missing epithelium, especially the anterior tympanomeatal angle, must be carefully reconstructed.

De-epithelialized Bone

After drilling without sufficient irrigation the bone may suffer heat damage. These areas often remain bare of epithelium and they may be followed up in the office. If the defect does not heal, the ear must be reoperated on, and the superficial layer of the bare bone is drilled off with sufficient irrigation and covered with fascia and a split-thickness skin graft.

Blunting

The anterior meatal wall and the tympanic membrane are positioned at an angle of about 70° to each other. This is the tympanomeatal angle. It is a "sacred" area and should not be touched if it can be avoided. Any surgery in this area carries the risk of blunting, which is scar formation. The tissue fills the tympanomeatal angle, and the angle becomes blunt. It is obvious that the sound conduction abilities are reduced. If the epithelium has to be removed or the anterior angle has to be reconstructed, for instance in malformation surgery, it must be reconstructed very carefully. Small split-thickness skin grafts from the posterior side of the auricle are used. They are sheathed with silicone.

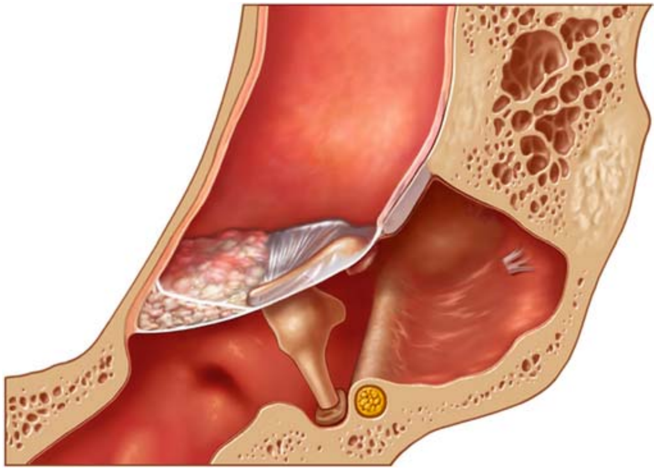


Fig. 8.3

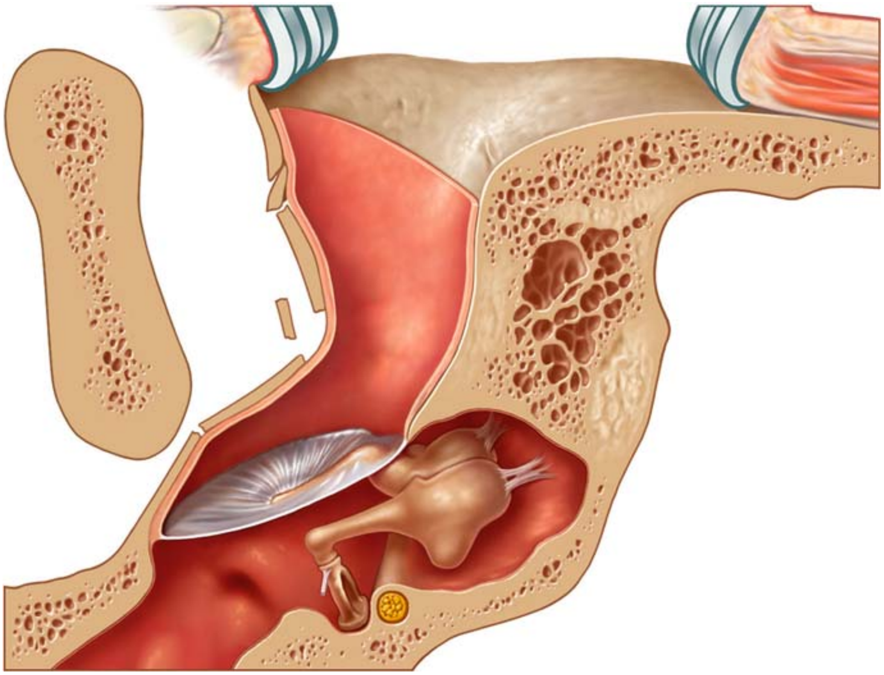


Fig. 8.4

Trauma

Surgery should be customized depending on the nature of the injury. Fractures of the posterior wall are often associated with middle ear, inner ear or facial nerve damage. The surgery for these is described in later chapters. In any case of reconstruction the ear canal must be wide enough and well aerated. A cavity with a wide meatoplasty is an alternative. If the ear is completely deaf, the ear canal may be obliterated if the meatal skin can be completely removed; if not, cholesteatoma formation may result.

Fractures Into the Medial Cranial Fossa

Fractures into the medial cranial fossa may need a transtemporal approach and a team approach with the neurosurgeon. Fractures of the anterior wall are often limited to the canal. In cases where they are accompanied by herniation of the perimandibular tissue, repositioning is possible but generally not successful because of the very high pressure during chewing. For smaller defects a septal or auricular cartilage placed on the mandibular side of the fractured tympanic bone can be a solution. More extended fractures (**Fig. 8.4**) cannot be stabilized by temporary immobilization of the jaw by the maxillofacial surgeon. It is easier to remove the posterior meatal wall in these cases and to create a cavity allowing sound and air to reach the tympanic membrane.

Post-traumatic Atresia

The prognosis for post-traumatic atresia depends on the extent of the damage. If the middle ear is shown to be aerated in the CT scan, the Eustachian tube is most likely to be affected and hence hearing improvement is not probable. However, surgery might be necessary due to cholesteatoma behind the atresia.

The ears are opened with an endaural incision. The scar forming the atresia is removed as well as bony fragments obliterating the ear canal. Defects of the posterior wall can be reconstructed with cartilage. Epithelial defects are replaced by split-thickness skin grafts.

Inflammation and Sequelae

Postinflammatory Stenosis

This condition may develop after long-standing external otitis. The subepithelial tissue is thickened and cannot be reduced by local treatment. The tympanic membrane is generally not or little affected. The epithelium is altered by infection and therapy.

Routinely we use an endaural incision. The posterior meatal skin including the subepithelial tissue is removed and replaced by spit-thickness skin grafts from the backside of the auricle after widening the ear canal by drilling in all possible directions. If the meatal skin can be reused after resecting the subepithelial tissue and the aspect of the epithelium appears fairly normal, meatal skin should be preferred. Generally a partial replacement by skin grafts is necessary. The canal must be widely exposed to provide a good aeration as prerequisite for healing. The epithelium of the anterior tympanomeatal angle should be spared to prevent anterior blunting.

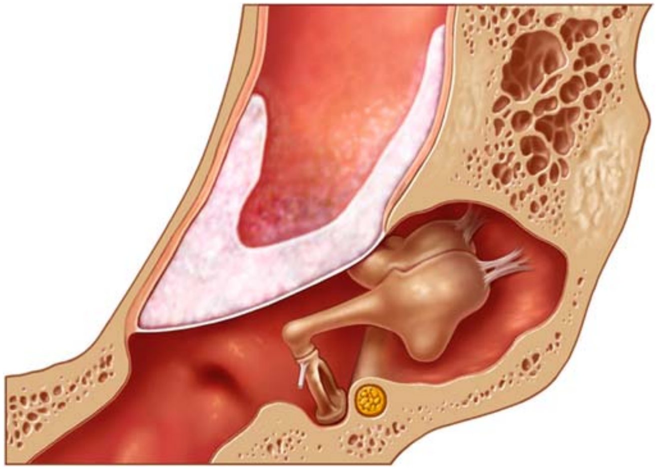


Fig. 8.5

Necrosis of the Floor or the External Auditory Canal

This condition appears to be a cholesteatoma of the external auditory canal generally localized in the medial part of the floor. However, it behaves differently. It seems that the epithelium has invaded the defect secondarily to bone necrosis of the floor due to an insufficient vascular supply. Using an endaural approach the irregularities need to be smoothened by a diamond burr and covered by a split-thickness skin graft.

Postinflammatory Meatal Fibrosis

This condition is supposed to develop from chronic myringitis with medial external otitis. Fibrotic scar tissue up to 1 cm thick is found under non-inflamed epithelium in the medial part of the ear canal (**Fig. 8.5**). The fibrous layer of the tympanic membrane is generally intact or has a small central perforation. The middle ear and the ossicular chain are not affected. After circumcising the meatal skin above the blind sac, the fibrous mass is worked off the underlying bone and can generally be removed from the fibrous tympanic membrane without effort and damage. The epithelium should be carefully replaced by split-thickness skin grafts. The disease has a tendency to recur. The surgeon should take care to reconstruct the anterior tympanomeatal angle to avoid blunting.

Malignant External Otitis

This life-threatening condition may lead to extensive destruction of the ear canal and the temporal bone. It is mostly seen in elderly male diabetics. As a *Pseudomonas* infection it is generally treated by antibiotics. Long-term antibiotic treatment is recommended. Necrotic bone and tissue can be removed as a minor procedure. If the disease does not respond sufficiently, surgery might become necessary. According to the extension of the bone necroses, the procedure cannot be limited to the external canal. Partial petrosectomy or more extensive surgery may be necessary in combination with long-term antibiotic treatment. Hyperbaric oxygen is expected to improve the poor prognosis. The surgical treatment required in these high-risk patients is more demanding than that for normal middle ear surgery and should be done in very experienced centres.

Idiopathic Changes

Exostosis

The removal of exostoses is sometimes easy, but often difficult and time consuming. Some round prominent osteomas can be removed with a small chisel, which is less traumatic to the skin. Drilling and chiselling can be combined. The surgeon should be familiar with the use of the chisel, because uncontrolled work may be a hazard to the facial nerve, the middle ear and the inner ear structures.

An exostosis with a broad base may form a stenosis of the external meatus. The skin is vulnerable due to frequent previous inflammations that have led the patient to the surgeon. The endaural approach is faster and easier. The meatal skin is removed to be replaced later as a free graft. This is advisable when the skin is seriously damaged by previous infections or the canal is extremely narrow. Interiorly the skin is incised as deeply as possible over the exostosis and worked outward (**Fig. 8.6a**). The drill may sever the remaining flap. The skin medial to the exostosis should be advanced towards the tympanic membrane as the removal of the exostosis proceeds. The ear canal should be widened until the tympanic membrane is completely visualized. We advise the use of diamond burrs because cutting burrs are too traumatic to the skin (**Fig. 8.6b**). If the areas of free bone are too large, additional small thin split-thickness grafts from the backside of the auricle are used. Contact of the drill with the short process of the malleus may cause noise trauma and has to avoided.

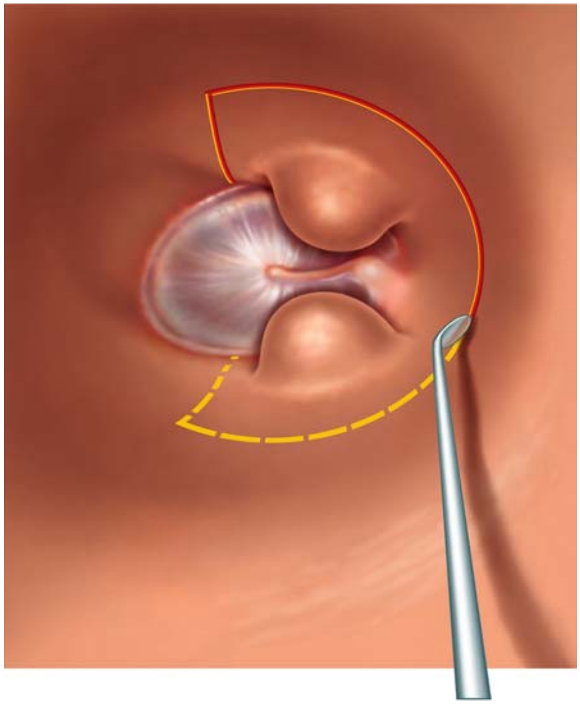


Fig. 8.6a

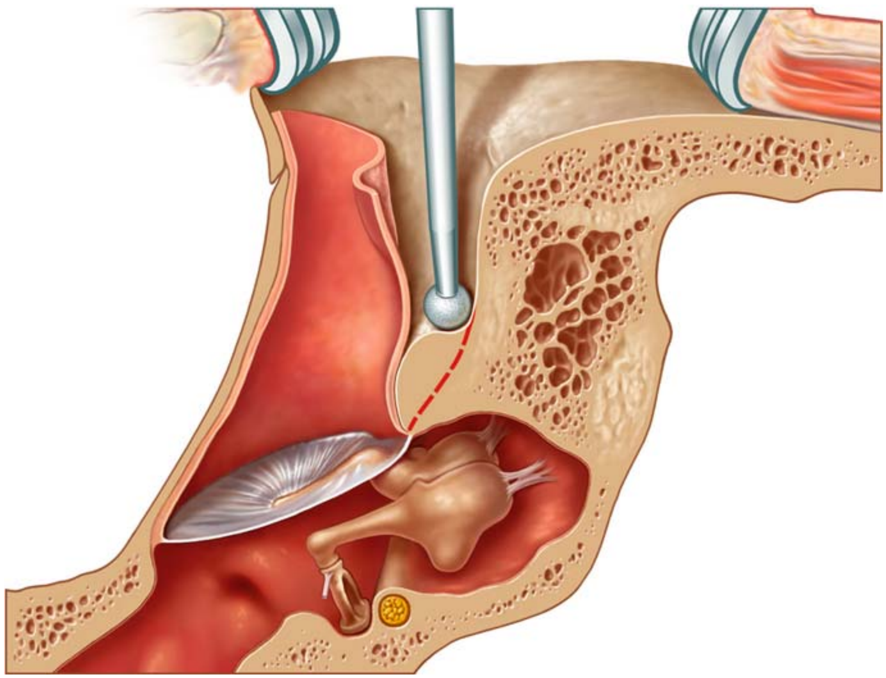


Fig. 8.6b

9 Tympanic Membrane Closure

Holger Sudhoff, Henning Hildmann

Transmeatal Approach

Small perforations and many traumatic perforations can be closed via a transmeatal approach without any incisions in the ear canal. The perforation is circumcised with a sickle knife and the epithelial edge removed with an alligator forceps. A piece of soft tissue or fat is harvested from the postauricular area or ear lobe has to be larger than the perforation. It is brought through the perforation and gently pulled back (**Fig. 9.1**). This technique prevents the inversion of squamous epithelium into the middle ear cavity. A support with silicone is not necessary. A small piece of antibiotic-soaked Gelfoam is generally sufficient. It does not affect hearing and remnants are removed after 14 days.

Larger traumatic perforations require an underlay of fascia or perichondrium. A type I tympanoplasty is performed using an endaural approach as described in Chap. 6. The middle ear should be checked if ossicular chain or inner ear damage is present as well as for foreign bodies that have been introduced inside the middle ear. The surgeon, especially the less experienced, should not hesitate to perform a regular type 1 tympanoplasty instead of trying a short cut of some sort and risking a luxation of the chain in the office under semisurgical conditions. Older traumatic tympanic membrane perforations require a different treatment. The edges must be roughened or excised. It may be helpful to roughen the adjacent undersurface of the tympanic membrane with a hook or sickle knife to produce a wound and facilitate healing. Usually the graft does not need support. If the graft has a tendency to drop into the middle ear, the fascia is supported by resorbable gelatine sponge or similar material, leaving an airway to the tympanal opening of the eustachian tube.

Central Perforations

Most of the central perforations in chronic otitis media can be treated using an endaural approach. Enlargement of the ear canal and partial reduction of the anterior canal wall to expose the anterior part of the tympanic membrane can be achieved by this approach.

The first steps in the closure of a central perforation have been described in Chap. 6.

Fig. 9.1

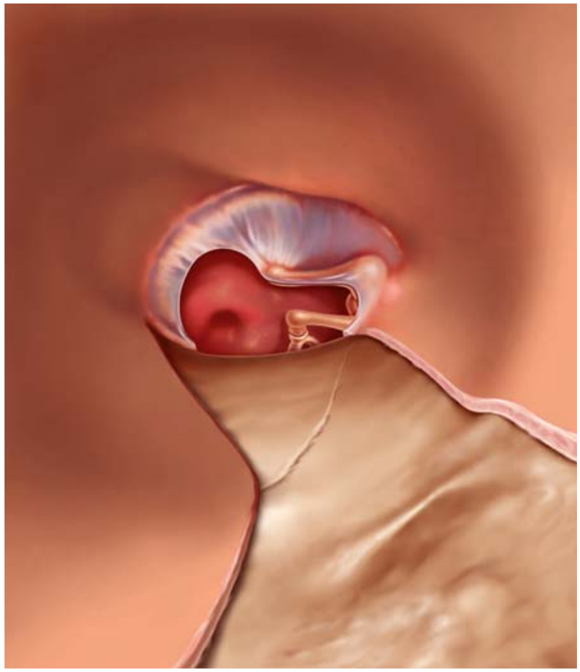


Fig. 9.2

Endaural Incision

The retroauricular incision is only used exceptionally, if, e.g. (1) an antrostomy or mastoidectomy is planned, (2) a cholesteatoma is suspected or (3) the anterior meatal wall is prominent and the anterior margin of a perforation is not visible, particularly if the surgeon wants to avoid reducing the anterior wall by drilling. The retroauricular approach allows a better view to the anterior tympanomeatal angle.

Harvesting of the Graft

Fascia is harvested on the way to the middle ear prior to the development of the tympanomeatal flap. Removing the fascia later would mean that the surgeon would have to remove the retractors and interrupt work in the middle ear. If perichondrium or cartilage is chosen, the material is usually harvested when the necessary amount of material is known exactly at a later stage of the procedure. Cartilage is especially selected for total or subtotal perforations, complete adhesive otitis, suspected tubal dysfunction, and as a cover for alloplastic prostheses.

Preparation of the Skin Flap

The tympanomeatal flap is formed according to the size and location of the perforation as described previously (**Fig. 9.2**). Rigid soft tissue connections often have to be dissected at the tympanomastoid fissure line. The instruments are always in direct contact with the bone. The suction should be applied behind the instrument to avoid displacement of the flap. Close to the tympanic membrane we use the angled knife to lift the annulus out of the sulcus. If drilling in the outer ear canal is necessary, the meatal skin flap including the posterior part of the annulus is removed and reimplanted as a free graft at the end of the operation. This allows more space for drilling and saves the flap from injury by the revolving burr. In addition it improves the overview and speeds up the procedure.

The perforation is routinely closed by an underlay technique, which prevents annulus cholesteatomas, lateralization of the graft and blunting of the anterior tympanomeatal angle. The perforation is circumcised after stabbing small incisions into the margin of the perforation with a sickle knife. The margin is then pulled away with a cupped forceps. The undersurface of the membrane is scarified to provoke a slight bleeding to improve the attachment to the graft. It normally sticks to the undersurface without support. In subtotal perforations there is not enough material for circumcision. Careful roughening of the adjacent undersurface is sufficient. Support may be necessary especially in the upper superior part of the perforation in front of the short process of the malleus. Especially fascia tends to retract during healing and should be well positioned. If the mucosa is thick, especially the area above the orifice of the eustachian tube, it may be split with a sickle knife. If fascia is not available, perichondrium from the tragus or the posterior side of the concha is a good, stable alternative. Periosteum can also be used. The fascia is placed under the handle of the malleus whenever possible. If the handle is close to the promontory, cutting off the tensor tympani tendon allows more space. The mucosa of the middle ear should not be removed to prevent adhesions. The production of mucus by the goblet cells of the inflamed mucosa may serve as good protection against adhesions. Polyps should be removed. In rare cases a small piece of silicone is placed on the promontory, avoiding contact of the graft with the promontory.

Before placing the membrane graft the middle ear should be checked for unsuspected squamous epithelium and for the condition of the ossicular chain.

If the incudostapedial joint and the round window niche are not visible, the chorda tympani must be gently advanced forward without stretching it. The posterosuperior bony annulus is removed with a House curette until a sufficient overview is achieved. The mobility of the chain is checked by moving the handle of the malleus with a sickle knife or needle, observing the stapes. The mobility of the round window membrane can generally not be seen directly.

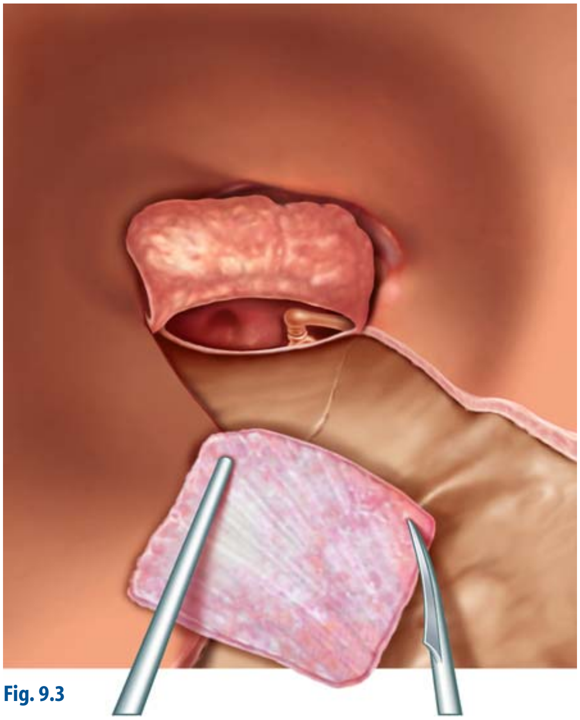


Fig. 9.3

Fig. 9.4

With a little water or blood in the round window niche, a moving reflex can be observed.

To close the perforation the tympanomeatal flap is pushed to the anterior meatal wall unless it has been removed previously as a free flap (**Fig. 9.3**). In type 1 tympanoplasty the ossicular chain is mobile and intact. The fascia is spread out on the posterior wall and is moved along the posterior wall with the sickle knife and a suction tip well under the anterior margin of the perforation (**Fig. 9.3**). Normally the transplant does not need further support. It should partly rest – especially in posterosuperior perforations – on the posterior bony wall to ensure its stability (**Fig. 9.4**). An ear hook can be used to press the fascia to the tympanic membrane remnants from the middle ear side. Support from the middle ear side is seldom necessary. Small quantities of resorbable gelatine sponge or similar material may be used (**Fig. 9.5**).

If the tympanomeatal flap has been used as a free graft, it can be partially placed on the fascia to speed up healing and to reduce the possibility of atrophic scar formation. These atrophic scars are seen years after tympanoplasty and are attributed to the resorption of collagen fibres of the graft.

Larger defects are additionally covered with postauricular split-thickness skin grafts to speed up epithelialization. The graft should fit properly edge-to-edge.

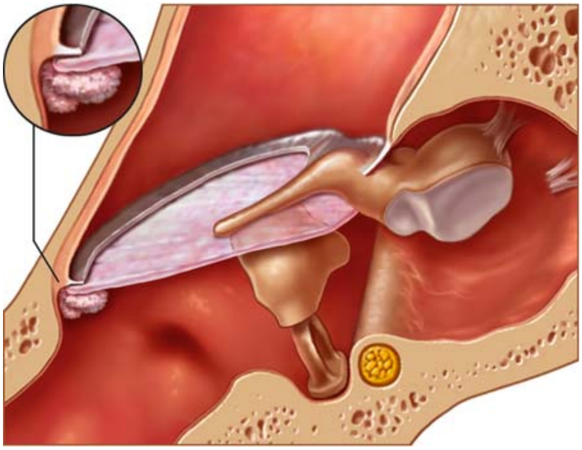


Fig. 9.5

For subtotal perforations we also favour the underlay technique. Generally the fibrous annulus is intact. The mucosa underneath is roughened to facilitate healing. Small pieces of Curaspon gelatin sponge can be used to support critical areas. The orifice of the eustachian tube must remain patent. The transplant should be positioned 2 mm underneath the anterior margin of the perforation to prevent a reperforation due to retraction of the graft. Recurrent perforations occur most frequently at the anterior tympanomeatal angle and the anterosuperior quadrant.

A further method of ensuring transplant stability is a pull through of the underlay fascia graft behind the fibrous annulus anteriorly. Occasionally granulations may occur which hamper the postoperative treatment.

If sufficient material of the tympanic membrane is left, Gerlach recommended small incisions at the anterior edge of the tympanic membrane with a sickle knife. The fascia is then placed under the remnant tympanic membrane and pulled through the incisions with a tip suction or a cup forceps through the incision. Tedious granulations can be treated with caustic solutions.

Cartilage

Cartilage is excellent material if stiffness of the graft is required, especially for total or subtotal perforations and for cases of extensive adhesive otitis media, when negative pressure in the middle ear is expected. Thick cartilage should be split, which increases the amount of material available. It should be held in mind thick cartilage used in an underlay technique may block the airway in the middle ear and lead to recurrence of the perforation. For total or subtotal reconstruction we prefer Heermann's palisade technique (**Fig. 9.6**). He recommended the use of strips of cartilage placed alongside each other. These small

Fig. 9.6

strips are more easily placed once the surgeon has become used to handling the material, which takes a little practice. The strips adapt better to the individual anatomy of the middle ear. Positioning is easier and more precise. The application of strips in the underlay technique is generally possible. The material normally adheres to the undersurface of the membrane remnant. Sometimes support with Gelfoam or even small cartilage blocks is necessary. We place palisaded cartilage parallel to the tubal orifice. The first palisade has to keep the eustachian tube entrance open and to form the anterior tympanomeatal niche. The palisades are then placed side by side. Generally three to six palisades are sufficient to close a total defect (**Fig. 9.6**). The use of palisades allows a sustained ventilation of the antrum and mastoid. If prostheses are used they should be inserted after the first two palisades are in place.

If a retroauricular approach is used, it is helpful to place all the palisades on the mastoid plane. The surgeon then has his material in his surgical field and can select the cartilage palisade that may fit best.

Cartilage islands with overlapping perichondrium are good material for closing perforations of the posterior part of the tympanic membrane. They serve at the same time as cover for alloplastic material, i.e. titanium prostheses or others, to prevent protrusion or extrusion.

10 Cartilage Palisade Tympanoplasty

Manuel Bernal-Sprekelsen

This chapter illustrates the ideas of the author on the use of cartilage in tympanoplasty based on the evaluation of a series of patients operated on with the palisade technique.

The materials used for reconstruction of the tympanic membrane, such as fascia or perichondrium, offer only limited resistance to the negative pressure in the middle ear, leading to retraction, adhesions, or atelectasis. Autologous cartilage from tragus or cymba is resistant to negative pressures in the middle ear cleft due to its rigidity and convexity. It is therefore an alternative material for the reconstruction of the tympanic membrane in cases where the eustachian tube is not patent or the gas exchange in the middle ear is insufficient.

Compared to fascia and perichondrium, which need a new vascular supply, cartilage gets its nourishment by diffusion. It therefore seems to offer a good resistance both to lack of vascularization and to infections. However, the rigidity and thickness of the new tympanic membrane has raised questions regarding the functional recovery of the middle ear.

The cartilage palisade technique, as first described by Heermann [1, 2], has been modified by reducing the number of cartilage strips from six to three [3]. This modification seems to enhance the transmission of sound waves because of the increased width of the strips and the improved contact with the prosthesis. On the other hand, it reduces the possibility of bending being observed in the cartilage plates.

Surgical Technique

In our series of patients, cholesteatomas were operated on as a single-stage procedure from a retroauricular approach, following the extension of the cholesteatoma in an anterior-posterior procedure. Therefore, the selection criterion for canal wall up (CWU) or CWD depended mainly on the extension of the cholesteatoma. Atticotomies or minor antrotomies were closed with cartilage grafts in contact with the preserved canal. Open cavities were partially or subtotally obliterated with cartilage from the cavum conchae. In these cases smaller pieces of cartilage were used to fill up the anterior epitympanum and antrum, and to cover the horizontal semicircular canal. A meatoplasty with cartilage excision from the concha (subsequently used for obliteration) was performed in all CWD procedures.

The cartilage for tympanic membrane reconstruction was obtained from the cymba when the incision was retroauricular or from the tragus when the approach was endaural.

Autologous incus or malleus heads were used for ossicular chain reconstruction as a first choice. The Ceravital prosthesis ($n = 14$) was used initially, but mainly the Ionos TORP (total ossicular replacement prosthesis) and PORP (partial ossicular replacement prosthesis) ($n = 292$) were used for ossicular reconstruction when the malleus or the incus was not available.

Evaluation

The preoperative air-bone gap (ABG) (mean of the four-tone thresholds at frequencies of 0.5, 1, 2, and 4 kHz) was compared with the postoperative ABG. Patients were then classified into groups of 0 – 10 dB, 11 – 20 dB, 21 – 30 dB, and greater than 30 dB overall postoperative ABG. To compare different types of ossicular chain reconstruction, two groups were formed: ossicular reconstruction from the footplate, and ossicular reconstruction from the stapes. Data processing and statistical calculations were done with the SPSS program, and Student's *t-test was used for matched sample analysis.*

Results

Four hundred and twenty-one type III tympanoplasties were performed from October 1992 to October 1998. Fifty-nine (14 %) patients were lost to follow-up and were excluded from the analysis. One hundred and ninety (52.5 %) left ears and 172 (47.5 %) right ears from 131 men (37 %; 6 on both sides) and 225 women (63 %; 12 on both sides) were treated surgically for previously untreated cholesteatoma.

One hundred and seventy-seven (48.9 %) tympanomastoidectomies were modified radically (CWD) and 185 (51.1 %) were performed with conservation of the posterior wall (CWU). Two hundred and twenty-nine (63.2 %) operations were performed with the patient under general anaesthesia, and 133 (36.8 %) with the patient under local anaesthesia with sedation.

In 306 cases, the Ceravital or Ionos prosthesis was used as a PORP or a TORP, respectively, from the stapes or the footplate towards the cartilage. In the other 56 cases, the autologous incus was replaced either as a PORP or as a TORP.

The mean follow-up time was 54 months (range 36 – 106 months) for the complete series. Six reperforations (1.7 %) were observed. Four of them occurred after infection in the first 3 weeks after operation. All patients underwent reoperation, and the tympanic membrane was again reconstructed with cartilage.

Nine retraction pockets (2.5 %) of variable extent were found. Eight recurrent cholesteatomas (2.2 %) and one extrusion of a TORP were observed. In the revision surgery, cartilage was used to cover the prosthesis. There was little or no evidence of cartilage resorption, and there was no extrusion of the prosthesis.

All procedures revealed a statistically significant difference between the preoperative ABG and the postoperative ABG ($p < 0.001$, t-test for paired samples) at all frequencies. The overall preoperative four-frequency pure-tone average (PTA) ABG was 34.4 dB; the postoperative PTA-ABG was 18.1 dB. In the PORP group, the preoperative PTA-ABG was 28.3 dB hearing level (HL), and at 54 months it was 16.8 dB HL. In the TORP group, the average PTA-ABG was 40.5 dB HL, and at 54 months it was 19.4 dB HL. The differences between PORP and TORP were not statistically different. At 54 months, the postoperative results for TORP with CWU and TORP with CWD were 18.1 dB and 20.7 dB, respectively, and for PORP with CWU and PORP with CWD they were 15.4 dB and 18.8 dB, respectively.

According to the two-tailed Student's t-test for independent samples to compare functional results in the groups, the average ABG improved at all frequencies, showing a significant statistical difference in favour of CWU procedures ($p < 0.05$) for 0.5 kHz and 1 kHz. Speech reception scores showed no significant changes in the threshold for 224 of 362 procedures. Speech discrimination scores, determined in 151 of 362 patients at 40 dB above the speech reception threshold, showed no significant decrease (i.e. 10 %) in any of the patients. We observed no significant differences between the functional and anatomic results according to sex or ear sides.

Postoperative complications included two cases of complete hearing loss, one of them associated with the fracture of the stapes footplate in an ear with tympanosclerosis, and five cases of sensorineural hearing loss. These seven cases were considered in the audiologic calculations.

Conclusions

The cartilage palisade procedure (partial or total) was used in 362 cases. The basic differences between our modification and the original procedure described by Hermann [1, 2] consist of using two to four palisades and taking care that one has a broad contact with the ossicular reconstruction [3]. Handling and lacing the grafts needs some training. In our experience, obtaining, measuring, and positioning of the cartilage strips lengthens a routine surgical procedure by approximately 15 – 20 min.

Tympanic closure was achieved in 98.3 % of our cases, the reperforation rate being 1.7 %. Cartilage seems to be an appropriate graft for the reconstruction of subtotal or total perforations, providing rigidity and stability. The support given by both the intratympanic cartilage and the prosthesis prevented retraction of the membrane in the majority of our patients' ears. Retraction pockets (2.5 %) or recurrent cholesteatoma (2.2 %) may have been due to improper use of cartilage; for example, the number or size of cartilage fragments may have been insufficient to obliterate the epitympanum, the attic or the antrum, or the reconstruction with cartilage may have developed only partial retractions in unsupported areas.

Wiegand [5] reported excellent anatomic results, with a perforation rate similar to ours in more than 600 cases. Milewski [6] obtained similar results after 5 years of follow-up with the use of one piece ("plate") of cartilage for tympanic closure, and Schulte et al. [7] obtained good anatomic and functional results using irradiated rib cartilage graft. Amedee et al. [8] used cartilage composite grafts, also with satisfactory results. These reports are consistent with our results. Furthermore, our study demonstrates persistent results after a long-term follow-up.

From a functional point of view, in our series, PORP and CWU proved to be predictors of better sound transmission, although the results were not significantly different from those of TORP or CWD.

Preliminary results with the same surgical technique, but using a titanium prosthesis instead (PORP and TORP), showed much better results in the hearing outcome [9]. Thus, 43 % of the patients were in the hearing group 0 – 10 dB, and more than 80 % had a gap of 0 – 20 dB after more than 1 year of follow-up [9]. The better outcome may be attributed to the low weight of the titanium prosthesis of about 4 mg, which would offer a lower resistance in sound transmission compared to hydroxyapatite, Ceravital or bioceramics, which have an overall weight of about 60 mg.

Following our results, sound transmission seems to be improved when a piece of cartilage is in broad contact with the prosthesis. This did not seem to be an obstacle to sound wave transmission at the frequencies measured. We therefore emphasize that the prosthesis or the autologous ossicle used for reconstruction should be situated columella-like in an upright position, in contact with the strip of cartilage. In vitro studies on the mechanical properties of tympanic membrane transplants demonstrate that the acoustic behaviour of cartilage slices smaller than 500 µm (0.5 mm) is almost the same as that of the normal tympanic membrane [10]. Therefore, the assumption that the tympanic membrane must be thin and mobile to allow good sound transmission should be reconsidered.

Our mean follow-up of 54 months (range 36 – 107 months) allows us to claim that the results are stable [11]. The palisade technique allowed functional recovery in CWD procedures as well, although there was a statistically significant difference between the functional results of the groups undergoing CWD and CWU at the two frequencies mentioned.

In totally reconstructed tympanic membranes, it is not possible on postoperative checking of the middle ear cleft to assess whether there is either a collection of mucus or a persistence of cholesteatoma. In the latter case, the tympanic membrane tends to lateralize and prior good sound transmission may worsen. In unclear cases a CAT scan in "w" mode may help distinguish between scar and cholesteatoma.

Complications such as sensorineural hearing loss are not believed to have resulted from the use of cartilage grafts or the ossicular replacement prosthesis.

Our 15-year experience with the modified cartilage palisade technique is summarized in the indications shown in **Table 10.1**. The greatest benefit has been achieved in total and subtotal perforations. Our results with a long-term follow-up corroborate our preliminary results [4].

The study shows the reader long-term results of the cartilage palisade technique for tympanoplasties, revealing anatomic and functional benefits that remain stable after long-term follow-up. Used properly, cartilage is able to prevent new retraction pockets and recurrent cholesteatomas. Palisades were used instead of cartilage plates because the palisades adapt more easily to the varying anatomy of the middle ear. Placed close to each other they are as resistant as plates. Gaps between the cartilage stripes should be avoided since squamous epithelium may enter and develop a cholesteatoma. A thorough obliteration of the anterior epitympanum, the supratubaric fossa, and the attic is strongly recommended to avoid recurrent cholesteatoma. Supporting cartilage fragments are important when the anterior aspect of the tympanic membrane needs to be reconstructed in order to avoid medialization leading to reperforation. In badly aerated middle ear clefts the stripes may suffer a partial retraction. Prosthesis can protrude through the graft. The use of cartilage on an alloplastic graft reduces considerably the tendency of protrusion but does not always prevent it. Revision surgery after palisade reconstruction is more difficult because the cartilage changes its consistency, becomes brittle and frequently shows fibrous adhesions to promontory. To avoid "fracturing" of the plates a broad tympanomeatal flap is recommended. Sometimes a reuse of the original reconstruction is impossible, and the old graft has to be discarded and replaced completely. For prosthesis replacement or repositioning, fibrous adhesions between the cartilage and the "old" prosthesis need to be sectioned.

Table 10.1. Indications for cartilage tympanoplasty

- Total and subtotal perforations
- Perforations with tympanosclerotic plaques
- Perforations within atrophic membranes
- Revision surgery for failed myringoplasty or tympanoplasty type I
- Anterior and inferior perforation with tubal discharge
- Retraction pockets
- Partially or completely atelectatic tympanic membranes
- Tympanic adherences
- Revision surgery for failed tympanoplasties and tympanomastoidectomies

11 Ossicular Chain Reconstruction

Holger Sudhoff, Henning Hildmann

The pathology and degree of ossicular chain destruction in chronic otitis media and cholesteatoma are very variable. Therefore there is no single strategy applicable to all different conditions. Wullstein in 1968 accomplished the classification of tympanoplasty into five types based on the necessary technique for reconstruction. In 20%–25% of cases of chronic suppurative otitis media, the ossicular chain is involved, and in cholesteatoma cases 80% need chain reconstruction, either because the pathology has destroyed the ossicular chain or parts of it, or the chain has to be separated by the surgeon. Also in malformation surgery the chain reconstruction surgery follows the same principles.

The extent of the destruction differs. Overall smaller defects have better prognosis. The ossicles can be reused in about 50% of cholesteatomas and in 80% of cases with chronic otitis media.

For reconstruction, organic and alloplastic material can be used as described in a later chapter.

Of the organic materials available, the patient's own ossicles, parts of the incus or the head of the malleus are the most frequently used reconstruction materials. However, they must be free of cholesteatoma, which means without viable keratinocytes. The long-term stability of the use of these materials has been proven. They are especially useful when the stapes has remained intact. Contact with the surrounding bone may lead to osseous or fibrous ancylosis and may result in a recurrent conductive hearing loss. In revisions it can be difficult to separate the transposed ossicles from the head of the stapes.

Cartilage can be used to bridge short distances, for instance for stapes elevation. Long cartilage reconstructions between the stapes footplate and the tympanic membrane tend to necrotize because the cartilage does not contain vessels and depends on nutrition by diffusion. Therefore it tends to become unstable over time.

Bone is easily available from the mastoid plane. Animal experiments have shown that the cortical bone tends to remodel and change its preformed shape. Compared to the ossicles it is a material of second choice.

Alloplastic material is used as plastics, ceramics metals and compound grafts. It is extensively discussed in the next chapter by Yung.

All alloplastic materials are generally costly. Most synthetic materials are easy to remove; however, titanium implants may develop intensive interaction with bone corresponding to an ancylosis. This has to be remembered, especially in revisions. Nevertheless it is our favourite alloplastic material for prostheses.

Most operations can be completed in one stage, removing the cholesteatoma and then reconstructing the ossicular chain at the same time. A two-stage procedure is indicated only in special situations. When the surgeon has doubts over whether he or she has removed a cholesteatoma completely or, in rare cases, it is not possible to remove all the squamous epithelium from the oval window or between the crura of the stapes, a second-look operation is recommended 1 (in children) or 2 years later. By that time the residual epithelium will have formed pearly masses that are much easier to locate and remove. Occasionally the epithelium will disappear in the interval, probably due to atrophic deficit. In non-compliant patients who have good postoperative hearing and most likely will not present for follow-up, it may be wise to postpone hearing improvement until a second stage.

Second look operations are not routinely done except for the situations mentioned above.

The following situations with ossicular chain defects can be distinguished:

1. The incus or part of the incus is missing (**Fig. 11.1**).
   This is the most common situation requiring reconstruction. Most frequently the long process of the incus is destroyed. This allows the reuse of the incus, which can be shaped by drilling and can be placed between the stapes and malleus or the stapes and drum graft. The incus autograft is fashioned to bridge the gap between the head of the stapes and the handle of the malleus according to the anatomical situation. In the drawings the base of the long process of the incus is placed on the head of the stapes. A hole is drilled into the base of the long process and a notch into the body to receive the handle of the malleus (**Fig. 11.1**). Controlled force is applied to lift the handle of the malleus until the interposed incus is in a correct position. It is not always possible to place the incus between the malleus and stapes; the body may also be placed parallel to the handle of the malleus. Placing the underlay fascia graft in this situation is difficult. Depending on the anatomical situation in the middle ear, the body of the incus autograft can also be placed parallel to the handle of the malleus. The incus is leaned against the handle after placing the underlay graft. If the tip of the malleus handle is close to the promontory, distance can be gained by cutting or stretching the tensor tympani tendon. We prefer this to a partial resection of the distal part of the handle because we think that the sound transmission properties are not as good with a short handle. The incus can be stabilized by the chorda tympani (**Fig. 11.2a**). Ossicular bone grafts should never be in contact with the bony walls of the middle ear because ancylosis may develop. Alternatively the head of the malleus

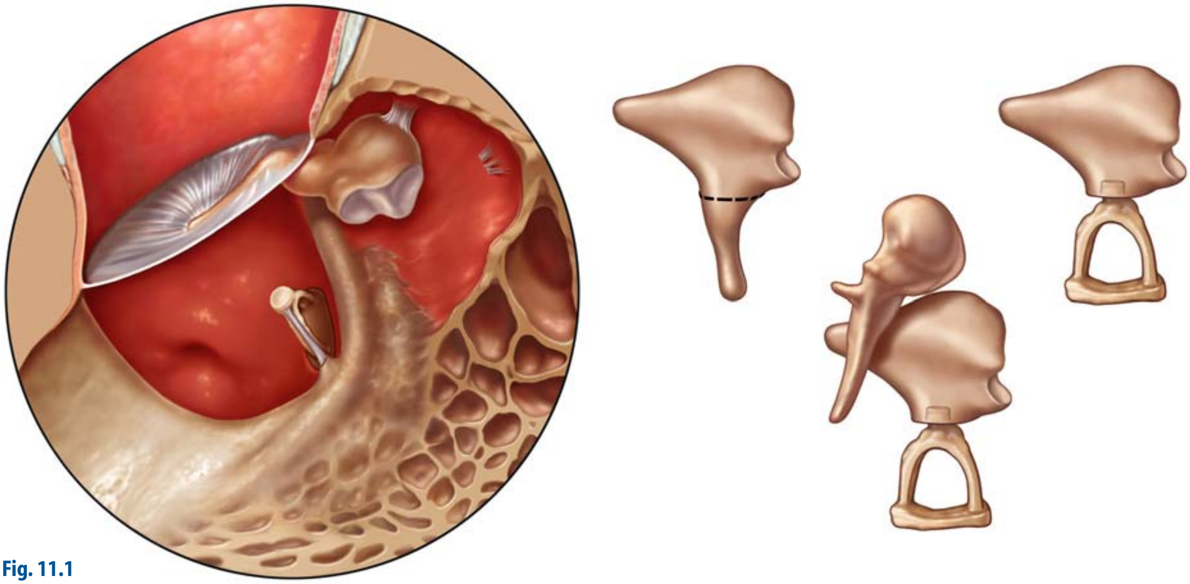


Fig. 11.1

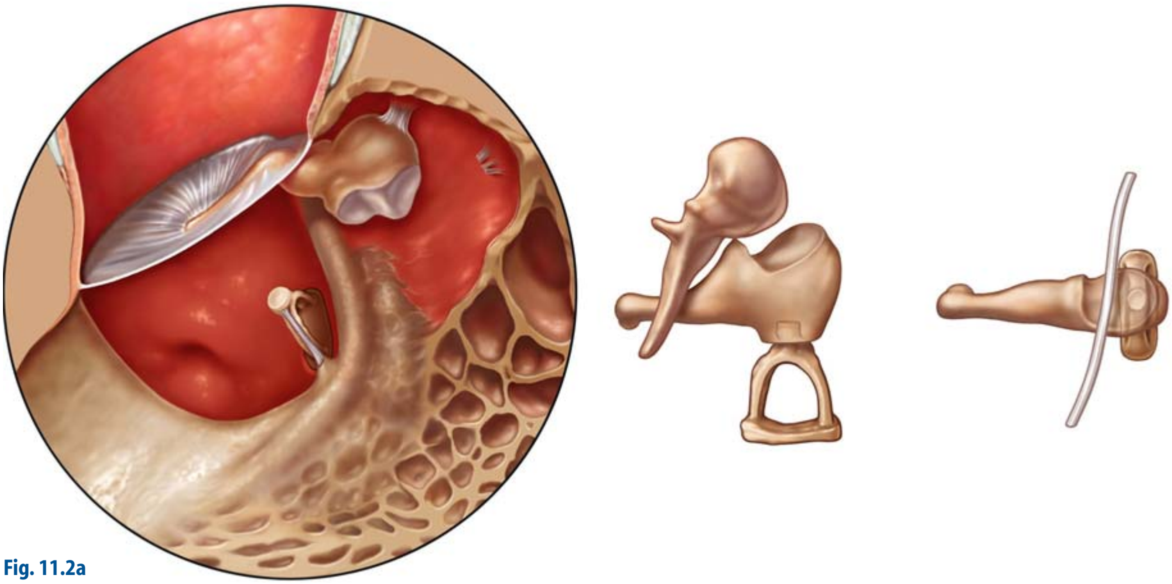


Fig. 11.2a

is utilized. If the head of the stapes has enough height, a piece of cartilage can be used for transmission. We should keep in mind, however, that cartilage depends on nutrition by diffusion and tends to necrose if used to bridge large distances.

For alloplastic material, partial prostheses to be placed on the head of the stapes (partial ossicular replacement prosthesis, PORP) (**Fig. 11.2b**) and total prostheses to be placed on the footplate (total ossicular replacement prosthesis, TORP) are available (**Fig. 11.2c**). There is a large variety of designs (see Chap. 12). The surgeon, especially the beginner, should not use too many variations. He or she needs experience and dexterity with a few designs. As pointed out by Yung, several materials are in use by experienced surgeons. The drawings show titanium prostheses, because of the frequent use of this material in Europe. Other materials can be inserted similarly.
A suction tip is used to pick up the prosthesis from its packaging and place it into the middle ear. The PORP prosthesis is centred on the stapes head with its cuplike opening using the suction tip and a sickle knife.
If a TORP prosthesis is used, it can be positioned on the footplate, supported by the stapes suprastructure.
Both types of prosthesis should be covered by cartilage to prevent extrusion.

2. Only the stapes is preserved:
Generally a stapes elevation technique is used. We advise the reuse of the ossicles if possible, and stapes elevations by cartilage or titanium allografts are further alternatives. Sometimes a TORP placed between the crura of the intact stapes gives the implant a very stable position. Allografts must be covered by cartilage to prevent extrusion.

3. The malleus or handle of malleus is preserved, and the incus and stapes suprastructure are missing.
This is a rare situation. We use a titanium allograft (TORP) with a cartilage covering to prevent extrusion. If the implant can be placed under the handle of the malleus, the situation is more stable (**Fig. 11.2c**).
A suction tip is used to pick up the prosthesis from its packaging and place it into the middle ear. The PORP is positioned on the food plate using the suction tip and a sickle knife. To stabilize the position of the prosthesis, small pieces of Gelfoam can be used. If cholesteatoma or tympanosclerosis has covered the footplate, the bone of the footplate may be very thin. The prosthesis should be placed and later covered with cartilage on the tympanic membrane side without applying pressure to avoid perforation. A small thin piece of cartilage can be used for protection.

4. All ossicles except the stapes footplate are destroyed.
In these cases a total or subtotal perforation is generally found. Reconstruction in one stage is rather unstable but should be tried. Using cartilage palisade tympanoplasty, we obtain a good stability for the tympanic membrane and provide reinforcement for the titanium allograft. The

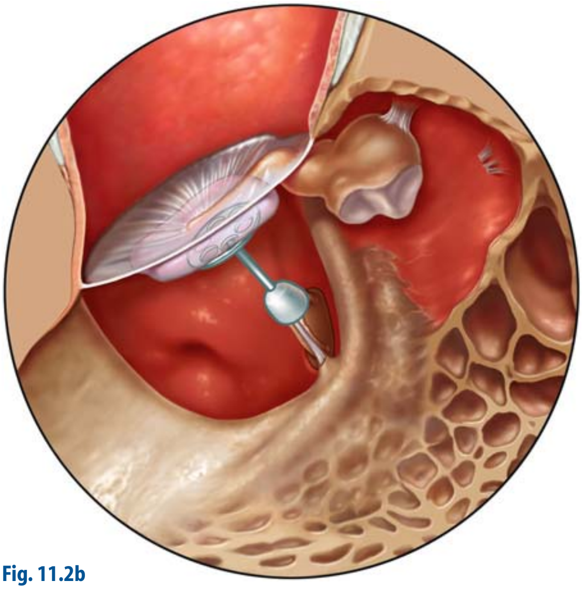


Fig. 11.2b

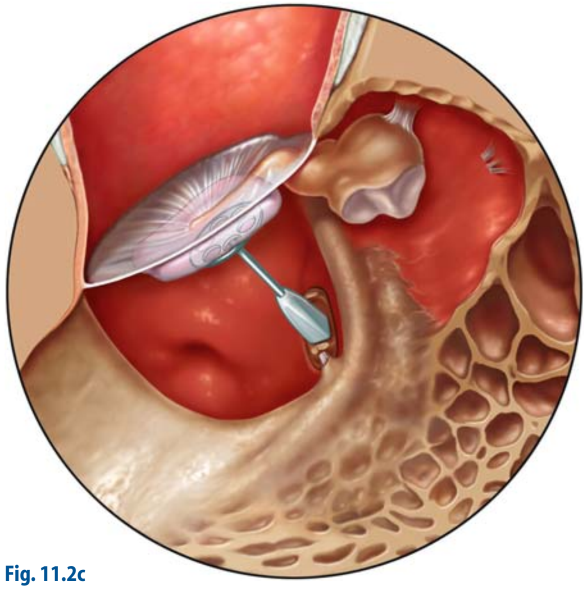


Fig. 11.2c

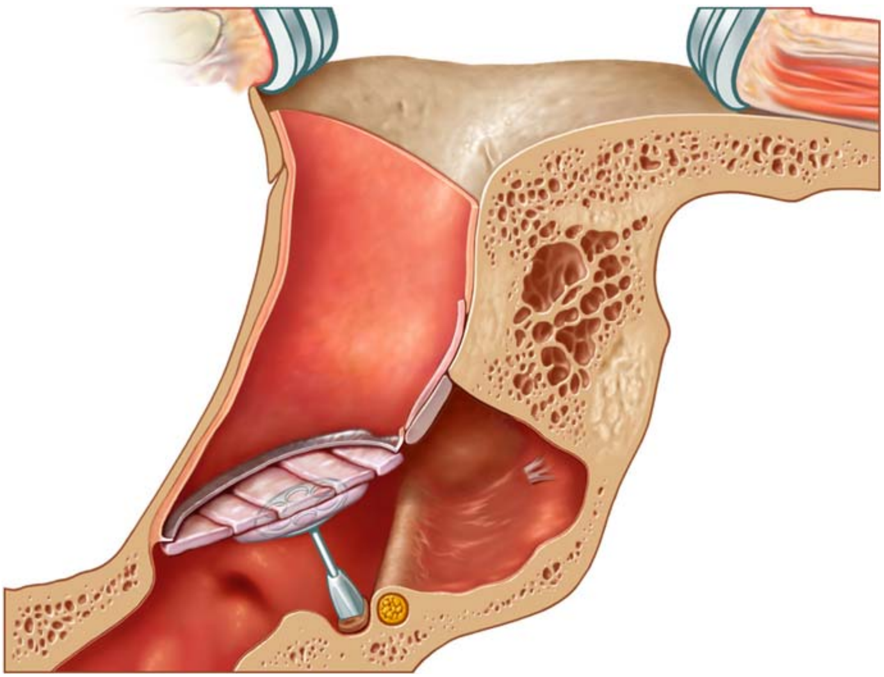


Fig. 11.3

TORP position is stabilized by surrounding the foot with Gelfoam (**Fig. 11.3**).

All reconstructions have to allow enough space between the promontory and reconstructed membrane to create an aerated middle ear, if the posterior wall is preserved. An airway to the mastoid is necessary to prevent retraction and new cholesteatoma formation.

12 Materials for Ossicular Chain Reconstruction

Matthew Yung

There are many different materials currently being used for ossiculoplasty. They can be categorized into autografts, homografts and allografts. In the 1999 Smith & Nephew Otology Catalogue alone, 54 different designs of alloplastic ossicular prosthesis were being marketed [1]!

In general, there has been a paucity of long-term comparative studies on different ossiculoplasty materials. There has been only one randomized study in the literature comparing one particular material with another (Plastipore vs Ceravital) [2]. Virtually all other reports have been either personal series of one particular type of prosthesis or comparisons of results of different prostheses based on historical data. The criteria used by different authors to describe success have varied, e.g. different methods have been used to calcu-

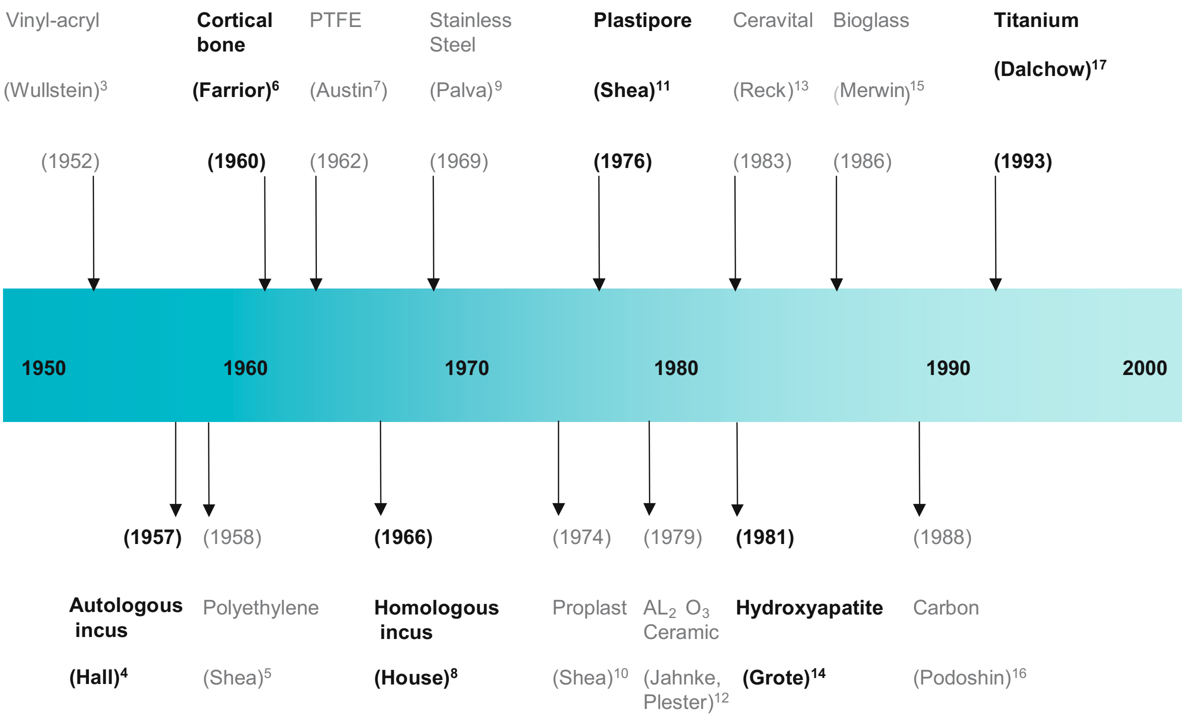


Fig. 12.1. Time line showing the specific year each alloplastic material was introduced for clinical use (the alloplastic materials in boldface are discussed at greater length in the text)

late the frequency average and postoperative air-bone gap. Some authors have only reported extrusion but not exposure of the prosthesis. Furthermore, the case mix amongst these reports has been different. It is therefore difficult to draw any conclusions from the literature as to which ossiculoplasty material gives the best results.

The present chapter is a literature review of the various ossiculoplasty materials. In order to make the comparison between different reports meaningful, the author considered both extrusion and exposure of the prosthesis as "prosthesis related complications". A postoperative air-bone gap of 20 dB or less was used as the criterion for "success following ossiculoplasty" since this has been described by the majority of authors. Particular attention was given to the size of the population, the length of the follow-up period and the average frequency for reporting of hearing results.

Of the many ossiculoplasty materials that have been described, not many have stood the test of time. In **Fig. 12.1**, a time line with the specific year each material was first reported in clinical use is shown [3–17]. Some materials were more popular than others, at least for a period. Some are still being used. The specific materials highlighted on the time line are given a more detailed review.

In 1957, Hall and Rytzner first described the technique of repositioning or autotransplanting the incus remnant in ossicular reconstruction [4]. The patient's incus is not always available for repositioning, and Farrior first advocated the use of cortical bone as an ossicular substitute [6]. In 1966, House and associates suggested the use of homograft incus in ossiculoplasty [8]. Since all these bone grafts are basically "dead" bone, their long-term fate has been the subject of many investigations. These investigations were based on the histopathology of a small number of implants retrieved at revision surgery, therefore biasing the histological findings [18–22]. On the whole, these reports indicated that these "dead" bone grafts underwent new bone formation and remodelling by a slow process of "creeping substitution". They maintained their morphologic structure even when the bone was "dead". However, resorption by rarefying osteitis occurred in an environment of chronic suppurative otitis media, similar to their living counterpart.

It is generally agreed that ossicular bone grafts are less likely to be extruded from the ear than alloplastic materials; however, ankylosis can occur between the bone graft and the adjacent bony structures, such as the facial canal. The functional results reported by several authors are listed in **Table 12.1**. These are mainly reports from the 1970s and 1980s, when the three-frequency average of 0.5, 1 and 2 kHz was commonly used in reporting results. It is therefore difficult to compare these results with more recent reports concerning alloplastic materials (**Tables 12.2–12.6**). The "success" rate of bone PORP (partial ossicular reconstruction prosthesis) was between 50% and 90% and that of bone TORP (total ossicular reconstruction prosthesis) was between 35% and 81% (defined by a postoperative air-bone gap of 20 dB or better).

Table 12.1. Comparison of the functional results of ossicular bone grafts between different clinical reports

Author (year)	No. cases	Follow-up period	Materials	Postop. ABG •20 dB PORP	Postop. ABG > 20 dB TORP
Wehr (1978) [23]	262	> 1 year	Homologous ossicle	90 % (freq. not specified)	76 % (freq. not specified)
Austin (1972) [24]	207	> 1 year	Autologous and homologous ossicle	83 % (freq. not specified)	71 % (freq. not specified)
Vartiainen (1985) [25]	246	2 years	Autologous ossicle and cortical bone	50 % (3 freq.)	35 % (3 freq.)
Glasscock (1975) [26]	69	> 1 year	Autologous and homologous ossicle	65 % (3 freq.)	
Penington (1978) [27]	216	> 1 year	Autologous and homologous ossicle and cortical bone	Combined PORP and TORP = 85 % (3 freq.)	
Gersdorff (1989) [28]	103	> 1 year	Homologous cortical bone	78 % (freq. not specified)	56 % (freq. not specified)
Vercruyysse (2002) [29]	60	1 year	Homologous ossicle		81 % (3 freq.)
Siddiq (2004) [30]	24	> 4 years	Autologous ossicle	71 % (4 freq.)	

ABG air-bone gap, *4 freq.* 4-frequency average of 0.5, 1, 2 and 3 kHz, *3 freq.* 3-frequency average of 0.5, 1 and 2 kHz

The introduction of alloplastic materials in ossiculoplasty took place in the 1950s. Early implant materials include vinyl acrylic [3], polyethylene [5], PTFE (polytetrafluoroethylene) [7] and metal [9]. The early results of these materials were so disappointing that by the time of the Fourth Shambaugh-Shea Workshop on Middle-Ear Surgery in 1971, there was general agreement that these solid plastic and metallic implants had no place in the surgical treatment of chronic otitis media [31].

Plastipore was the first alloplastic material that was commercialized and used worldwide [11]. It is a semi-soft white sponge of high-density polyethylene. Although the short-term results were encouraging, there was an unacceptable long-term extrusion rate. Smyth reported a 12 % extrusion rate at 5 years and Portmann reported a 30 % extrusion rate at 2 years when the Plastipore prosthesis was placed in direct contact with the tympanic membrane [32, 33]. Kerr examined 52 Plastipore prostheses removed at revision surgery. He noticed that multinucleated foreign body giant cells were present in large numbers in both types together with histological evidence of breakdown of the prostheses [34].

Many authors tried to reduce the extrusion of Plastipore by placing a cartilage disk over the prosthesis. This modification of technique has reduced the extrusion rate to less than 10%, at least in many medium-term studies [35–39]. In spite of many other alloplastic materials being introduced since then, Plastipore is currently still being favoured by some otologists [38, 39]. **Table 12.2** lists the prosthesis extrusion/exposure rates and the functional results reported by different authors. From two separate reports that have provided long-term follow-up data (3 and 4 years) on Plastipore, the success rate of Plastipore PORP (partial ossicular reconstruction prosthesis) was 59% and 80% and that of Plastipore TORP (total ossicular reconstruction prosthesis) was 27% and 44%. Both studies involved interposition of cartilage between the tympanic membrane and the head plate of the prosthesis.

Aluminium oxide ceramic (Al_2O_3) ossicular prosthesis was introduced into clinical practice by Jahnke and Plester in 1979 [12], and at least from the relatively few clinical reports in the literature the results have been comparable to those of Plastipore (**Table 12.3**) [40, 41]. Like Plastipore, cartilage interposition is recommended between the prosthesis and the tympanic membrane. Furthermore, a piece of perichondrium needs to be placed between the footplate and the Al_2O_3 TORP to reduce the risk of perforation of the footplate. It is not entirely clear why this material was never accepted widely amongst otologists, when there was no major concern over its biocompatibility.

Ceravital was another alloplastic material that became very popular in the 1980s before it was eventually withdrawn from the market. It is a glass ceramic material composed of the oxides of silicon, calcium, phosphorus, sodium,

Table 12.2. Comparison of the functional results and extrusion rates of Plastipore ossicular prostheses between different clinical reports

Author (year)	No. cases	Follow-up period	Extrusion/ exposure	Postop. ABG •20 dB PORP	Postop. ABG >20 dB TORP
Smyth (1983) [32]	116	5 years	12%		
Portmann et al. (1984) [33]	146	2 years	30%		
House et al. (2001) [39]	1040[a]	2 months	3.7%	69% (4 freq.)	61% (4 freq.)
Bayazit et al. (1999) [38]	156[a]	<1 year	4.2%	63% (3 freq.)	43% (3 freq.)
Brackman et al. (1984) [37]	1042[a]	>6 months	7%	53% (freq. not specified)	33% (freq. not specified)
Jackson et al. (1983) [36]	141[a]	>1 year	10%	43% (freq. not specified)	49% (freq. not specified)
Mangham et al. (1990) [2]	53[a]	3 years		59% (3 freq.)	27% (3 freq.)
Slater et al. (1997) [35]	37[a]	4 years	1.3% at 6 months	80% (3 freq.)	44% (3 freq.)

[a] indicates that cartilage disks were used to interpose between the prosthesis and tympanic membrane
ABG air-bone gap, *4 freq.* 4-frequency average of 0.5, 1, 2 and 3 kHz, *3 freq* 3-frequency average of 0.5, 1 and 2 kHz

Table 12.3. Comparison of the functional results and extrusion rates of aluminium oxide ossicular prostheses between different clinical reports

Author (year)	No. cases	Follow-up period	Extrusion/ exposure	Postop. ABG •20 dB PORP	Postop. ABG > 20 dB TORP
Yamamoto et al. (1988) [41]	173	> 1 year	7 %	66 %	53 %
Plester et al. (1981) [40]	112	2 years		Combined PORP and TORP = 64 % (freq. not specified)	

Table 12.4. Comparison of the absorption and extrusion rates of Ceravital ossicular prostheses between different clinical reports

[a] Bone paste was not used between the prosthesis and tympanic membrane

Author (year)	No. cases	Follow-up period	Absorption rate	Extrusion/ exposure rate
Portmann et al. (1984) [33]	50	1 year (mean)	0	8 %
Babighan (1985) [44]	70	> 1 year	0	8 %
Blayney et al. (1986) [43]	128	2 years (mean)	1.6 %	3 %
Gersdorff et al. (1986) [45]	53	2 years (mean)	0	4 %
Niparko et al. (1988) [46]	37	3 years (mean)	0	3 %
Reck (1988) [13]	1056	7 years (maximum)	0.7 %	
Mangham et al. (1990) [2]	39	3 years (mean)	5 %	
Austin (1985)[a] [47]		1 year		29 %
Brewis (2003) [48]	25	6.5 years (mean)	36 %	12 %

potassium and magnesium [42]. It is bioactive and when implanted bonds to adjacent bone [43]. The first clinical report on the use of Ceravital ossicular prosthesis was by Beck in 1983 [13].

Several authors have reported good short- and medium-term results with Ceravital ossicular prostheses with reference to hearing gain and extrusion rate [2, 13, 43 – 47]. In clinical trials with longer follow-up, it became apparent that some prostheses eventually became absorbed. The absorption rate was quoted as being 0.7 %, 1.6 % and 5.1 % in three different reports (**Table 12.4**) [2, 13, 43], but a high proportion of patients in these trials were lost to the long-term follow-up. There was enough concern for the manufacturer to stop the production of Ceravital prostheses. In a more systematic long-term follow-up study of up to 14 years, the incidence of absorption of Ceravital was found to be 36 %, and only 16 % of the implanted ears maintained a good audiological outcome [48].

The most popular alloplastic material to date is hydroxyapatite (HA) or calcium triphosphate. It is a bioactive ceramic that resembles the mineral matrix of bone. The clinical results of HA in middle ear reconstruction were first reported by Grote in 1981 [14]. It is still being used worldwide and has so far stood the test of time. The prosthesis extrusion/exposure rate is generally observed to be less than 10 % (**Table 12.5**) [39, 49 – 52]. However, it is surprising that there are only a few long-term follow-up studies in the literature. Grote observed 4 % extrusion in a long-term study using HA. Using a postoperative air-bone gap of 20 dB or less as "success", he reported 84 % success for PORP and 64 % success for TORP [52]. The only exception to the relatively "favour-

Author (year)	No. cases	Follow-up period	Extrusion/ exposure	Postop. ABG •20 dB PORP	Postop. ABG > 20 dB TORP
House (2001) [39]	127	3 months	7.9 %	57 % (4 freq.)	39 % (4 freq.)
Wehr (1994) [49]	42	1 years	30 %	89 % (3 freq.)	78 % (3 freq.)
Murakami (1995) [50]	106	2 years	7.5 %	62 % (freq. not specified)	56 % (freq. not specified)
Shinohara (2000) [51]	106	> 5 years	16 %		
Grote (1996) [52]	170	> 3 years	4 %	84 % (freq. not specified)	64 % (freq. not specified)

Table 12.5. Comparison of the functional results and extrusion rates of hydroxyapatite ossicular prostheses between different clinical reports

ABG air-bone gap, *4 freq.* 4-frequency average of 0.5, 1, 2 and 3 kHz, *3 freq.* 3-frequency average of 0.5, 1 and 2 kHz

able" results of HA was a long-term study by Shinohara, who reported a prosthesis extrusion/exposure rate of 16 % [51]. One of the difficulties in comparing the results of various clinical reports is that the surgical techniques differ amongst surgeons, with some surgeons using cartilage sheets over the prosthesis to prevent extrusion [53].

The biocompatible nature of HA allows the head plate of the ossicular prosthesis to be placed directly in contact with the tympanic membrane. In order to make the HA prosthesis more user-friendly, various composite HA prostheses have been subsequently developed. These prostheses consist of an HA head plate and a malleable shaft made from other materials, so that they can be trimmed easily with a scalpel. These materials include Plastipore [54], Polycel (thermal-fused Plastipore), PTFE, Flex-HA (a mixture of HA and silastic) and HAPEX (HA reinforced polyethylene composites). Some prostheses even incorporate a stainless steel core in the shaft to aid sound conduction [55]. The various combinations resulted in an explosion of the number of designs of composite HA prostheses, making direct comparison of results between different surgeons even more difficult. On the whole, these composite HA prostheses also had a medium- and long-term extrusion rate of less than 5 %, but the success rate varies greatly between reports.

Ossicular prostheses made from Bioglass were first introduced by Merwin in 1986 [15]. Although commercially available, they have not gained worldwide popularity and hence the number of clinical reports is relatively small. Ossicular prostheses made from carbon were also tested in a clinical trial by Podoshin in 1988. In spite of their biocompatibility, carbon ossicular prostheses are not available commercially because the material is brittle and difficult to handle [16].

Furthermore, in a small clinical study using carbon fibre reinforced carbon as the ossicular prosthesis, Blayney et al. reported a 40 % extrusion rate at 9 months and a further 8 % with inflammatory responses around the implant [56].

Titanium (Ti) was established as an excellent biocompatible material by Branemark in the 1970s [57]. It was first introduced as an alloplastic material for ossiculoplasty in 1993 [17]. The material is light and strong, allowing many possibilities in the prosthetic design. The shaft of the prosthesis can be thin and yet rigid. All the current designs have an open head plate rather than a solid plate. This allows surgeons to observe the position of the bottom end of the prosthesis during the placement of the prosthesis. The bottom end of the Ti PORP has a better fit over the stapes head due to its "claw-like" design instead of a "cup-like" design. A piece of cartilage needs to be interposed between the head plate and the tympanic membrane to prevent extrusion. Like hydroxyapatite, Ti ossicular prostheses are being marketed worldwide. As new designs of Ti prosthesis are developing all the time, it makes the direct comparison of clinical results in the literature more difficult; in particular some manufacturers are producing composite prostheses using Ti for the head plate and hydroxyapatite for the shaft. On the whole, medium-term follow-up reports on Ti ossicular prostheses indicate that the extrusion rate is less than 5% and the "success" rate is comparable to that of the hydroxyapatite prosthesis (**Table 12.6**) [17, 58–60].

In summary, the most popular materials used in ossiculoplasty at the present time are bone, Plastipore, hydroxyapatite and titanium using a large number of different designs of prosthesis. Many are composite prostheses combining two or three different alloplastic materials. Prostheses with a Plastipore or titanium head plate require the interposition of a cartilage disk between the prosthesis and the tympanic membrane, whereas bony or hydyroxyapatite prostheses can be placed directly in contact with the tympanic membrane. It is impossible to determine which is the best prosthesis, as there is a paucity of prospective randomized trials and systematic long-term follow-up studies. Long-term surgical failure is often due to the pathology in the middle ear cleft rather than being prosthesis related.

Table 12.6. Comparison of the functional results and extrusion rates of titanium ossicular prosthesis between different clinical reports

Author (year)	No. cases	Follow-up period	Extrusion/ exposure	Postop. ABG •20 dB PORP	Postop. ABG > 20 dB TORP
Begall et al. (2000) [58]	528 (14 hospitals)	6 months	4%		
Wang et al. (1999) [59]	124	> 1 year	0%	Combined PORP and TORP = 59% (3 freq.)	
Zenner et al. (2001) [60]	114	> 1 year		70% (at 2 kHz)	60% (at 2 kHz)
Dalchow et al. (2001) [17]	1304	> 6 months	1%	Combined PORP and TORP = 76% (4 freq.)	

ABG air-bone gap, *4 freq.* 4-frequency average of 0.5, 1, 2 and 3 kHz

13 Antrotomy and Mastoidectomy

Holger Sudhoff, Henning Hildmann

Definition

The procedure of antrotomy involves the exposure of the antrum, exhibiting the posterior part of the body of the incus.

The procedure of mastoidectomy includes the removal of the mastoid cells, exposing the sinus dural angle, the bony shell of the sigmoid sinus, the middle fossa and the posterior fossa, the skeletonization of the labyrinth and the opening of the antrum to the epitympanum. This extreme exposure as described is seldom necessary in clinical practice and is modified according to the pathology.

Indications

Indications are acute mastoiditis and its complications, occult mastoiditis in children, removal of long-term middle ear effusion and of pathologic tissue in middle ear surgery, chronic otitis media with persistent discharge, neoplasms of the mastoid, part of the approach to the labyrinth, and inner auditory canal, and for cochlear implantation.

The skin incision is done approximately 1 cm postauricularly behind the posterior auricular sulcus by pulling the auricle anteriorly (see **Fig. 13.1**). In very young children the inferior portion of the incision is placed more laterally so as not to injure the facial nerve. The development of the mastoid tip is still incomplete. The surgeon pulls the auricle anteriorly, incising the skin and subcutis from the superior to the inferior portion. Afterwards the scalpel has to be used under permanent contact to the bone. The middle finger of the hand not holding the scalpel is placed in the ear canal. This helps to feel the position of the incision in relation to the ear canal.

The soft tissue is completely removed by a raspatory. Henle's spine and the temporal line are exposed as landmarks. The mastoid tip should only be exposed if this area has to be opened. In this case the tendinous insertions of the sternocleidoid muscle should be sectioned.

Two self-retaining retractors with sharp edges are inserted to expose the mastoid cortex (**Fig. 13.2**). The approach is marked by the red dashed line.

The opening should be wide to allow a good overview over the surgical field also if a complete antrotomy is not intended (**Fig. 13.3**). After opening the cortical bone the first landmarks and structures at risk are the sigmoid sinus and the dura of the medial fossa. Due to the late development of the mastoid tip

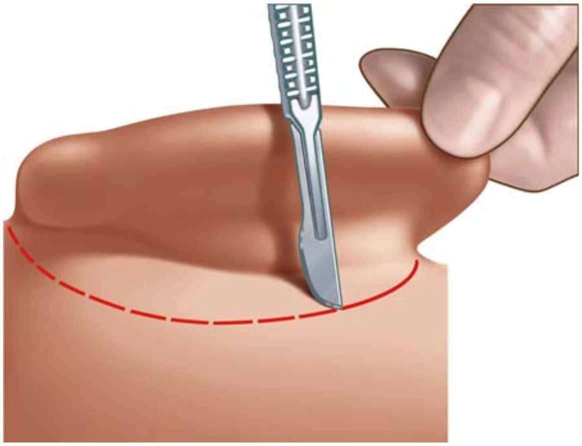


Fig. 13.1

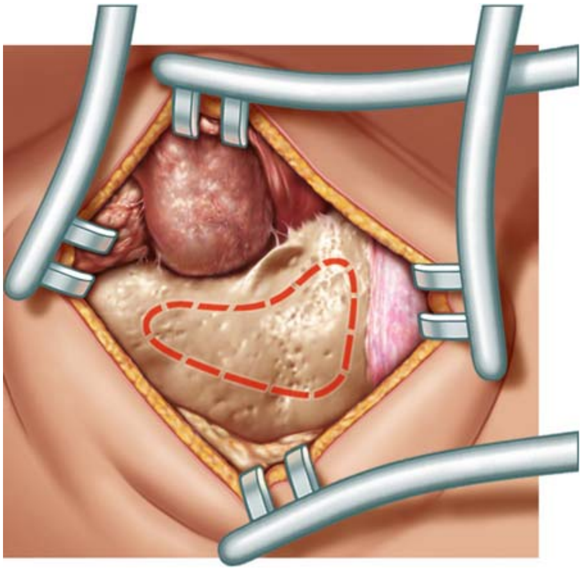


Fig. 13.2

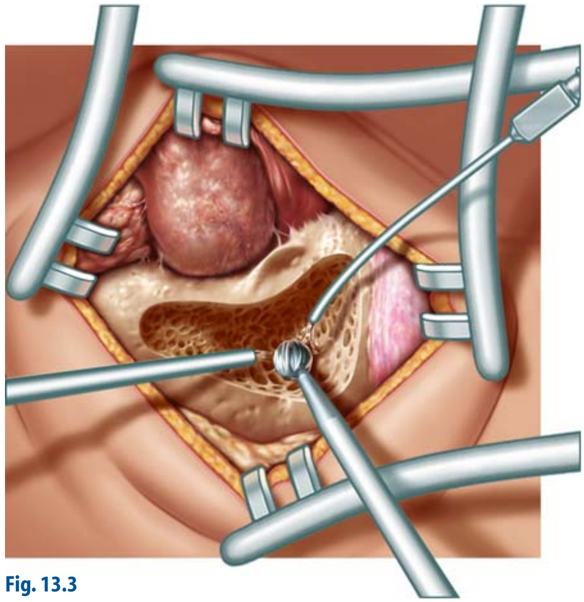


Fig. 13.3

and the growth of the tympanic bone, the lateral position of the facial nerve must be respected especially in younger patients.

After the delineation of the antrum the aditus ad antrum is enlarged with a curette from its medial to the lateral aspect. Attention is paid not to dislodge the incus (**Fig. 13.4**). This procedure reduces the probability of a recurrent mastoiditis. Landmarks such as the lateral semicircular canal and the short process of the incus have to be identified. Children aged 3–4 years may already have a well pneumatized mastoid.

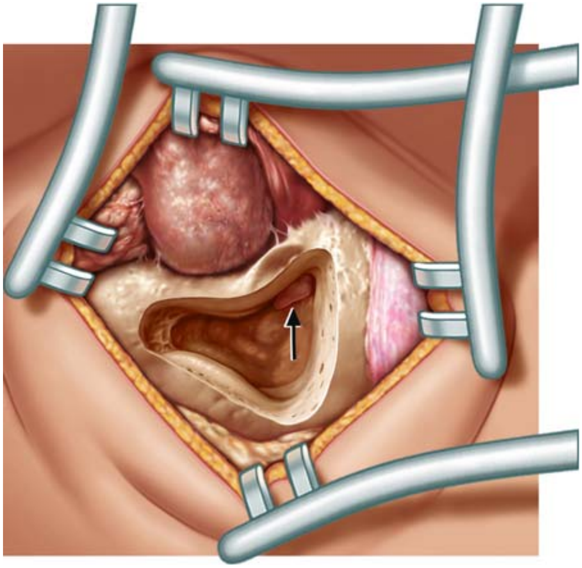


Fig. 13.4

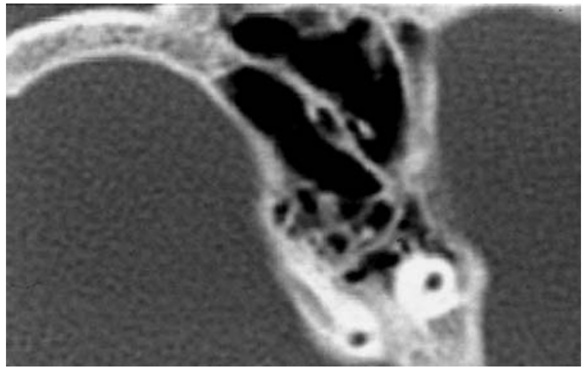


Fig. 13.5

In older children and adults large burrs reduce the risk of inadvertent damage to vital structures. It is pivotal not to drill holes but to have a large area approach to the mastoid. The linea temporalis and Henle's spine serve as landmarks. The thin bone of the tegmen tympani is skeletonized, leaving the dura covered with bone. Körner's septum may exist deep in the mastoid within the air cells of the pneumatized mastoid (see computed tomogram in **Fig. 13.5**). If present, it is a solid wall separating the superficial mastoid bone from the deeper cells.

The sigmoid sinus and the lateral semicircular canal are identified. The lateral semicircular canal and the medial wall are the landmarks with which to identify the facial nerve and the attic. In badly pneumatized mastoids the dura over the tegmen tympani can be used for orientation. In the antrum it is preferable to use a diamond burr. Strict attention must be paid to the incus to avoid its dislodgment or acoustic trauma to the inner ear. The antrum is blocked straight after its exposure with Curaspon pieces to prevent the intrusion of bone dust into the epitympanic and middle ear spaces. Bone dust may lead to a bony closure of the eustachian tube or the windows or to a fixation of the ossicular chain. The fossa incudis is identified by removing bone in the zygomatic arch overlying the antrum.

Mastoidectomy comprises modelling of the sinus dura angle, the bony covering of the sigmoid sinus and the posterior fossa. The posterior meatal wall is thinned. The attic is opened to visualize the head of the malleus and the body of the incus. This is impossible in a sclerosed mastoid and a low middle fossa.

Fig. 13.6

A wide exposure facilitates the orientation. A cutting burr is used at the mastoid tip until the digastric ridge is visualized (**Fig. 13.6**).

Identification of the lateral semicircular canal and the mastoid portion of the facial nerve: For the less experienced it is helpful to identify the facial nerve in its mastoidal course by drilling the bone over the nerve until it is seen along with the remaining thin layer of bone. A diamond burr larger than the diameter of the nerve should be used to reduce the danger of injury. The drilling must be performed parallel to the course of the nerve.

In treatment of mastoid disease causing intracranial complications, each mastoid cell and piece of diseased tissue should be removed. The dura of the middle and posterior cranial fossa are partly uncovered. In case of granulations, bone should be removed further until whitish healthy mucosa appears. With suspected sinus thrombophlebitis or thrombosis, the sigmoid sinus should be exposed and checked for patency by puncture. Thrombophlebitis normally requires no additional surgical treatment other than complete mastoidectomy. Only in cases of sepsis, extension of the thrombus or pulmonary complications ligation of the jugular vein should be performed in addition to anticoagulation and antibiotic therapy.

The surgical treatment of any brain abscess should be done by or in cooperation with the neurosurgeon. Abscesses adjacent to the temporal bone are more easily reached from the site of origin of the disease and punctured from the mastoid (see computed tomogram and magnetic resonance images in **Figs. 13.7, 13.8a, b** by courtesy of PD Dr. Randolf Klingbiel, Department of Neuroradiology, Charité, Berlin).

Fig. 13.7

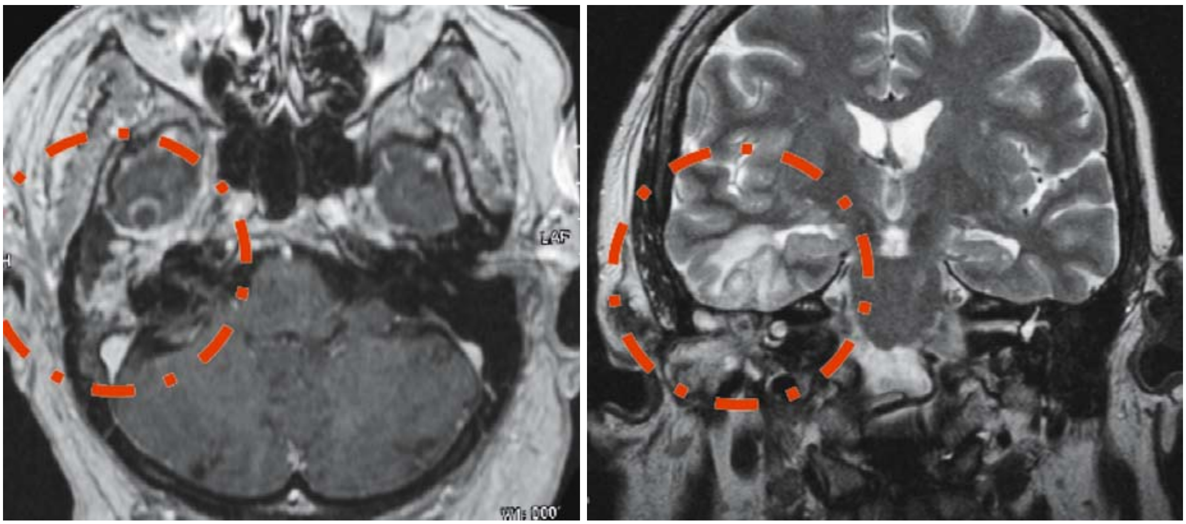


Fig. 13.8a, b

14 Cholesteatoma Surgery

Holger Sudhoff, Henning Hildmann

Introduction

History in the case of cholesteatoma is often non-specific. Patients may complain of periodic or constant aural and often fetid discharge. Pain is unusual. The degree of hearing loss is highly variable. A cholesteatoma may develop insidiously for some time without otorrhoea and may be detected incidentally during an ear examination. Involvement of the vestibular system, auditory system or facial nerve will cause vertigo, sensorineural hearing loss, tinnitus, or facial palsy. Intracranial complications are extremely rare in the absence of premonitory signs and symptoms. However, in children these prodromi might pass unnoticed.

Diagnosis is made under the otomicroscope after secretions have been aspirated and the external canal and tympanic membrane have been cleaned. Endoscopic evaluation can be useful and surgical exploration. Exploration may be necessary. With a typical epitympanic or attic cholesteatoma, a perforation (usually peripheral) can be seen in the tympanic membrane. Polyps,

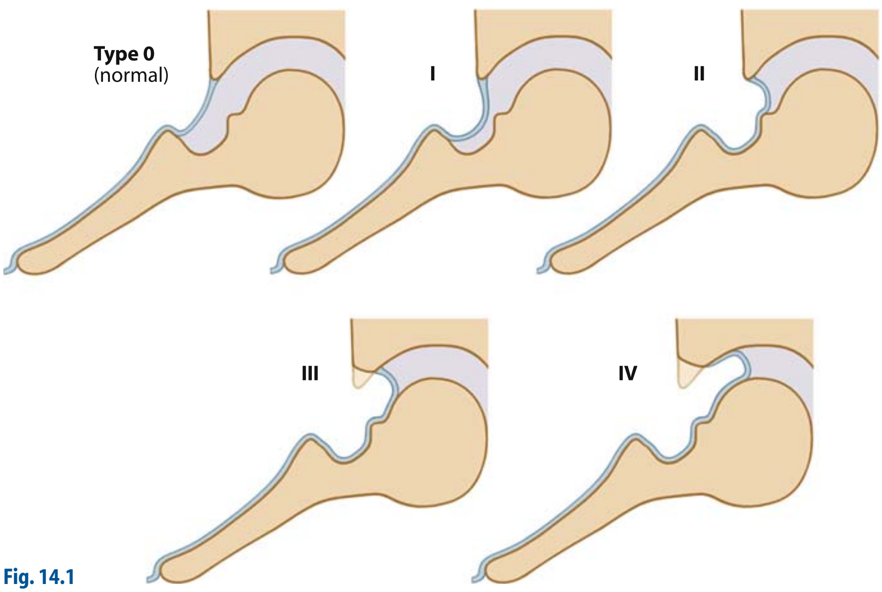


Fig. 14.1

especially when located at the posterior superior margin of the membrane or in the epitympanum, can occasionally provide evidence of disease even when squamous
debris is not visible. Special imaging procedures, such as high-resolution computerized tomography (CT), are necessary especially when involvement of the cochlea, the labyrinth, facial nerve and skull base is suspected. Magnetic resonance imaging (MRI) may in the future become useful for detecting recurrent cholesteatomas behind an intact graft, when differentiation between scar and inflammatory tissue becomes reliable.

Cholesteatomas are epidermal inclusion cysts of the middle ear or mastoid. In the case of a retraction pocket cholesteatoma, the "cyst" opens into the external auditory canal developing from a retraction pocket (**Fig. 14.1**). The cyst contains desquamated debris (principally keratin) from their keratinizing, squamous epithelial lining. Cholesteatomas of the temporal bone may be congenital or acquired. Acquired cholesteatomas are the consequence of otitis media with effusion (OME) or acute otitis media (AOM) or both. An understanding of the pathogenesis and pathophysiology of aural cholesteatoma is particularly important because it is the destructive nature of this entity that is responsible for much of the morbidity associated with chronic otitis media. The propensity of cholesteatomas to erode bone and the lack of effective, nonsurgical management add importance to the understanding of this disease.

Any squamous epithelium in the middle ear with the possibility of destruction of the surrounding structures and intracranial life threatening complications must be considered to be a cholesteatoma.

A cholesteatoma consists of layers of keratin in a cavity lined by squamous epithelium, called matrix, and the underlying subepithelial connective tissue, called perimatrix. It is mainly confined to the middle ear but may also occur in other areas such as the skull base, meninges, brain and temporal bone. Cholesteatoma gradually expands as a result of progressive exfoliation of keratinous material and causes complications by eroding surrounding structures. Within the middle ear, bony erosion may result in hearing loss, vestibular dysfunction, facial nerve palsy and intracranial complications. Due to its pathogenesis, cholesteatoma can be divided into congenital and the much more frequent acquired cholesteatoma.

There are four basic theories of the pathogenesis of acquired aural cholesteatoma: (1) invagination of the tympanic membrane (retraction pocket cholesteatoma), (2) basal cell hyperplasia, (3) epithelial ingrowth through a perforation (the migration theory), and (4) squamous metaplasia of middle ear epithelium. Recently, Sudhoff and Tos proposed a combination of the invagination and basal cell theories as an explanation for retraction pocket cholesteatoma formation [1]. The loss of self cleaning will result in a transition from the retraction to the expansion stage of cholesteatoma (**Fig. 14.2**).

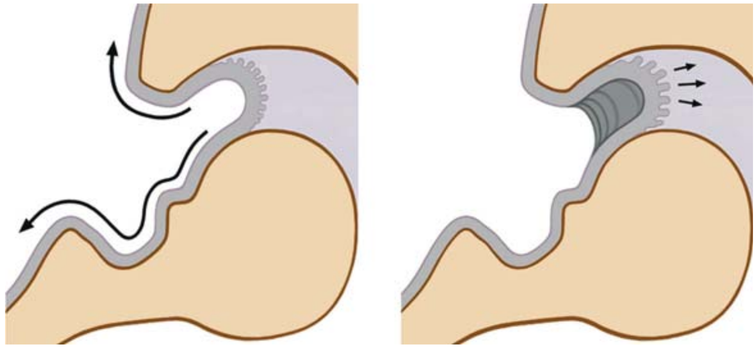


Fig. 14.2

Acquired cholesteatomas of the middle ear are divided into:

1. Attic cholesteatoma, originating from Shrapnell's membrane and extending primarily into the attic.
2. Sinus cholesteatoma, originating from the posterosuperior retraction of pars tensa and extending primarily into the tympanic sinuses. From here it may extend along the prominence of the facial nerve, medial to the incus body, into the posterior attic and antrum, while the anterior part of the tympanic cavity and the anterior attic are not involved.
3. Tensa-retraction cholesteatoma, originating from an entirely retracted pars tensa, draping over the posterior and anterior walls of the tympanic cavity, extending from here into the hypotympanic cells and tubal orifice. Furthermore it may extend, medially to the malleus folds, towards the posterior and anterior attic.

This classification, proposed by Tos for a better understanding of the pathogenesis, has become widely accepted. He classifies the pars tensa cholesteatomas into sinus cholesteatomas originating from a posterior retraction and tensa retraction cholesteatomas developing from the anterior, inferior and posterior parts of the tympanic membrane. Such a classification is also important for the evaluation of the natural history, prognosis, surgical methods and results.

General Principles for Surgery

The basic goal of cholesteatoma surgery is the complete removal of the squamous epithelium to minimize the risk of recurrence. Cholesteatoma is a life-threatening disease due to its intracranial complications. Therefore it may be necessary to sacrifice even functionally important structures such as the auditory ossicles and even the inner ear in cases of extended disease. The first step is the complete removal of the epithelium. Only after complete removal is reconstruction to be planned. Comparable to tumour surgery, it is dangerous when the surgeon worries about reconstruction while removing the disease. This results in compromises and may increase the incidence of recurrent disease.

Due to the amount of drilling that may become necessary, we prefer general anaesthesia for cholesteatoma surgery. If the time required for surgery does not exceed 2.5 h, surgery using local anaesthesia is possible.

Endoscopy can be a supplementary tool for preoperative microscopic diagnosis in selected cases. It can be used, for example, in deciding whether a retraction pocket or a spontaneous cavity requires operative treatment. In a central perforation, it may even be possible to evaluate the auditory ossicles under favourable conditions. However, endoscopes are not routinely used in cholesteatoma surgery. Hopkin's wide-angle endoscopes are intraoperatively useful for checking areas of epithelium which cannot be looked at with the microscope. If the site of inspection is clear, drilling for direct inspection and removal may not become necessary.

Surgical Steps

1. Incision. Generally, if work in the mastoid becomes necessary, a retroauricular incision is used. This approach allows extensive exposure of the mastoid according to the extent of the disease. A cavity can be reduced in size by removing the tip of the mastoid and the outer bone of the mastoid if required. Larger flaps for obliteration can be harvested. Only for smaller sinus cholesteatomas not extending into the mastoid is the endaural incision preferable.

2. The meatal flap is prepared as described above. In most cases it should be wider than in tympanoplasty for a central perforation. The incisions are made at 12 and 6 o'clock. Since drilling in the ear canal is necessary, we remove the posterior meatal skin and reimplant it at the end of the operation as a free graft. This allows more space for drilling and prevents damage of the flap by the drill. Additionally it improves the overview and saves time. Ear canal widening is important in cases of narrow ear canals to facilitate the postoperative follow-up and care.

3. The ear canal is widened by drilling some of the bone free from the flap. If an overhanging anterior meatal wall obscures the vision, the skin must also be removed from the anterior wall for drilling until the anterior tympanomeatal angle is seen. This anterior tympanomeatal angle is a vulnerable area. Whenever possible the epithelium must not be damaged to avoid blunting.

4. If the cholesteatoma extends into the attic, antrum or mastoid, it is usually followed and exposed by drilling until the sac can be looked at and removed. Only for or sinus cholesteatomas and tensa cholesteatomas confined to the middle ear might it be sufficient to widen the ear canal. If the epithelium invades the sinus tympani, the region cannot be completely

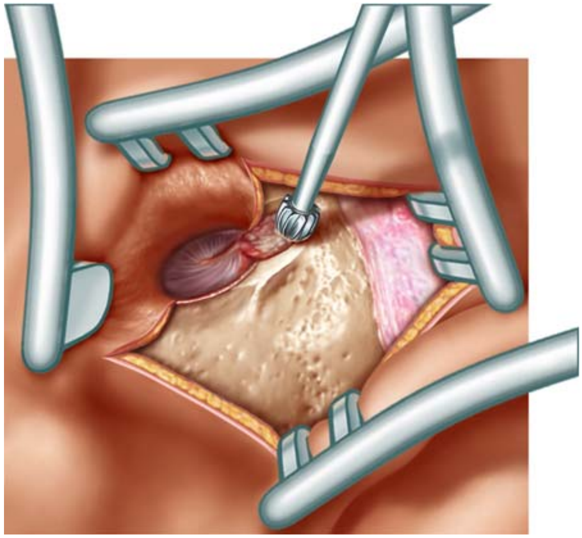


Fig. 14.3

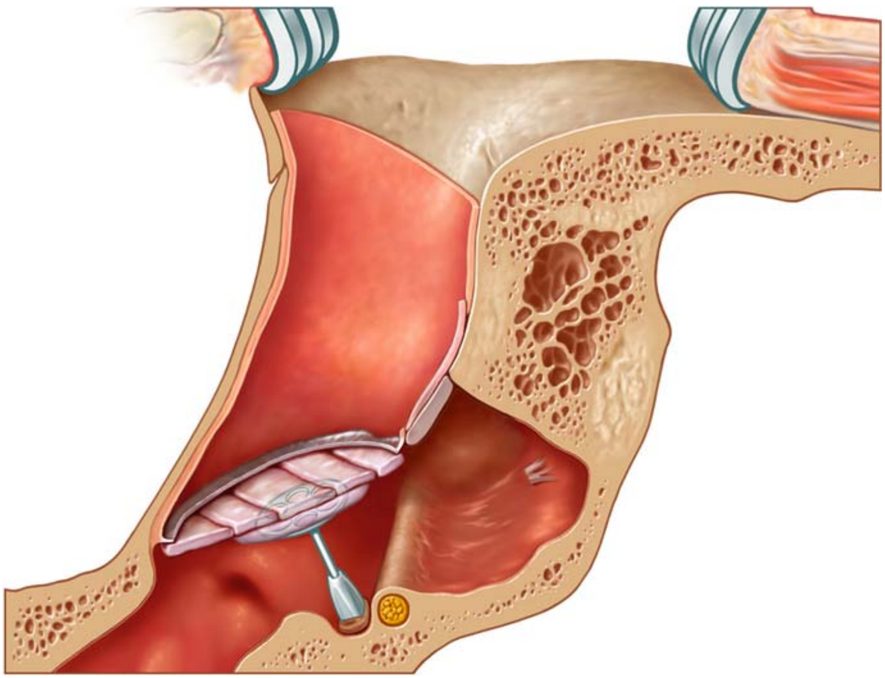


Fig. 14.4

exposed if the sinus extends under the facial nerve. The use of an endoscope can be helpful.

5. As standard procedure the epithelial sac is exposed by removing the covering bone of the posterior meatal wall (**Fig. 14.3**). The epithelium is followed until the sac is completely exposed and can be removed. Then the drill should not touch the epithelium and should avoid spreading cholesteatoma particles. Living epithelial cells might be spread and be implanted. If the cholesteatoma is small, a small amount of drilling should be done and the posterior wall is reconstructed with cartilage (**Fig. 14.4**). For extended cholesteatomas the entire posterior wall should be removed, resulting in a mastoid cavity. This surgery and the problems associated with it are described below. The epithelium may also extend under the head of the malleus and the anterior epitympanum. This part can escape detection if the surgeon does not meticulously check this area. The defect is reconstructed with cartilage if the middle ear is aerated. The techniques and problems of reconstruction are described in Chap. 15, "Mastoid Cavity".

6. Whenever possible the cholesteatoma sac should not be opened. Parts of the sac obscuring the surgical field, however, can be resected. If the surgeon works underneath the epithelium within the perimatrix, he or she can be sure to remove the epithelium completely. The epithelium should not be torn out, but removed in continuity. This is especially difficult in invasive types of cholesteatoma where one cell needs to be cleaned after the other. The bony partitions between the cells are removed with a curette or a diamond burr. Smoothing of the denuded bone allows improved self-cleaning and accelerated healing.

7. The classical intact canal wall technique for the removal of cholesteatoma is only used in selected cases. The recurrence rate, especially in inexperienced hands, has been too high. We see an indication in patients with extensive mastoids. The procedure is described next in Chap. 15, "Mastoid Cavity".

15 Mastoid Cavity

Holger Sudhoff, Henning Hildmann

Indications

The main indication for a mastoid cavity is cholesteatomas, especially larger cholesteatomas. Rare indications are destructive inflammations, such as eosinophilic granulomas of the temporal bone, fractures of the anterior meatal wall and tumours.

Generally cholesteatomas are treated by following the disease with the drill backwards into the mastoid until the end of the sac can be seen and the epithelium can be safely removed. Often only a little drilling is necessary because the sac ends on the body of the incus or on the lateral semicircular canal. The reconstruction of the posterior wall is done with cartilage. The classical intact canal wall technique (posterior tympanotomy) exposing the chorda facial angle and working the epithelium forward from the mastoid into the middle ear is only indicated in extensive mastoids when a radical cavity would be extremely large. Especially in cholesteatomas, the pneumatization is generally reduced and the overview is poor using an intact canal wall technique.

Definition of Open and Closed Techniques

There are three possible methods of dealing with an operated mastoid: (1) preserving or reconstructing the posterior meatal wall with an aerated mastoid (closed technique); (2) obliteration of the mastoid completely or partially after removal of the posterior wall (closed technique); and (3) leaving the cavity open for inspection (open technique). In our opinion every technique where the mastoid is not open for inspection must be called a closed technique because cholesteatoma residuals can develop undetected.

The goal of surgery is an ear that is easy to care for and is free of recurrent or residual cholesteatoma. Hearing improvement is of secondary importance. The patient must be aware that a cholesteatoma may be a threat to their life. Nevertheless the sound conduction system is generally reconstructed in a one-stage procedure. The surgeon can only preserve or reconstruct the posterior meatal wall with an aerated mastoid, when a good tubal function is expected and an unimpaired airflow through the middle ear to the antrum and the mastoid.

The decision to make an open cavity or to preserve or reconstruct the posterior meatal wall depends on the extension and the size of the cholesteatoma,

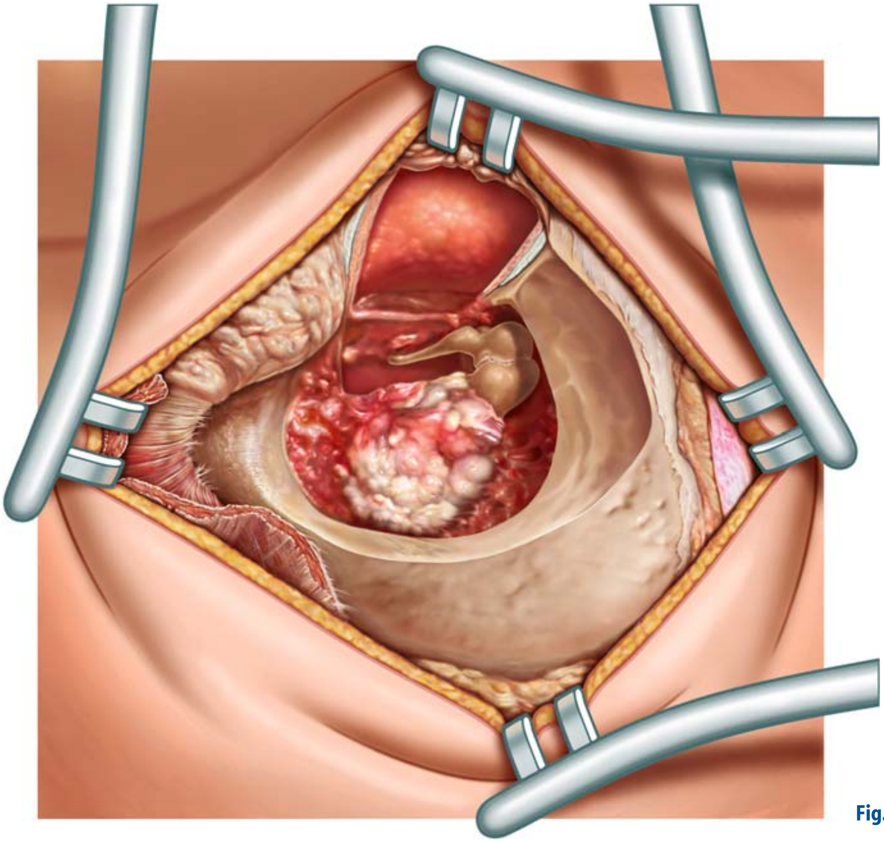


Fig. 15.1

the extent of the mastoid, the tubal function, the possibility of follow-up and individual factors. In sclerotic mastoids a small cavity may be the better solution. A patient with a cleft palate does not have a normal tubal function; therefore a cavity is generally preferable. If a child is an enthusiastic swimmer we might choose reconstruction or preservation of the posterior meatal wall and second look surgery.

Second look surgery should be limited to special cases, i.e. children with extensive mastoids.

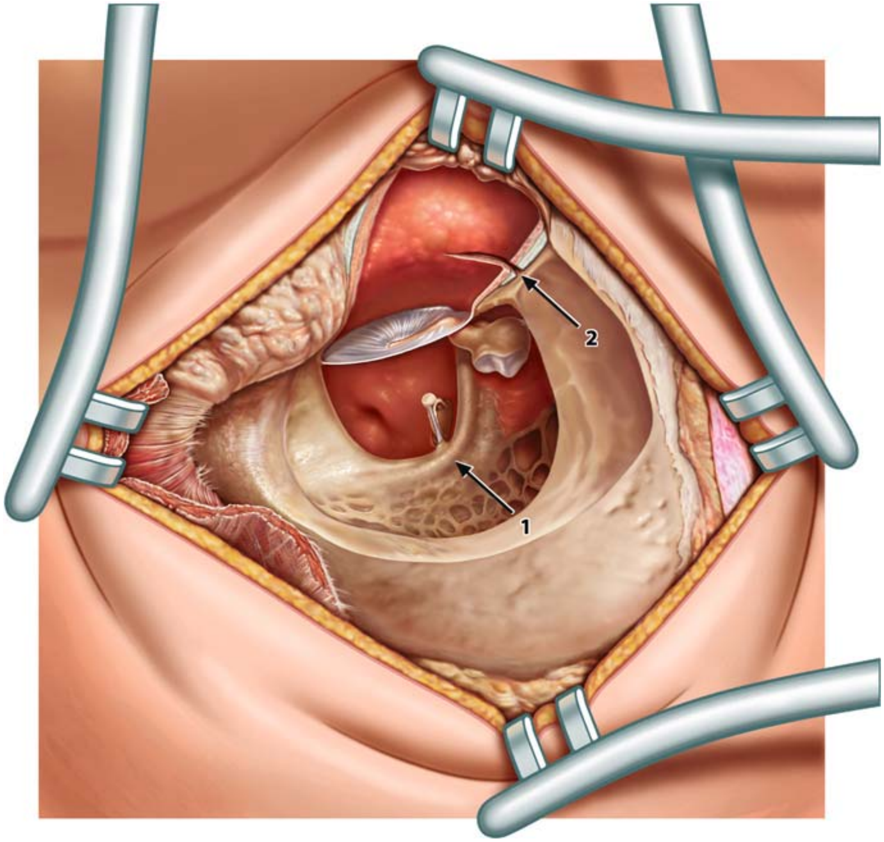


Fig. 15.2

Open Cavity

An open cavity allows the inspection of the mastoid at the end of the operation (**Fig. 15.1**). The technique should be combined with a tympanoplasty (canal wall down technique). A closed middle ear is the prerequisite for a dry cavity. The ideal cavity is small, self-cleansing, and smooth without niches with a low facial ridge (**Fig. 15.2, arrow 1**) and a wide meatoplasty supported by an additional anterior incision (**Fig. 15.2, arrow 2**).

Surgical Steps

1. Retroauricular incision. This allows the removal of the tip of the mastoid and ample bone removal of the cortex if a reduction of the size of the cavity becomes necessary.

2. Preparation and removal of the tympanomeatal flap. It is reimplanted as a free graft at the end of the operation.

3. Widening of the ear canal (**Fig. 15.3**). The cholesteatoma is followed from the ear canal backwards. As long as the surgeon has no information about the condition of the chain he should avoid touching the ossicles to avoid noise trauma (**Fig. 15.4**). Approaching the ossicles, generally the incus and the continuity must be checked and if necessary the incudostapedial joint interrupted (**Fig. 15.5**).

4. The mastoid is cleaned from the cholesteatoma, trying to leave the matrix intact. The surgeon should try to stay behind the matrix and follow it if it extends into cells. The bone has to be drilled down to the facial nerve, leaving it covered by a thin layer of bone. Problem areas are the anterior epitympanum, the subarcuate tract, and the retrofacial region and perilabyrinthine cells. Niches where debris accumulates in those areas later cannot be avoided. Therefore they should be obliterated if removal of the epithelium has been complete. The epitympanum is checked and cleaned, and the head of the malleus is resected (**Fig. 15.6**).

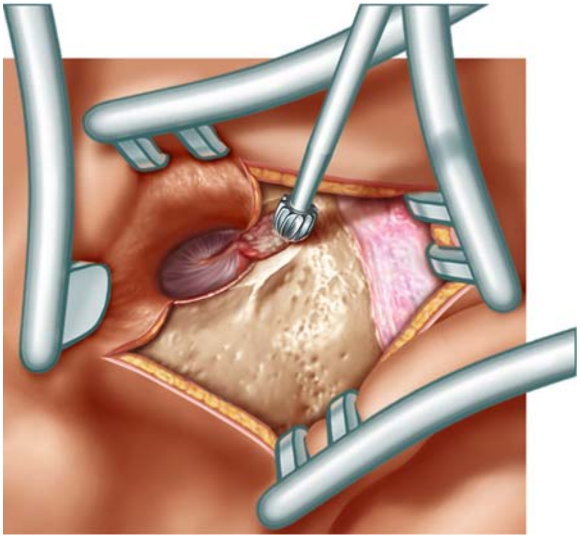


Fig. 15.3

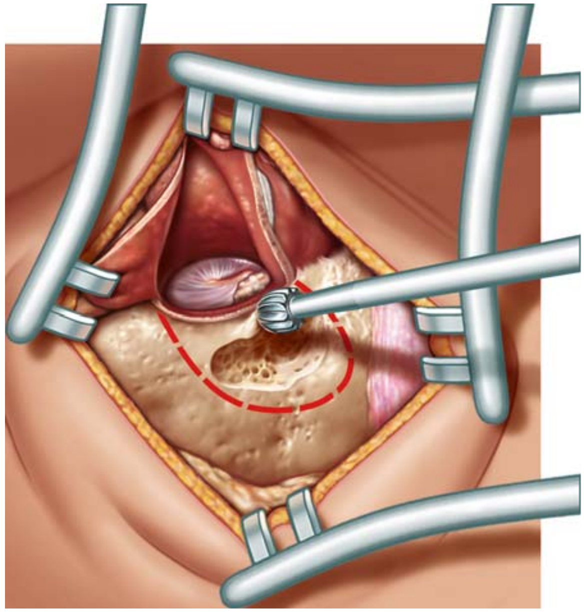


Fig. 15.4

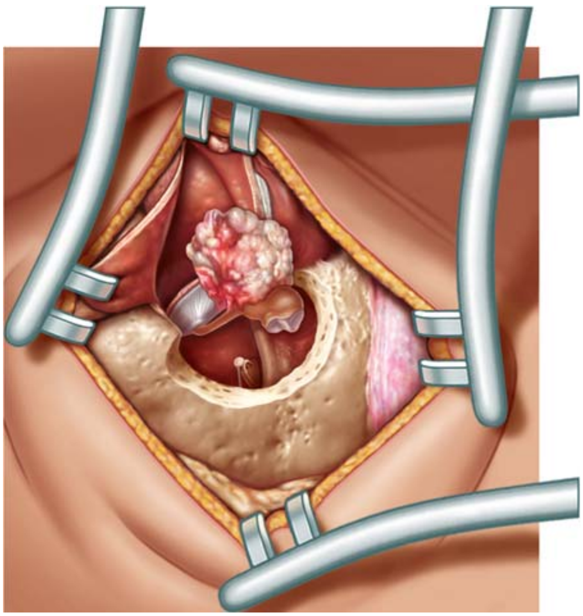


Fig. 15.5

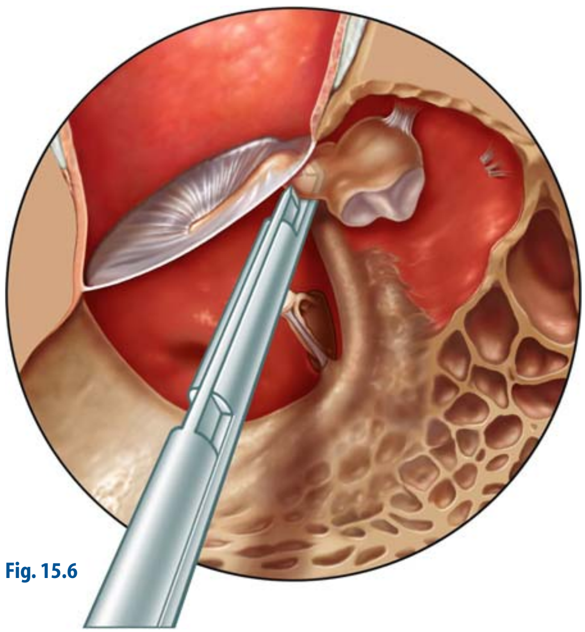


Fig. 15.6

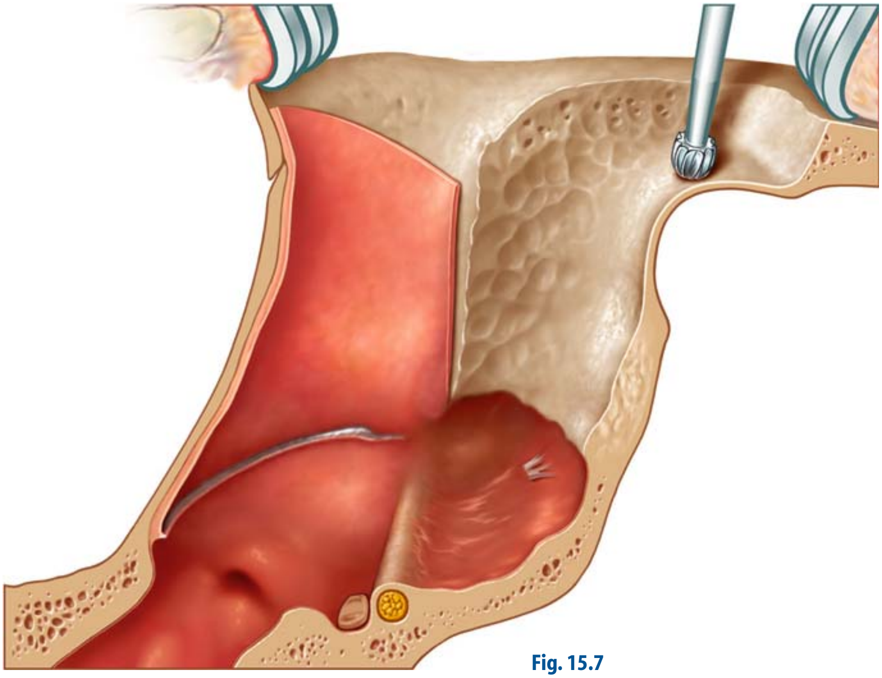


Fig. 15.7

5. The aim is a round smooth cavity (Fig. 15.7). Sharp edges are drilled off. Using a large diamond drill with little irrigation reduces bleeding. Especially in larger cholesteatomas landmarks such as the lateral semicircular canal are not reliable because the disease might erode them. Therefore the facial nerve must be identified. The disease may expose it. In a normal mastoid the lateral semicircular canal serves as a landmark. The nerve is anterior and approximately 1 mm more medially. If the cholesteatoma has destroyed some of the bone of the lateral semicircular canal, the nerve might be at the same level and can be injured. Drilling in the region of the

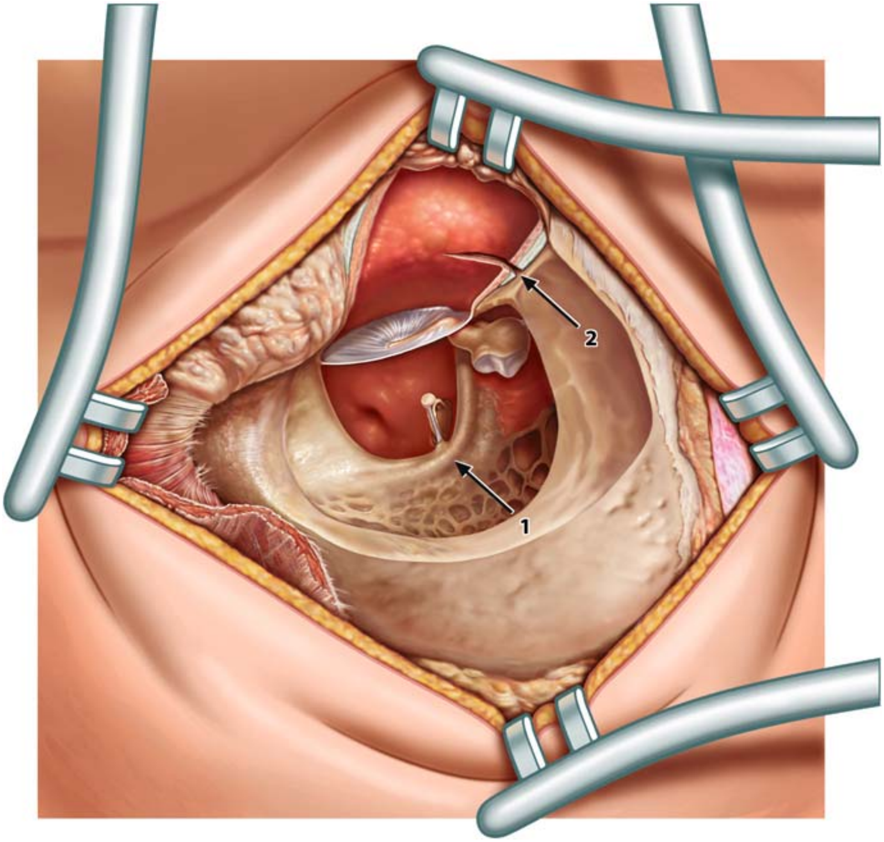


Fig. 15.8

facial nerve should be parallel to the route of the nerve with a diamond drill larger than the diameter of the nerve. Constant irrigation prevents heat trauma (arrow 1, Fig. 15.8). The remnants of the tympanic membrane are lowered (arrow 2, Fig. 15.8) to allow a reconstruction in one plane at the end of the operation.

The epithelium extends rarely medially to the labyrinth. In these cases the treatment might require the destruction of the labyrinth or an additional transtemporal approach. For the less experienced surgeon it is better to interrupt the operation or ask for help.

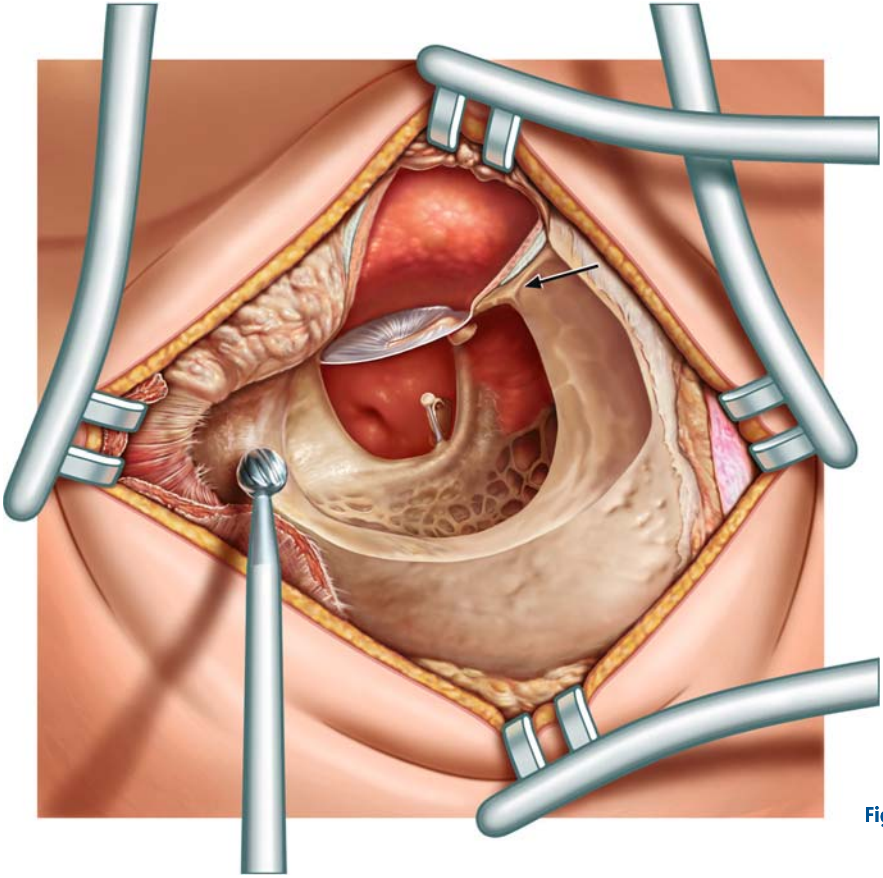


Fig. 15.9

Reduction of Volume

The only possible way of reducing the volume of a cavity without obliteration is to remove as much as possible of the outer cortex of the mastoid, the base of the zygoma and the posterior part of the tympanic bone. The bone is removed until the sigmoid sinus is seen. In addition, the tip of the mastoid with its cells can be removed (**Fig. 15.9**).

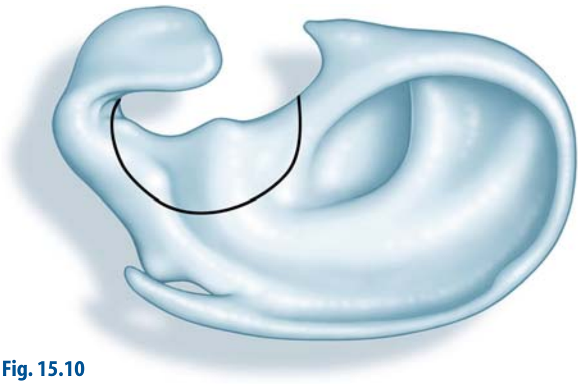


Fig. 15.10

Meatoplasty

To achieve a dry cavity a good aeration by a wide meatoplasty is crucial. On the other hand, an extremely wide entrance of the outer ear canal is cosmetically unpleasant and air currents in the cavity can cause vertigo. Our routine procedure is Körner's flap after a generous excision of the adjacent cartilage of the cavum down to the floor of the ear canal (**Fig. 15.10**). The flap is formed by incising the outer meatal skin at the end of the operation at about 12 and 6 o'clock. The flap is pulled backwards by subcutaneous sutures. Without cartilage excision a sufficient opening is impossible.

Pulling the flap backwards generally secures a sufficient opening. However, the procedure leaves areas uncovered with epithelium. These areas might contract during healing, reducing the size of the meatus. Therefore in revisions split-thickness skin grafts from the postauricular region and/or a pedicled flap cranially based on the preauricular or postauricular regions should provide a sufficient epithelial lining. Complete covering of the cavity with epithelium is not necessary.

Closed Techniques

As pointed out above, any technique where a direct inspection of the cavity is not possible is considered a closed technique. There are obliteration techniques on one hand and techniques preserving or reconstructing the posterior wall on the other. The reconstruction can be partial or total. Most frequently partial reconstruction techniques are used after following the cholesteatoma from the attic as described in the previous chapter.

Intact Canal Wall Technique

For treatment of cholesteatoma nowadays this technique is an exception. The number of recurrences or residuals is high especially in the hands of the inexperienced surgeon. Therefore it should only be used in cases of extensive pneumatization, when a wide antrum allows a view to the posterior epitympanum and the facial recess can be drilled wide enough for a good check of the posterior middle ear. Since the same procedure is generally used for cochlear implantation, this approach will be described more extensively.

In cases with extensive pneumatization a transcortical approach with mastoidectomy is an alternative to the procedure more commonly used, following the cholesteatoma from the attic. It leaves the choice for an intact canal wall technique if the pathology permits this.

Surgical Steps

1. A retroauricular approach is used (**Fig. 15.11**). The bone of the mastoid is exposed and a mastoidectomy is performed (**Fig. 15.12**).

2. The incus and the lateral semicircular canal, if not covered with cholesteatoma, are identified and the facial recess is opened. Unfortunately, especially in more extensive disease the incus may be partially destroyed, the lateral semicircular canal might be eroded, and the bone over the facial nerve might be destroyed (**Fig. 15.13**). A labyrinthine fistula is possible. The epithelium is worked towards the antrum from the less dangerous regions towards the facial nerve and the semicircular canals that lie upwards from the tip of the mastoid, forwards from the sinus and posterior fossa and downwards from the middle fossa. These structures are generally covered by bone.

3. The facial nerve is identified in its mastoidal course. If anatomically possible, a diamond drill is used larger than the diameter of the nerve. The danger of injury is reduced by using a large diamond drill and by drilling in the expected direction of the nerve. The bone is thinned until the white structure with small vessels can be seen through the bone (**Fig. 15.14**). Bleeders and cells can cause difficulty in orientation. Polishing the cavity with a large diamond drill can control bleeding. In rare cases the nerve can pass through a cell without bony covering.

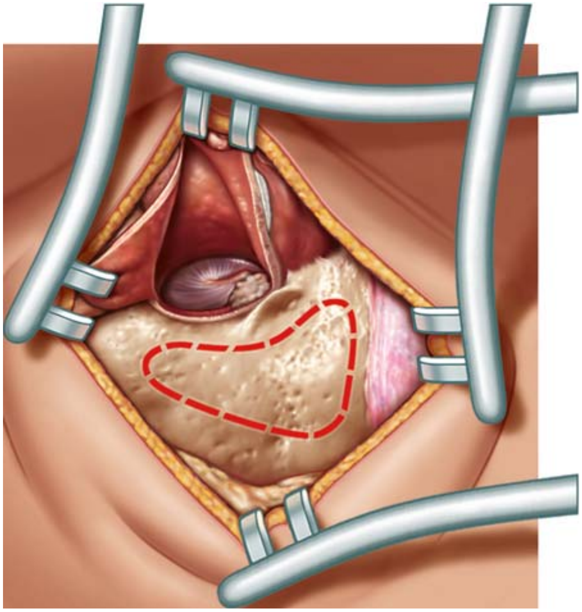


Fig. 15.11

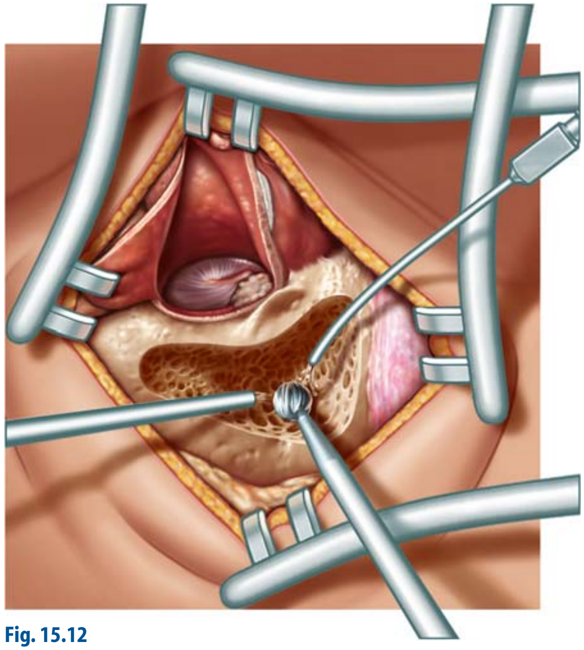


Fig. 15.12

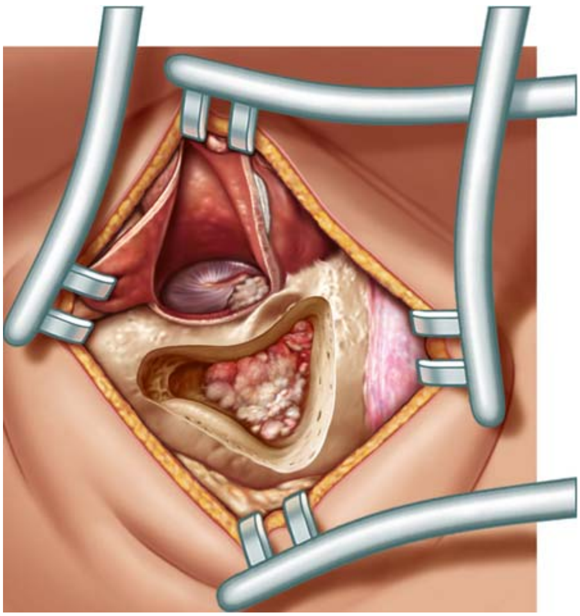


Fig. 15.13

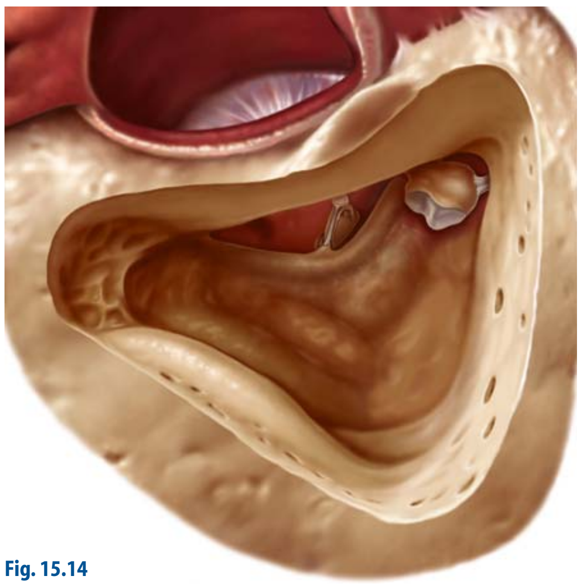


Fig. 15.14

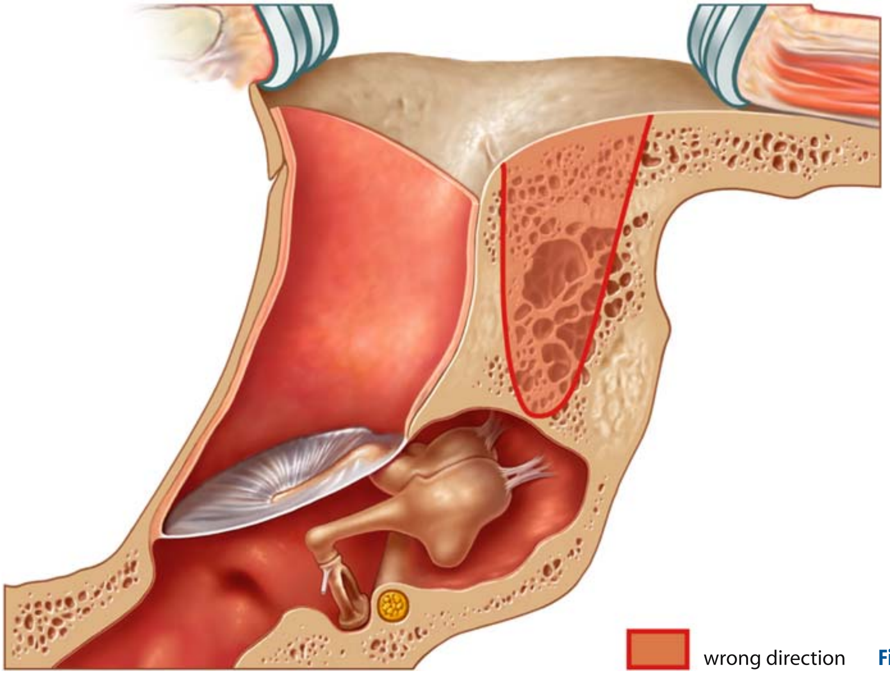


Fig. 15.15

It should be remembered that the posterior wall is not perpendicular to the surface of the mastoid. To reach the antrum the direction of drilling should be medial and forward (**Figs. 15.15, 15.16**). Irrigation water must flow freely from the mastoid to the middle ear. Granulations blocking the water flow must be removed (**Fig. 15.17**). A wide opening with identification of the landmarks – sigmoid sinus, bone on the dura of the medial fossa, the lateral semicircular canal, the facial nerve and the chorda – speeds up the surgery and avoids the risk of damage. If the bony shell of the sigmoid sinus is very prominent, the bone might be thinned, fractured (egg-shelled) and pushed backwards.

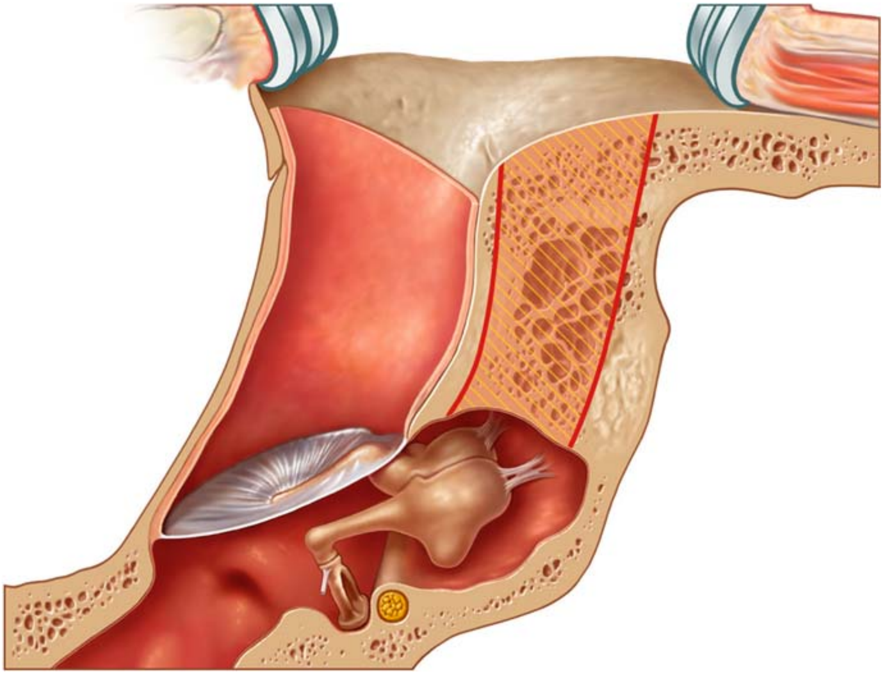


Fig. 15.16

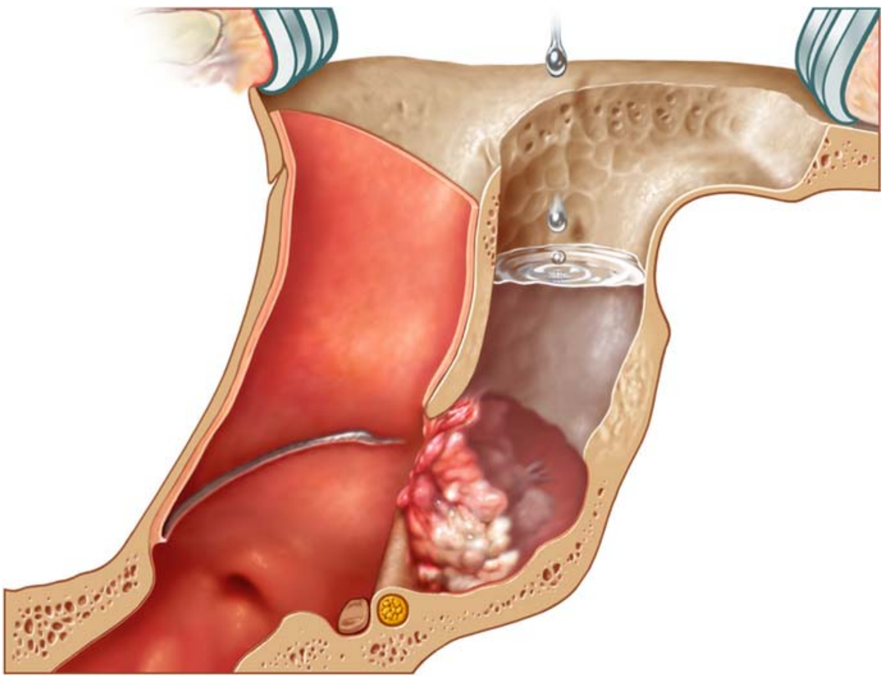


Fig. 15.17

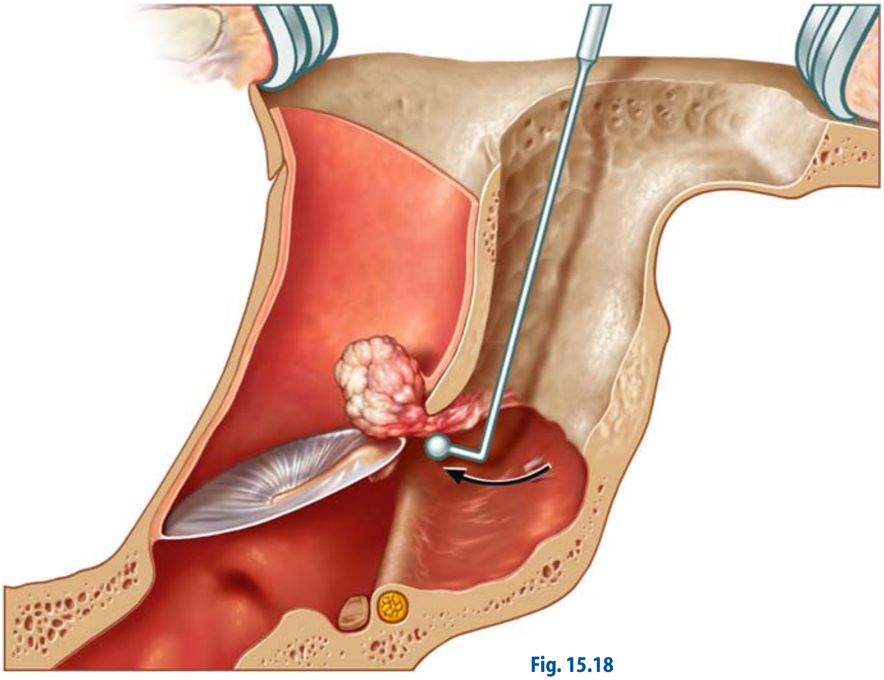


Fig. 15.18

Some cholesteatomas are not invasive and can easily be worked forwards through the antrum without extensive opening of the facial recess (**Fig. 15.18**). If the sac is worked forwards totally, its removal is safe. If it tears, the interior bony rim of the posterior wall must be controlled with an endoscope and the bone is cleaned with a large diamond burr. For larger cholesteatomas (**Fig. 15.19**), a wider access to the middle ear through the facial recess is necessary. A final check with an endoscope is helpful (**Fig. 15.20**).

The anterior epitympanum, the sinus tympani and the hypotympanum cannot be checked by this approach. If in cholesteatoma surgery the epithelium cannot be removed safely, the procedure must be converted to open surgery.

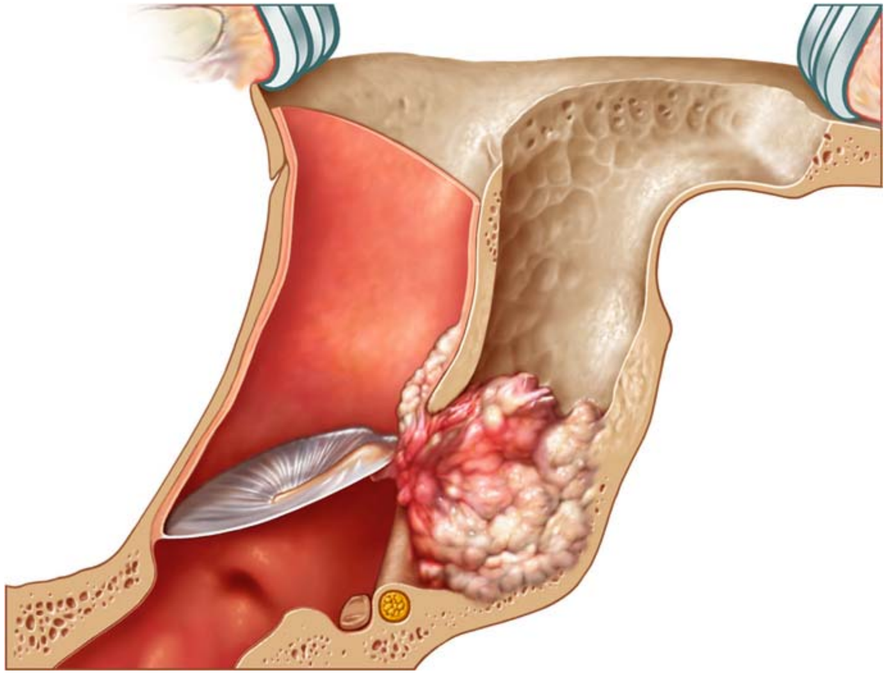


Fig. 15.19

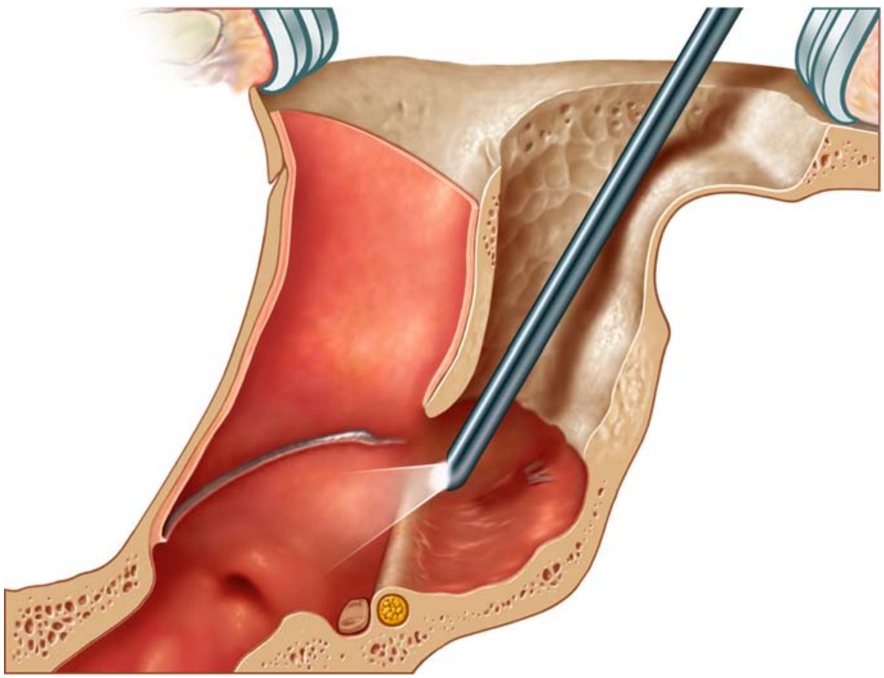


Fig. 15.20

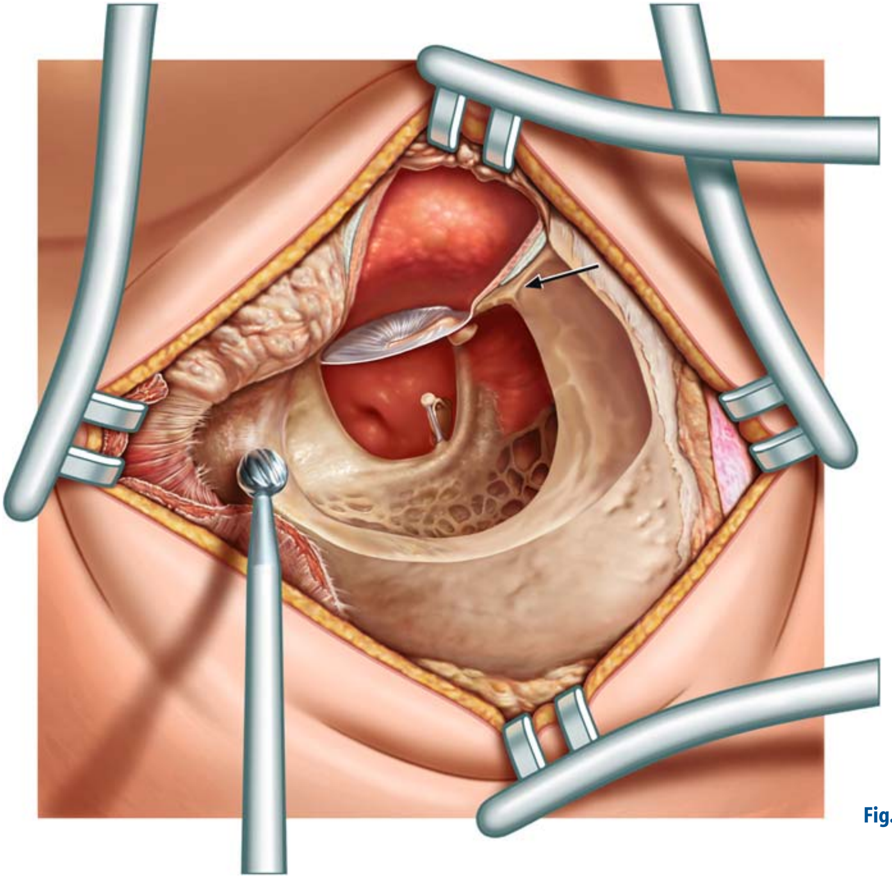


Fig. 15.21

Obliteration

Complete obliteration (abdominal fat) with closure of the outer ear canal is seldom performed: especially after tumour removal or in very rare cases in deaf ears with large cholesteatomas and excessive extension of the pneumatic system. In these situations a blind sac closure of the outer ear canal without obliteration is another rare option if there is a possibility of residual cholesteatoma.

After removal of large cholesteatomas a large cavity requires a partial obliteration to facilitate the postoperative treatment and the comfort of the patient. Especially niches and recesses should be levelled to prevent the accumulation of debris. The critical areas are indicated in **Fig. 15.21**: anterior epitympanum, perilabyrinthine cells, subarcuate tract, retrofacial area, sinus-dura angle, and tip of the mastoid.

For obliterations different materials are described. We use bone paté, cartilage and soft tissue flaps. The bone paté is collected, and during drilling a col-

Fig. 15.22

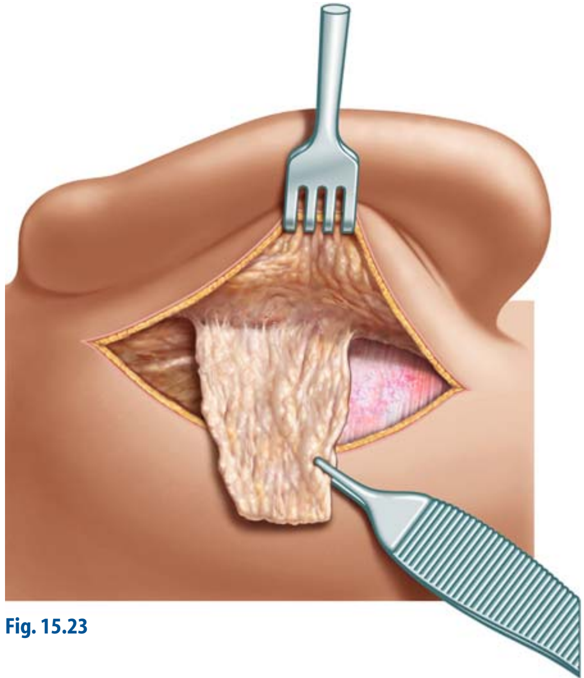


Fig. 15.23

lector may be used (**Fig. 15.22**). It can easily be pressed into niches to produce a smooth cavity. The paté must always be covered with connective tissue flaps or cartilage; otherwise it will not remain in place and cannot induce new bone formation.

If cartilage is used it can be placed as large plates or as palisades. Steps and irregularities must be avoided because the covering connective tissue flaps atrophy over time and the irregularities are seen and prevent self-cleansing.

Soft tissue flaps are harvested from the postauricular region. Besides larger free fascia grafts our standard flap is the Palva flap (**Fig. 15.23**). It is based retro-auricularly and covers the outer part of the cavity well. However, it is seldom long enough to reach the lateral semicircular canal. This area should be covered with a free fascia graft (**Fig. 15.24**).

If a larger flap is needed, especially in revision surgery, the vascularized temporalis fascia flap supplied by a posterior branch of the temporal artery is used in combination with obliteration material. Autologous rib may be used for instance in brain hernias. These procedures require more extensive skin incisions.

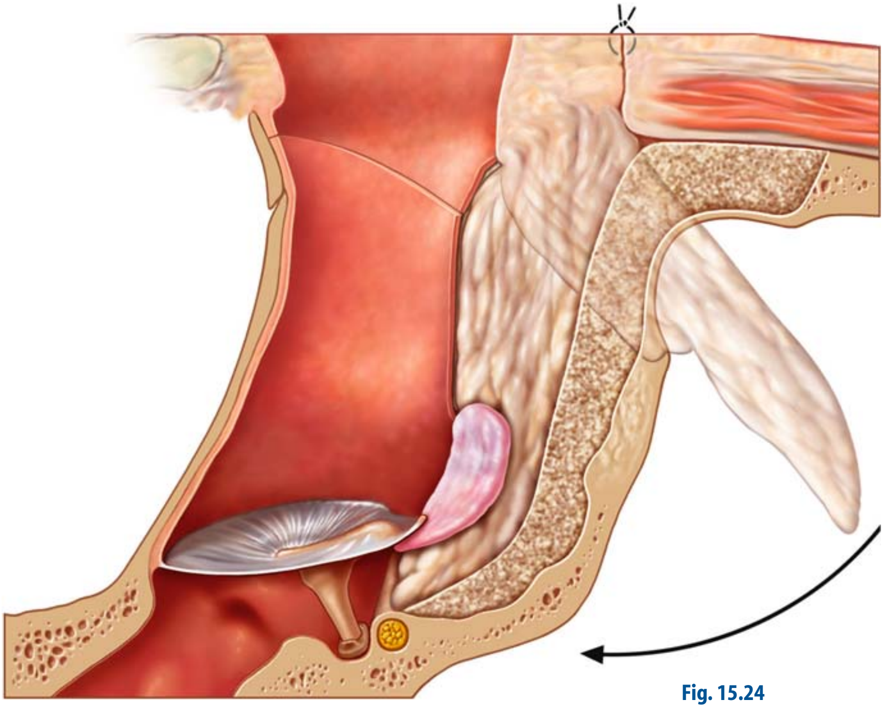


Fig. 15.24

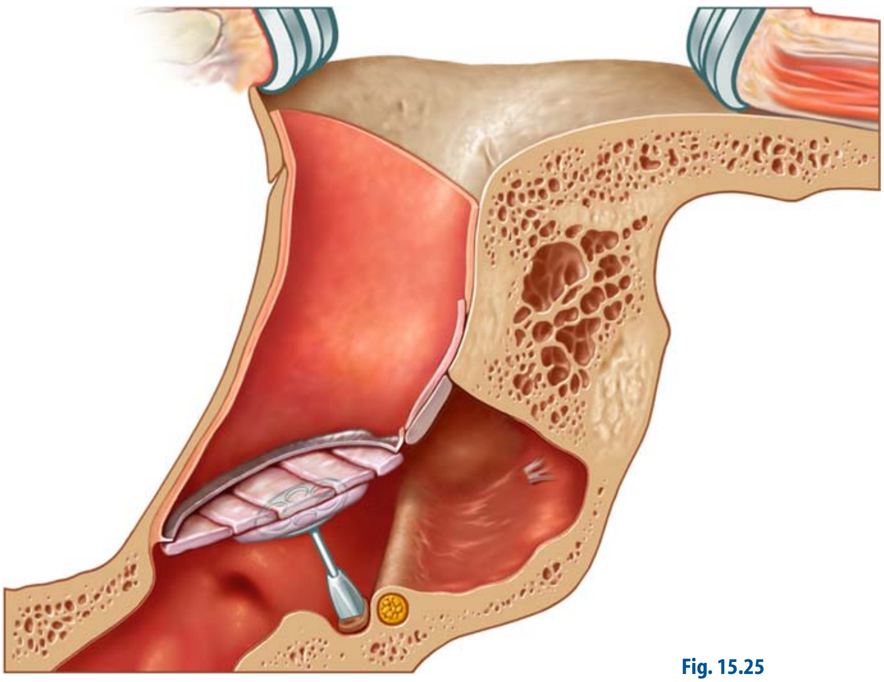


Fig. 15.25

Reconstruction

The posterior wall can only be reconstructed if the middle ear is aerated and the airway to the mastoid is secured. As described above in small cholesteatomas, the disease is followed with the drill until the sac is removed. The middle ear is checked. There might be a block of aeration between the promontory and handle of the malleus. The chain is reconstructed. Finally the defect is closed with cartilage. Often the cartilage from the cymba fits well due to its slightly rounded shape. Generally one piece with overlapping perichondrium can be fitted (**Fig. 15.25**). Sometimes the perichondrium is used as additional covering separately. If the cartilage cannot be placed well, insertion as palisades (stripes) may be easier. No edges should be seen on the posterior wall since they might slow down epithelial migration after healing.

Total Reconstruction

For total reconstruction, in our experience cartilage has proven to be the easiest material to work with (**Fig. 15.26**). The fixation of larger plates is difficult

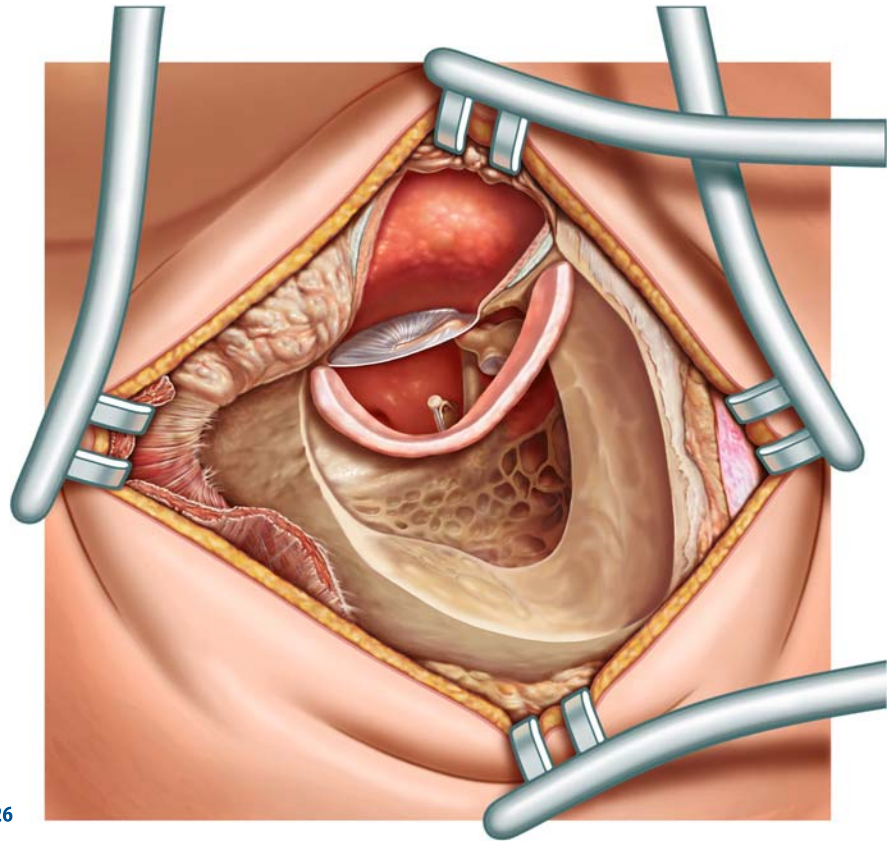


Fig. 15.26

because the cartilage plates tend to be unstable. Fibrin glue resorbs too early. For fixation notches are drilled into the remaining bony walls. Additional cartilage pieces may be necessary to cover spaces at the medial end of the inserted wall, preventing epithelial ingrowth.

Titanium Stabilization

Large defects of the posterior external auditory canal wall resulting from canal wall down technique or which are present in revision surgery have been eliminated by reconstruction using a titanium mesh in selected cases.

The titanium mesh is bent by manual manipulation and cut using special wire scissors, correcting the size to cover the defect of the posterior ear canal wall. It is placed slightly anterior to the facial ridge and reaching in depth the former bony tympanic annulus. The correct size is judged by intraoperative microscopic control of fitting and occasionally supports a 30°-angled endoscope. It is helpful to drill small ridges into the bone to facilitate the stabilization of the titanium mesh. The finally shaped titanium mesh is then removed from its future position. The mesh is subsequently covered with cartilage harvested generally in sufficient amounts from the cavum conchae. In cases of revision it may be helpful to split the cartilage in half to obtain ample material. The perichondrium is left attached to the cartilage. The conchal cartilage is secured with clamps and fixed with two resorbable sutures, such as Vicryl 4.0, on the mesh in order to keep it from moving. The knots are positioned towards the mastoidal segment of the titanium mesh. Uncovered titanium areas must be strictly avoided and access material resected. The composite titanium mesh is then attached to the remaining parts of the adjacent superior and inferior cortical bone and secured with two 3-mm titanium screws (**Fig. 15.27**). Subsequently it is covered with temporalis fascia and retroauricular split-thickness skin grafts. The canal is packed with Curaspon with an antibiotic ointment. The postauricular incision is closed in the usual manner and the packing removed 21 days after surgery.

Fistulas of the Semicircular Canals

Cholesteatoma tissue eroding a semicircular canal should be left in place until the completion of the procedure. Fistulas of the lateral semicircular canal are more frequent than those of the posterior or superior lateral canal. Fistulas should be expected in about 5%–7% of cholesteatoma cases. Ninety percent of these fistulas are found in the lateral semicircular canal; in 6% almost the complete labyrinthine portion was destroyed. A positive fistula sign was only present in about 60% of the affected patients. Therefore the lack of a fistula sign does not exclude its existence. The removal of cholesteatoma matrix adjacent to the semicircular canals needs extra attention. Especially the facial nerve may be dehiscent and the matrix should be gently removed. The cholesteatoma matrix and granulation tissue are cautiously detached. The fistula is

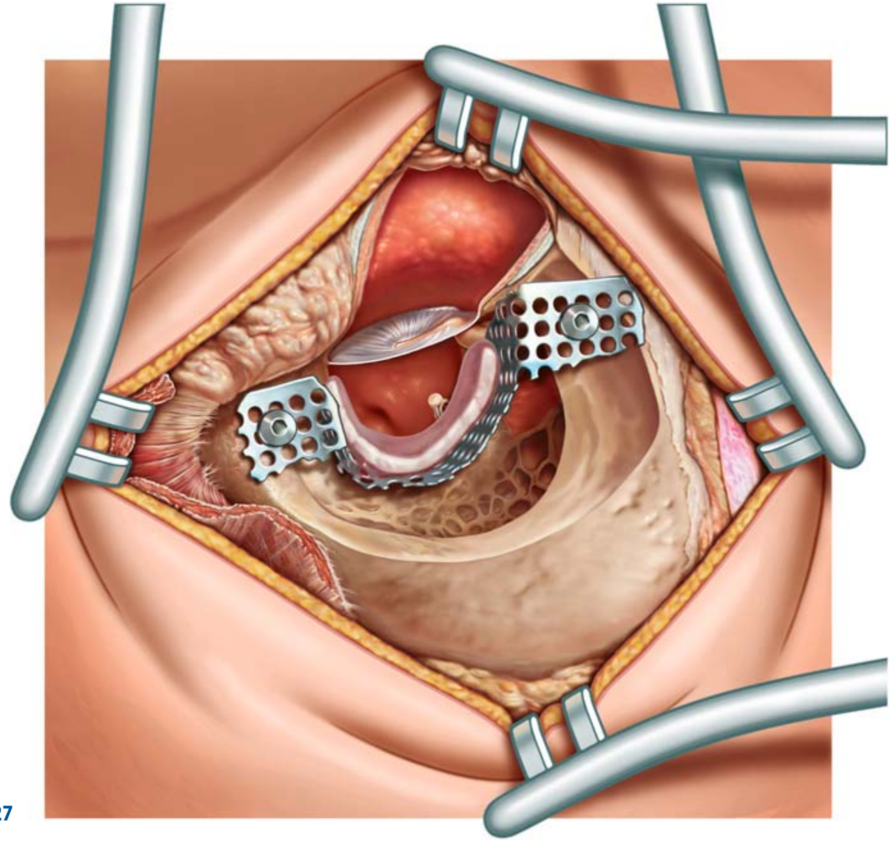


Fig. 15.27

closed with bone paté and fascia. The paté in over 75 % of patients will lead to osteoneogenesis, achieving its closure in 2–3 months. If there are heavily inflamed granulations, the matrix will be removed during second look surgery. The ingrowth of matrix into the lumen of the semicircular canals is rare.

Packing

The mastoid bowl is covered with silicone foil and packed with Curaspon with antibiotic ointment. The package should be left in place for at least 3 weeks.

16 Specific Infections

Holger Sudhoff, Henning Hildmann

Specific infections are generally not expected before surgery but are diagnosed during the histological evaluation of the specimen. The surgical outcome does not differ in comparison to cases of unspecific infection if sufficient medical treatment is started. Even though tissue removal for histology is not routinely done in most centres, surgeons should be encouraged to take specimens more frequently at least in suspected cases.

Middle ear tuberculosis often has a typical whitish appearance and its granulations have a little tendency to bleed. The multiple perforations of the tympanic membrane described in some textbooks as being typical for middle ear tuberculosis have not been seen in our material. Biopsies should be sent for histology where typical Langerhans' cells are found. As cultures may but often do not produce tubercle bacilli, identification by polymerase chain reaction has become of high diagnostic value. Postoperative general examination of the patient mostly shows other manifestations of the tuberculosis. The treatment is generally done by a pulmonologist according to the localizations and the extent of the disease.

Sarcoidosis may also be seen in patients with pulmonary affection. It is extremely rare and can be diagnosed by histological examination. Sarcoidosis should be considered in patients with lung disease.

Actinomycosis of the middle ear has been described in the literature and can also be identified by histological examination.

Wegener's granulomatosis is a systemic inflammatory condition affecting the nose, kidneys, lungs and other organs.

17 Complications

Jürgen Lautermann, Holger Sudhoff

Complications of infected and draining ears may arise from acute otitis media, cholesteatoma, and rarely from chronic suppurative otitis media. Bacteria and their toxins may spread by direct infective bone erosion, by preformed pathways such as the oval and round windows and by passing along vascular channels (osteo-thrombophlebitis). Anatomically, infective complications of the ear may be roughly divided into intratemporal, extradural and intradural complications. A high-resolution CT scan should be performed in every suspected complication supplemented by MRI if necessary. Rare causes are tuberculosis, Wegener's granulomatosis and malignant external otitis.

Acute mastoiditis is the most common complication of an otitis media. It presents with retroauricular painful swelling, reddening, general sickness and an elevated erythrocyte sedimentation rate. The early stage of mastoiditis without signs of bone erosion in the CT scan may be treated with systemic antibiotics for a limited period of time. If symptoms progress or do not resolve within 24 h, a mastoidectomy in children simultaneously with myringotomy and/or grommet insertion and adenotomy should be performed to improve the tubal drainage to the epipharynx and to remove a source of inflammation. If uncontrolled the infection can spread into the surrounding tissues. Cholesteatoma can cause the similar complications.

Labyrinthitis and Facial Palsy

Labyrinthitis and facial palsy are rare intratemporal complications.

1. If facial paralysis originates from a cholesteatoma or mastoiditis, an immediate operation is obligatory. The cholesteatoma must be removed, the facial nerve must be identified and decompressed and the neural sheath must be incised if necessary.
2. Sensorineural hearing loss, vertigo and tinnitus indicate inner ear involvement and require revision of the mastoid as well as antibiotic treatment. Purulent labyrinthitis requires opening of the labyrinth.

Extradural Complications

1. A subperiosteal abscess develops if pus spreads through vascular channels in the suprameatal triangle and displaces the periosteum on the planum mastoideum. In these cases a protrusion of the posterosuperior meatal wall may be seen.

2. Bezold's abscess results from a perforation of pus through the tip of the mastoid with concurrent swelling of the sternocleidomastoid muscle and the lateral neck.

3. If the zygoma is well pneumatized it may be involved in the infection (zygomaticitis) with preauricular reddening and swelling.

4. If the pus extends into the digastric fossa (Muret's abscess), trismus may be observed.

5. Citelli's abscess results form spread of infection from the retrosinous cells to the occipital bone with osteomyelitis of the calvarium.

6. Infections of the petrous apex may involve the cavernous sinus and lead to paralysis of the abducens nerve and pain in the trigeminal nerve (Gradenigo's syndrome). If symptoms do not resolve after systemic antibiotics, surgical exenteration of the petrous apex may become necessary through an infracochlear, transmastoid-infralabyrinthine approach, a middle fossa approach or a translabyrinthine approach in a deaf ear.

7. In extradural (also called epidural) abscess pus collects between dura and bone. Further diagnosis should exclude intracanial involvement.

8. If the infection spreads towards the lateral sinus, an infected mural thrombus can develop which may cause septic emboli. The source of the sinus involvement must be eradicated; that is the acute or chronic mastoiditis or the cholesteatoma must be operated on independently of the decision to treat the thrombosis of the sinus. The latter can be treated with anticoagulants as recommended today or by removing the thrombus surgically. During mastoidectomy the sinus should be checked from the outside for signs of inflammation such as granulations or pus. In addition the presence of clinical indications such as fever or septic symptoms necessitate removal of the thrombus and the lateral sinus should be ligated or packed. Before ligation the bone over the lateral sinus should be generously removed with a diamond drill. Before opening the sinus the patient must be placed in a "head down" position to prevent air embolism. Using a Deschamps' ligature carrier sutures are brought around the sinus and the sinus is ligated. Intracranially the Deschamps' carrier must be passed close to the sinus to prevent damage to the arachnoidal vessels. The sinus may be too rigid and may be attached to the surrounding dura

hence ligation may tear the vessel. Therefore it is often easier to pack the sinus with a muscle plug, which has to be sutured to the sinus in order to prevent emboli. If the MRI picture shows that the thrombosis has descended to the bulb or the upper jugular vein, we recommend ligation of the jugular vein to prevent septic emboli.

Intracranial Complications

1. Otogenic meningitis must be treated by immediate removal of the source of the infection, which means mastoidectomy and treatment of the complications mentioned above if present. Conservative treatment and/or delayed surgery is not justified.

2. Otologic brain abscesses most frequently develop in the temporal lobe and less frequently in the cerebellum. This complication should be diagnosed by CT scan or MRT. The operation should be performed together with the neurosurgeon. It is reasonable to open an abscess adjacent to the temporal bone from its origin, that is from the mastoid and not through healthy brain tissue. This is the most dangerous complication of mastoiditis and carries the highest lethality. Treatment consists of operating in the infected ear combined with drainage of the intracerebral abscess.

18 Tympanosclerosis

Holger Sudhoff

Tympanosclerosis presents as white tissue changes within the tympanic membrane and in the middle ear. It is composed of calcified hyaline collagen. The lack of blood vessels may lead to necrosis of the underlying bone. Steinbach found varying degrees of tympanosclerosis in 10% of 2000 cases with chronic ear disease, 1.4% of which were seen in cases of cholesteatoma. Tympanosclerosis may be found behind an intact tympanic membrane. Small plaques are harmless and can be disregarded. Large incrustations in the tympanic membrane remnants should be removed because the avascular material may prevent the integration of the graft. It can affect the ossicular chain especially the head of the malleus and the incus in the epitympanum. Mobilization is not advisable because refixation often occurs. The head of the malleus should be resected and the incus removed. For reconstruction the incus can be placed between the stapes if mobile. If the stapes is immobilized by tympanosclerosis it can sometimes be removed under high magnification. In extensive disease, however, the surgeon should be careful not to perforate the footplate or to luxate the stapes, which sometimes is extremely vulnerable due to bone destruction underneath the tympanosclerotic layers. Since the tympanosclerotic masses interrupt the vascular supply, the underlying bone may become necrotic. In extreme situations the promontorial bone covering the basal coil of the cochlea may be lifted off when large tympanosclerotic masses are removed. Tympanosclerosis on the stapes footplate is more common. The underlying footplate may be thin or even replaced by fibrous tissue. In these cases a prosthesis placed on the footplate may perforate through it.

Two-stage surgery is necessary. Since the prognosis for hearing improvement in extensive tympanosclerosis is not good, and the ear is safe after the first operation, a second stage surgery for hearing improvement must be discussed with the patient if the contralateral ear hears is normal. The option of hearing aids should be discussed as well with the patient.

19 The Atelectatic Ear

Henning Hildmann

Middle ear pressure is influenced by tubal function, the elasticity of the tympanic membrane, the middle ear volume and the gas exchange in the middle ear. Disturbances of these factors may lead to middle ear atelectasis. In our clinical routine these factors are difficult to assess. We can see partial or complete atelectasis with the microscope. We have few indicators for disturbed tubal function and no clinically valuable tubal function test. We suspect tubal dysfunction in children when we see an adhesive otitis on one side and a middle ear effusion on the other side. In this situation it might be wise to delay middle ear surgery.

Patients, especially children with cleft palates, and patients with neurological diseases and hypomobility of the orofacial muscles, have disturbances of the tubular muscles as well as patients with cranial deformities. These cases are relatively rare. In other cases we learn by our failures.

While partial atelectasis, especially in the posterior, superior part of the tympanic membrane, is a sequela of inflammation and possibly past tubal dysfunction, complete atelectasis often indicates permanent tubal dysfunction and has a poor prognosis for middle ear reconstruction and hearing improvement. The first group can be operated on following the normal principles of tympanoplasty, whereas recurrences in the latter often fail again when reoperated on. For these patients a hearing aid may be the better option.

Complete atelectasis indicates serious tubal dysfunction. These cases are an indication for a cartilage tympanoplasty to increase the elastic resistance of the tympanic membrane and the resistance to underpressure in the middle ear. When the mucosa of the middle ear is missing, scar contraction of the healing tissue is another explanation for the high frequency of failures in these cases. Therefore any remnants of mucosa should be respected carefully. Insertion of silicone does not always prevent readhesions.

20 Revision Surgery

Henning Hildmann, Holger Sudhoff

Early Revisions

If facial paralysis persists after tympanoplasty longer than that anticipated to be cauced by the effect of local anaesthetic, the ear should be revised immediately to exclude or revise facial nerve damage.

Immediate reoperation during the first postoperative days is indicated, if the patient complains of sensory neural hearing loss (i.e. lateralization of the tuning fork into the contralateral ear) and severe vertigo not responding to conservative treatment (i.e. steroids, antibiotics, rheological and antivertiginous drugs). Even a type I tympanoplasty may cause deafness. Rarely unexplained high fever and severe pain can require revision to exclude the formation of an abscess. The early revision surgery does not reduce the chances of the final outcome of a tympanoplasty.

Infection of the wound can require the removal of some sutures and the removal of the packing to drain the ear. If necessary local and/or general antibiotic treatment may be required. Necroses are removed with microscissors. The necrotic tissue should not be pulled out with forceps to prevent total removal of the graft.

Late Revisions

1. For cholesteatoma recurrences the ear must be revised following the rules of tympanoplasty as described in this book. The preservation or removal of the posterior meatal wall is discussed in another chapter.

2. For recurrent perforations in chronic suppurative otitis media, the surgeon should consider arguments which reduce the chances of success. These are signs of disturbed tubal function or adhesive otitis as discussed above. Small perforations with a mucoid secretion might indicate a block of drainage in the middle ear caused by adhesions between the membrane graft and the promontory. Careful treatment of the promontorial mucosa or silicone covering can reduce this possibility. Dry small perforations may close after applying a caustic agent to the margins and covering with silicone or cigarette paper. Large perforations due to retraction, displacement or necrosis do not heal spontaneously. The revision operation does not differ technically from the original one. A cartilage graft gives more

stability in a large subtotal or total perforation. Since central perforations rarely cause serious complications, the patient's wishes, anxieties and needs should be considered and discussed. Serious chronic discharge can often but not always be controlled by a tympanoplasty. We must accept that we are performing our surgery on a diseased ear and that sometimes we will be defeated by nature.

3. Revisions for hearing improvement should consider the chances of success and the personal situation of the patient. Can we achieve serviceable hearing for the patient? How is the contralateral ear? What is the professional and home situation? A difference of more than 20 dB from the contralateral ear normally does not allow stereophonic hearing. The better ear may remain the leading ear. However, acoustic orientation in space may improve. Is a hearing aid the best solution for the patient? Should the patient try a hearing aid before deciding? Replacing a displaced prosthesis in an aerated non-inflamed ear and normal inner ear function carries a very good prognosis. The ear should be examined carefully with the microscope for aeration, scarring, blunting and remaining structures. Surgical reports should be studied closely. Was the facial nerve exposed? Was a fistula seen in the previous surgery? Were the sinus or the dura exposed? Did the surgeon encounter complications? Unfortunately the reports are not always correct and the surgeon must be prepared for surprises. With revisions after excessive tympanosclerosis and excessive scar formation in an empty middle ear, on the other hand, there is a low chance of achieving a useful hearing. Dizziness or vertigo should be dealt with by surgery. Tinnitus is seldom successfully treated by a tympanoplasty.

Special Problems

Basically the revisions steps are the same as those of the first intervention. Surgical reports should re-read critically. The previous surgeon might have forgotten or omitted important details such as an exposed facial nerve, an exposed sigmoid sinus or a fistula to the inner ear. Persisting inflammation or progressive disease might have exposed or destroyed structures previously present. Subcutaneous scar formation can cause difficulties after the skin incision. Since after extensive surgery the sigmoid sinus or the dura may have been exposed, the first landmark should be the intact temporal bone, which can be felt under the scar tissue. Fascia may not be available for tympanic membrane graft. Alternatives are: perichondrium, cartilage or periosteum. Orientation in the middle ear may be difficult as disease or previous surgery may have destroyed or hidden the usual landmarks. The facial nerve might be exposed or have an abnormal course, scar tissue or granulations may surround the stapes, and fistulas to the inner ear may be hidden. Occasionally a high jugular bulb can protrude into the floor of the middle ear without bony covering. The exposure of the intratemporal course of the internal carotid artery is rare; nevertheless the possibility must be kept in mind. Fairly persistent landmarks are the cochleariform process, the round window and the tubal orifice. Orientation should start from these structures. The facial nerve integrity can be checked by going backwards from the cochleariform process and the tubal orifice. The oval window should be approached with reference to the round window over the promontory upwards and to the facial nerve canal downwards. Sometimes remnants of the stapedial tendon and the pyramidal eminence give additional orientation. Within the mastoid the facial nerve and the lateral semicircular canal are the structures most at risk. If the anatomy is unclear, we do not proceed until the nerve is clearly identified. The overlying bone is slowly removed with a diamond drill until the nerve is clearly seen under the thin cover of bone. Unusual sites of fistulas, prolapse of the dura and a protruding sigmoid sinus are further hazards.

Cavity problems are discussed in Chapter 15.

21 Facial Nerve Surgery

Orlando Guntinas-Lichius, Holger Sudhoff, Henning Hildmann

Indications

- Immediate onset complete palsy after traumatic temporal bone fracture
- Iatrogenic lesion during ear surgery
- Postoperative complete palsy after ear surgery in patients with normal preoperative facial nerve function
- Preoperative complete palsy in patients with chronic inflammatory disease or tumour

Intratemporal facial nerve surgery has a wide range and can include the decompression and exploration of parts of the nerve, e.g. of the mastoidal or

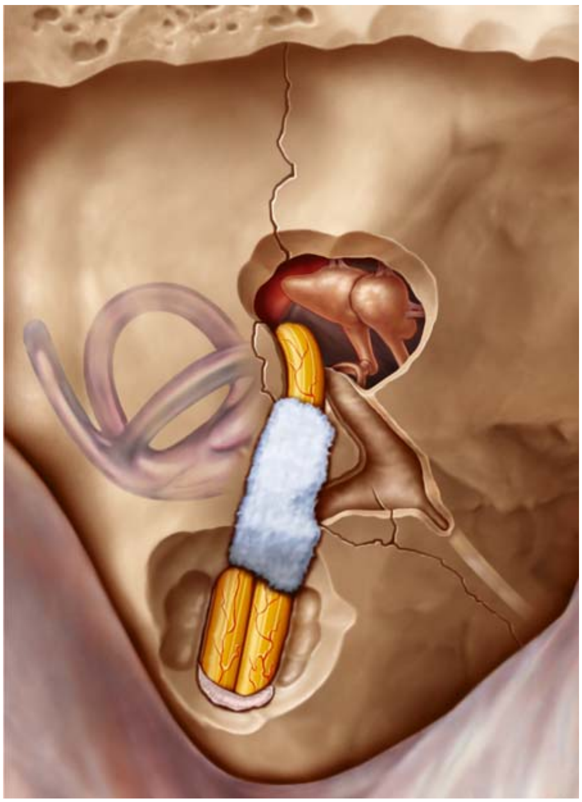


Fig. 21.1

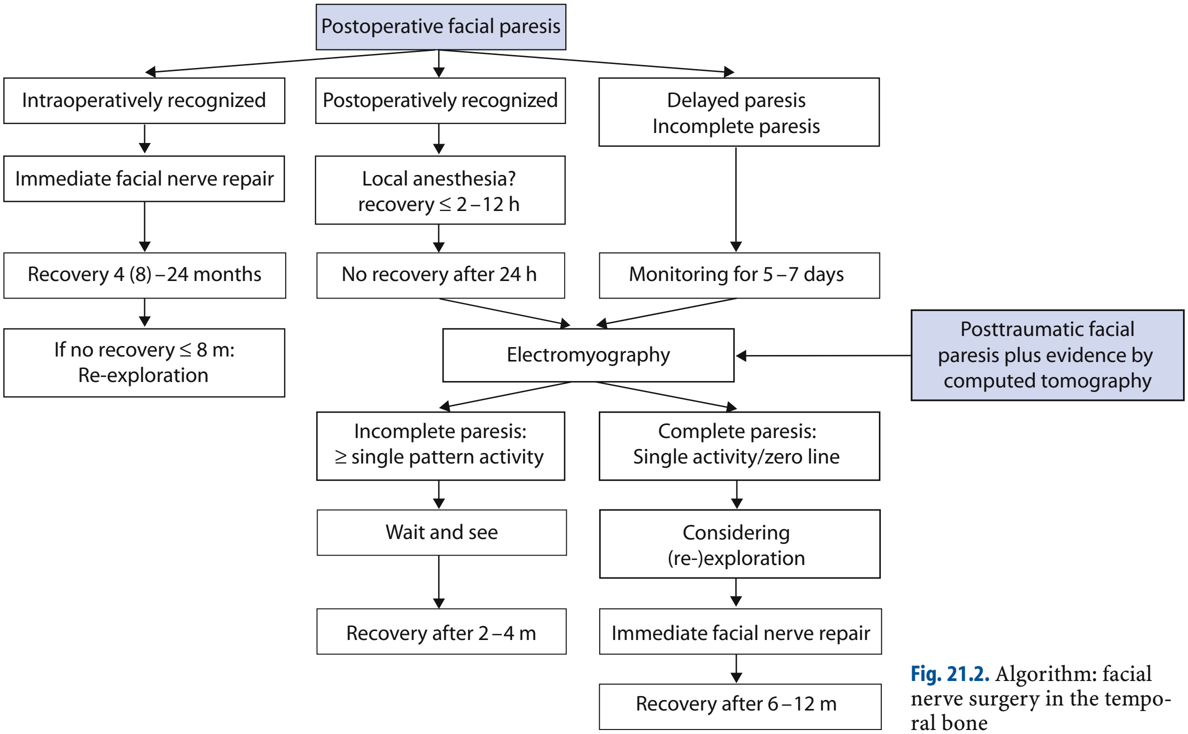


Fig. 21.2. Algorithm: facial nerve surgery in the temporal bone

tympanic segment, but can also mean a complete exposure of the nerve beyond the inner acoustic meatus as far as the cerebellopontine angle using a transtemporal approach (**Fig. 21.1**). The causes for the palsy are manifold. Facial palsy can be caused by cholesteatoma or other inflammatory diseases, destruction of the nerve, traumatic laceration in cases of temporal bone fracture, gunshot injuries, bony spicules, thermal injuries (e.g. welding beads), and, of course, iatrogenic lesions in any case of ear surgery. In some situations, especially in cases where the nerve is damaged over longer distances, an extratemporal reconstruction of the nerve might give better functional results. Early detection, evaluation and intervention are important for optimal functional recovery after any kind of facial nerve injury. A helpful algorithm of the diagnostic course is given in the flowchart in **Fig. 21.2**.

Facial Nerve Palsy After Temporal Bone Fracture and Other Traumas

Traumatic facial nerve palsy with immediate onset, seen after transverse temporal bone fractures or complex temporal bone fractures, is an absolute indication for surgery in a medically stable patient. A direct injury to the facial nerve is to be expected in these cases. A later onset of facial nerve palsy (most often 2–5 days after the trauma) is more often observed in longitudinal temporal bone fractures. These delayed facial palsies often result from an intraneural haematoma or post-traumatic oedema of the facial nerve. Generally, all patients with delayed onset of palsy have a good chance of spontaneous recovery of facial nerve function. A computed tomography (CT) scan, or better still a high resolution CT scan, of the temporal bone is the method of choice to define the course of the fracture and its relationship to the facial nerve. Modern CT examination is much more reliable in detecting the lesion site than classical topodiagnostic testing. Unfortunately, using CT or even magnet resonance imaging (MRI) the nerve itself or the site of a nerve lesion cannot be visualized.

Electrodiagnostics are an important diagnostic tool in patients with facial palsy. If electroneurography shows a dramatic loss of the amplitude of the compound action potential in the mimic musculature in relation to the healthy side and/or electromyography is showing a severe loss of voluntary activity, these signs are noticeable indicators for a severe and degenerative facial nerve lesion. Patients with these electrodiagnostic signs and a history of immediate onset of the palsy after the trauma are explicit candidates for surgery and exploration of the nerve. On the other hand, if the patient shows voluntary activity in some facial muscles, this confirms an incomplete (partial) paresis. In such cases, and regardless of the causative factor, exploration of the nerve is unnecessary. Of course, the electrophysiological test should be repeated daily for the next 5 days to monitor the function of the nerve. In general, the outcome without surgery will not be worse than after surgery in patients with incomplete palsy.

Decision-making for surgery can be difficult for several reasons: Swelling after head trauma might hamper the clinical evaluation of the nerve function. Furthermore, in general, all routine electrophysiological tests such as electroneurography or electromyography give indirect findings about the functional state of the facial nerve, because the tests are performed distal to the intratemporal site of injury at the foramen stylomastoideum (electroneurography) or in the mimic musculature (electromyography). Therefore, definite signs of nerve degeneration do not become obvious using these tests until the Wallerian degeneration has reached the distal facial nerve, i.e. about 2 weeks after the injury. Before that time, electrophysiological testing cannot be used as a single tool for the indication of surgery in patients with facial palsy. The expectation that transcranial magnetic stimulation might solve the problem has not been fulfilled. It is possible to stimulate the facial nerve proximal to the lesion site by magnetic stimulation, but the reliability of the evoked potential in the mimic musculature is too imprecise to specify the severity of the nerve lesion.

After severe trauma and other life-threatening conditions the distinction between immediate and delayed onset is secondary to the stabilization of the vital functions. Diagnosis and surgical treatment must be postponed. Longitudinal fractures may disrupt the ossicular chain and should be repaired combined with facial nerve surgery. If the patient was initially unconscious and awakened with a complete palsy, a distinction between immediate and delayed facial palsy is impossible. But if in such a situation the patient has a complete paresis and the electrodiagnostics show a severe lesion, explorative surgery is recommended. As a general rule, immediate reconstruction will lead to better functional results than delayed repair.

Approaches for Facial Nerve Exploration and Decompression

The approach depends on the localization of the damage. A transmastoidal, transtemporal or combined approach to the facial nerve is possible. If the inner ear function is lost, more extensive mastoid surgery is possible through the labyrinth. An obliteration of the cavity with abdominal fat with a blind sac external auditory canal can be considered. If the paresis was caused by a cholesteatoma, however, obliteration is not advisable because an extensive cholesteatoma might recur.

The exploration and decompression of the facial nerve are started from a cortical mastoidectomy. In trauma cases, the fracture lines can often be seen. Nevertheless, the mastoidectomy should be extensively completed before the nerve is further inspected. The fracture lines lead the surgeon to the possible damage. If the inner ear function is lost, parts of the labyrinth can be sacrificed to give room to mobilize the nerve. This is extremely helpful if the whole course of the intratemporal facial nerve from the geniculate ganglion to the stylomastoid foramen has to be exposed. If the patient is bilaterally deaf, the inner ear must be preserved for cochlear implantation and should not be destroyed by surgery. If necessary, the transmastoidal approach can be combined with a transtemporal approach. The transtemporal approach allows exposure of the facial nerve from its exit in the cerebellopontine angle up to the perigeniculate region. Using a combined approach, the facial nerve can be followed from both ends to the geniculate ganglion. Intracranial extension of the damage requires cooperation with the neurosurgeon.

Techniques of Facial Nerve Reconstruction

The decision about the best type of reconstruction depends on many factors and is always a very individual decision. The most critical aspects are: duration of the lesion, site of the lesion, extent of the nerve damage, and wishes of the patient. The chances of a satisfying functional recovery after reconstruction are highly dependent on the time lapse between lesion and repair. Immediate repair gives very good results, and reconstructions within 2 months give good results, but after a year the results are significantly worse. After more than 2 years good results are seldom seen. After 5years the chances of recovery are extremely low unless preoperative electrodiagnostics can demonstrate functioning motor plates in the facial muscles. The most important methods for nerve reconstruction are:

- Decompression of the facial nerve and preservation of its continuity
- Direct facial nerve suture
- Facial nerve interposition graft
- Hypoglossal facial nerve jump anastomosis
- Re-routing of the facial nerve

The rationale for facial nerve decompression surgery is the identification and exposure of the injured nerve to release the post-traumatic haematoma or oedema and remove bony spicules. The integrity of the nerve must be proved under the microscope with extraordinary diligence. If the continuity is preserved, removal of bone splinters and perhaps incision of the epineural nerve sheath to allow room for ongoing swelling is sufficient to prevent further damage of the facial nerve. If the continuity is not preserved, even when some fibres seem to be intact, a facial nerve reconstruction is recommended.

The facial nerve is most frequently injured in the mastoid segment. After transversal fractures of the temporal bone the injury is often found in the

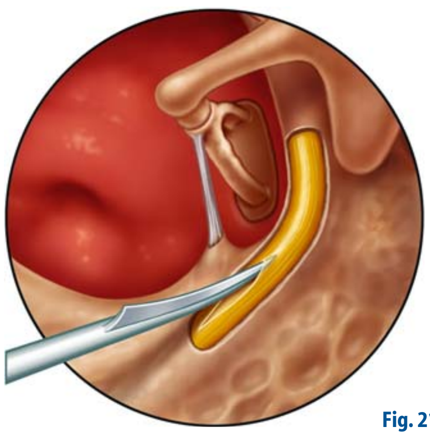


Fig. 21.3

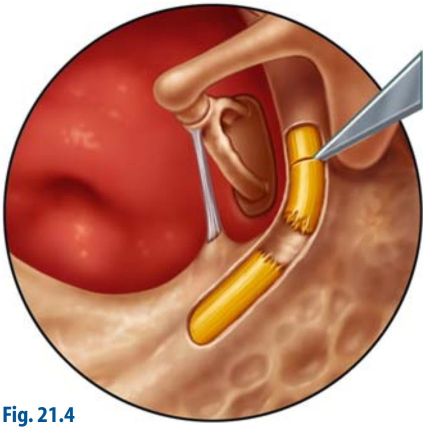


Fig. 21.4

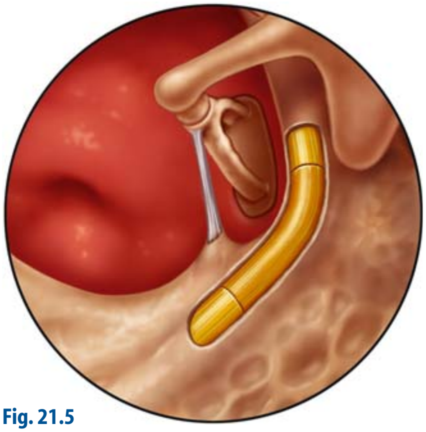


Fig. 21.5

region of the second knee of the nerve, i.e. the perigeniculate region. In some cases it is necessary to decompress the nerve and to incise the epineurium to detect the full amount of the lesion (Fig. 21.3). If the nerve is interrupted, and if the nerve stumps can be brought together without tension, a direct facial nerve suture gives the best functional results. The nerve endings are freshened. If the bone canal is intact, this helps to readapt the nerve stumps. The situation is stabilized with fibrin glue. Sutures, however, become necessary when the bony canal is completely destroyed or re-routing is planned. Monofilament 8-0 to 10-0 suture material is used. The suture layer is the epineurium. A fascicular nerve suture is not possible. Typically, two to four individual sutures are placed. The mobility within the temporal bone is low; hence, fewer sutures are necessary than for extratemporal reconstructions.

If a tensionless suture is not possible, or in any case with greater defects, a nerve graft is necessary. Tension must be avoided by all means. The nerve ends are evened with a No. 11 blade (Fig. 21.4) and a graft from the greater auricular nerve is tightly placed between the ends (Fig. 21.5) and covered with fascia. Longer nerve grafts, like the sural nerve, are normally not required. If grafting is done as indicated in the drawings, the situation is stable, perhaps supported by fibrin glue, and often no suturing is necessary. The shorter the graft the faster the regeneration and the better the outcome. The regeneration takes 6 – 12 months to complete.

To bridge larger defects and to gain length the nerve can be followed and mobilized from the stylomastoid foramen to the geniculate ganglion after drilling the posterior meatal wall (Fig. 21.6). Further mobility is gained by removing the labyrinth and following and mobilizing the nerve to the internal auditory canal. The reconstruction must be individualized according to the different traumatic patterns. In our observation, involvement of the region of the geniculate ganglion is less frequent as found in the literature. Re-routing with

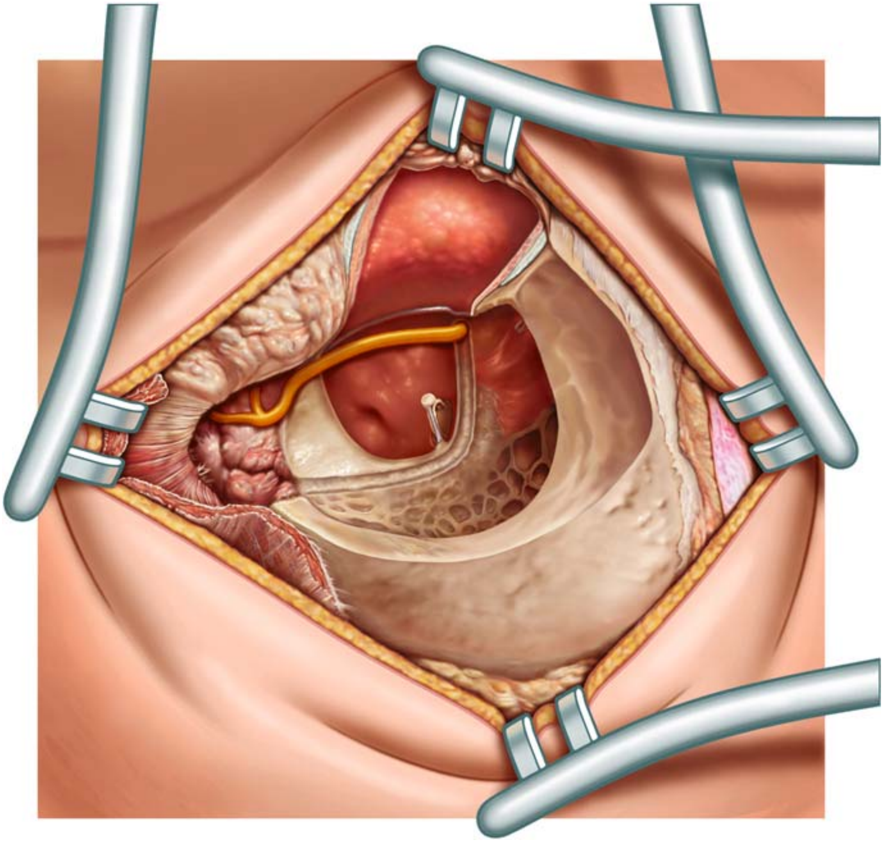


Fig. 21.6

or without graft interposition can be performed by a transtemporal approach. The major petrosal nerve is cut generally including the geniculate ganglion. The nerve must be freed to the entrance to the internal auditory canal and on the other end into the middle ear.

In cases with a very long defect not favourable for grafting, reconstruction with the hypoglossal nerve is an excellent alternative. Or in cases with intracranial or intratemporal complex lesion demanding difficult re-routing, a hypoglossal-facial nerve jump anastomosis gives good results. Hypoglossal-facial nerve jump anastomosis should also be considered if the time window for a good direct nerve repair has passed 6 – 12 months. The cross-anastomosis offers satisfactory results up to 2 years after injury. Sensory input is very important. Synchronous loss of function of the trigeminal nerve considerably reduces the chances of recovery. Because of its good results in tongue and facial function, hypoglossal facial nerve jump anastomosis is nowadays the preferred cross-nerve suture technique. Onset of facial movements occurs on average after about 7 months. Because of the permanent difficulties in masticating and swallowing, the classical hypoglossal facial nerve anastomosis can no longer be recommended when a jump anastomosis is technically possible.

Iatrogenic Lesions During Ear Surgery

The surgical rules given for trauma cases hold true for iatrogenic lesions. After identification of the lesion site, the stumps should be freshened. If the duration of the lesion is longer, all scar tissue on the nerve stumps should be resected. Often the gap between the nerve stumps becomes larger than thought previously. If it is a doubtful proposition to re-connect the stumps without tension, an interpositional graft should be preferred.

Postoperative Complete Palsy After Ear Surgery in Patients with Normal Preoperative Facial Nerve Function

If the patient wakes up after ear surgery with a sudden complete facial palsy, first it should be clarified whether local anaesthesia was used during the procedure. If this is the case, sufficient time must elapse to ensure that its effects have dissipated, and facial function will recover 2–12 h after local anaesthesia. If recovery is not seen within the next 24 h, electrodiagnostics must be performed. If electromyography, as described above, reveals no or only minimal voluntary activity, re-exploration should be considered.

Facial Nerve Palsy in Patients with Chronic Inflammatory Disease

Immediate ear surgery is mandatory in patients with cholesteatoma and facial palsy. Surgery is primarily directed by the cholesteatoma and not by the palsy itself. Most often the tympanic segment is affected and the fallopian canal is destroyed. Typically, the nerve itself is intact and the cholesteatoma only needs to be removed from the nerve. In cases where preoperative electrodiagnostics has shown signs of a degenerative lesion, the affected part of the nerve must be resected completely. The resection is followed by an immediate reconstruction of the nerve by an end-to end-anastomosis, or by coadaptation of the nerve stumps with fibrin glue with or without a cable graft. A prompt reconstruction is more important than the type of reconstruction. In cases where the nerve is not destroyed in its full continuity, the same types of reconstruction should be applied. Comparable to trauma cases or iatrogenic lesion, partial resection of the nerve and a partial reconstruction, e.g. reconstruction of half of the nerve diameter, cannot be recommended.

In patients with facial palsy related to a fulminate acute otitis media or other inflammatory diseases, surgery of the facial nerve itself is seldom necessary. Treatment of the primary disease will treat also the facial palsy. Facial nerve decompression surgery is not necessary because it will not yield better functional results.

Postoperative Adjuvant Treatment

Non-surgical therapy can improve functional outcomes after intra- and extratemporal surgery postoperatively. Botulinum toxin therapy, especially in the eye region, is an effective treatment of synkinesis and hyperkinesis. Although physiotherapy has been given to patients after facial nerve reconstructions for many years now, only minimal data regarding the effectiveness of exercise therapy, massage, low-frequency electrotherapy, and biofeedback are available. The role of electrical stimulation therapy is controversial. In fact, there is no significant proof for efficacy of electrotherapy. Many reports have even demonstrated that postfacial palsy synkinesis can be observed more frequently after regular electrical stimulation of the mimic musculature. Regular electromyographic follow-up examinations not only are able to help detect the first reinnervation potentials even when the face still does not show any tonus or movement, they also help to support the patient psychologically in this critical period, which can take 4–9 months. In cancer patients undergoing postoperative radiotherapy, the nerve regeneration is delayed but the final results are no different from those of other patients. Physiotherapy as neuromuscular training should only start when the first muscular reactions appear. Otherwise, physiotherapy will become frustrating and useless for the patient.

22 Stapes Surgery

Holger Sudhoff, Henning Hildmann

Stapes surgery can be performed using local or general anaesthesia. The majority of patients are operated on under a combination of local anaesthesia and adequate sedation. There is less bleeding with local anaesthesia and the surgeon can ask the patient about hearing improvement intraoperatively. Many experienced surgeons use a transcanal technique. We prefer an endaural approach, which we believe provides a better overview in difficult situations. The nurse assists with the incision, retracting the auricle posterior-superiorly. This straightens the incision line and keeps and protects the cartilage of the anterior helix (**Fig. 22.1**).

The lateral portion of the ear canal is opened using a nasal speculum. The surgeon gains a good view over the superior opening of the external ear canal between the helical and the tragal cartilage. The intercartilaginous incision starts with a No. 10 blade with permanent contact to the bony external ear canal. To reduce tension a parallel incision to the anterior portion of the helix upwards in a smoothly curved line is performed. This procedure reduces the risk of cutting the superficial temporal vein and avoids bleeding. A second skin medial circumferential incision is placed 4–5 mm medial to the opening of the external bony ear canal between the 1 and 5 o'clock positions for the left ear and is extended to the intercartilaginous incision. The underlying soft tissue and periosteum are pushed laterally using a raspatory, revealing the suprameatal spine and tympanomastoid suture.

A small portion of the mastoid plane will be exposed as well. A self-retaining retractor with sharp edges will elevate the laterally based skin flap. A second self-retaining retractor is positioned at a 90° angle to the first retractor with its blunt edge against the anterior inferior portion of the external ear canal and the tragus. The retractor's joint is pointed upwards to provide a good access to the middle ear (**Fig. 22.2**).

Generally a No. 15 scalpel is used to incise the posterior wall skin of the external meatus between a 1 and 5 o'clock position. The incision is repeated with the straight round knife – Plester's knife – and for preparation of the meatal flap the Plester's knife is also used. The surgeon should always stay in contact with the bone with the instrument to minimize the risk of tearing the flap. Special attention is necessary at the tympanomastoid fissure, and fibrous attachments have to be cut. The suction should be applied behind the instrument and not directly on the flap; otherwise the flap is continuously pulled back into the field of surgery and slows down the progress.

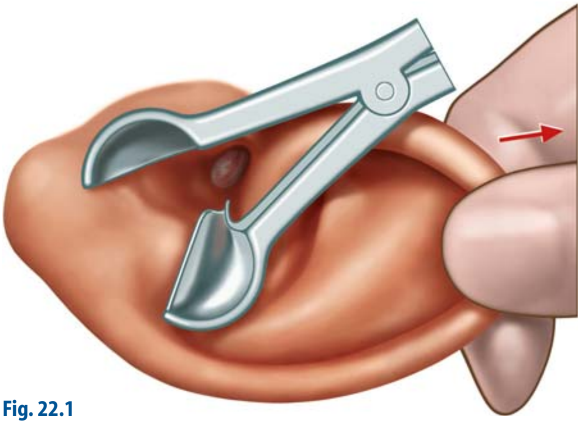


Fig. 22.1

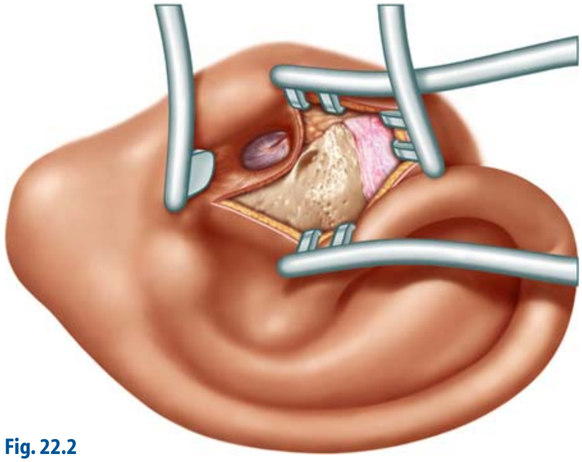


Fig. 22.2

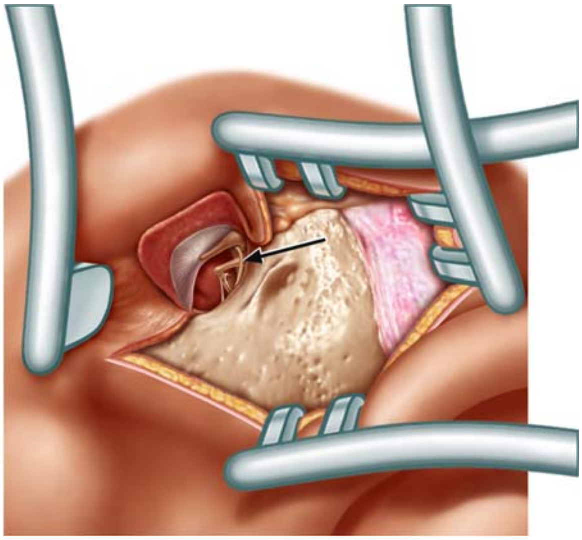


Fig. 22.3

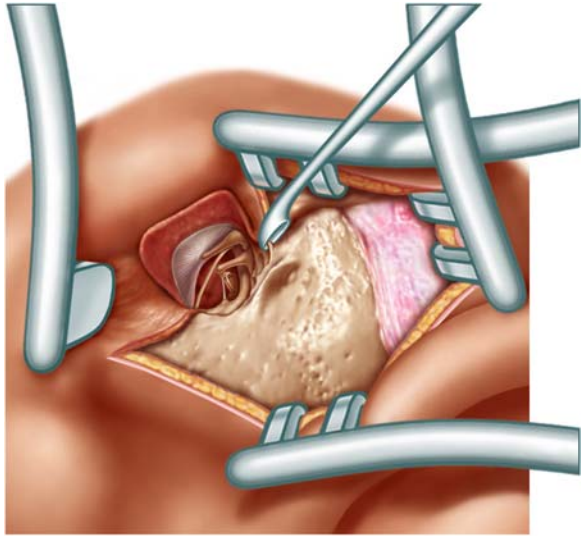


Fig. 22.4

Near the annulus the angled round knife is used to lift the annulus out of the sulcus and the middle ear is opened. Adhesions separated with the sickle knife can be viewed posteriorly and circumferentially. Unincised skin adjacent to the annulus can be cut with Bellucci scissors to avoid disruptions in the tympanomeatal flap.

The annulus is raised and the middle ear opened. Generally the long process of the incus and the incudostapedial joint are sometimes visible, often also the chorda (**Fig. 22.3, arrow**). A curette is used to remove bone from the lateral attic wall up to the stapes; the facial nerve over the oval window and the pyramidal eminence are exposed, paying attention to and avoiding injury of the chorda tympani (**Fig. 22.4**). The bony canal of the chorda tympani should be followed for 3 – 4 mm and may be opened to mobilize the nerve sufficiently. In the vast majority of cases the nerve can be kept intact. If the chorda is still obstructing the view, a sharp dissection is preferable to distension of the nerve. A slight turning of the patient's head towards the surgeon may improve the view. The chorda tympani is freed and pushed forwards to contact the handle of the malleus.

The mobility of the ossicular chain is tested by gently lifting the handle of the malleus with a sickle knife. No movement of the malleus indicates chain fixation in the epitympanon and requires a different procedure. Otosclerotic foci may be seen as white alterations of the bone. The fixation of the stapes due to otosclerosis should be confirmed. The facial nerve is identified, and the footplate is perforated with a perforator at this stage if there is sufficient space. This gives early information about a possible gusher and allows an easier removal of the footplate if the total footplate becomes mobile at a later stage of the procedure.

The stapedial tendon is cut with Bellucci scissors or a sickle knife (**Figs. 22.5 – 22.8**). The incudostapedial joint is separated using a hook (Figs. 22.5 – 22.8). Then, using a hook, the crus of the stapes is fractured, turning the hook towards the promontory (Figs. 22.5 – 22.8). The footplate is perforated with the perforator if not already done previously. Mucosa should be removed with a needle to grant a full view to the footplate, facilitating later removal of fragments (**Figs. 22.9 – 22.12**).

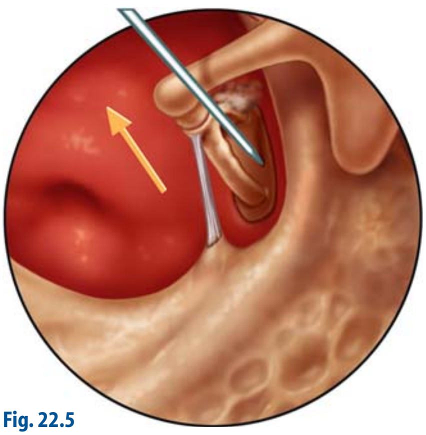


Fig. 22.5

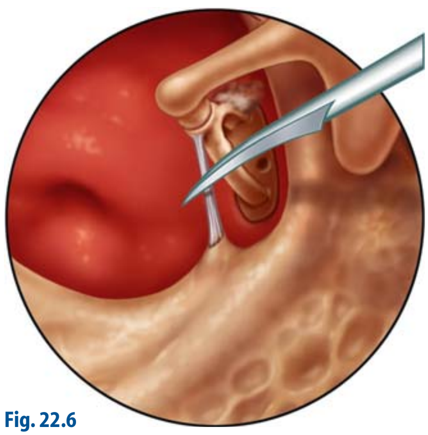


Fig. 22.6

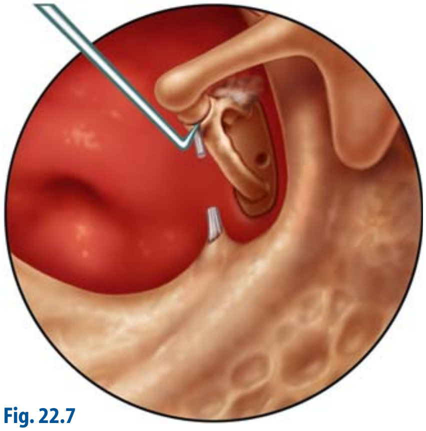


Fig. 22.7

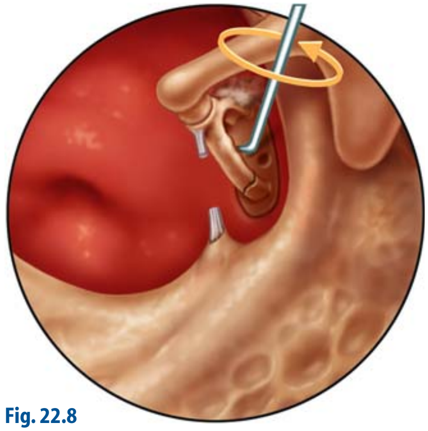


Fig. 22.8

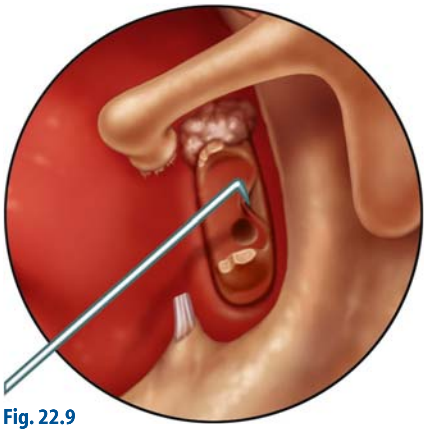


Fig. 22.9

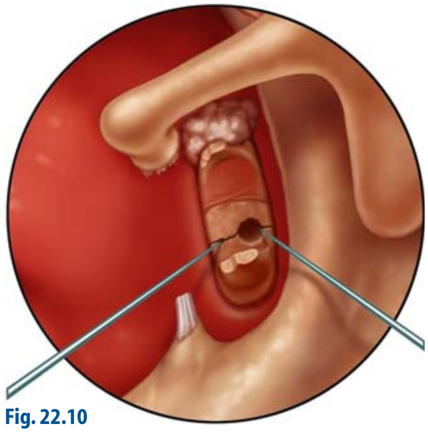


Fig. 22.10

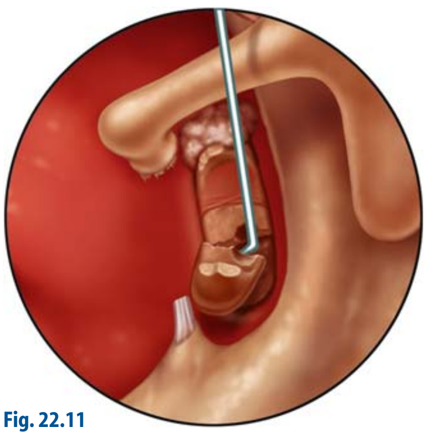


Fig. 22.11

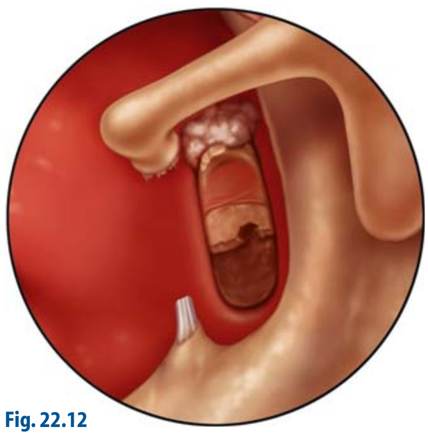


Fig. 22.12

The footplate perforation is widened with the perforator. Often the edges are fractured, in which case the fragments are removed with small hooks (0.2 – 0.4 mm), creating an opening of the posterior third or fourth of the posterior part of the oval window (**Figs. 22.9 – 22.12**). Alternatively, for the opening a microdrill may be used, especially for thick biscuit-type footplates. Suction should be strictly avoided over the opened vestibule. If fragments of the footplate fall into the vestibule, the surgeon should not try to extract them. The risk of inner ear damage is high. On the other hand, these fragments rarely cause serious vertigo. The prosthesis is placed into the posterior part of the vestibule because the sacculus and utriculus are situated anteriorly and superiorly and the risk of causing vertigo by contact of the prosthesis with these structures is reduced (**Figs. 22.13 – 22.16**).

Bleeding may obscure the vision. A small piece of Gelfoam can be placed into the oval window region. If the surgeon removes the material after 5 min, the bleeding has usually stopped. The prosthesis is grasped by alligator forceps at an angle of 150° and positioned with the wire loop over the long process of the malleus. The wire loop is crimped to the long process using the McGee forceps (**Figs. 22.13 – 22.16**). The correct fixation is checked with a hook. If the ring is loose it should be crimped again. Often it is sufficient, however, to move the ring of the prosthesis slightly to the periphery where the long process becomes thicker. The oval window is sealed with soft tissue harvested at this stage from the endaural incision site (**Figs. 22.13 – 22.16**).

Generally a 4.25- to 4.5-mm prosthesis is adequate for the majority of cases. Measuring devices are available for doubtful situations. It should be remembered that the generally used alloplastic prostheses are costly. Therefore the fat-wire prosthesis (Schuknecht) is worth considering for institutions with a low budget.

Floating Footplate

If the footplate becomes completely mobile during the perforation or the fracture of the suprastructure, bone can be cautiously removed from the promontorial edge of the oval window to gain space (**Fig. 22.17**). Subsequently the footplate is lifted with a 0.5-mm hook and can be completely detached. Problems with a floating footplate can be avoided if the footplate is perforated before the suprastructure is removed. If the total footplate becomes mobile the preformed hole can be used to insert a hook and lift out the footplate. The use of a laser avoids this problem.

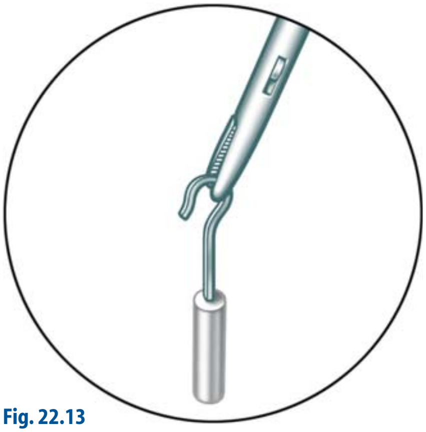


Fig. 22.13

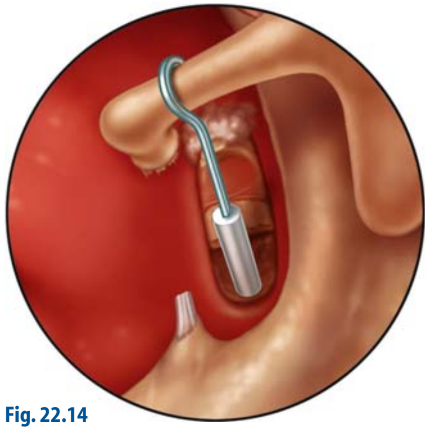


Fig. 22.14

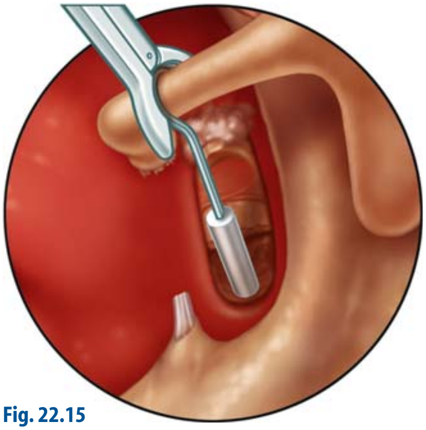


Fig. 22.15

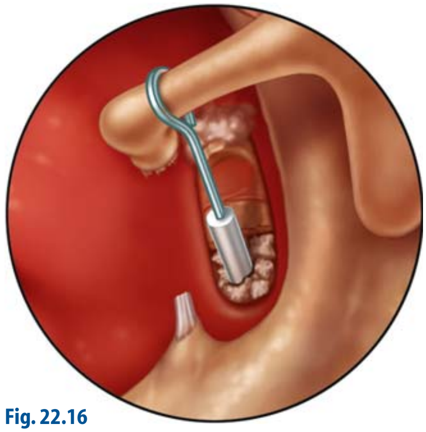


Fig. 22.16

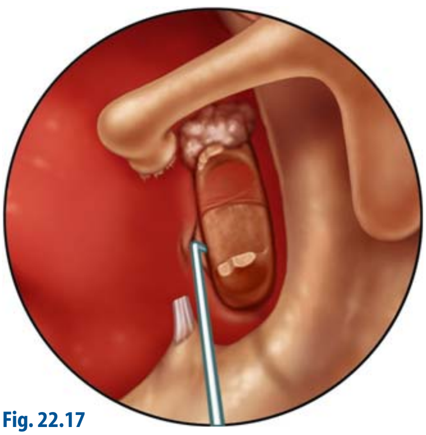


Fig. 22.17

Abnormal Course of the Facial Nerve

An overhanging facial nerve might obstruct the footplate. In partial obstruction the bone of the adjacent promontory can be drilled with an 8-mm diamond drill and a stapes prosthesis can be inserted.

In the case of a severely overhanging facial nerve, for example in a malformation, sound transmission can be reconstituted by an opening in the promontory (promontorial window, Plester). Drilling should be performed 1.5 mm above and 1 mm in front of the oval window niche. A drill diameter of 1 mm is achieved using a diamond burr, resulting in a “blue circle” comparable to the double blue line of fenestration of the lateral semicircular canal. A needle and hook are used to remove access bone. The shortened Teflon-platinum piston is attached to the malleus handle (**Fig. 22.18**).

A persisting stapedial artery may be seen between the crura of the stapes. It does not serve the inner ear and can be cauterized. A gusher develops when an open connection of the perilymphatic space with the cerebrospinal fluid is present. This is more frequently seen in malformations. After opening of the oval window the clear fluid rapidly fills the middle ear and even the ear canal. Less pronounced fluid leaks (oozers) indicate a narrow communication with the intracranial space.

If the inner ear is in danger, a sensorineural hearing loss may occur, and the surgeon should wait. Often the flow subsides or can be controlled with a small connective tissue plug around or under the prosthesis. We pack the middle ear additionally with Gelfoam before closing it in the usual way. In some cases a slight liquorrhoea persists which normally stops after a few days. In malformations, however, a surgical revision with tight packing and even lumbar drainage may become necessary. Antibiotics and high doses of steroids (e.g. 1 g/day) are given to protect the inner ear.

Malleovestibulopexy

If the malleus is mobile and the incus is absent, a malleovestibulopexy can be performed for the reconstruction of the ossicular chain. A tunnel is prepared for the wire loop of the piston between the handle of the malleus and the tympanic membrane (**Fig. 22.19**). Defects do not close over the ring of the wire. Therefore attention should be paid to the integrity of the tympanic membrane. Depending on the position of the handle of the malleus, the wire loop should be bent. After the fixation of the malleus the piston is inserted into the vestibule to avoid inner ear damage (**Fig. 22.20**). Malleovestibulopexy can be very difficult. If the malleus head is fixed, it is exposed and resected and the Teflon-platinum piston is attached to the handle of the malleus.

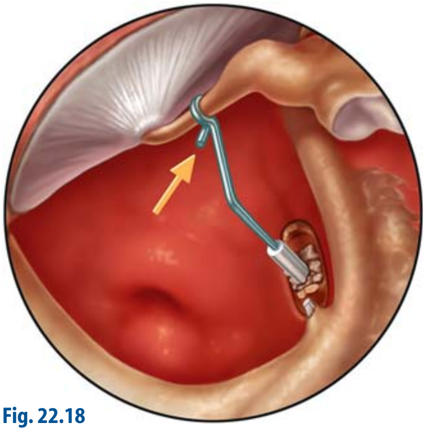


Fig. 22.18

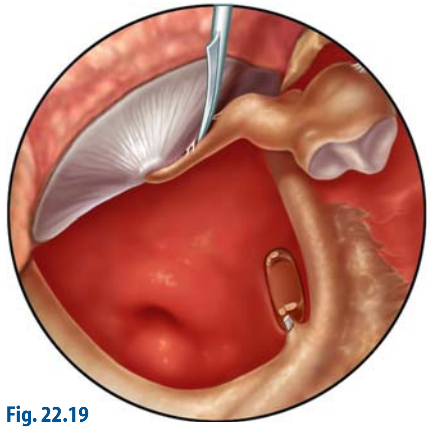


Fig. 22.19

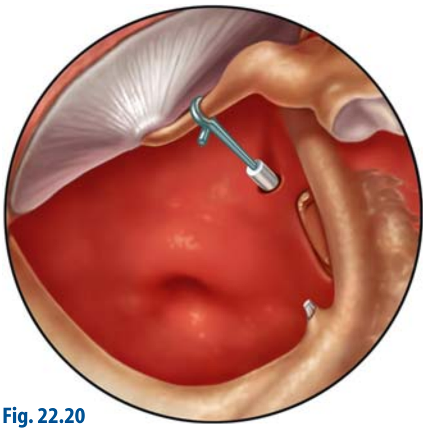


Fig. 22.20

23 Laser Stapedotomy

Sergije Jovanovic

The editors of this book prefer classical techniques for stapes surgery. However, since laser stapedotomy is of much interest we are pleased that an experienced laser surgeon has agreed to contribute his concept of the technique to this book.

Introduction

The goal of laser stapedotomy is to create a precise opening while protecting the inner ear and avoiding damage to the remaining middle ear structures. Advocates of the laser technique agree that non-contact vaporization of the bone covering the vestibule with the laser beam is less traumatizing to the inner ear than manual instrument extraction or perforation of the stapes footplate. It is also true, however, that the absorption of laser energy and the generation of heat during the stapedotomy pose a potential hazard to the membranous structures of the inner ear.

Owing in part to experimental and clinical studies by the present author on the suitability of the CO_2 laser, with its far-infrared emissions, as a stapedotomy tool [17–41], the laser has become more widely accepted and used as an otosurgical instrument in recent years. In primary operations and especially in revision stapedotomies, clinical studies document significantly better hearing results with the CO_2 laser than with conventional methods [3–5, 7, 8, 11, 26, 36, 41, 43–46, 49, 51, 55, 57, 62, 67–70, 72–75].

Laser Equipment

CO_2 Laser

The CO_2 laser in continuous wave (cw) mode is effective for removing soft tissue, and it can vaporize thin bony structures when focused to a small spot [27, 32, 33]. One of the main advantages of the far-infrared emission of the CO_2 laser is its strong absorption by water, resulting in a shallow penetration depth of only 0.01 mm from the irradiated surface. This property of CO_2 laser light is particularly useful in stapes surgery. During a stapedotomy, the perilymph completely absorbs the CO_2 laser energy and thus protects the inner ear structures from direct injury.

Micromanipulator

CO_2 laser energy cannot be transmitted efficiently through optical fibres without significant losses. The output of the CO_2 laser is delivered to the operative site through an articulated arm and a micromanipulator coupled to an operating microscope. A joystick is used to move the laser beam within the operative field. The micromanipulator and the attached articulated arm of the laser can limit the mobility of the operating microscope. The new generation of micromanipulators, with their lower weight (approximately 500 g) and size and shape better adapted to otologic surgical requirements, make the microscope easier to handle and allow the comfortable use of additional surgical instruments.

The CO_2 laser can be used with micromanipulators, allowing a spot size of 0.18 – 0.2 mm at a working distance of 250 mm. With a good beam profile and perfect alignment of the helium neon (HeNe) aiming beam with the CO_2 treatment beam, extremely fine microsurgical work can be carried out on middle ear structures. The systems also offer a variable working distance of 200 – 400 mm, which can be changed simply by turning a knob on the micromanipulator, eliminating the need for cumbersome lens changes. This is particularly advantageous when the CO_2 laser is used for other indications requiring a different focal distance.

Delivery systems can differ greatly in their ability to transmit laser power. With the CO_2 laser, the delivered output ranges between 70 % and 90 % of the primary output, depending on the laser system and micromanipulator. The surgeon must be knowledgeable about the amount of power loss and use a correspondingly higher power setting on the laser device to correct for it and achieve the desired effect on middle ear structures.

Scanner System

When a CO_2 laser beam is directed with microprocessor-controlled rotating mirrors known as scanner systems (SurgiTouch, Lumenis), the beam is automatically tracked in a spiral-shaped pattern within a designated pulse duration. In this way the CO_2 laser can deliver high power densities even over a relatively large treatment area with minimal collateral effects. At a working distance of 250 mm, the size of the treated area can be freely selected in accordance with the local anatomic configuration and the desired size of the perforation. In middle ear surgery, the treated areas will range from 0.3 mm to 0.8 mm in diameter. Thus, an opening of a specified diameter can generally be made with one shot in the stapes footplate when the correct laser parameters are used.

Safe and Effective Energy Parameters for CO_2 Laser Stapedotomy

The safe and effective parameters for CO_2 laser stapedotomy (type 40c with the Lumenis Acuspot 712 micromanipulator) have been determined based on data obtained in the petrous bone, in the cochlear model, and in experimental animals [21, 28, 33, 38] (**Tables 23.1, 23.2**).

The laser is operated in the cw mode. A power of 1 – 22 W and pulse duration of 0.03 – 0.05 s are recommended as the most effective settings for vaporizing soft tissue and bone with minimal thermal injury to surrounding tissues. The resulting power density ranges from 4000 W/cm^2 to 80,000 W/cm^2. A single laser application with the scanner system (SurgiTouch, Lumenis) will generally produce a precise footplate opening 0.5 – 0.7 mm in diameter (one-shot technique). If necessary, the diameter of the opening can be enlarged by firing additional pulses without a scanner. If a scanner system is not available, a series of short, low-power pulses are laid down in a slightly overlapping rosette pattern using a small beam diameter (multishot technique). A good beam profile allows for optimum tissue results with minimal thermal side effects.

Strict adherence to the recommended laser energy parameters will minimize the risk of thermal and/or acoustic damage to middle and inner ear structures.

Table 23.1. Effective laser energy parameters for CO_2 laser stapedotomy (1030, 1041, 20c, 30c and 40c CO_2 laser, Lumenis). The wattage data represent the actual power levels at the output of the delivery system (see under "Micromanipulator"). When the SurgiTouch scanner system (Lumenis) is used on the stapes footplate, additional single applications without the scanner (6 W, pulse duration 0.05 s) may be necessary to enlarge the opening. Focal length *f* = 250 mm. Focal size: 0.18 mm (Acuspot 71)

Anatomic structure	Real power (W)	Power density (W/cm²)	Pulse duration (s)	Mode	Diameter of irradiation (mm)	Number of pulses	Diameter of perforation (mm)
Stapedius tendon	2	8000	0.05	cw	0.18	2 – 3	
Incudostapedial joint	6	24,000	0.05	cw	0.18	8 – 14	
Crura	6	24,000	0.05	cw	0.18	4 – 8	
Stapes footplate	20 – 22[a]	80,000 – 88,000	0.03 or 0.05	cw	ca. 0.5, 0.6 or 0.7	1	0.5 – 0.7

[a] Application of laser irradiation with rotating mirrors (SurgiTouch)

Table 23.2. Effective laser energy parameters for revision stapedotomy (1030, 1041, 20c, 30c and 40c CO_2 laser, Lumenis). The wattage data represent the actual power levels at the output of the delivery system (see under "Micromanipulator"). When the SurgiTouch scanner system (Lumenis) is used on the stapes footplate, additional single applications without the scanner (6 W, pulse duration 0.05 s) may be necessary to enlarge the opening. Focal length *f* = 250 mm. Focal size: 0.18 mm (Acuspot 71)

Anatomic structure	Real power (W)	Power density (W/cm²)	Pulse duration (s)	Mode	Diameter of irradiation (mm)	Number of pulses	Diameter of perforation (mm)
Soft tissue	1 – 2	4000 – 8000	0.05	cw	0.18		
Bony stapes footplate	6 or	24,000	0.05	cw	0.18	6 – 12	0.5 – 0.7
	20 – 22[a]	80,000 – 88,000	0.03 or 0.05	cw	ca. 0.5, 0.6 or 0.7	1	0.5 – 0.7
Connective-tissue	1 – 2 or	4000 – 8000	0.05	cw	0.18	6 – 12	0.5 – 0.7
neomembrane	4 – 8[a]	16,000 – 32,000	0.03 or 0.05	cw	ca. 0.5, 0.6 or 0.7	1	0.5 – 0.7

[a] Application of laser irradiation with rotating mirrors (SurgiTouch)

Surgical Technique of CO_2 Laser Stapedotomy

The external auditory canal is infiltrated with 1 % lidocaine (Xylocaine) and with 1:200,000 epinephrine, and the tympanomeatal flap is elevated to enter the middle ear. The canal bone covering the oval window niche is removed with a sharp House curette or diamond bur, preserving the chorda tympani. As in conventional surgery, sufficient access to the oval window is gained when the pyramidal process and tympanic segment of the facial nerve are clearly visible. Before the CO_2 laser is used, test firings are made on a wooden spatula or other suitable object to check for any misalignment between the HeNe aiming beam and the invisible CO_2 laser beam. Then the stapedial tendon, incudostapedial joint, and crura are vaporized and the footplate is perforated with the CO_2 laser beam using non-contact technique.

The *stapedial tendon* is vaporized with two or three separate pulses of 0.05 s duration at 2 W (power density 8000 W/cm^2) (**Fig. 23.1**). In some cases it may be possible to preserve the tendon if anatomic conditions are favourable.

The *incudostapedial joint* is generally separated by conventional means in cases with complete stapes fixation. If the footplate is only partially fixed, laser-assisted separation of the joint is performed. The joint is opened with 8 – 14 pulses of 0.05 s duration at 6 W (power density 24,000 W/cm^2), vaporizing the stapes capitulum. Since the CO_2 laser beam often does not strike the joint precisely at a perpendicular angle, the joint should also be probed with a manual instrument, which is used to clear any remaining connections between the lenticular process and stapes capitulum.

The *posterior crus*, which is generally thicker, longer, and more curved, is transected close to the footplate with four to eight pulses of 0.05 s duration at 6 W (power density 24,000 W/cm^2), the same settings used on the incudostapedial joint (**Fig. 23.2**). When this relatively high wattage is used to vaporize the joint and posterior crus, care should be taken that the beam does not acciden-

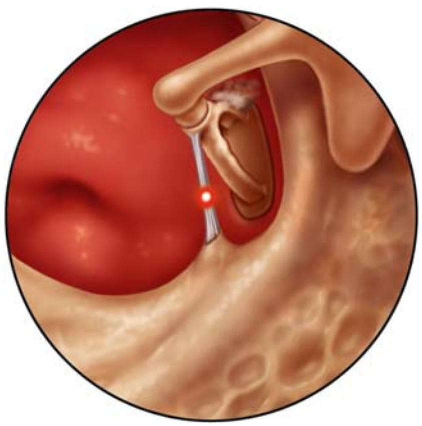


Fig. 23.1. The stapedial tendon is divided with two or three low-wattage laser pulses (2 W)

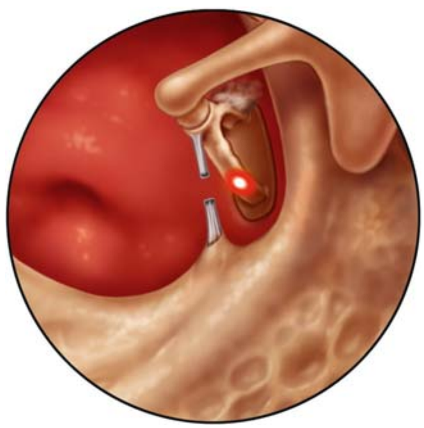


Fig. 23.2. The posterior crus of the stapes is transected with four to eight laser pulses (6 W, pulse duration 0.05 s)

tally strike middle ear structures that lie in the path of the beam (footplate, facial canal). This can be prevented by filling the middle ear with physiologic saline solution or covering these structures with moist gelatin sponge (Gelita or Spongostan). If the posterior crus remnant is still too long after the suprastructure has been removed, it can be vaporized to the level of the footplate using the same laser parameters to obtain better posterior exposure of the footplate.

The *anterior crus* of the stapes is fractured with a small hook using conventional technique. If all or part of the anterior crus is still visible, it is vaporized with the CO_2 laser beam using the same parameters as for the posterior crus. If this does not completely transect the crus, the vaporized site can be fractured using controlled pressure on the small hook. This virtually eliminates the danger of mobilizing the footplate or even partially or completely extracting it. The stapes superstructure is then extracted with a small forceps. Again, it is advisable to protect the surrounding structures (footplate, facial canal) by covering them with moist gelatin sponge or instilling physiologic saline solution.

After the suprastructure has been removed, the *stapedotomy* opening is created, usually placing it in the posterior half of the footplate. The goal is to create an approximately round, reproducible fenestra 0.5 – 0.7 mm in diameter, applying the beam either in a single application (one-shot technique) or in a slightly overlapping pattern (multishot technique), without causing significant thermal alteration of the peripheral zones.

The present author has been able to create a smooth, round fenestra 0.5 – 0.7 mm in diameter in approximately 70 % of cases with a single 20- to 22-W laser application of 0.03 – 0.05 s duration (**Fig. 23.3**). In cases where a single application did not make an opening of the desired diameter (•0.3 mm), a second shot was applied to the same site with the scanner or multiple shots were applied without a scanner (approximately 15 % of cases each).

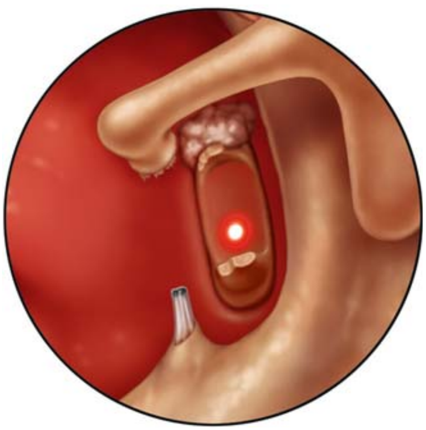


Fig. 23.3. The stapes footplate is perforated with a single CO_2 laser application using the SurgiTouch scanner (20 W, pulse duration 0.04 s, scan diameter 0.6 mm)

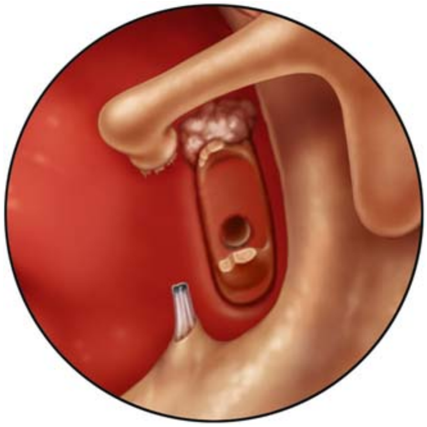


Fig. 23.4. Appearance after perforation of the footplate

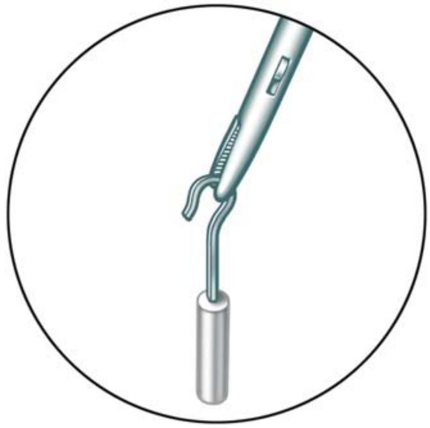


Fig. 23.5. Prosthesis held by forceps

Fig. 23.6. Appearance after implantation of platinum-fluoroplastic prosthesis

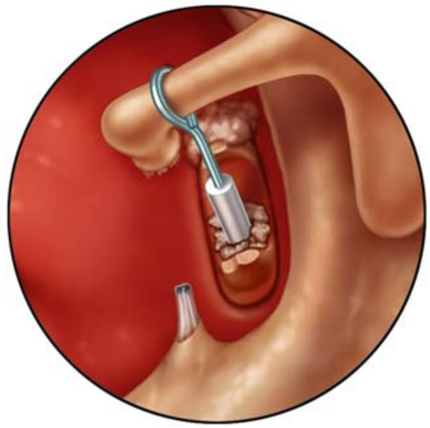


Fig. 23.7. Perforation of the stapes footplate surrounded with soft tissue. Platinum-fluoroplastic prosthesis in situ

If a scanner is not available, the footplate can be perforated using the multishot technique. A beam 180 μm in diameter is used at a power of 6 W and pulse duration 0.05 s. From 6 to 12 shots are needed to create a fenestra 0.5 – 0.7 mm in size, depending on the footplate thickness.

Care should be taken that the vestibule is filled with perilymph to ensure adequate protection for inner ear structures and prevent damage from direct irradiation. If the perilymph is jnadvertently suctioned from the vestibule, no additional laser energy should be applied to the footplate. Lasing of the footplate is continued only after additional fluid has seeped into and adequately filled the vestibule. It may be necessary in some cases to fill the vestibule with physiologic saline solution.

A platinum-fluoroplastic piston 0.4 – 0.6 mm in diameter is then inserted into the fenestra and connected to the long process of the incus (**Figs. 23.4 – 23.6**). Finally the oval window niche is sealed with connective tissue or clotted blood (**Fig. 23.7**).

Special Cases

Obliterative Otosclerosis

The incidence of obliterative otosclerosis is between 2% and 10% of all cases [6, 16, 58, 61]. It was 5% in the present author's series. Drilling through a thick footplate obliterating the oval window niche can cause significant vibration-induced inner ear trauma. The CO_2 laser, on the other hand, can vaporize a fenestra in the stapes footplate, regardless of its thickness or degree of fixation, without mechanical trauma to the inner ear.

The settings on the SurgiTouch scanner are the same as for a laser stapedotomy. After the suprastructure is removed, the otosclerotic foci obliterating the oval window niche are uniformly removed over a broad front by laser application with the SurgiTouch scanner. This is continued until the lateral margins of the oval window can be clearly identified. Lower power may have to be used at the periphery of the window niche to avoid accidentally entering the inner ear. Large amounts of char are produced as the bony material is vaporized. Since crystalline char reflects the CO_2 laser energy and reduces its ablative effect, it must be removed with a suitable instrument. The vestibule in the posterior part of the oval window niche is opened with the scanner using the same laser parameters as for a one-shot stapedotomy in a footplate without obliterative changes (see Table 23.1). If the diameter of the fenestra is too small to accommodate the prosthesis, the opening can be enlarged either by re-treating the same site with the scanner or by applying a concentric pattern of laser flashes without a scanner. The prosthesis is placed in a routine fashion.

Overhanging Facial Nerve

An overhanging tympanic facial nerve segment, whether covered by bone or occasionally exposed, can be a serious obstacle to surgical access. If the facial nerve is covered by bone, the CO_2 laser beam can be carefully applied tangentially at low power (1–2 W), using short pulse durations of 0.05 s, to remove the bone. Scanner settings of 4–5 W, 0.03–0.04 s pulse duration, and 0.3–0.4 mm scan diameter are safe and effective. Occasionally this measure is sufficient to obtain a clearer view of the footplate. It is best to avoid completely freeing the facial nerve rom its bony covering to protect it from a direct laser strike and prevent nerve prolapse through the resulting bone defect, which can hamper visibility.

In cases where the facial canal completely obstructs access to the oval window niche and removal of the frequently very thin bone will not significantly improve access, or if the tympanic facial nerve segment is not covered by bone, laser use should be suspended in favour of, e.g. a conventional stapedotomy with a curved perforator. Another option for difficult access is to redirect the CO_2 laser beam with a mirror. This may enable the surgeon to perforate a footplate that is not directly accessible to the laser beam.

Overhanging Promontory

Narrowing of the oval window niche by an overhanging promontory wall projecting into the niche generally poses only a minor surgical problem. Using the precautionary measures described earlier (covering the footplate with saline solution or moist gelatin sponge), the bony overhang can be ablated with a tangential beam using the parameters given above to provide a clearer view of the oval window niche.

During removal of the overhanging promontory bone, care is taken to avoid opening the scala tympani. The risk of opening the scalar tympani and damaging the inner ear with the CO_2 laser beam, however, is far less than with a conventional instrument such as a diamond bur owing to complete absorption of the laser energy by the perilymph and the very low penetration depth of 0.01 mm. Thus, the inner ear structures are well protected from a direct CO_2 laser strike and are safe over a relatively large range of energies.

Inaccessible Footplate

If the footplate is not accessible, for example, due to an abnormal course of the facial nerve or a vascular anomaly, restoration of the sound conduction apparatus may require fenestration of the promontory using the technique described by Plester et al. [56]. Apart from using the CO_2 laser to make the fenestra, the surgery is done according to conventional technique. The experimentally determined laser parameters are the same as those recommended for a stapedotomy. The present author has no personal experience with CO_2 laser fenestration of the promontory, as he has been able to define the oval window niche in all cases.

Floating Footplate

In a conventional stapedotomy, it is not uncommon for manipulations of the stapes to accidentally mobilize the smallest of the ossicles and create a floating footplate, especially if the stapes is partially fixed. Often it is no longer possible to perforate the footplate in these cases, necessitating a stapedectomy. The CO_2 laser, on the other hand, enables the otologic surgeon to create a fenestra of the desired diameter even in a floating footplate. A platinum-Teflon piston can then be placed into the fenestra. The incidence of a floating footplate in laser-assisted surgery is very low, however, compared with a conventional stapedotomy. In the author's series the incidence was 0.5 %, and none of the cases required a stapedectomy.

Problems in Revision Procedures

Successful restoration of hearing in revision stapedotomies involves precise identification and correction of the causative abnormality without traumatizing the inner ear.

The otosurgeon faces a dilemma when exploring the middle ear of a patient after a failed stapedectomy. To determine the reasons for the conductive hearing loss, the surgeon must test the mobility and integrity of the entire ossicular chain and accurately evaluate the status of the oval window and the position of the prosthesis at the entrance to the vestibule. Often one is unable to determine the depth and lateral margins of the oval window or see the connective tissue covering the structures behind the oval window niche. When palpation of these structures is minimized to avoid inner ear trauma, the surgeon may be unable to identify the exact cause(s) of the conductive hearing loss and therefore cannot provide adequate treatment.

Surgical Technique of CO_2 Laser Revision Stapedotomy

The tympanomeatal flap is outlined and elevated, and the middle ear is inspected. The malleus and incus are probed with a needle to assess their integrity and mobility. Adhesions are frequently present and are vaporized with the CO_2 laser using the safe and effective laser parameters determined experimentally (see Table 23.2). With a beam diameter of 0.18 mm, it is sufficient to use a low power setting of 1 – 2 W with a pulse duration of 0.05 s. When the SurgiTouch scanner is used, settings of 4 – 8 W, pulse duration 0.03 – 0.05 s, and scan diameter 0.3 – 0.7 mm are adequate for soft-tissue ablation. These parameters are used to expose the prosthesis by vaporizing the soft tissue surrounding it.

In patients with a wire prosthesis (e.g. platinum) attached to a connective tissue graft over the oval window, it is not dangerous to strike the wire directly with the laser beam. If the prosthesis is a piston with a fluoroplastic component (e.g. a platinum-fluoroplastic piston), following stapedotomy it should not be struck directly with the beam because the fluoroplastic cannot withstand high temperatures (> 300 °C) and its surface will swell into a “mushroom” shape without disintegrating or combusting.

The prosthesis is exposed by non-contact vaporization of the fibrous attachments. This technique avoids mechanical trauma to the inner ear. Next, the soft tissue covering the oval window niche is uniformly vaporized on a broad front until the lateral margins of the oval window are clearly visualized. If the prosthesis is still embedded in connective tissue, the vaporization is continued until it has been completely freed. Once the distal end of the prosthesis has been cleared of all fibrous attachments, it is detached from the incus and extracted with a 90° hook 2 mm long. If dizziness occurs (under local anaesthesia), the surgeon should stop all manipulations at once and reinspect the distal end of the prosthesis for any remaining fibrous attachments that might be pulling on the inner ear.

The tissue at the centre of the oval window is then uniformly vaporized to create a fenestra 0.5 mm or 0.7 mm in diameter. Vestibular perilymph should be visible through the opening. Depending on what is found in the oval window (a fibrous neomembrane and/or bony footplate), a 4 – 8 W or 20 – 22 W laser application beam with a pulse duration of 0.04 s is applied with a scanner system using one-shot technique, or a 1 – 2 W or 6 – 8 W laser application (pulse duration 0.05 s) is applied in a slightly overlapping pattern of 6 to 12 shots without a scanner.

The length of the revision prosthesis is determined by measuring the distance from the lower surface of the incus to the vestibule and adding 0.2 mm. (The most common is 4.5 – 4.75 mm.) The prosthesis should extend 0.1 – 0.2 mm into the fenestra to help prevent recurrent migration. The platinum-Teflon piston is inserted into the fenestra and, if the incus is intact, attached to the neck of the incus. If the incus is badly eroded, a malleovestibulopexy will re-establish sound conduction. Finally, the oval window niche is sealed with connective tissue.

Conclusions

Before a new technique can become established, its success rates must be compared with those of traditional techniques. This comparison is difficult to make, however, due to differences in recruitment and data analysis. For example, while the average air-bone gap in older studies was determined for frequencies of 0.5, 1, and 2 kHz, it has additionally been determined for 3 kHz in more recent studies.

Nevertheless, a comparison of the results in major publications shows that the postoperative hearing gain after primary laser stapedotomy [1, 3, 4, 15, 45, 46, 51, 52, 62, 71] does not differ from the good results of conventional surgery [2, 10, 12, 13, 48, 53, 54, 59, 60, 63, 65, 66]. The results published in the literature clearly demonstrate, however, that complications after CO_2 laser stapedotomy are less frequent and less severe than after conventional operations [4, 41, 60, 62]. The present author's results are consistent with these findings.

Laser use in revision surgery offers significant advantages over conventional technique. The principal advantages are improved diagnostic and therapeutic precision, the ability to better stabilize the new prosthesis at the centre of the oval window niche, and the reduction of inner ear trauma. Based on an improvement of the air-bone gap to 20 dB or less, the success rates with laser revision surgery were 70 – 92 % compared with 49 – 85 % with conventional surgery. The higher success rates and lower complication rates are statistically significant and do not depend on the type of laser system used [9, 11, 14, 41, 46, 47, 50, 64, 76].

The CO_2 laser appears to be suitable for use in stapes surgery. With advances in laser technology, one-shot stapedotomy can be done in most patients. With strict adherence to recommended settings, the laser helps to optimize this very exacting procedure and should reduce the incidence of inner ear damage. It is superior to conventional techniques, particularly in the surgery of obliterative otosclerosis and in revision procedures.

Although the relatively new technological advance of laser use in middle ear surgery is gaining acceptance, it must be emphasized that the laser is only a tool, though a highly developed one, and is no substitute for the knowledge, experience, judgment, and manual skills of the surgeon.

24 Stapes Revision Surgery

Stefan Dazert, Henning Hildmann

Early Revisions

Immediate reoperation during the first postoperative days is indicated if the patient complains of sensorineural hearing loss (i.e. lateralization of the tuning fork into the contralateral ear) and severe vertigo that do not respond to conservative treatment (i.e. steroids, antibiotics, rheological and antivertiginous drugs).

These symptoms may be caused by granulation tissue inside the oval niche and the tympanic cavity probably due to foreign bodies sucked in from the air during primary operation. Prosthesis and granulations should be carefully removed and the opening of the footplate needs to be covered with connective tissue. Reoperation for hearing improvement is performed after about 6 months.

Furthermore, the prosthesis might have slipped into the vestibule if it is not tightly clipped to the incus or if it is too long (**Fig. 24.1**). In this case, the prosthesis should be replaced and properly clipped to the long process of the incus. Similar symptoms may be found with too long a prosthesis that needs to be replaced with an appropriate length.

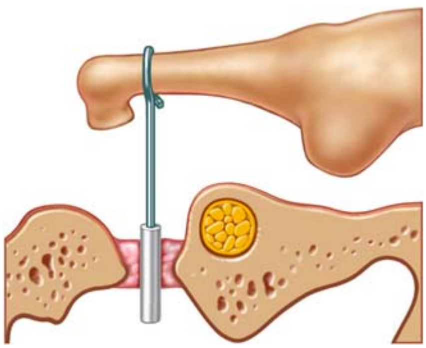


Fig. 24.1

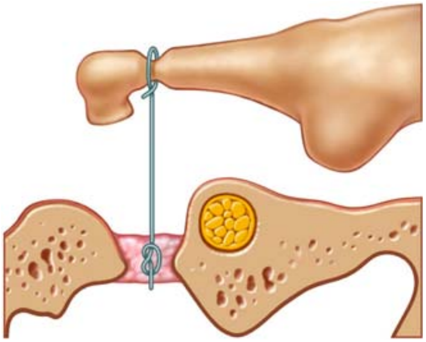


Fig. 24.2

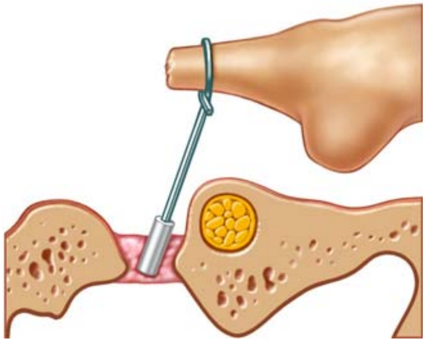


Fig. 24.3

Late Revisions

Displacement of the Prosthesis

Incus erosion with loosening or displacement of the prosthesis is the most common finding in stapes revision surgery after several years (**Fig. 24.2**). Patients complain of deterioration of hearing, which often improves shortly after Valsalva's maneuver. The prosthesis may be refixed by clipping (**Fig. 24.3**). In cases of severe destruction of the long process of the incus, the prosthesis can be clipped to the proximal part of the long process. Sometimes a groove must be drilled to prevent the prosthesis from slipping. The new prosthesis may have to be bent to adapt to the new anatomical situation. Alternatively, the prosthesis may be fixed using bone cement.

Complete Destruction of the Incus

If refixation of the prosthesis to the incus is impossible, a new slightly longer prosthesis may be attached to the handle of the malleus (malleus to oval window technique = malleovestibulopexy). After creating a tunnel between the fibrous tissue of the tympanic membrane and the bony handle, the wire of the prosthesis is positioned. The surgeon must be careful not to perforate the tympanic membrane because the tissue does not close over the metal ring of the prosthesis. If perforation accidentally occurs, a small thin piece of cartilage should be placed between the metal ring and tympanic membrane.

Reclosure of the Oval Window

The oval window may reclose under a short prosthesis. The reopening of the footplate is more dangerous than the primary operation because scar adhesions may have developed between the inner ear structures, and the footplate and the utricule or the saccule could be torn. Therefore we identify the promontorial side of the footplate and remove some adjacent bone until the vestibulum can be seen. A bony reclosure can now be perforated. Connective tissue can just be pushed cranially without removing tissue.

Fixation of Incus or Malleus

Malleus or incus fixation should not be overlooked during the first operation. It may also occur later after surgery due to inflammatory reaction after surgical trauma. The malleus to oval window technique as described above is the surgical solution. Drilling away the bony fixations is possible but requires much more extensive surgery.

Schuknecht's Prosthesis

If a Schuknecht's wire prosthesis is encountered during revision surgery, the wire must not be removed but cut and left in place. A new opening to the vestibulum is created next to the wire to place an additional new prosthesis.

Perilymphatic Fistula

Perilymphatic fistulas (PLFs) can develop in the region of the oval window inside the connective tissue around the prosthesis due to head injuries or rapid pressure shifts, etc. Patients usually complain of inconsistent vertigo, which might appear a long time after surgery. PLFs can be accompanied by a fluctuating or continuous sensory hearing loss, and in revision surgery they cannot be identified in any case. However, the fistula or the area of the oval window is covered with connective tissue after the tissue in the oval window especially around the fistula is scratched to bleeding.

Vertigo

Slight vertigo after stapes surgery is not uncommon and generally subsides. Disabling vertigo is extremely rare. Hearing can be normal or impaired. If vertigo cannot be controlled by conservative methods, the middle ear must be treated surgically. The prosthesis may be too long, it may have slipped from an eroded incus or a perilymphatic fistula may be seen; extremely seldomly a neurectomy may be indicated, depending on the hearing, using either a translabyrinthine or a transtemporal approach.

25 Middle Ear Trauma

Henning Hildmann, Holger Sudhoff

Traumatic Tympanic Membrane Perforation

Ninety percent of traumatic perforations of the tympanic membrane will heal spontaneously. Myringoplasty must be performed in ears that fail to heal after 3 months, with a typical success rate of 95 %. No surgery should be performed before 3 months unless more serious destruction or foreign bodies are seen or suspected or inner ear symptoms indicate additional inner ear trauma. Subtotal perforations should be revised as soon as the patient is in a stable condition. Otherwise the patient should be instructed to keep water out of the ear and to return for regular checkups and treatment of any infection. Small perforations can be reconstructed by everting the edges with a hook the reconstruction is covered with silicone or cigarette paper. If the situation is unstable, Gelfoam or similar material soaked with an antibiotic solution can be placed on the promontory for support. Larger perforations require an underlay of fascia, performing a type I tympanoplasty using an endaural approach as described below. The middle ear should be checked if ossicular chain or inner ear damage is suspected or foreign bodies may have been introduced into the middle ear. The surgeon, particularly the less experienced, should not hesitate to perform the regular type I tympanoplasty he or she was trained to do instead of trying to reposition large defects. The latter carries the risk of chain subluxation in the office under semisurgical conditions.

Ossicular Chain Trauma

Injuries of the ossicular chain have various aetiologies. Skull traumas from blows to the temporal, parietal or occipital region with or without fracture of the temporal bone are the main causes; direct trauma, explosions, or thermal injuries are other possible causes. The type of injury that results depends upon the type of trauma. Mainly subluxations, luxations and fractures are seen. The incus is most frequently affected. Reconstruction follows the general rules of tympanoplasty. The surgeon should check for foreign bodies during surgery. Wooden splinters, moulding mass for ear moulds, cotton and other materials have been reported.

The stapes may be subluxed. In this case the oval window should be sealed. In complete luxations the stapes is replaced by a prosthesis as in otosclerosis surgery. Subluxations may be treated with repositioning of the footplate and surrounding it with connective tissue.

Perilymph Fistula

The perilymphatic fistula is an opening between the perilymphatic space and the middle ear. They occur rarely in the setting of trauma and are most likely following barotraumas. Patients complain of varying intermittent vertigo. The symptoms may not be immediately apparent. Most frequently a stapes luxation is found, and more seldomly fractures involving other parts of the middle ear can be seen and have to be closed. After previous middle ear surgery a total ossicular prosthesis may perforate the footplate.

The fistulas in areas other than the round and oval window are covered with bone paté and a fascia graft or connective tissue grafts.

As a rare cause of vertigo, fistulas of the superior canal to the middle fossa have been described. The aetiology is unknown. After careful imaging and exclusion of the causes, the superior canal can be approached by a transtemporal approach.

Rupture of the Round Window

Ruptures of the round window are rare, occurring after head trauma and barotrauma. Bilateral ruptures are more likely after head trauma. Patients complain of vertigo tinnitus and a sensorineural hearing loss. The symptoms might be incomplete and fluctuating. The diagnosis is difficult since the fistula can only be visualized when a perilymph leak is seen after opening of the middle ear. The absence of perilymph does not exclude a fistula.

If a rupture is suspected the middle ear is opened as in stapes surgery. The round window niche is identified.

To expose the round window the bony ridge over the round window is removed with a small curette or a small drill. The round window membrane is almost perpendicular to the line of inspection. Sometimes an oozing of perilymph can be seen. The round window niche is covered by a small piece of connective tissue and the tympanomeatal flap is reflected to its normal position.

Traumatic Stenosis or Atresia

See surgery of the external ear canal.

Fractures of the Temporal Bone

Fractures of the temporal bone may be caused by direct or indirect impact. Extensive destructions of the lateral skull base exceed the scope of this book. The reconstruction should be adapted to the individual situation often in cooperation with the neighbouring specialities. The reconstruction of the tympanic membrane and the ossicular chain follows the principles of tympanoplasty and ear canal reconstruction as described in this book. Closure of the tympanic membrane prevents later infections of the middle ear and ascending infections of the intracranial space from outside. Reconstruction procedures of the ossicular chain are only sensible if the inner ear is not or is slightly affected. Persistent vertigo over 6 months might require a labyrinthectomy or vestibular nerve section. If bilateral severe sensorineural hearing loss occurs, cochlear implantation is often indicated and surgery is done when the patient becomes stable.

Leak of CSF indicates dural injury. Generally the tegmen or the mastoidal region is involved. Leaks from the internal auditory canal through the labyrinth are possible. If the tympanic membrane is ruptured, liquorrhoea through the external canal occurs. If the membrane is intact, the fluid drains through the eustachian tube and should be differentiated from a defect in the frontal skull base. In most cases the tears of the dura of the lateral skull base heal spontaneously. The ear is covered with a sterile dressing and the patient is observed. If there is concomitant infectious ear disease, especially cholesteatoma, the ear must be operated on to prevent an ascending infection. Ascending air can cause pneumatocoeles and may change the surgical concept. If the liquorrhoea persists the leak must be closed. CT mostly reveals the site of injury. Many defects can be closed via a mastoidectomy approach. The dura and the defect are exposed, bony splinters removed and the defect closed with large pieces of temporalis fascia placed on the intracranial side of the temporal bone and fixed with fibrin glue. Larger defects are stabilized with cartilage.

If necessary, especially for repair of the medial region of the upper plane of the petrous bone, a transtemporal approach can be used.

If the hearing is not preserved, the middle ear spaces can be obliterated with abdominal fat.

Haemorrhages may be life threatening and call for immediate revision. They may be due to injury of the sigmoid or the superior petrosal sinus. Sinus bleeds are low pressure bleeds and can be dealt with by drilling away surrounding bone to expose the sinus and subsequent packing. Bleeding from the carotid artery or the medial meningeal artery usually cannot be controlled by an otological approach and requires the help of an interventional radiologist.

26 Endolymphatic Sac Surgery

Holger Sudhoff, Henning Hildmann

The aim of endolymphatic sac surgery is to expose and drain the endolymphatic sac using a transmastoidal approach as a treatment for Meniere's disease. This disease is characterized by episodic vertigo attacks with nausea or vomiting, sudden or fluctuating sensorineural hearing loss of different degrees and tinnitus of varying intensity. A frequent symptom is the sensation of pressure or fullness in the affected ear. The pathophysiology is commonly explained by a distension of the membranous labyrinth by the endolymph, also called endolymphatic hydrops. Bilateral Meniere's disease is rare, often occurring within a period of 5–30 years in the primarily unaffected ear. Preoperative evaluation should include electronystagmography, or balance test (ENG), electrocochleography (ECOG), brainstem evoked response audiometry (BERA) and magnetic resonance imaging (MRI) with gadolinium to exclude an acoustic neuroma or other brain tumours as a possible source of symptoms. In spite of today's technical knowledge, the diagnosis of Meniere's disease still relies mainly on the clinical symptoms: fluctuating hearing loss, tinnitus, attacks of vertigo and sense of fullness in the ear. In the beginning it is often monosymptomatic, with fullness or tinnitus in the affected ear. It may also present as a sudden hearing loss. Vertigo can present very dramatically and distressingly with insatiable emesis and may be misdiagnosed as cardiac infarction, apoplexia, intoxication or severe gastrointestinal infection. The lack of aetiological knowledge about Meniere's disease and its difficult differential diagnosis explains the whole variety of medical and surgical treatment options. Its unresponsiveness to medical treatment is the indication for surgery. In cases with useful hearing, saccotomy is preferred before neurectomy is considered. We perform the exposure and drainage of the endolymphatic sac using a sac sialastic stent. In theory, the endolymphatic sac operation should decompress the excessive fluid within the inner ear and improve resorption of endolymph. Vertigo subsides or disappears after surgery in about 66%, tinnitus in 50%, improvement of hearing in 28% and fullness in 80% of Meniere's cases within 3 years of surgery. Vertigo symptoms may reappear in some individuals.

Surgical Procedure

Using a retroauricular approach the mastoid is opened and the following landmarks are identified: the bony shell of the sigmoid sinus and the middle and posterior cranial fossa, the lateral and the posterior semicircular canals and the short process of the incus (**Fig. 26.1**). More experienced surgeons may use a less extended exposure. In any case, the sinus, the posterior fossa below the sinus and the lateral and posterior semicircular canals need to be clearly seen. The antrum is blocked after its exposure with Curaspon pieces to prevent bone dust entering the epitympanic and middle ear spaces. Bone dust may lead to a bony closure of the eustachian tube or the windows or to a fixation of the ossicular chain.

Anatomical Position of the Endolymphatic Sac

The dashed lines illustrate the direction of the lateral and the posterior semicircular canals. The arch of the lateral canal is about 3 mm more lateral than that of the posterior canal. The blue line of the posterior canal should be seen. The bone posterior to the posterior semicircular canal overlying the posterior fossa dura is removed. The distance between the posterior semicircular canal and the posterior fossa is very variable. In a well-pneumatized mastoid the endolymphatic duct leading from the sac to the vestibule can be identified. The endolymphatic sac is found below the line drawn from the lateral semicircular canal crossing the posterior canal. Avoid damage to the dura. The endolymphatic sac is situated in a shallow groove of the posterior aspect of the temporal bone as marked by the yellow lines (**Fig. 26.2**). It can often be identified by its change of structure of the dura of the posterior fossa. The endolymphatic duct, which is occasionally visible, has to remain intact (**Fig. 26.3**). The eggshell-thin bone over the posterior fossa dura is removed with a curette. It is important to note that its superior portion of the posterior semicircular canal is closer to the posterior fossa dura than its inferior portion. The endolymphatic sac is incised with a sickle knife and is identified after the detection of a lumen. Sometimes even experienced surgeons incise the dura accidentally, mistaking it for the clearance of the endolymphatic sac (**Fig. 26.4**). The position of the endolymphatic sac is often assumed as being too far superiorly. In cases of Meniere's disease it is frequently small due to fibrosis. After identifying and opening the sac, possibly also identifying the entrance to the duct, a small triangular silicone sheath is inserted into the incision. The exposed area can be covered with soft tissue. Poor pneumatization and a prominent sigmoid sinus may complicate the procedure. If the sinus is very prominent, the covering bone may be thinned and fractured.

The posterior semicircular canal may be hard to find in a sclerotic mastoid. The lateral canal can always be identified. It can be helpful to identify the blue line of the lateral canal before identifying the blue line of the posterior. The sinus can be protruding. Space can be gained by thinning the bone over the sinus and fracturing (eggshell) the bone and pushing it towards the vessel.

Fig. 26.1

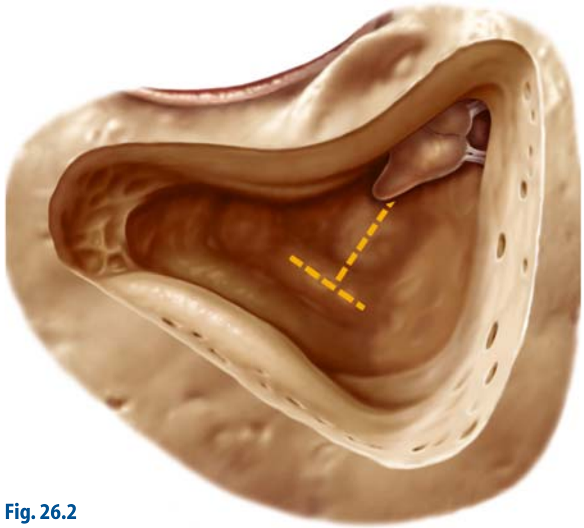


Fig. 26.2

Fig. 26.3

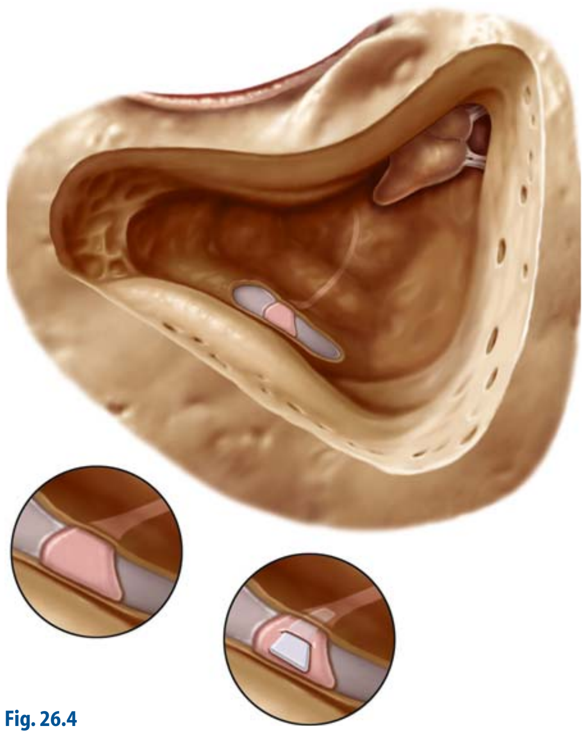


Fig. 26.4

27 Malformation Surgery

Henning Hildmann

Surgery of Middle Ear Malformations

For surgical purposes malformations can be subdivided into minor and major malformations. This classification seems practical because minor malformations with a normal or nearly normal tympanic membrane can generally be operated on with the techniques of tympanoplasty and stapes surgery. Major malformations are associated with atresia or stenosis of the outer ear canal and need a more extensive diagnosis. The indications for surgery must be very precise and consideration should be given to fitting a temporary hearing aid depending on the individual's age. Only cases with a well developed middle ear have the chance of a good surgical outcome. Major malformations may be associated with malformations of the outer ear and the face.

Minor Malformations

Minor malformations can be present when there is a normal outer ear canal and a normal or nearly normal tympanic membrane. Patients can have had a conductive unilateral or bilateral hearing loss since birth. High-resolution computerized tomography scans should be scrutinized for abnormalities of the internal auditory canal, with the possibility of a gusher, which is seen in 2% of our material, for the course of the facial nerve and for abnormalities of the ossicles (**Fig. 27.1a**). Three-dimensional reconstruction can be helpful in selected cases (**Fig. 27.1b**; courtesy of PD Dr. Randolf Klingbiel, Department of Neuroradiology, Charité, Berlin). Stapes fixation is the most frequent finding (41%) and can be treated as in otosclerosis surgery. A malformed stapes or a stapes remnant may be found at the site of the oval window which is ossified. However, malformations of the other ossicles can be found in different combinations. Behind an intact tympanic membrane, which may be smaller than normal, abnormalities can be seen: of the incus and stapes in 31% of cases and of the complete chain in 11% of cases. In other malformations, the malleus, the malleus and incus, malleus and stapes or malleus alone may be affected. Reconstruction procedures depend on the extent of the malformation and the necessity for chain reconstruction using techniques as described in the tympanoplasty chapters.

A persisting stapedial artery is found in 4% of malformations. The artery can be coagulated.

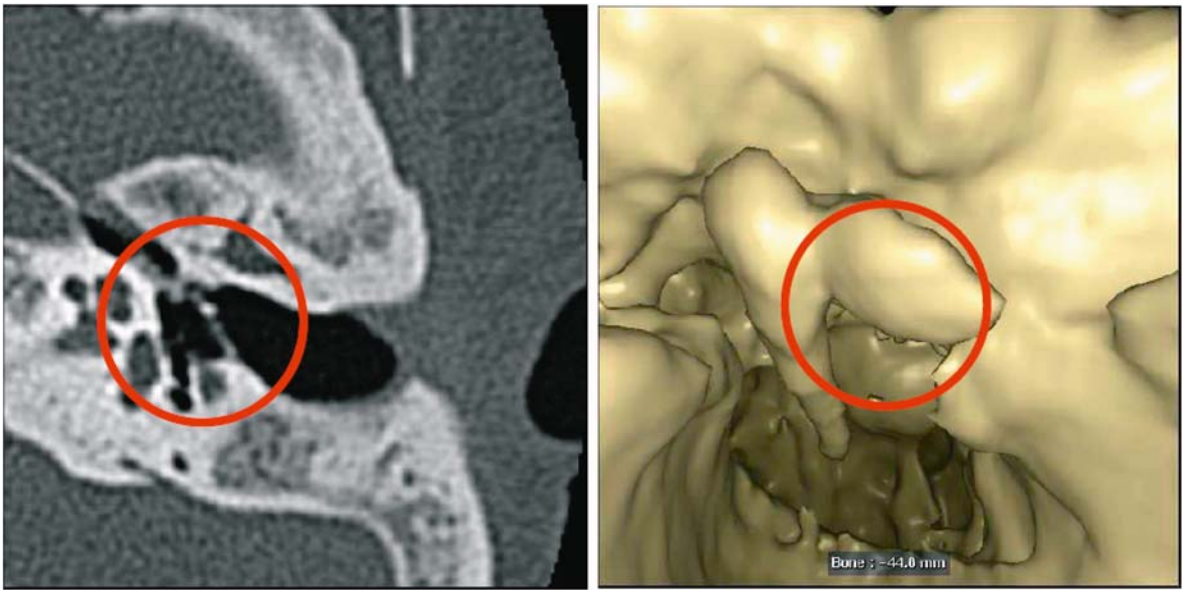


Fig. 27.1a **b**

The occlusion of the round window can be opened by drilling; however, the opening generally recloses.

For surgery an endaural approach is chosen. Sometimes the outer ear canal is narrow and has to be widened after elevation of the skin. The skin of the posterior canal wall can either be worked towards the tympanic membrane as a tympanomeatal flap or partially removed and reimplanted as a free flap. For the anterior wall the same procedures are used as for exostosis surgery or for surgery of a protruding anterior meatal wall in tympanoplasty. The skin should be treated gently to avoid postoperative meatal stenosis. Diamond burrs should be used since they are less traumatic to the skin. Cutting burrs cause more turbulence in the water used for irrigation and may draw the skin flap into the revolving burr.

Small Tympanic Membrane

The tympanic membrane may be smaller than normal. In this situation an underlay graft is used after widening the outer ear canal and the posterior rim of the bony frame of the tympanic membrane. If the ossicular chain has to be reconstructed, a cartilage graft may be necessary.

Chain Reconstruction

A fixed stapes is often accompanied by an obliterated footplate. If the inner ear is normal and the round window is open, an opening at the site of the oval window is drilled. The chain is reconstructed according to the techniques used in the surgery of otosclerosis. If possible a prosthesis is crimped to the long process of the incus as in surgery of otosclerosis. If this is impossible, a connection to the handle of the malleus can be made. A total reconstruction with a cartilage footplate in the new oval window is possible but difficult. The hearing results are less reliable.

The facial nerve may have an abnormal course. It should therefore be identified before opening the vestibule. Abnormalities of the course of the facial nerve are found in 10% of cases. The nerve may cover the region of the oval window and make a normal reconstruction impossible. An opening of the basal turn of the scala vestibuli (promontorial window, Plester) is an elegant solution (**Fig. 27.2**). A prosthesis connects the inner ear to the handle of the malleus.

Major Malformations

Major malformations with complete atresia or stenosis of the ear canal can be associated with absence or dysplasia of the outer ear, downwards dislocation of the auricle and facial malformations. Atresia or stenosis is due to the absence or incomplete development of the tympanic bone. Therefore the facial nerve leaves the temporal bone in a different position and turns forwards into the parotid gland higher than normal. With the lack or incomplete development of the tympanic ring, the temporomandibular joint may be positioned more posteriorly and force the surgeon to drill the ear canal more posteriorly than normal (**Fig. 27.3**). This results in a different approach to the middle ear cavity, which is situated more posteriorly, with the centre of the new canal in the region of the lateral semicircular canal and the upper mastoidal portion of the facial nerve.

Timing of Diagnosis

Diagnosis for hearing impaiment should be done immediately after birth. In cases of complete atresia the patient has a conductive hearing loss of 60 dB. Generally the inner ear function is normal.

The child is generally fitted with bone conduction hearing aids as early as possible. Bone anchored hearing aids cannot be fitted at that early stage due to the thinness of the cortical bone.

The parents must be counselled. Hearing and speech development is monitored until the age of 7 years.

The preconditions for surgery are: sufficient inner ear function, a favourable anatomy as seen on computerized tomography and family support with acceptance of the possibility of failure. A reduction of the 60 dB hearing loss to 20 dB is a good result. In cases with malformations of the face or the auricle, planning should be done in cooperation with the plastic and maxillofacial surgeon. Incisions should be made avoiding scars in the regions necessary for reconstruction of the auricle. As Jahrsdorfer indicated in his grading system,

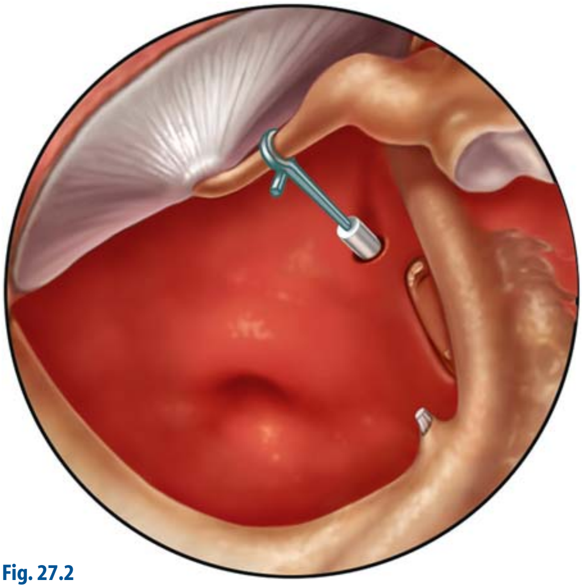


Fig. 27.2

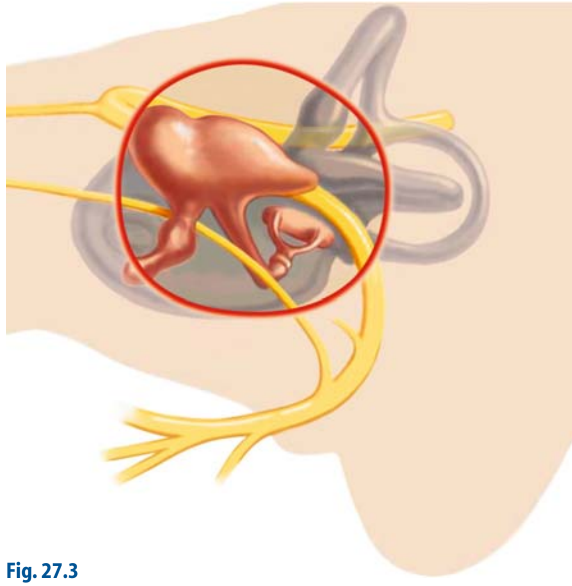


Fig. 27.3

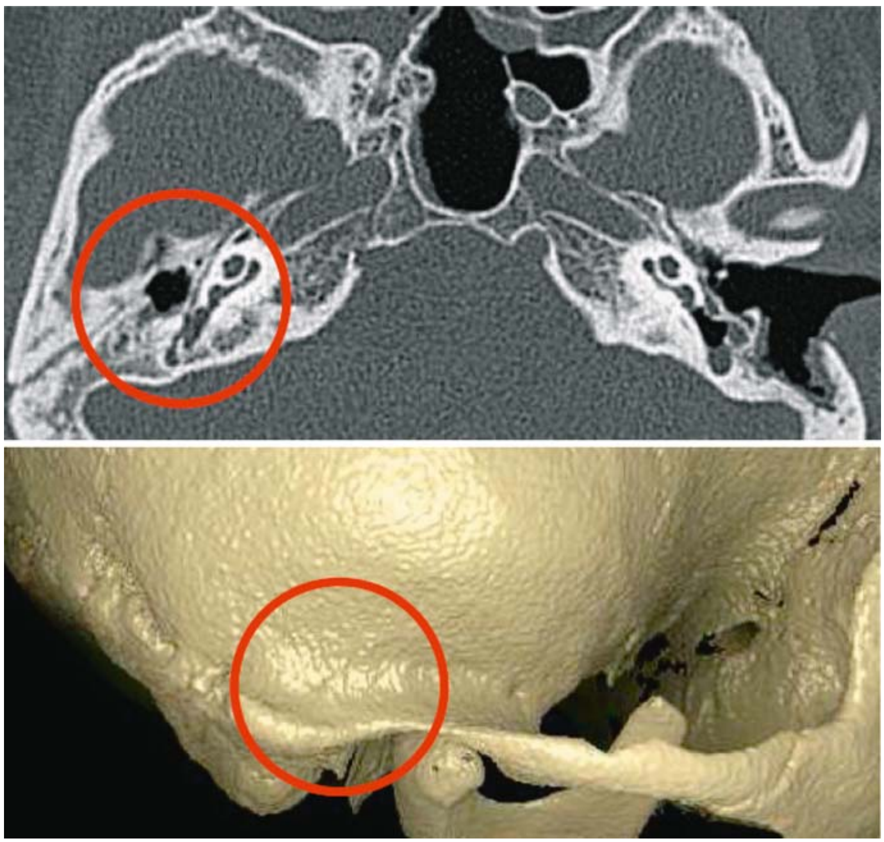


Fig. 27.4a, b

computerized tomography is the basic investigation that determines suitability for surgical reconstruction if the inner ear is normal. The mastoid should be sufficiently large to allow the drilling of a new ear canal. The middle ear must be aerated and have a normal or near normal size. If the stapes is present and the facial nerve is in its normal position, the chances for successful surgery are good. Patients with an unfavourable anatomy are not candidates for surgery. They should be fitted with bone anchored hearing aids.

Computerized tomography on the right (Fig. 27.1) shows a favourable anatomical situation with a normally wide middle ear and a wide mastoid with sufficient space for a new external canal. The narrow middle ear and the lack of space in the mastoid are predictive of there being little chance of successful surgery (**Fig. 27.4a, b**; courtesy of PD Dr. Randolf Klingbiel, Department of Neuroradiology, Charité, Berlin). A bone anchored hearing aid is the better solution.

Surgical Steps and Landmarks

To start with the landmarks are the temporomandibular joint and the tip of the mastoid. The skin is incised behind the temporomandibular joint (**Fig. 27.5a**). If the auricle is present, an endaural incision is done. It should be noted that the auricle may be placed downward in malformations. A circular skin incision in the area of the future auditory canal should ensure a sufficiently wide entrance at the end of the operation (**Fig. 27.5b**). A circular ear canal of 1.5 cm is drilled as close as possible to the temporomandibular joint, leaving a bony partition preventing protrusion of connective tissue. The drill hole finds the antrum with the lateral semicircular canal in the centre. The aditus can be identified and worked forward towards the incus. It is often synostotic with the head of the malleus and varies in shape. The end of the malleus handle is malformed and is fixed to the anterior side of the middle ear cavity (**Fig. 27.5c**). In favourable cases selected as described above the stapes is often intact and mobile. If it is in contact with the incus and the handle of the malleus, the chain can be mobilized and the handle of the malleus detached from the anterior bone of the cavity. The total chain can be used for sound transmission. To prevent noise trauma the separation of the handle is done with a small curette (**Fig. 27.5d**). If the incus and malleus cannot be preserved, reconstruction is more difficult. Prostheses should be used analogous to tympanoplasty techniques. The results are less favourable. The middle ear is closed with palisades or a thin slice of cartilage of the auricle or the ear remnant. This gives a plain tympanic membrane and avoids niches behind the lateral semicircular canal. The ear canal is covered with a split-thickness skin graft as proposed by Jahrsdorfer. The outer skin is sutured to the bone of the entrance of the canal to avoid narrowing and granulations. The graft is covered with silicone and packed.

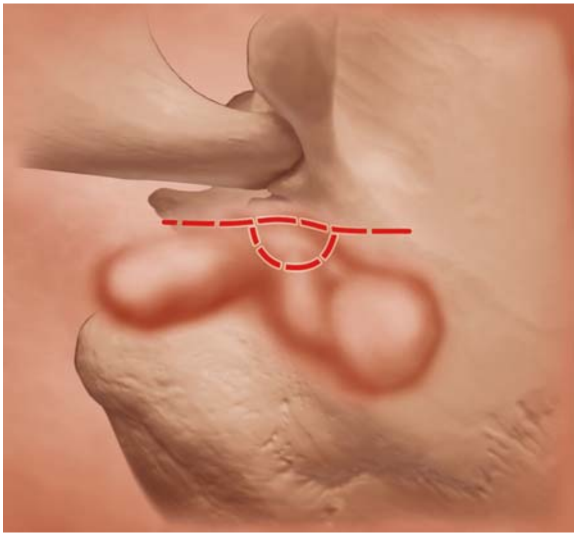
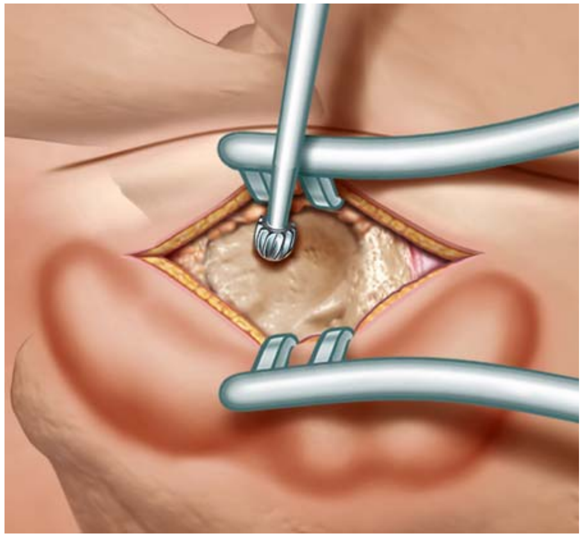


Fig. 27.5a



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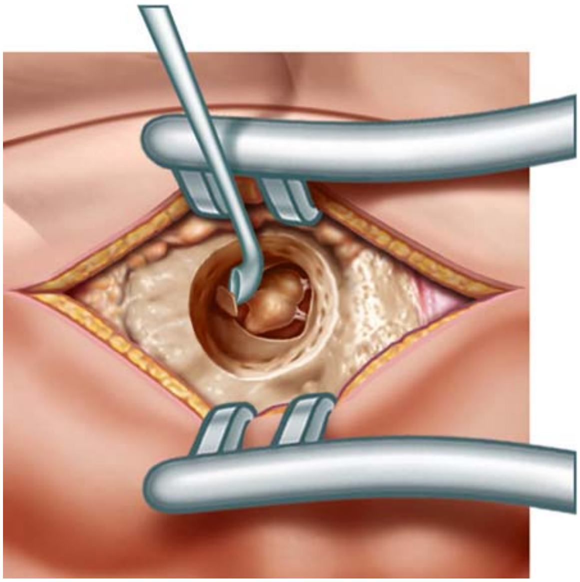

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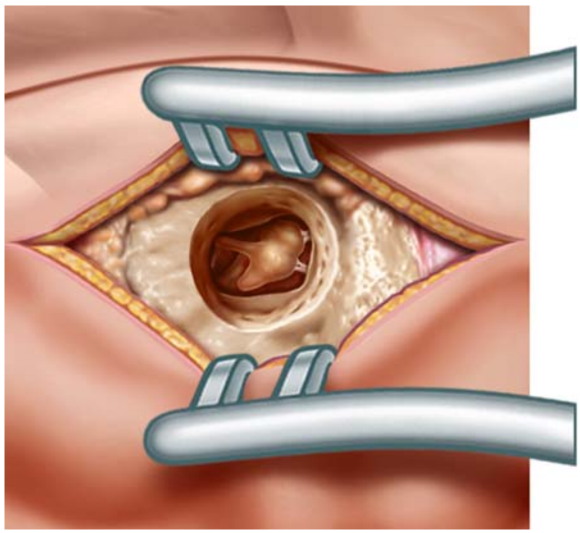

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28 Cochlear Implantation

Stefan Dazert, Holger Sudhoff, Henning Hildmann

The surgical technique for cochlear implantation described is the standard procedure performed in our department and has been proven to be reliable and safe for many years. We propose a cochlear implant (CI) electrode placement through a transmastoid–facial recess approach and a cochleostomy in the promontory. This method is applied both in children and in adults. An infected ear should not be implanted. However, a non-purulent middle ear effusion does not seem to cause problems. A pneumoccal and *Haemophilus* vaccination is generally recommended in children before implantation. In children not previously vaccinated, vaccination after surgery is recommended to reduce the risk of bacterial meningitis.

Surgical Approach

The majority of surgeons use the transmastoid approach and the introduction of the electrode through the facial recess as described below.

Cochlear implant surgery is routinely performed with the patient under general anaesthesia. Hair is shaved about 2 cm above and about 4 cm behind the ear. Prior to the skin incision, the position of the internal receiver should be chosen in such a way that it does not interfere with the external processor behind the ear. The skin incision is performed as indicated in the drawing (**Fig. 28.1**). Different products require slightly different size incisions. However, in our opinion the importance of extremely small incisions is overstressed at the moment. A good overview of the surgical field is more important than an incision a little smaller. Flap necroses do not occur with the described incision.

Raising of the Flaps

An external skin muscle periostium flap is raised, exposing the bone of the skull above the mastoid area. In adults a thick flap must be thinned over the implant area by excising parts of the muscle if the thickness exceeds 7 mm. The decreased thickness of the flap covering the receiver improves the magnet fixation of the speech processor and supports the transcutaneous information transfer.

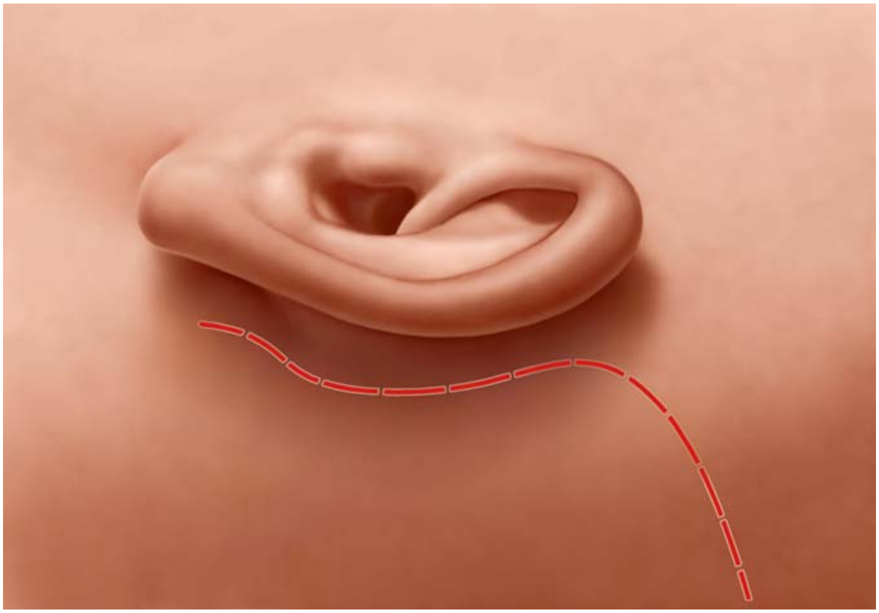

Fig. 28.1

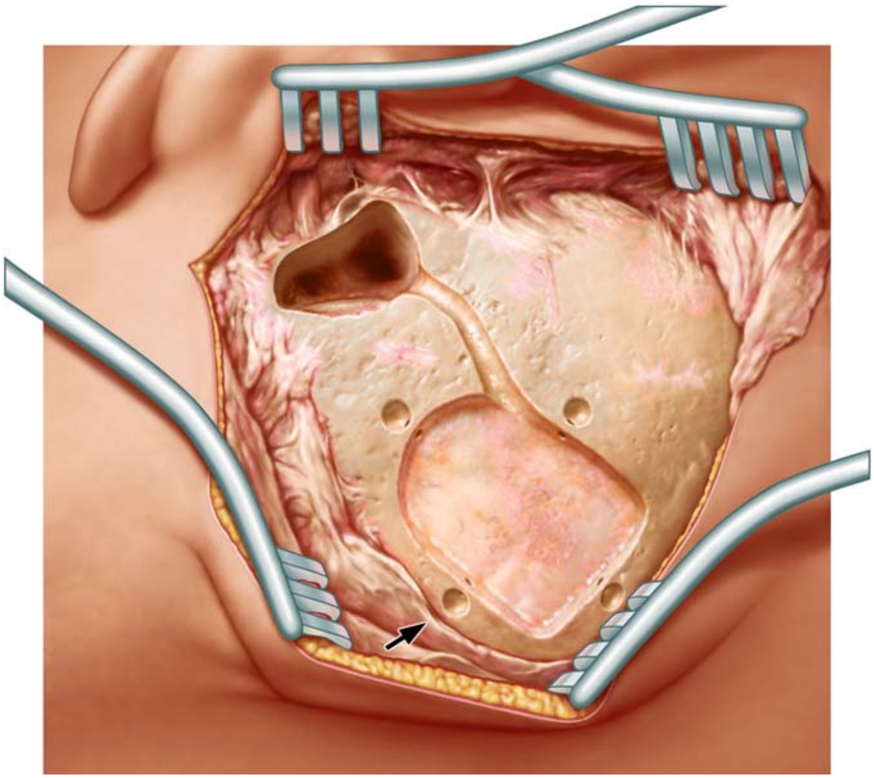

Fig. 28.2

Preparation of the Implant Bed for the Receiver

The entrance of the outer ear canal is identified by showing the spine of Henle. Next, the site for the internal receiver inside the skull is prepared using cutting and diamond burrs. The bony excavation is drilled according to the shape of the provided template (**Fig. 28.2**). As shown in the drawing, burr holes are drilled at the border of the implant bed for the sutures fixing the implant. The surgical procedure for the different products is basically identical, but since the size of the implant and the size of the electrodes vary, the size of the implant bed and the handling of the electrode differ slightly (**Figs. 28.2, 28.3**). Drilling the posterior hole needs a larger exposure. Therefore we often use the periosteum behind the implant bed for posterior placement of the fixing suture. Just showing the implant under the periosteum does not seem sufficient for us because the implant may displace. More important is the prominence, especially in children, and the greater chance of damage due to trauma. A groove is drilled into the bone to lead the electrode from the bony seat of the receiver to the mastoid cavity. The size of the bed and the amount of bone work vary according to the different types of implants. However, we believe that an implant bed must be prepared in the bone to avoid prominence of the implant. This increases the risk of damage due to trauma especially in children.

Mastoid Work

A typical cortical mastoidectomy is done after identification of the spine of Henle and the temporal line. The landmarks are consecutively exposed and identified: the sigmoid sinus, the bone covering the middle fossa, the lateral semicircular canal and the short process of the incus.

Posterior Tympanotomy

The facial nerve must be identified under a thin layer of bone before opening the facial recess between the facial nerve and the chorda tympani, which usually can be preserved. This has become more important since bilateral implantation has proven to be advantageous, especially with background noise. The facial recess is widened inferiorly and posteriorly, respecting the previously identified facial nerve. The distal end of the long process of the incus, the incudostapedial joint, the stapedial tendon, the promontory and the round window niche are seen. Under unfavourable anatomical conditions the round window cannot be identified under the facial nerve. During the drilling procedure, continuous irrigation is of great importance in removing bone dust and avoiding heat damage to the surrounding tissues especially to the facial nerve. The revolving shaft of the burr must not touch the nerve or the bone covering it.

The bony buttress between the facial recess and fossa incudis is preserved by most surgeons and this is the standard procedure. The buttress is used to fix

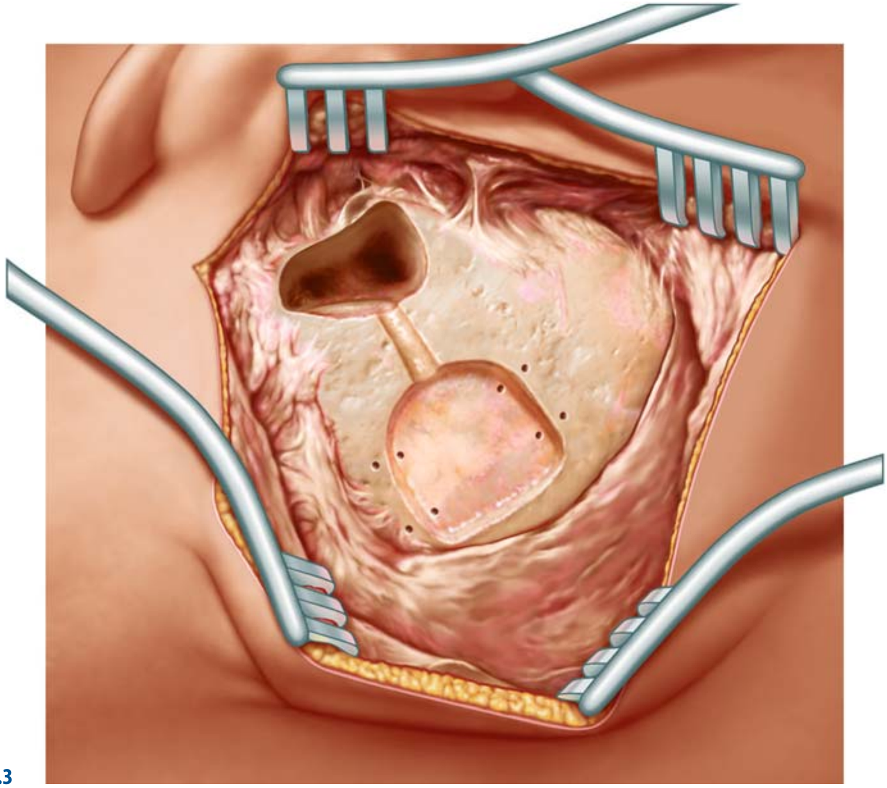

Fig. 28.3

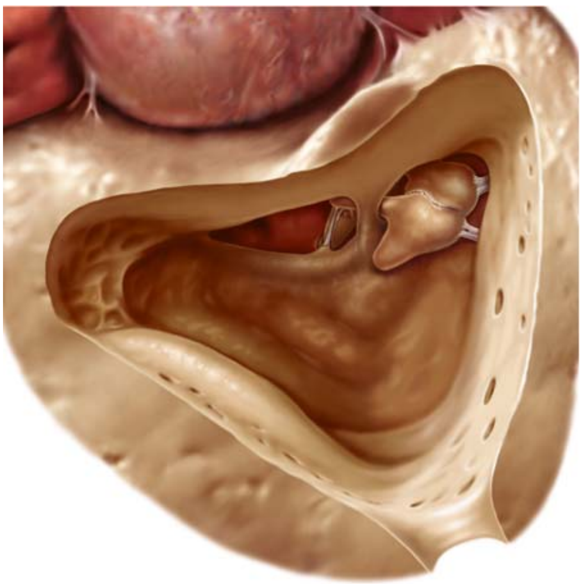

Fig. 28.4

the CI electrode. Revisions have shown that this fixation is not necessary. Consequently it may be removed if necessary. This can be helpful in unclear anatomical situations. The incus is exposed and the fossa incudis opened following the long process of the incus. This procedure protects the underlying facial nerve (**Fig. 28.4**). If necessary the long process of the incus can be removed, but the annulus of the tympanic membrane and the posterior meatal wall need to remain intact during this procedure.

Cochleostomy

To determine the precise location of the cochleostomy, the burr hole on the promontory is placed according to Helms at a distance twice the diameter of the head of the stapes (**Fig. 28.5**). The cochleostomy towards the scala tympani is drilled through the posterior tympanotomy without touching the facial nerve with the 1.2-mm diamond. During this phase of surgery the shaft of the diamond burr is close to the facial nerve and may cause heat damage while the surgeon is concentrating on the promontory. The position of the cochlea in relation to the axle of the temporal bone varies slightly. A larger diamond burr can be used on the promontory until the grey white endostium of the cochlea is seen. The cochlea is opened with a smaller diamond burr. A small hook may also be used. The edges of the opening to the basal coil of the cochlea must be smoothened. This makes the insertion easier and avoids bending of the electrode during insertion. Bone dust should not enter the cochlea to reduce the risk of ossification, which may make revisions, and reinsertion of a new electrode, impossible. The position of the electrode must be clearly seen within the cochleostoma and routinely checked before proceeding to avoid false placement of the electrode (**Fig. 28.6**). The insertion of the electrode into the cochlea through the round window is no longer used because the electrode has to be bent to follow the course of the cochlea. The area of the round window should remain intact.

Placement of the Receiver and Electrode Insertion

Prior to electrode insertion, the internal receiver is secured inside its bony bed by sutures and the neutral electrode is positioned under the temporal muscle and the periostium with contact to the bone for the MEDEL and Nucleus Systems (**Figs. 28.7, 28.8**). If the electrode is placed on the muscle, it moves while the patient chews. This will cause a break of the electrode. The cochlear electrode is then gently inserted into the scala tympani via the cochleostoma without any administration of force. We like to use a long straight forceps. After full electrode insertion, pieces of soft tissue are placed around the electrode at the cochleostomy site to create a seal and prevent labyrinthitis.

In cochlear implantation, open communication with the endocranial space is more common than in otosclerosis patients. If the liquorrhoea cannot be stopped by sealing with connective tissue (too much force can damage the

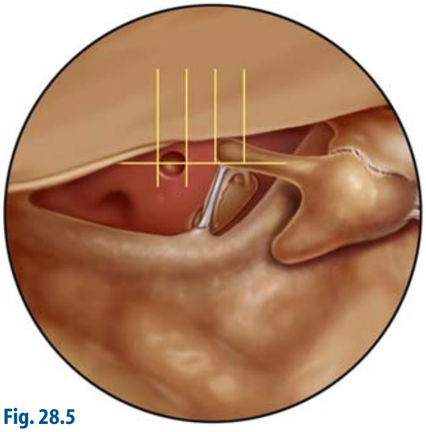

Fig. 28.5

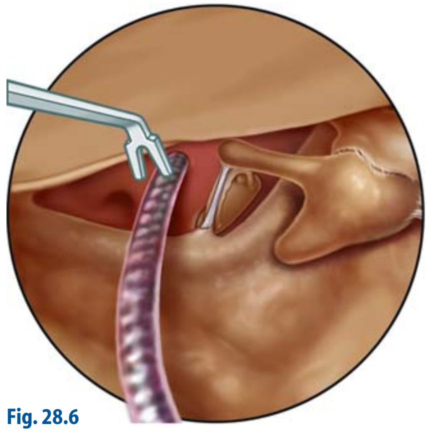

Fig. 28.6

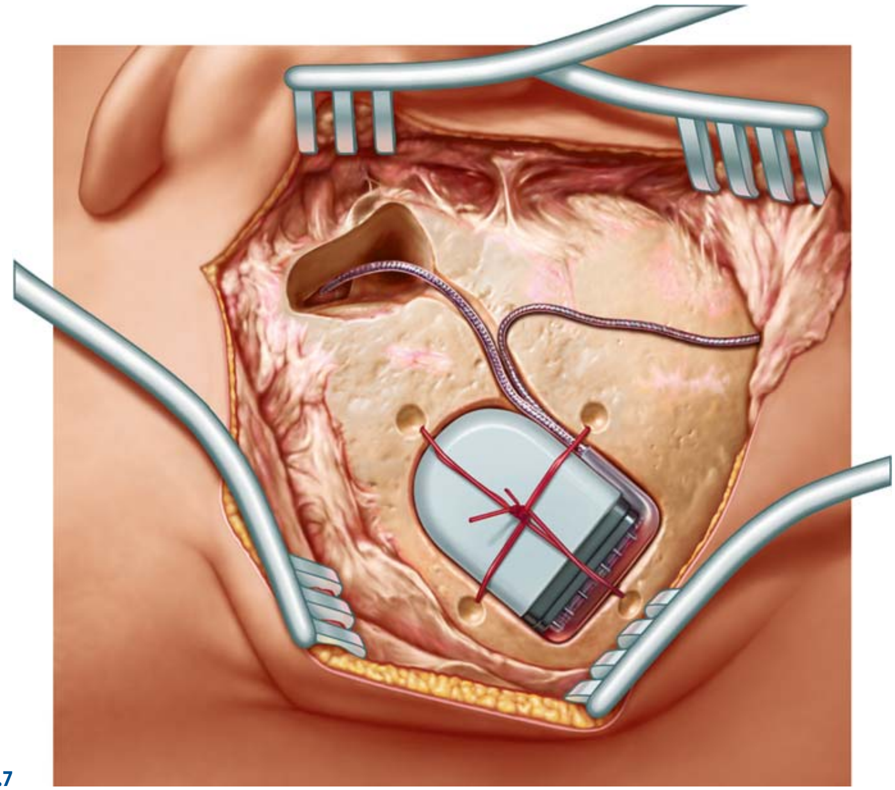

Fig. 28.7

electrode), we inject fibrin glue into the cochlea and insert the electrode immediately afterwards before the fibrin coagulates. This is effective in stopping the liquorrhoea. However, we do not know yet whether this technique may cause problems in revisions.

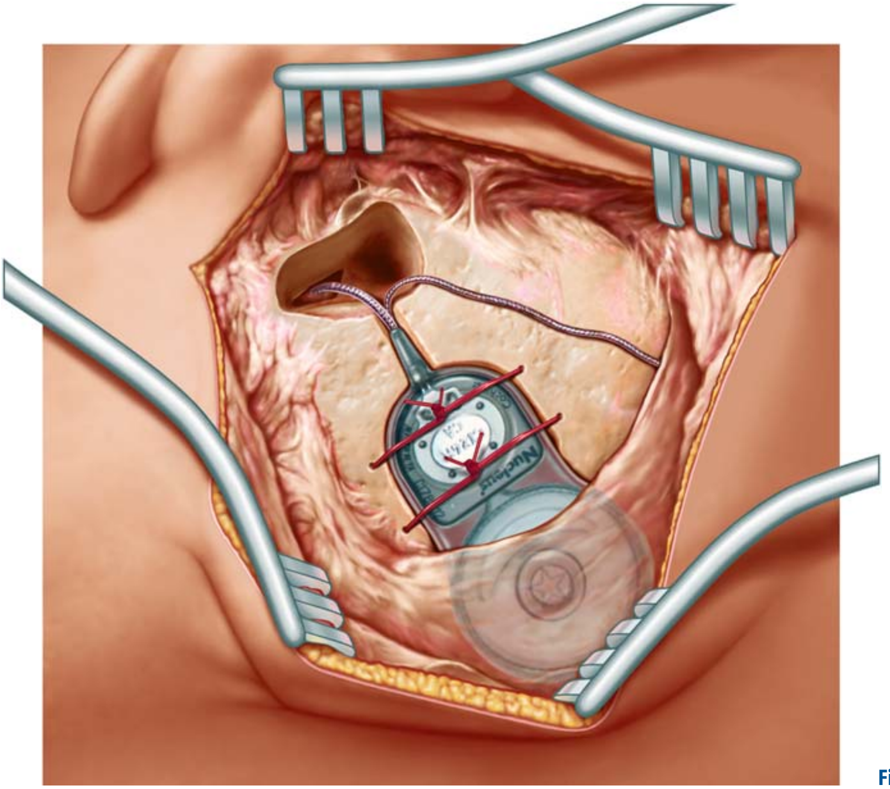

Fig. 28.8

Closure

The periostial flap then replaced over the receiver implant, and the wound is closed by suturing the skin muscle flap. Rubber foam under the ear bandage is useful as it applies slight pressure and prevents haematomas.

Mastoiditis

If mastoiditis develops on the implanted side, the indication for opening the mastoid is the same as in other patients. The surgeon should obtain a lateral skull X-ray and a computed tomography scan to identify the exact position of the electrodes. Normally the implant does not have to be removed unless there are signs of labyrinthitis. If labyrinthitis is suspected the diagnosis is difficult, due to the absence the usual signs such as inner ear hearing loss and vertigo. The lateral semicircular canal may be diagnostically opened.

29 Revision Surgery After Cochlear Implantation

Joachim Müller, Holger Sudhoff, Henning Hildmann

For decades cochlear implants have been the standard treatment for deaf adults, teenagers, and children. As with all technical devices, the lifetime of cochlear implants is limited, and as with all surgical procedures, complications during or after cochlear implantation may occur. Also malfunction of the device may happen earlier than expected due to device failure or for other reasons.

In the literature cochlear implant failure rates or revision rates vary from ~2 % to 18 %. A direct comparison of revision rates or failure rates published in the literature or given by the manufacturers is practically impossible on account of the different inclusion criteria and the extreme variations in data sources (such as different age groups: adults or children, implant generations, sample size, period under review). For detailed failure analysis it is necessary to specify implant failures more precisely and to differentiate between "patient related failures" and "failures which come within the manufacturer's field of responsibility".

Revision Surgery Can Become Necessary for Several Reasons

Medical Reasons

Medical reasons are all those related to surgery including flap problems, infections, surgical complications, incorrect positioning of the active or reference electrode, failures following fixation of the electrode, meningitis cases or cochlear implantation due to incorrect diagnosis.

Electronic Failures

Failures of the implant system can be due to electronic faults.

Trauma

An external trauma may lead to a fracture of the cochlear implant, such as may occur with ceramic implants, or may result in a broken housing, which was previously described to result from external forces in implants with metal housings.

Electrode Failures

A trauma can also damage the electrode and lead to fractures of the electrode wires. This category also includes damage to the electrode during insertion or surgery.

Soft Failures

With increasing numbers of implantations we may be faced with a new category of "soft failures" which lead to revision. This includes revisions where the patient complains about clinical symptoms of malfunction and postoperative device testing showed device function within the manufacturer's specifications. In general it can be said that trauma is a common reason for revision surgery.

Cochlear implant revision seems to occur more often in children than in adults.

Lower revision rates for the latest implant generations reflect the increasing surgical expertise and the continuous modifications and improvements in cochlear implant hardware made by the manufacturers. Recent studies on the latest implant generation showed remarkably low failure rates of less than 2% in Würzburg.

During revision surgery, the reinsertion of the new electrode remains the crucial point. For the Nucleus System it has been reported in the literature that in 7% of reimplantations the insertion of the new electrode was limited [1], whereas other studies found that the reinsertion of the electrode carrier in 21 revisions was as deep as achieved in primary surgery. In single cases an even deeper electrode insertion was observed during upgrade surgery. In principle, the risk and the tendency of ossification of the basal turn of the cochlea remain possible. It has been discussed that the initial insertion trauma may lead to ossification and impedes reimplantation. There is a small chance of this but the option for implanting the contralateral side should be mentioned before surgery. Usually, a soft tissue tube surrounds the electrode carrier. This soft tissue envelope also protects against infection from the middle ear to the inner ear at the side of the cochleostoma.

Especially in children the mastoid plane shows a high tendency for neo-osteogenesis and ossification. The new bone formation may close the cavity partially or completely and surround the electrode on its way into the mastoid. We have never, however, observed bone new formation in the cavity or in the facial recess.

New bone formation may also cover parts of the implant housing. Bony fixation of the electrode carrier inside the growing mastoid does not usually present any difficulties.

It is important to do all the preparations during revision surgery systematically and leave the electrode carrier in place. As a last step the electrode should be removed and the new electrode should be introduced immediately to avoid a collapse of the soft tissue tube around the electrode.

In general, the aim is to remove the implant completely without cutting off any of the electrodes or damaging the device to allow for postoperative evaluation. However, in selected cases it can be helpful to cut off the active electrode at the side of the facial recess to facilitate better preparations in the mastoid and the facial recess.

Generally, reimplantation should be performed immediately after confirmation of the device failure. If reimplantation is not possible on the previously operated side, the patient should be informed about the possibility of implantation of the contralateral side.

With the tendency to implant more and more younger children, the number of cochlear implantees at very young ages is increasing. Thus we are faced with a population that is frequently experiencing courses of otitis media. This may result in the necessity for surgical interventions due to otitis media or mastoiditis as in children without cochlear implants. As in every case of purulent mastoiditis, mastoiditis in cochlear implant patients should also be immediately treated surgically. Draining the mastoid and removing the inflammatory tissue is mandatory. Depending on the individual situation the device can be left in place. If not, the electrode carrier should be cut off and left as a placeholder inside the cochlea to allow for a later reinsertion of a new device. An involvement of the cochlea or the labyrinth seems to be extremely rare. We should keep in mind, however, that the typical clinical symptoms – vertigo, tinnitus and hearing loss – cannot be observed.

30 Labyrinthectomy

Henning Hildmann

Definition

- Removal of the labyrinthine portion of the inner ear with opening of the vestibule and destruction of the neuroepithelium

Indications

- Labyrinthectomy – purulent labyrinthitis
- Extended cholesteatoma
- Malignant lesions
- Vestibular vertigo without serviceable hearing
- First step of approach to the internal auditory canal

Surgical Procedure

1. Extensive mastoidectomy with modelling of the sinus dura angle, the bony covering of the sigmoid sinus and the posterior fossa. The posterior meatal wall is thinned. The attic is opened to visualize the head of the malleus and the body of the incus. This is impossible in a sclerosed mastoid and a low middle fossa. A wide exposure facilitates the orientation.

2. Identification of the lateral semicircular canal and the mastoid portion of the facial nerve. For the less experienced it is helpful to identify the facial nerve in its mastoidal course by drilling the bone over the nerve until it is seen under the remaining thin layer of bone. A diamond drill larger than the diameter of the nerve should be used to reduce the danger of injury. The drilling must be performed parallel to the course of the nerve.

3. Identification of the superior and posterior canal and the subarcuate fossa with the artery.

4. Opening of the canals with a cutting burr preserving the medial part for orientation. The common crus of the posterior and superior canals are identified. The ampullae of the superior and lateral semicircular canal are lateral to the facial nerve. The medial fossa may bulge into the mastoid lateral to the superior semicircular canal. The dura should not be damaged.

5. The semicircular canals are removed and the vestibulum is widely opened. The vestibulum and the ampulla of the posterior canal are situated under the facial nerve. The superior vestibular nerve can be seen as a

white structure. It protects the facial nerve and indicates the superior end of the internal auditory canal.

All sensory structures should be removed in vertigo cases. The sacculus and utriculus are removed from the vestibulum with a hook. For purulent labyrinthitis it may additionally be necessary to open the cochlea, removing the stapes and drilling away the bridge between the round and the oval window.

Labyrinthectomy is the first step for vestibular neurectomy. The illustrations for this procedure are found the next chapter.

31 Vestibular Neurectomy – Translabyrinthine Approach

Henning Hildmann

Indications

- Vestibular vertigo and unserviceable hearing, temporal bone fractures with injuries of the facial nerve

Contraindications

- Infections of the mastoid and the middle ear

Surgical Steps

1. Extended mastoidectomy is performed. The sinus, media and posterior fossa are identified under a thin layer of bone as well as the body of the incus and the semicircular canals (**Fig. 31.1**). The nerve is identified in its mastoidal portion using a drill larger than the diameter of the nerve and drilling in the direction of the course of the nerve. A thin cover of bone protects the nerve from injury during the following steps. Before opening the internal auditory canal a good exposure of the surgical site is important. It should be larger than for a labyrinthectomy. The infra-, supra- and retrolabyrinthine cells are removed to model the semicircular canals to identify the landmarks for the next steps. The cavity is drilled downwards. The jugular bulb, which is very variable in height, may be reached. Generally it is more anteriorly situated. Its exposure is not mandatory as in tumour surgery. The cochlear aqueduct, which lies frontally above the jugular bulb, should be respected. The glossopharyngeal nerve exits the posterior cranial fossa immediately underneath and may be injured. If the sinus is protruding, the covering bone may be thinned and fractured backwards. After removal of the incus and if possible the head of the malleus the facial recess is opened and the facial nerve can be seen above the oval window. This helps to control the course of the nerve (**Fig. 31.2**). In a well-pneumatized temporal bone it can be followed to the cochleariform process.

2. The lateral semicircular canal is opened followed by opening of the posterior and superior semicircular canals. They should not be drilled away completely at this stage because they serve as landmarks. The ampulla of the superior canal protects the facial nerve (**Fig. 31.3**).

Fig. 31.1

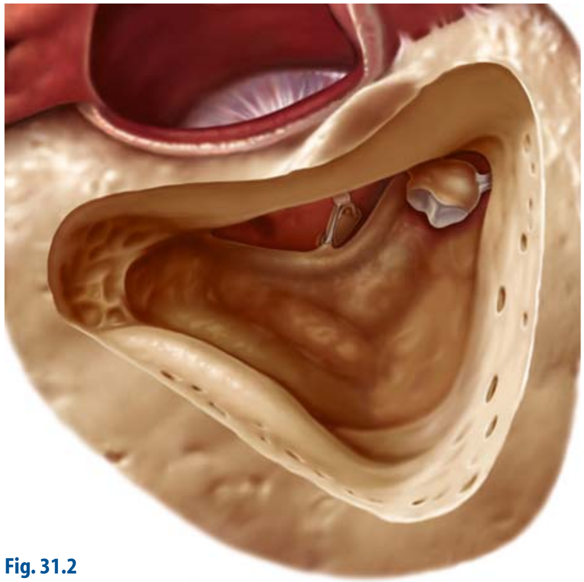

Fig. 31.2

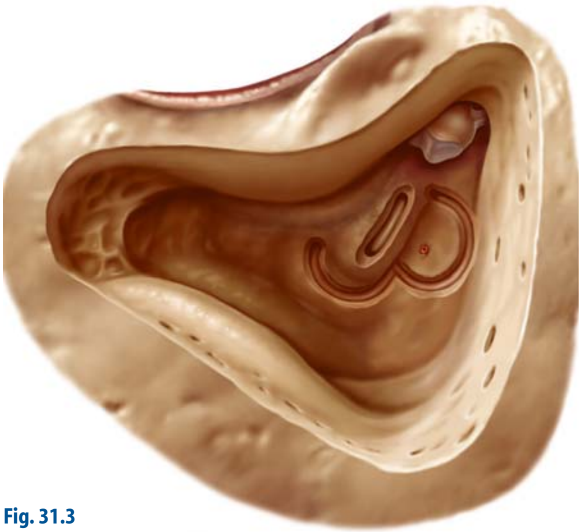

Fig. 31.3

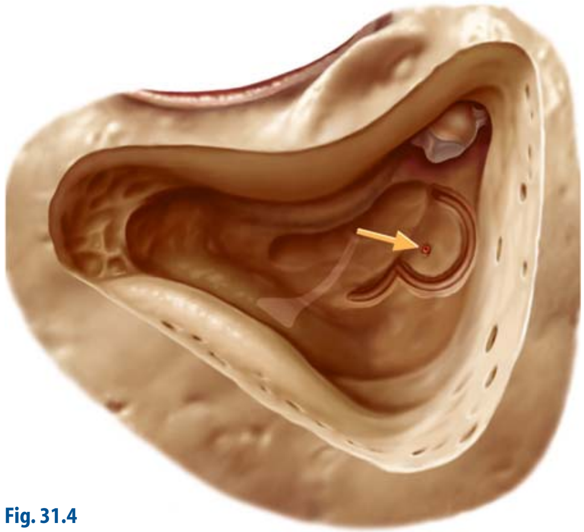

Fig. 31.4

3. The subarcuate artery is identified, bleeding may be controlled with a slowly revolving diamond drill or bipolar coagulation, and the lateral canal is removed. The vestibule is opened. After removal of the posterior canal the endolymphatic duct leading from the vestibule to the endolymphatic sac can be seen. There is a risk of the shaft of the drill contacting the facial nerve and causing heat damage (**Fig. 31.4**). After removing the bone over the lateral and superior ampulla superiorly and the ampulla of the posterior canal

inferiorly, the nerve ends of the superior and lateral ampullary branch can be seen superiorly and the singular nerve (to the posterior ampulla) inferiorly. The nerves outline the upper and lower limits of the internal auditory canal. The upper vestibular nerve is located lateral to the facial nerve and protects the nerve from injury in this region.

4. While the fundus of the internal auditory canal is located immediately under the vestibulum, its porus to the posterior fossa is about 1 cm more medial under hard bone. The exposure requires patient drilling. The dura of the internal auditory canal should not be opened to protect the nerves. The bone above and below the canal is removed generously downwards to the jugular bulb and upwards to the bone covering the dura of the middle fossa. The canal remains covered with a thin layer of bone and is exposed in about half of its circumference, about 180 degrees, before removing the remaining bone and opening the dura because after opening the escaping cerebrospinal fluid may push the facial nerve into the operation field and the revolving drill. Drilling may become dangerous. Towards the posterior fossa the dura may be exposed. However, wide exposure as in acoustic neuroma surgery is not necessary. The bone covering the dura of the canal is lifted off with a curette (**Fig. 31.5**).

5. The dura is incised and the nerves are seen. The vertical crest separates the facial nerve from the vestibular nerves (**Fig. 31.6**). The VIIth nerve must be identified before proceeding. If identification is difficult the bone covering the nerve in its labyrinthine portion may be carefully thinned. A nerve monitor should be used. Towards the fundus the end of the internal auditory canal and the transverse crest are identified. The vertical crest separates the vestibular nerves. The posterior ampullary nerve, part of the inferior vestibular nerve, is found inferior to the crest (**Fig. 31.7**).

6. After clear identification the nerves are cut towards the fundus and are separated with a hook (**Fig. 31.8**).

7. The internal auditory canal is closed with fascia and covered with abdominal fat. Fibrin glue is used.

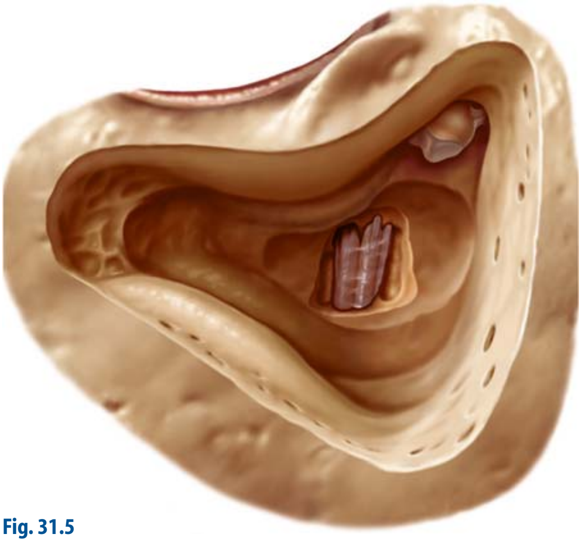

Fig. 31.5

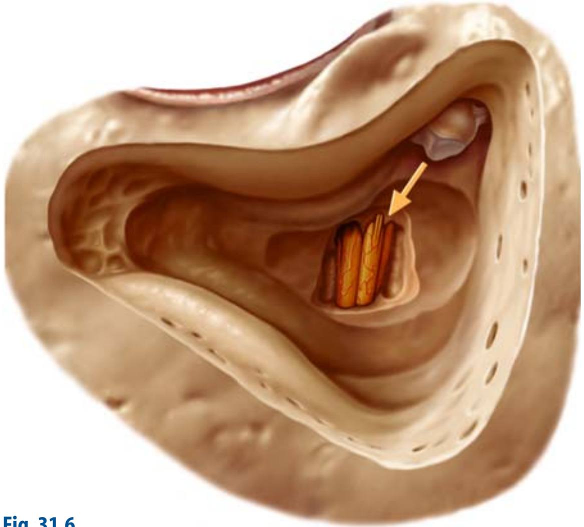

Fig. 31.6

→ vertical crest

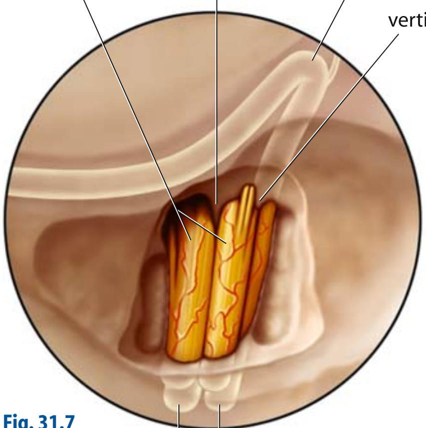

Fig. 31.7

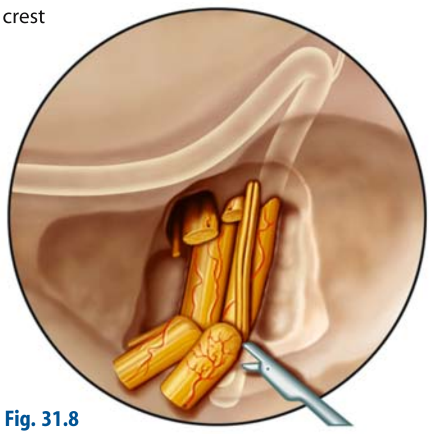

Fig. 31.8

32 Vestibular Neurectomy – Transtemporal Approach

Henning Hildmann

Indications

The vestibular neurectomy approach is used for surgical treatment of vestibular vertigo in patients with preserved hearing, especially Meniere's disease, temporal bone fractures with facial nerve damage in the region of the geniculate ganglion, supralabyrinthine cholesteatomas, cholesterol granulomas and CSF leaks from the middle cranial fossa; this approach is also used for the surgery of small acoustic neuromas. Acoustic neuroma surgery is not the subject of this book.

The internal auditory canal and its contents are exposed without compromising the labyrinth or the cochlea. The facial and cochlear nerve can be preserved.

Contraindications

- Infections of the middle ear or the mastoid. Patients over the age of 65 years may have problems due to the compression of the temporal lobe.

Complications

- CSF leak, haematoma, sensorineural hearing loss, facial nerve paralysis, meningitis.

Anatomy

The superior semicircular canal is used for orientation. In a pneumatized mastoid it is hidden under the supralabyrinthine cells. The internal auditory canal forms an angle of 60 degrees with the superior semicircular canal open towards the posterior fossa. The superior petrosal nerve is used as an additional landmark (**Fig. 32.1**). The eminence seen on the superior plane of the temporal bone corresponds to the superior semicircular canal but does not indicate the exact position.

Surgical Procedure

The surgeon sits at the head of the patient. A vertical skin incision is made 8 cm from the root of the zygoma, and the temporalis muscle is exposed. An incision is made to the temporal bone including the periosteum. The crossing branches of the temporal artery need to be ligated. Fascia for covering the internal audi-

Fig. 32.1

tory canal at the end of the operation is harvested. The exposure of the bone is followed by the craniotomy (4 × 4 cm) above the root of the zygoma, two-thirds in front and one-third behind.

The bone is removed by outlining the area with the drill and the dura is detached. The bone vessels and dural attachments are coagulated with bipolar forceps, the drill edges are smoothened and the opening is enlarged caudally towards the upper plane of the temporal bone. After a small incision of the dura to decompress the CSF, it is elevated from the temporal bone. The preparation should not expose the medial meningeal artery and the adjacent veins to avoid bleeding. If necessary the vessels are coagulated and packed with Surgicel. As landmarks the posterior edge of the petrous bone with the superior petrous sinus and the greater superior petrosal nerve are identified.

The dura is detached from the superior plane of the temporal bone working from back to front. In some cases the geniculate ganglion is not covered by bone.

The House-Fisch retractor is positioned (**Fig. 32.2**) and is tightly fitted in the craniotomy. The retractor blade is slowly advanced medially, its centre situated above the sulcus of the major petrosal nerve in contact with the medial surface of the pyramid. The dura of the temporal lobe should not be elevated more than 15 mm to avoid brain damage.

The arcuate eminence is sometimes difficult to see and does not always correspond directly to the superior semicircular canal. Overlying air cells may cause difficulties. The area of the eminence should be carefully drilled down, removing bone in a broad plane. The labyrinthine bone appears more yellow than the surrounding bone. The landmark is the blue line of the superior semicircular canal, which has to be clearly identified before proceeding. Drilling near the fundus of the internal auditory canal, the cochlea and the geniculate ganglion should be respected anteriorly as well as the semicircular canal and the vestibule posteriorly. The superior petrosal nerve emerges from the bone anterior to the geniculate ganglion. The thickness of the overlying bone and the distance to the ganglion varies. Extensive preparation to the sides of the surgical field provokes bleeding. Surgical cotton and cauterization become necessary.

The blue line of the superior canal is perpendicular to the superior petrosal sinus. The internal auditory canal meets the anterior end of the superior canal at an angle of 60°. The covering bone is drilled away respecting the cochlea and the labyrinth. A large amount of bone has to be removed. The internal canal appears as a grey area. It should be exposed from the posterior fossa to the fundus. The bone must be removed on the sides of the internal auditory canal exposing as much as possible of the circumference of the canal. This gives more room for the identification of the nerve. Especially close to the fundus the field is limited by the superior canal and its ampulla laterally, by the ganglion frontally and by the cochlea medially. A thin shell of bone and the dura must be left intact for as long as possible. Early opening of the internal auditory canal causes a flow of CSF. As a consequence drilling becomes more dangerous because the facial nerve is not protected by the dura. The turbulence in the CSF caused by the drill may pull the nerve into the revolving instrument. Only after complete removal of the bone is the dura exposed without opening and followed to the entrance of the facial nerve, which might be identified under the bone in its labyrinthine portion before entering the fundus (**Fig. 32.3**). The position of the superior petrosal nerve may be a help in estimating the position of the ganglion. A nerve monitor is used.

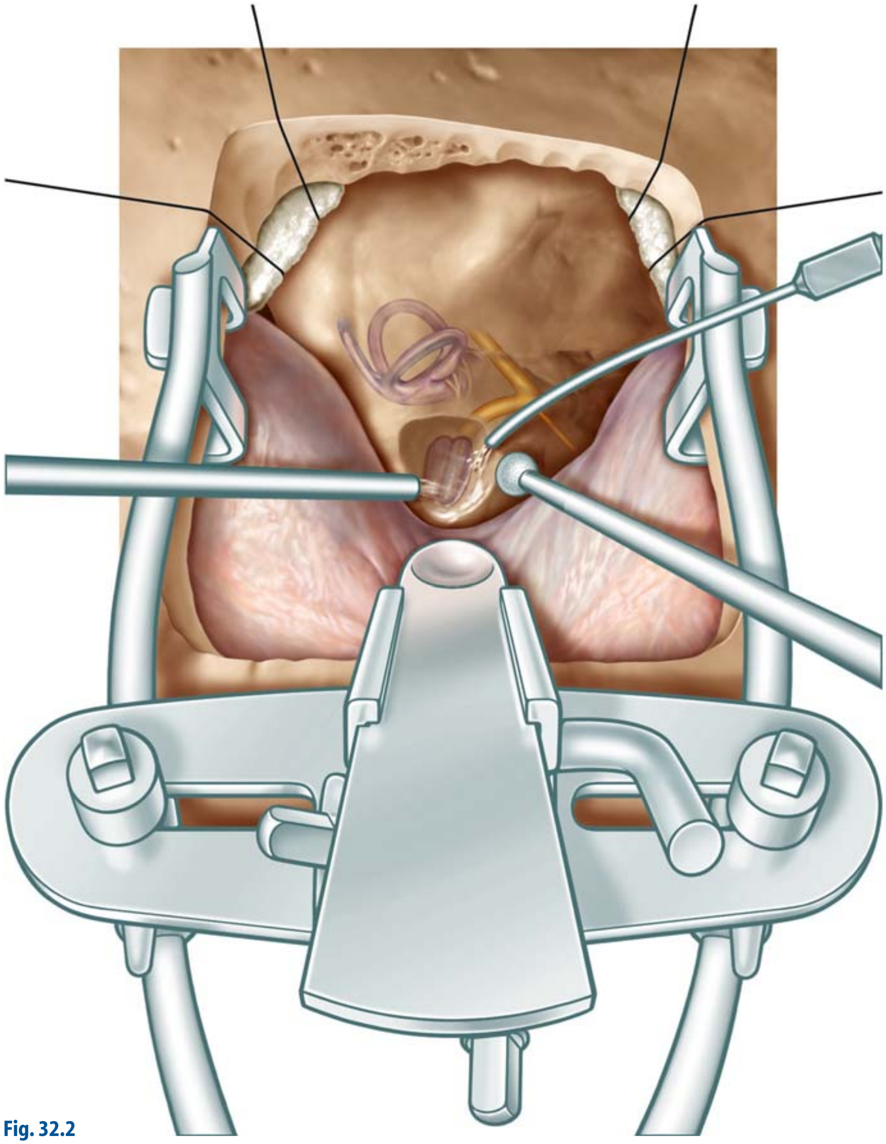

Fig. 32.2

After the opening of the dura the CSF may flush the nerves into the region of drilling. Injury is possible. The vertical crest (Bill's bar) and the entrance of the facial nerve into its labyrinthine course are identified. The nerve can be followed towards the posterior fossa. In acoustic neuroma surgery the position may be altered by the tumour.

The facial nerve must be clearly identified. The connections to the vestibular nerve are separated. Then the superior vestibular nerve can be sectioned

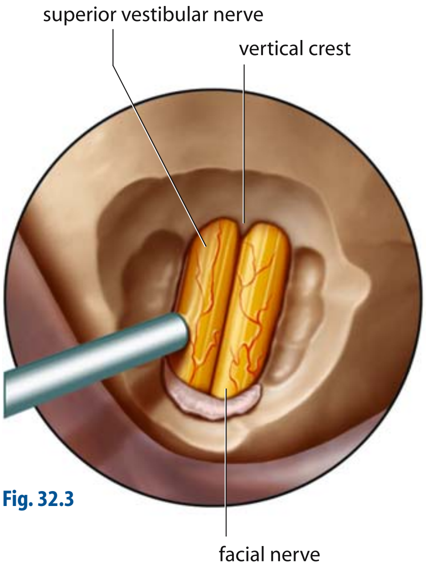

Fig. 32.3

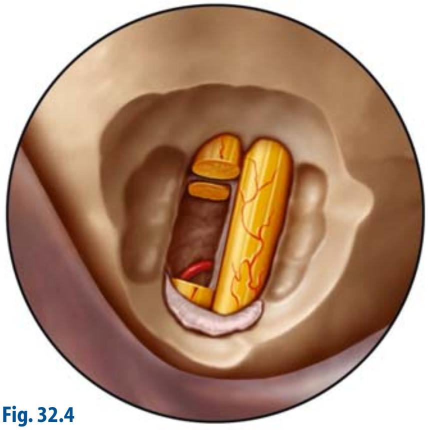

Fig. 32.4

followed by sectioning of the inferior nerve including the ganglion. Sharp dissection is preferable to prevent injury of vessels serving the cochlea nerve. Small vessels on the vestibular nerve are cauterized with bipolar forceps (**Fig. 32.4**).

The defect is closed with fascia and a muscle graft stabilized by fibrin glue. The bone removed by the craniotomy is replaced after suture of the dura incision. The covering tissue layers are sutured.

33 Retrosigmoidal Approach

Martin Scholz

Introduction

The vestibulocochlear nerve is composed of three parts: the inferior and superior vestibular nerves and the cochlear nerve. The two vestibular nerves fuse to become one nerve before they exit from the internal acoustic meatus. The vestibular nerve and cochlear nerve join to form the eight cranial nerves closer to the brain stem. Indications for the suboccipital retrosigmoidal approach to the vestibular nerve are extremely rare. Only limited clinical experience has been gained with microvascular decompression of the vestibulocochlear nerve for the treatment of tinnitus or vertigo. The procedure of cutting the vestibular nerve as a treatment for therapy-resistant vertigo should be used only in a small group of selected patients who have failed to respond to all other therapeutic modalities.

Surgical Procedure

Positioning

The operation can be carried out with the patient in a sitting or lateral position at the surgeon's discretion.

Sitting Position

In our opinion surgery performed for the treatment of complex cerebellopontine angle tumours should be carried out with the patient in a sitting position if the suboccipital retrosigmoidal approach is used. This approach offers perfect conditions for microsurgical manipulations since all fluid (e.g. blood) rinses out of the operative field. The surgeon has both hands free for operative manipulations; suction of collected fluid is not necessary. Despite this advantage, however, the sitting position poses the risk of air embolism.

The risk of air embolism can be reduced to nearly zero by optimizing several conditions. We recommend placing a special cushion under the patient's legs in order to lift the legs to the level of the heart and the teeth to the same level as the frontal region. The patient is now no longer sitting but is in more of an embryonic or astronaut position (**Fig. 33.1**). Following this procedure the pressure in the sigmoid sinus is not less than zero and air embolism is extremely rare.

If sinus opening occurs the assistant should rinse the operative field extensively so that fluid and not air will be aspirated by the sinus. If air is detected in the precordial Doppler, it can be aspirated by the anaesthesiologist using the central catheter. If sinus laceration cannot be detected, quick compression of the jugular vein by the anaesthesiologist is sometimes helpful. If depression of the cardiopulmonary circulation results, the head should be positioned lower and the feet higher using the table steering remote control. With this constellation it is necessary to cover the operative field with wet Cottonoid paddies.

With the patient in a sitting position two different devices can be used for the surgeon's armrest. The first device is a special board, connected to the operating table, which can be angled and fixed in different ways to meet the surgeon's individual requirements.

It is important to simulate the surgical procedure and arm position after positioning the patient but before sterile draping in order to create a comfortable situation for the surgeon. The patient's head position can vary according to his or her height. If the patient is sitting too low, it is not possible to collect cerebrospinal fluid. If the patient is sitting very high, in contrast, we have to operate free handed, which is very uncomfortable. The proper adjustment of the patient on the operating table allows the surgeon to proceed in a calm and totally satisfying manner. The other possibility for an armrest is the so-called "chicken ladder" (**Fig. 33.2**). This device is also adjustable; however, it is too narrow and causes pain in the forearm if used for long operations.

During positioning the head of the patient is turned slightly towards the side of the tumour and the chin is angled downwards (cave: compression of the jugular vein).

The risk of air embolism is the reason why the sitting position is rarely used in the United States, the United Kingdom or the Netherlands. Neurosurgeons in these countries prefer the lateral position, which is described in the following.

Lateral Supine Position

In our opinion this position is suitable for microsurgical vestibular neurectomy and is in fact the position of choice for this procedure. The patient selected for this intervention has to be placed in a supine position with a cushion supporting his/her shoulder. The arm should be stretched slightly to the opposite lower corner of the operating table to bring the shoulder out of the surgeon's reach (**Fig. 33.3**). The head is then turned to the opposite side; the chin should be brought upwards. The Mayfield clamp should be adjusted so that it does not hinder later microsurgical manipulations. Using the remote control for the operating table, the surgeon can also turn the patient to the opposite side if necessary. It is important to protect the patient from falling off the table with an additional holding device. If right-sided vestibular nerve neurectomy is planned, the surgeon and assistant surgeon are standing side by

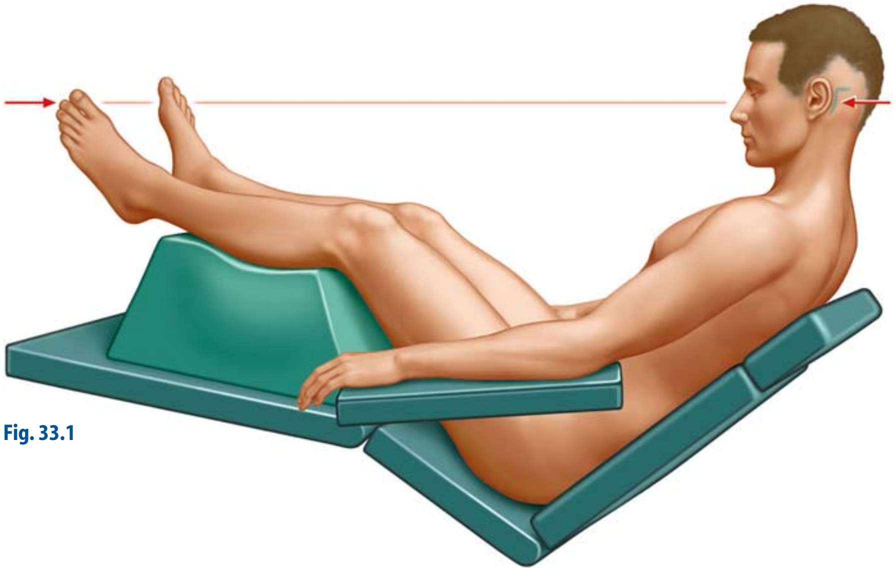

Fig. 33.1

Fig. 33.2

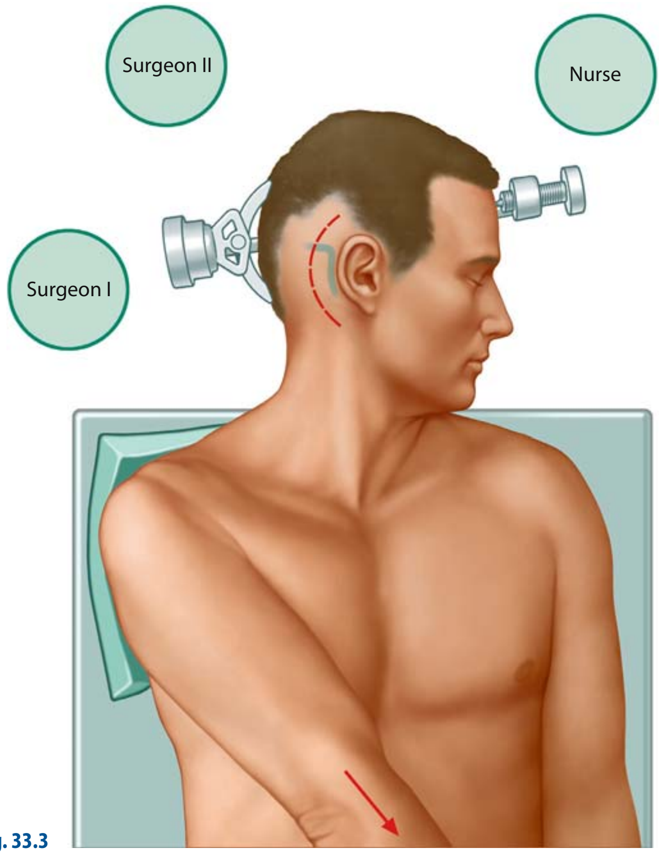

Fig. 33.3

side. For the left-sided procedure the surgeon and assistant surgeon are standing face to face.

Skin Incision

After local shaving of the hair behind the pinna and disinfection of the surgical field, a curved skin incision is made; this incision crosses a line running from the asterion to the protuberantia (**Fig. 33.4**). The asterion can be palpated behind the outer ear and is a nice bony landmark for the angle between the sigmoid and transverse sinuses. After undermining the skin edges inside the subcutaneous tissue for a distance of up to 2 – 3 cm on each side, the surgeon fastens several sterile compresses with metal clamps. It has to be stated clearly that exact haemostasis is extremely important at all stages of the intervention as a prerequisite for successful microsurgical manipulation.

The nuchal muscles (*m. semispinalis, m. splenius* and *in part the m. sternocleidomastoideus*) are split with the monopolar knife. The surgeon must be aware that, when the procedure is performed with the patient in a sitting position, an air embolism can also be produced by opened muscle veins.

Preparation of Subcutaneous Tissue and Nuchal Muscles

Normally the surgeon should be able to reach the suboccipital bone below the external occipital protuberance in the upper region of the incision. The muscle can then be pushed away easily using a rasp. Sometimes it is helpful during this step to use the monopolar knife to cut away the bony attachment of the muscles. If we insert a wound retractor into the operative field to stretch the muscles, the surgical procedure is much easier.

Care should be taken not to injure the occipital artery and to preserve the major occipital nerve (cave: development of neuroma). If we reach the pars horizontalis and lower portions of the muscles, damage to the vertebral artery is possible, especially if the surgeon steps too lateral and low. It is advisable to carry out these preparation steps in the time-honoured way with scissors, tweezers and bipolar coagulation if necessary and to refrain from using the monopolar at this point. During this part of the operation one big wound retractor in the upper part of the incision and one wound retractor below will be a good solution to open up the operative field (**Fig. 33.5**). If we have detected several bony landmarks, e.g. the origin of the mastoid, suboccipital bony structures with dimensions of approximately 4 × 4 cm, and the pars horizontalis, we can focus on the next part of the intervention – the trephination.

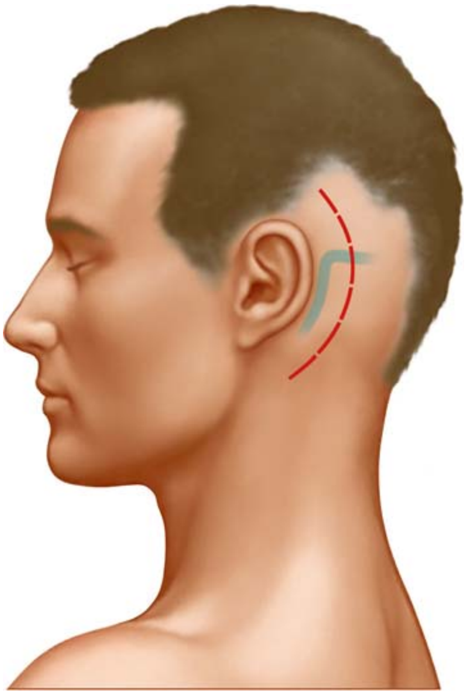

Fig. 33.4

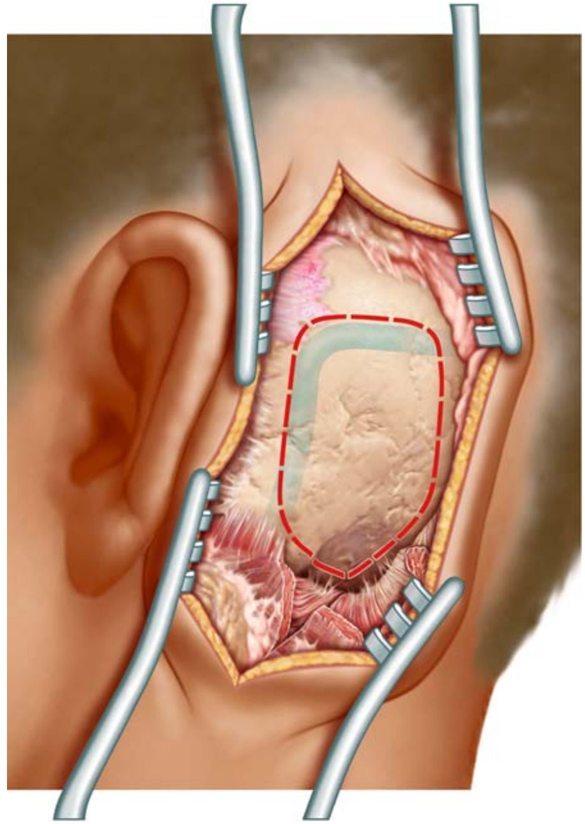

Fig. 33.5

Trephination

Either osteoclastic or osteoplastic bone resection can be performed. The surgeon has to bear in mind here that the dura is much more adherent in the cerebellar region than in the supratentorial areas. This poses the risk of sinus damage with possible air embolism. For safety reasons we normally use the big 15-mm trepanation head creating four to five bore holes nearby; the resulting bone dust is saved. Following the intracranial intervention and dura closure this bony material can be introduced into the bony defect to ensure good cosmetic results later. The size of the trephination has to be 3×4 cm at minimum. The complete sigmoid sinus and parts of the transverse sinus are now exposed with the drill. Attention should be paid to the emissary veins, which naturally lead to the sigmoid sinus. These openings can be closed easily with Tabotamp and a Cottonoid paddy or bone wax if there is a small bony layer lying above. Aggressive coagulation should be avoided in the sinus region. Parts of the pars horizontalis are taken with the Luer in a medial direction for the later opening of the cisterna magna and gain of cerebrospinal fluid.

Fine Work with the Drill

To reach the sigmoid sinus the surgeon has to drill away parts of the air-filled mastoid in nearly all cases; the drilling is accompanied by continuous rinsing with NaCl 0.9 % by the assistant. If the surgeon does not approach the complete sinus at this point, the subsequent dural incision will be too far toward medially, and pressure to the cerebellum with possible infarction will result (**Fig. 33.6**). During the closure procedure to be performed later the opened mastoid should be covered with some pieces of muscle mixed with fibrin glue.

Withdrawal of Cerebrospinal Fluid

This is a very important step during the operation. The aim of this procedure is to relax the cerebellum by opening the cisterna magna. Under microscopic magnification the dura should be opened in a triangular shape in the region of the pars horizontalis (**Fig. 33.6**). The surgeon enters the intracranial space between the dura and the cerebellum carefully using a suction tube and a forceps with a small Cottonoid paddy. If the cisterna magna is reached medially, it can be opened easily with the tips of the bipolar forceps. If a large amount of cerebrospinal fluid is withdrawn from the cistern, the intracranial space will relax and further intracranial microsurgical manipulation can be performed under better conditions.

Opening of the Dura

The dura has to be opened near the sinus via a curved incision that connects with the previous dural opening. The dura is fixed with sutures and the cerebellum is covered with Cottonoid paddies for protection. A spatula can be introduced into the operative field later to hold the cerebellum medially. It should be pointed out clearly that the use of a spatula is not necessary if the cerebellum is relaxed and all steps have been carried out correctly up to this point.

Intracranial Part

The intracranial procedure that now follows is complex. Monitoring of the facialis with a stimulation forceps serves as the gold standard here. Intracranial orientation should be undertaken via the visualization of the trigeminal nerve, petrosal vein and other structures. To achieve further relaxation of the cerebellum, the trigeminal cistern can be opened with the bipolar forceps. The cistern of the vestibulocochlear and facial nerve is then detected and has to be opened. From a topographic point of view the vestibular nerve with its superior and inferior part is located facing the surgeon coming from the described approach (**Fig. 33.7**). The nerve can be separated from the facial nerve with a small nerve hook. The separated nerve should be stimulated as well as the facial nerve in order to detect the facial nerve with both neurophysiological and anatomical methods.

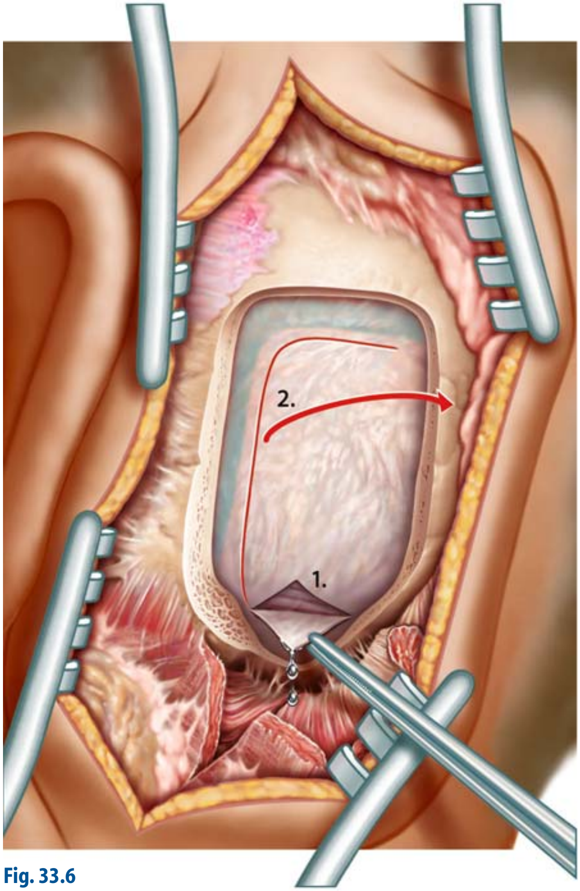

Fig. 33.6

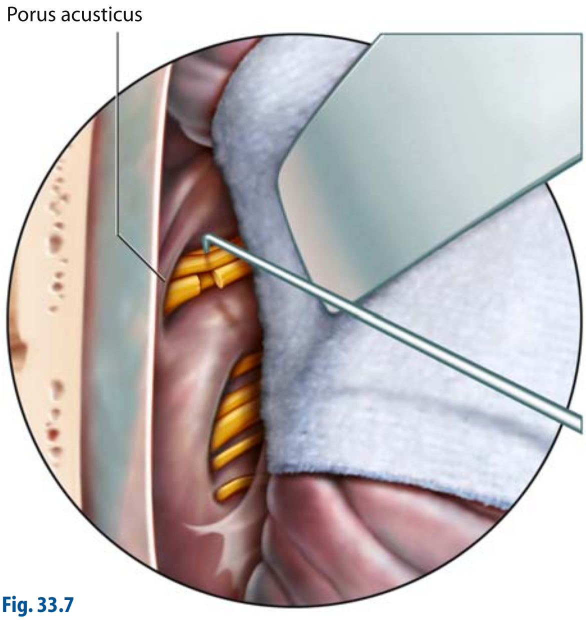

Fig. 33.7

In addition to monitoring the potentials received from the microelectrodes in the mimicry muscles, the anaesthesiologist should watch the face of the patient under the sterile drapes carefully for mimicry movements. It is logical that it is much easier to observe the patient's face when the patient is in the sitting position. If the vestibular nerve is detected correctly, it can be coagulated with low energy and cut with microscissors. The ends of the cut nerve can be coagulated again to shrink the nerve and prevent later regrowth. During all of these surgical steps, the application of energy to the facial nerve should be avoided. It must be stressed here that vestibular neurectomy is a destructive procedure with the inherent possible complication of damage to the facial and cochlear nerves if the anatomical situation is not entirely clear.

Closing Procedure

Closing of the dura in the posterior fossa is not easy and should be carried out with pedantic care. It is sometimes necessary to close small gaps in the dura with pieces of galea. If the dura is sutured in a watertight manner under microscopic magnification, layers of Tabotamp with fibrin glue are laid on the dura followed by the bone dust which is used to fill in the bony defect. It is important not to forget to close the mastoid with muscle. Should CSF fistula occur, otogenic rhinoliquorrhoea is possible if cerebrospinal fluid enters the opened mastoid. In this case a postoperative lumbar drain should be inserted and left in place for 5 – 10 days. The muscle layers should be sutured carefully; subcutaneous sutures and skin sutures follow closure of the muscle layers.

34 Otological Instruments

Jürgen Lautermann, Holger Sudhoff, Henning Hildmann

Not all instruments are used for every procedure. A set of instruments should be small enough to avoid any loss of time searching for the required instrument. This is not only time efficient but also cost efficient and makes assisting the surgeon easier.

There are different sets for different otosurgical procedures. We recommend small sets for paracentesis and positioning of ventilation tubes; sets for mastoid surgery, surgery of chronic ear inflammations and their sequelae; sets for stapes surgery; and special instruments for skull base surgery.

Instruments for Middle Ear Surgery (**Fig. 34.1**)

Instruments for Stapes Surgery (**Fig. 34.2**)

Special Instruments

- Footplate microdrill (Skeeter drill) for stapes surgery
- House-Urban midfossa dura retractor (Fisch modification) for acoustic neuroma surgery
- Facial nerve monitor for acoustic neuroma surgery, surgery for middle ear malformations

Operating Room Arrangement

For middle ear surgery the surgeon sits on the side of the ear which is to be operated on and the scrub nurse sits at the top of the table. The instruments are placed between the surgeon and the assisting nurse. The microscope, if not fixed to the ceiling, is placed opposite the surgeon. The anaesthesiologist is positioned either opposite the surgeon or on the same side. The patient is in a supine position, the head slightly tilted to the opposite side.

For the transtemporal approach (middle fossa approach) in skull base surgery, the surgeon is seated at the head of the patient with the scrub nurse at the side of the table.

Fig. 34.1. Instruments for middle ear surgery

1	double fork retractor
2	retractor with biprong blade on one side and solid blade on the other side
3, 4	surgical blades
5	surgical handle
6	preparation plate
7	nasal speculum
8	magnetic instrument rack
9	seeker, 45°
10	ear hook, size 1
11–14	picks, 90°, 0.4 mm, 0.5 mm, 0.8 mm, 1 mm
15	needle, light curve
16	Plester elevator
17	medicine cup
18–20	ear specula, OD 7.5 mm, 6 mm, 5 mm
21	round knife, 45°
22	sickle knife
23	knife, round
24	retractor, sharp
25	curette, large size
26	curette, small size
27	scissors, straight
28	scissors, curved
29	needle holder
30	bipolar forceps
31	Wullstein forceps
32–34	Plester suction tubes, 9 Fr., 7 Fr., 5 Fr.
35	diamond straight shaft burrs
36	tungsten carbide shaft burrs
37	rack for burrs
38	handle, angled
39–43	suction cannulas, angular, 2 mm, 1.5 mm, 1.3 mm, 1 mm, 0.7 mm
44	adaptor with cut-off hole
45	ear forceps
46	scissors, very delicate
47	malleus nipper
48	Hartmann ear forceps


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Fig. 34.2. Instruments for stapes surgery

1	retractor
2, 3	surgical blades
4	surgical handle
5	preparation plate
6	nasal speculum
7	magnetic instrument rack
8	needle, light curve
9	needle, straight
10–13	picks, 90°, 0.4 mm, 0.6 mm, 0.8 mm, 1 mm
14, 15	picks, 45°, 0.5 mm, 1 mm
16, 17	hook, footplate, 0.2 mm, 0.6 mm
18	perforator
19	Plester elevator
20	medicine cup
21–23	ear specula, OD 7.5 mm, 6 mm, 5 mm
24	round knife, 45°
25	sickle knife
26	knife, round
27	retractor, sharp
28	curette, large size
29	curette, small size
30	scissors, straight
31	scissors, curved
32	needle holder
33	bipolar forceps
34	Wullstein forceps
35–37	Plester suction tube, 9 Fr., 7 Fr., 5 Fr.
38	diamond straight shaft burrs
39	rack for burrs
40	handle, angled
41–45	suction cannula, angular, 2 mm, 1.5 mm, 1.3 mm, 1 mm, 0.7 mm
46	adaptor with cut-off hole
47	ear forceps
48	scissors, very delicate
49	wire crimper
50	Hartmann ear forceps


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Chapter 29

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