6. Operations

Operations in the Nasal Cavity

Septoplasty

In many cases correction of the nasal septum is a prerequisite for good exposure, for safe operating conditions, and for the creation of an ideal shape for the nasal cavity. Furthermore, it is often indicated on its own merits to improve ventilation of the chronically inflamed mucosa. The treatment plan should therefore include mobilization and straightening of the septum.

Septal resection as described by Killian with destruction of cartilage should be abandoned because it robs the septum quite unnecessarily of its support, and does not improve the function of the upper segment that is so important in the physiology of the airstream. It has been replaced by the cartilage-sparing technique originally described by Cottle. The method can naturally be modified in the individual case, and the following personal method is only one of many variations (Wigand, 1978).

Firstly, a hemitransfixion incision is made along the edge of the septal cartilage in the left or right nasal vestibule at the mucocutaneous junction. Cutting diathermy is particularly suitable for this incision. The perichondrium is completely elevated through this incision down to the floor of the nose on both sides using a semi-sharp elevator. This dissection is continued under vision posteriorly and inferiorly over the junction of cartilage and bone. Tunneling is unnecessary if the surgeon has learned to release the inrolled edge of the quadrilateral cartilage from the premaxilla by sharp dissection, and to free it completely from the base of the septum posteriorly over the vomer (an area described by Masing as the septal pouch).

The anterior edge of the bony perpendicular plate of the ethmoid is now demonstrated by dividing the junction of bone and cartilage. After exposing the perpendicular plate on both sides it is divided above and below with a sagittal chisel cut, elevated from the sphenoid and the vomer using a special punch with large blades, and removed in one piece. It is then straightened, narrowed if necessary, and preserved until the end of the operation in saline solution.

The perpendicular plate is only replaced after straightening of the septum, partial resection of the triangular block of the vomer, removal of projecting pieces of cartilage and chiseling off the obstructing ridge projecting laterally from the premaxilla and the palatal ridge. It is wedged, glued or stabilized by splints of silastic sheeting. Good end-to-end adaptation to the posterior edge of the quadrilateral cartilage should be achieved. The last step of septal correction should be left until the endoscopic sinus procedure is finished to take full advantage of the septal mobility.

The last step of the septal procedure is the vestibular stitch, a special stitch that not only adapts the wound edges but also rotates the quadrilateral cartilage in an anterosuperior direction. The cartilaginous septum thus regains its previous tension with respect to the nasal dorsum which it often loses after removal of the perpendicular plate. The cartilage is held in its original position by the rotation suture, and sinking of the weak triangle is prevented.
Posterior rotation of the quadrilateral cartilage is much more often the cause of saddling of the nasal dorsum than resection of cartilage at the lower border. In addition to the cartilaginous rotation suture, two further deep interrupted sutures are placed through the wound edges to close the hemitransfixion incision securely. Additional use of fibrin glue may be helpful both in the case of damage to the mucosa and for replantation of bone or cartilage. An adhesive is not usually needed.

**Turbinectomy**

The various indications and techniques for narrowing the nasal turbinates, particularly the inferior, do not need to be considered here. However, many ethmoid operations demand reduction of the inferior or middle turbinate, particularly if the nasal airway must be improved, or the surgical field must be extended to give a good view and allow instrumentation for the treatment of sinusitis.

The best procedure for reduction of the inferior turbinate is submucosal resection of the length of the turbinate bone using Legler's method after using a cutting snare to remove a hyperplastic posterior end of the turbinate. This technique preserves the mucosa and can be individually modified. However, it is often essential to resect the excessively hypertrophic turbinate itself. In these cases longitudinal resection with cutting diathermy could be considered. In the author's experience a strip turbinectomy with the long nasal scissors applied along the free lobular edge of the inferior turbinate has proved useful, although crusting and bleeding from the wound edges in the initial postoperative phase, and pain during postoperative treatment, are quite common. The open wound edge can be treated with caustic or fibrin glue.

The middle turbinate may also require limited resection if its anterior end is polypoid and blocking access to the middle nasal meatus or the olfactory cleft. In this case conservative removal of the excess tissue with the curved nasal scissors, or diathermy is indicated. The tissue removed must be subjected to histology to show whether the lesion was a polyp rich in glands, a papilloma or some other tumor. If a voluminous bullous turbinate obstructs the middle meatus, thinning by longitudinal splitting is suitable.

Posterior partial resection of the middle turbinate is often necessary during complete ethmoidectomy because the body of the middle turbinate blocks access to the posterosuperior ethmoid cells. This can easily be dealt with by a curved scissors; the mobilized part of the turbinate is removed with a forceps or punch. For many years the place of partial or sub-total resection of the middle turbinate has been controversial, but wide experience has shown that these operations carry no ill effects, in particular ozena due to drying of the nasal mucosa by excessive volume of air. However, no more of the turbinate should be removed than is necessary because superiorly it carries olfactory fibers, and its medial lamina contributes decisively to the structure of the olfactory cleft.

**Biopsy and Tumor Removal**

Biopsies can be taken for histology, and localized areas of tissue can be removed very precisely using the endoscope. A self-retaining speculum and the operating microscope may be useful for dissection in the nasal introitus and the anterior third of the nose, for example,
for precise excision of papillomas from the nasal vestibule. However, the surgical endoscope comes into its own for manipulations in the posterior third of the nasal cavity. The endoscope is also a great help in transnasal biopsy of the nasopharynx. In most cases, local anesthesia suffices, but general anesthesia with packing of the pharynx may be more comfortable for both patient and surgeon if severe bleeding is to be expected, for example after a punch biopsy of a nasopharyngeal angiofibroma or if anatomical narrowing makes access for the biopsy forceps difficult. The high-frequency diathermy needle with a slender grip and interchangeable hooks, loops, etc, has proved invaluable for bloodless removal of tissue specimens, and for dividing adhesions.

Intranasal endoscopic surgery for tumors may be successful, depending on the site, extent and pathology of the lesion, and it may also be used as a palliative partial resection or for complete excision with a healthy margin. Lesions with a narrow base or those confined to one turbinate are particularly suitable for complete removal. The endoscopic findings must be supplemented by tomography in most cases, to exclude extension beyond the nasal cavity, and invasion of the skull base. Preferably the tumor should have been shown to be benign by previous biopsy. The technique is determined by circumstances: lesions with a soft pedicle can be removed with the cutting snare, but broad-based sessile lesions require excision, possibly with division of their bony base by the chisel, and if necessary resection of the turbinate. Bulky benign lesions can be removed piecemeal by the punch forceps under endoscopic control. The base should be removed by drilling the underlying bone with a diamond burr. This method is particularly suitable for the treatment of circumscribed inverted papillomas, as personal experience extending over many years has shown.

Intranasal excision of a malignant tumor confined to the nasal cavity, under endoscopic control, can be practiced with success, after preoperative CT scan for careful assessment of the extent of the lesion. However, this procedure is only justified for very small lesions whose complete extent is within the vision of the endoscope. The treatment plan must include histological assessment of specimens taken from the apparently healthy margin of the wound, vigorous drilling of the underlying bone and continuous close endoscopic follow-up. Under these circumstances, intranasal surgery for small malignant tumors may be justified for frail patients who are unwilling to undergo an operation producing a scar on the face, or for patients in poor condition.

Endoscopic Use of the Laser

Division of a choanal atresia in the newborn and infants using the operating microscope and a carbon dioxide laser has proven to be very valuable. It is simple, but application of the beam to the correct point can be obstructed by the turbinates or septal spurs. The nasopharynx should be protected before beginning coagulation. The technique and the aftercare will not be discussed at this point.

The carbon dioxide laser can be controlled carefully under the operating microscope but can be directed upon only part of the nasal mucosa because the beam is directed forwards. For this reason the argon or the Nd:YAG laser are useful in the angular nasal cavity. In the latter case the laser beam can be conducted around corners by a flexible cable directly to the target using special curved hollow probes, and its action monitored by the irrigating-suction endoscope. The laser is the treatment of choice for coagulation of bleeding lesions, such as
hereditary telangiectasia, and for the localized cautery of a hypertrophic inferior or middle turbinate.

If the laser is used for coagulation or excision of tissue with a cartilaginous framework such as the septum or the nasal ala the inevitable spread of heat can lead to chondronecrosis.

**Removal of Foreign Bodies**

Small foreign bodies such as pieces of paper, parts of plastic toys or pellets, may impact in the nasal airways and be difficult to remove without injuring the mucosa, turbinates or septum. The exact position of the foreign body, and the precise application of the instruments can be monitored endoscopically. Endoscopy is of particular value for removal of foreign bodies and particles of ointment from the antral cavity after antrostomy, and has proved particularly useful for identifying and removing remnants of foam or gauze packing hidden in a newly created antrostomy.

**Operations on the Maxillary Antrum**

**Indications**

- recurrent acute inflammations and empyema of the maxillary sinus,
- chronic maxillary sinusitis,
- as one of the procedures for pansinusitis,
- complications of inflammatory disease,
- foreign bodies and trauma,
- biopsy and drainage of tumors.

**Principles**

The purpose of the operation is to create a unilocular antral cavity, lined by mucosa, with secure ventilation and drainage through a permanent outflow of the middle and/or the inferior meatus. Mucosa should be preserved as much as possible to encourage mucosal regeneration, and to prevent the formation of scar tissue, so that only gross disease should be removed. A middle meatal antrostomy is preferred to an inferior meatal antrostomy. Correct manipulation of the instruments prevents perforation of the orbit. Endoscopic control with an angled telescope is mandatory, and care should be exercised during curettage because of the danger of injury to the tooth buds and to the infraorbital nerve.

**Operative Technique**

Intranasal antral procedures can be divided into two phases: (1) antrostomy, (2) intracavitary manipulation. Often the latter is unnecessary, and antrostomy is then the sole purpose of the procedure. Revision operations after a previous intranasal or transoral (Caldwell-Luc) operation are more difficult, demanding a partly intranasal and a partly transoral procedure via the canine fossa.
Inferior Meatal Antrostomy

Topical anesthesia with 4% xylocaine, infiltration with xylocaine 1%, and vasoconstriction of the mucosa of the inferior meatus using pledgets soaked in 1/1000 adrenalin are all worthwhile. The inferior meatus is brought into view by elevating the constricted inferior turbinate and displacing it medially using Killian's speculum. The medial wall of the antrum is perforated with a semi-sharp elevator or chisel at the point where the bony wall is thinnest, about 8 mm behind the anterior insertion of the inferior turbinate and about 5 mm above the floor of the nose. The thin bone behind the perforation is pushed into the meatus by medially directed pressure. The posterior half of the antrostomy is punched out using Blakesley's semi-sharp nasal punch (size 2 or 3) or a conchotome, using the sharpest cut possible to prevent laceration of both the nasal and antral mucosa. Blunt avulsion of fragments of bone often strips the neighboring mucosa from the bone, leading to necrosis and abnormal ciliary transport. The anterior part of the antrostomy is now created using acute-angled forceps or punches such as Ostrom's. A specially curved bone hook is available for levering out pieces of bone which have been pushed into the cavity (see instrumentation in Chapter 4). Pieces of bone displaced into the antrum may cause neuralgia and continuing secretion, probably due to disturbance of the mucociliary self-cleaning mechanism.

The antrostomy should have vertical and horizontal diameters of at least 8 x 10 mm, since it has a marked tendency to contract or even become obliterated, and its edges should be smooth. Lining of the antrostomy by everted antral mucosa is recommendable. Removal of the covering bone, three radial incisions of the adjacent mucosa, and eversion of the latter into the nasal meatus are the steps necessary in this technique. The upper edge of the new window should not reach as far as the insertion of the inferior turbinate, otherwise scar tissue retraction pulls the inferior turbinate into the antrostomy, particularly if a turbinectomy is performed at the same time. The lacrimal canal must not be damaged during punching out of the anterior edge of the antrostomy because scar tissue can obstruct the dura, leading to permanent epiphora. Spacers, for example that described by Bumm, may be useful for maintaining the patency of the antrostomy.

Middle Meatal Antrostomy

An antrostomy should preferably be created at the point where nature has decreed that the short canal from the antral cavity opens, where secondary ostia are more often found, and where the physiological pathways draining the antral mucosa end.

The simplest procedure is to enlarge the natural ostium, particularly the secondary ostium in the fontanelle (Buiter's fontanellotomy). A very limited resection of the medial antral wall can be done beneath the semilunar hiatus under endoscopic control.

However, the need to manipulate instruments within the antral cavity usually demands the creation of a larger window. Personal experience with several hundred middle meatal antrostomies, and Hosemann's photographic studies (1985), show that even large defects of the centre of the antral wall above the inferior turbinate do not interfere with the drainage of the secretions and particles. Depending on the presence of polyps, or on the need for freedom of movement for instruments within the antral cavity, the author creates a modest sized (8-10 mm) or sub-total window in the middle meatus. The details of endoscopic anatomy determine
which structures are sacrificed, but the window should be made as small as possible to avoid unnecessary disturbance of the natural transport pathways. Whether the creation of a window at any site other than the natural ostium can be challenged on basic principles, as indicated by Hilding's experiments, has so far not been determined scientifically. The 45° upward-cutting pointed ethmoid punch is suitable for opening the antral cavity: the author has designed his own model with prolonged jaws. Correct control of the instruments is vital to ensure the security of the contents of the orbit: the closed pointed punch (or the half-open punch in the hands of an experienced surgeon) is placed on the dorsum of the middle turbinate about halfway along its long axis. This is followed by a controlled forward thrust, directed in a strictly horizontal plane. As the frontal sections in Chapter 2 show, the orbital wall can never be perforated in this direction of thrust. If perforation can be achieved under endoscopic vision, then the opening is usually created through the posterior fontanelle (Buiter and Straatman, 1981) at the point where the semilunar hiatus expands between the edge of the bulla and the uncinate process, and where the medial antral wall is membranous.

If the half-opened punch has been used, closure of the forceps achieves the first limited resection, and the antral cavity can be inspected through this opening using an angled telescope. Generous resection of the medial antral wall to create a defect 8 mm high and 10 mm wide is needed for extensive intracavitary manipulations, and to create a permanently open window. Ostrom's backward-cutting punch is particularly valuable for this step.

If the lower edge of the antrostomy lies far inferiorly on account of individual circumstances such as polyps or the necessity to manipulate instruments, the inferior meatus can easily be opened lateral to the body of the turbinate, but this does not usually have any ill effects. Posteriorly and above, the party wall is best removed with a cutting conchotome or the straight Blakesley's forceps, and in complete antro-ethmoidal operations this can be continued to its upper edge (see below). Endoscopic checking and smoothing of the rim of the antrostomy is important after every procedure. Brisk bleeding from the posterior edge of the window can be controlled by bipolar coagulation or compression with pledgets soaked in adrenalin.

The author has recently stopped simple excision of a large antrostomy but tries to dissect the lateral nasal wall: while the nasal mucosa and the underlying bone are removed, the antral mucosa is radially incised and eversed into the middle nasal meatus (eversion technique). This maneuver is to enhance mucociliary transport into the nose.

**Operations within the Maxillary Cavity**

Whereas an intranasal antrostomy can be carried out at least partially under direct vision, manipulations within the antrum itself must always be performed using an angled telescope. Blind operations do not achieve the goal of the operation, endanger important structures and must be avoided. Almost all procedures can be undertaken either through an inferior or a middle meatal antrostomy. If the field of vision is inadequate a better view can be gained by using an endoscope introduced through an anterior, canine fossa, antrostomy. All experienced surgeons agree that the degree of freedom when using small gripping instruments passed through the endoscope is very limited, whereas all situations can be tackled with instruments, suction, laser, etc, passed *alongside* the endoscope (para-endoscopic surgery).
The figures show examples of the removal of polyps and cysts under endoscopic control. Orientation in space and accurate identification of the target always have precedence. Only grossly abnormal lesions which appear to be irreversible should be removed, whereas hyperplasia, edematous swellings, etc., which are capable of resolution should be given the chance to do so. Sadly there are no macro- or even microscopic mucosal characteristics on which to base the decision, so that mucosa should be preserved as far as possible. It is very easy to elevate or tear healthy mucosa with unsuitable instruments, leading to worsening of the situation. At the moment, it is not clear whether non-touch laser surgery or electrocautery will be of a greater help in this area. Mucosa which has been stripped from bone by forceps or suction should be replaced immediately, but sadly does not always heal.

The infraorbital nerve is sometimes exposed in the roof of the antrum; it must never be damaged. Also, roots of the teeth lying in the antral cavity must be respected. They are yellow in color and can be confused with retention cysts, and the beginner may be tempted to use the obsolete technique of curettage. On the other hand, inferior recesses must be opened completely otherwise scar tissue can form loculi in which a concealed empyema can develop. The author has found concealed purulent foci using the endoscope in an unsuspected maxillary cavity at reoperation after a previous Caldwell-Luc antrostomy. These loculi had obviously been overlooked at the first operation, and only came to light after an energetic search stimulated by an abnormal CT scan.

It may be necessary to create a second window in the inferior meatus if suitable instruments are not available to grasp a lesion, such as a cyst, lying in an unfavorable position, and which cannot be reached from the middle meatus. The author has seen no particular postoperative problems from the creation of a second window, but avoids it if possible.

The last step of the operation is hemostasis using bipolar coagulation or pledgets soaked in adrenalin. Once the lumen appears to be free, the edges of the antrostomy are inspected with the endoscope, and freed of mucosal tags or bone spicules. It is usually not necessary to pack the antral cavity: indeed, packing induces a foreign body mucosal reaction, as does blood clot. Loose packing for 24 hours with strips of gauze impregnated with ointment, or plastic foam in a finger cot, usually suffices but can often be dispensed with.

The above brief remarks establish the central role of the endoscope and angled telescope in antral surgery. There is a widespread but false view that endoscopic maxillary surgery is limited to carrying out a simple antrostomy. However, the comprehensive endoscopic treatment of the antrum demands greater knowledge of topographic anatomy, better instruments and is technically more difficult than the transoral Caldwell-Luc operation.

Revision Surgery

Second operations, particularly after a previous radical antrostomy, are much more difficult because the scar lining and changes in the bony framework of the maxilla make orientation much more difficult, and obstruct access or even make it impossible. The CT scan is a necessary part of the work-up and may cast doubt on the place of an intranasal procedure if a transoral revision appears to be inevitable. However, a transoral revision can often be
avoided, although the patient's consent should always be obtained for this procedure should it become necessary.

The principles of the procedure are identified to those of the first operation. The creation of an adequate antrostomy is the first priority, and it often exposed the disease. If a small antral cavity is found in the inferior meatus and another cavity is found beyond the remaining antrostomy in the middle meatus with an intervening plate of scar tissue demonstrated by a CT scan, it is worth attempting to cut out this plate using a perforator, curved forceps and punches. On the other hand if a CT scan has demonstrated a low-lying orbit, which is frequent after a Caldwell-Luc operation, posterior retraction of the facial soft tissues or an abnormal double cavity with a thick dividing wall, an intranasal endoscopic procedure would probably be too difficult, and a thorough transoral revision is indicated.

The previous operation may have included a transmaxillary ethmoidectomy, leading to scar tissue obliteration of the connections between the cells or recesses and the nasal cavity, causing loculated inflammation. Patients with this type of loculated disease may suffer bronchitis or neuralgia. Endoscopy or radiographs are often misleading, indicating that the antral cavity is open and free of disease, so that many of these patients are for a long time misdiagnosed as suffering from psychological overlay or depression, before a CT scan reveals the hidden focus.

Applications

Chronic Maxillary Sinusitis

Chronic antral mucositis with its intermediate forms from mucosal hyperplasia, via polypoid mucosal hypertrophy to an empyema resistant to treatment, provide the bulk of the indications for operation. Removal of cysts and polyps from the wall of the maxillary antrum will be used as examples of the operative procedure. The ideal procedure is the endoscopic removal of isolated cysts or polyps from an otherwise healthy antrum. These lesions do not always cause symptoms, but can contribute to bronchitis, pharyngitis, laryngitis, or even may constitute a focus with distant effects. Complete removal of these large cysts is not always simple. The double forceps often tears the thin wall, allowing the serous contents to gush out, so that the pedicle of the polyp or the lining of the cyst are not easy to find and remove without tearing the healthy mucosa lying on the wall of the antrum. Eradication using the diathermy loop or the argon laser has proved valuable. Pseudocysts often recur.

Operative treatment of diffuse polypod pansinusitis demands attention to the antrum. It is remarkable that the antral cavity often shows only a smooth mucosal thickening whereas marked polypoid formation is present in the ethmoid, indicating primary disease of the ethmoidal mucosa with secondary affection of the antrum. The prospects of recovery of the antrum are good if the diseased ethmoid mucosa is treated, whereas an operation on the antrum alone is illogical.

In other cases inflammation of the antral mucosa is pronounced, whereas the ethmoid is relatively healthy. However, the ethmoids are never completely healthy, since an antral inflammation of nasal origin always spreads via the ostiomeatal unit of the middle meatus which belongs to the anterior ethmoid sinuses. A pathologically important, circumscribed,
anterior ethmoiditis must be sought: it may not be visible on plain views but can be demonstrated before operation by a precise tomogram. From this it follows that it is necessary in chronic disease to plan a middle meatal antrostomy and demonstrate the drainage channel for the anterior ethmoid, that is the semilunar hiatus and the ethmoid infundibulum.

The best results are obtained if the antral mucosa is retained and the window is modest in size. However, if a pronounced polyposis is present in both regions, removal of the bony edge of the window should be considered so that no narrow ethmoid recesses remain. The upper wall of the antrum must then merge into the soft curve of the lateral ethmoid wall without any step. Otherwise recurrent polyps can easily develop in the narrow area.

Moderately severe inflammatory hyperplasia of the antral mucosa causing uniform mucosal thickening on radiographs resolves after simple opening of the nonfunctioning ethmoid infundibulum from the semilunar hiatus without creating an antrostomy, although the results are unpredictable and the patient should be warned of the possibility of a second procedure. However, infundibulotomy alone cannot guarantee healing of the antrum for long-standing severe polyposis of both the ethmoids and the antral cavity. A new antral window must then be created to allow access to the maxillary polyposis.

Maxillary Sinusitis of Dental Origin

Inflammation of the dental roots or an antro-alveolar fistula do not automatically demand transoral exposure of the antrum by the Caldwell-Luc technique. Endoscopic treatment of the antral cavity at the same time as, or after, treatment of the dental disease or closure of the fistula suffices to achieve healing of the antral cavity.

Complications of Inflammatory Disease

A radical exposure via the transoral approach is obsolete even for the treatment of inflammatory complications. In many cases, drainage of the suppurative by the intranasal route coupled with high doses of appropriate antibiotics suffices to control the osteitis, periostitis and inflammation of the facial soft tissues arising from the antral cavity. Similar satisfactory results can be obtained for early orbital complications, but in these cases the antral operation is usually combined with an ethmoidectomy.

Also an antral mucopyocele can be managed satisfactorily by marsupialization through a wide intranasal antrostomy. The figure shows such a pseudotumor with caries of the bony floor of the orbit and facial swelling, one of the main symptoms being boring facial pain with double vision. A generous antrostomy brought the acute symptoms under control within hours.

Antrostomy in Children

Antrostomy is rarely indicated in infants because ethmoiditis is the commonest form of sinusitis at this age. However, if antrostomy is necessary, two disadvantages must be borne in mind: (1) the septal correction which is so often necessary may be refused at this age, (2) the patient cannot be expected to tolerate the necessary intranasal aftercare, including suction, installation of drugs and endoscopy.
However, operation cannot be avoided in all cases. The decision is easier in children older than 10 years. In children of school age ethmoiditis probably precedes maxillary sinusitis so that antrostomy alone does not tackle the basic pathology. Nevertheless, an ethmoidectomy is undesirable at this age, and it may be necessary to carry out an antrostomy alone as a compromise; experience shows that this often leads to resolution of the ethmoiditis presumably because resolution of the inflammation in the maxillary cavity has a favorable retrograde effect on the drainage through the ethmoid infundibulum. In childhood the good results of Thornwald's drainage and irrigation of the antrum via a retained catheter is probably explained in the same way.

The technique of antral surgery in children is the same as that in adults. It is possible to create a middle meatal antrostomy, preferably using smaller forceps and punches than usual, but an inferior meatal antrostomy alone is usually not sufficient treatment for chronic sinusitis. If lasting resolution of the mucosal disease demands supplementary procedures such as adenoidectomy or adenotonsillectomy, an inferior meatal antrostomy can contribute to healing. The window often closes spontaneously, but by then aeration and drainage are achieved through the recovered ostium in the middle meatus.

Foreign Bodies and Trauma

Once the surgeon has become familiar with the techniques for intranasal operations on the antrum he is ready to proceed to the para-endoscopic removal of foreign bodies, and the treatment of trauma. It is easy to remove inspissated masses remaining after treatment by irrigation, yeast concretions, dental root fillings or bullets via a middle or inferior meatal antrostomy after careful radiological localization of the foreign body.

Debridement of the antral cavity after fractures of the middle third of the face, removal of bony splinters which may cause neuralgia and organized hematomas which can form a cholesterol granuloma can be carried out under favorable circumstances via the transnasal route. Penetration of the floor of the orbit with reduction of mobility of the bulb and impaction of the muscles and orbital fat is better dealt with by an external (infra-orbital) approach with splinting, but in suitable cases intranasal endoscopic assessment and temporary support of the orbital floor often succeed.

Antral Tumors

Benign tumors of the antrum are rare, so that endoscopic removal of such tumors is rarely indicated. Inverted papillomas may be controlled by an endonasal approach. Malignant tumors cause no symptoms when they are small, so that an approach through the inferior meatus is restricted to taking tissue for histology, creating drainage for necrotic material during radiotherapy, and for endoscopic follow-up. On the other hand an endoscope with an angled telescope can be used to supplement wide transfacial or transfrontal exposure of a tumor affecting several levels.
Operations on the Ethmoid Sinus

Indications

- chronic recurrent maxillary sinusitis,
- chronic hyperplastic polypoid sinusitis of the ethmoid and the maxillo-ethmoid junctional zone,
- complications of inflammation,
- foreign bodies and trauma of the ethmoid and of the anterior skull base,
- tumors of the ethmoid and neighboring areas,
- transnasal access to the frontal and sphenoid sinuses, and to the orbit and lacrimal duct.

Principles

The operation should be tailored to the individual patient and the extent of the chronic sinusitis, but the goal must always be restitution of free aeration and drainage of the ethmoid compartment. The middle turbinate with its attachment at the roof of the ethmoids is a key landmark ensuring the security of the procedure. It may be partially or completely removed depending on the extent of the disease, but the value of preserving or reconstructing the olfactory cleft must be stressed.

The middle meatus is the gateway to the ethmoids. The functional pathway from the semilunar hiatus to the ethmoid infundibulum and then to the frontal sinus, the anterior ethmoid cells and the antral cavity via the primary maxillary ostium should be exploited surgically. The posterior ethmoids are more clearly seen after a posterior partial resection of the middle turbinate. Ethmoid operations are usually combined with correction of the upper part of the nasal septum. The correct choice and direction of the instruments minimizes the danger of injury to the orbit and the anterior skull base, but a CSF fistula due to tearing of olfactory fibers may occur, and should be repaired immediately. Partial resections may be more difficult and more dangerous than complete clearance if the surgeon has not acquired sufficient experience with complete ethmoidectomy.

Operative Technique

Opening of the Semilunar Hiatus (Hiatotomy) and the Ethmoid Infundibulum (Infundibulotomy)

The functional ostiomeatal unit consisting of the middle meatus and the semilunar hiatus (Naumann, 1977) plays a pivotal role in mucosal disease of the sinuses, because most inflammations of the maxillary, frontal and ethmoid sinuses arise from this point (Messerklinger). In particular, swelling and hyperplasia of the mucosa in the ethmoid infundibulum obstruct aeration and drainage of the antrum, the anterior ethmoids and the frontal sinus leading to the development of sinusitis. Widening of the infundibulum alone therefore often leads to recovery of severe hyperplasia of the sinus mucosa (Messerklinger,
This principle of treatment has been less used as a routine in many clinics than ethmoid aeration via intranasal or transmaxillary access. Because of the individual variation in shape of the middle meatus surgical exposure of the infundibulum under endoscopic vision must be adapted to the type and extent of the resection of bone and mucosa.

The middle meatus can be well seen with the 25° telescope: The characteristic protrusion of the ethmoid bulla and the marked groove of the semilunar hiatus are easily located. A secondary antral ostium is often to be found close to its posterior end, but it may be concealed, covered by swollen mucosa or be absent. The ethmoid infundibulum is an anterior prolongation of the semilunar hiatus, lying between the ethmoid bulla and the uncinate process.

The ethmoid infundibulum can be exposed by opening the semilunar hiatus (hiatotomy) by careful removal of its walls, in particular the upper edge of the uncinate process. Polyps projecting from its gutter must often be removed first with a delicate grasping forceps. A strip of mucosa and bone is then removed from the uncinate process using a sickle knife carried forwards parallel to the upper edge of the hiatus. A fine cutting forceps is placed in the existing gutter and used to remove tissue from the uncinate process until the primary antral ostium, several anterior ethmoid cells and the frontonasal duct are visible in the now open infundibulum, allowing free drainage. If inflammatory hyperplasia is found in the cells of the bulla, the cells can be carefully opened from the hiatus, checked and if necessary removed. The procedure ends with minor procedures such as removal of polyps or minimal extension of the window at the maxillary ostium.

Strictly speaking simple enlargement of the semilunar hiatus by resection of the upper edge of the uncinate process should be termed a hiatotomy whereas infundibulotomy indicates wide opening of the ethmoid infundibulum including removal of cells and septa of the ethmoid bulla in most cases. The surgeon learns how much tissue to remove determined by the individual pathology and anatomy, and a strict division into two types of operation is not always practical.

**Anterior Ethmoidectomy**

Often chronic hyperplastic mucosal inflammation affects only the cells bordering the middle meatus, as can be well shown by CT scans. Circumscribed posterior ethmoiditis is less common. Clearance of different regions of the ethmoid may therefore be indicated.

The goal of anterior ethmoidectomy is complete exposure of the anterior ethmoid. The use of an operating endoscope with angled telescope is absolutely essential since residual cells walled off by scar tissue cause foci of recurrent ethmoiditis. Therefore it is also advisable to secure free drainage for the frontal sinus. Blind resection without optic control is dangerous because perforation of the orbit or the anterior cranial fossa and tearing of the olfactory fibers leading to a CSF leak can happen more easily in the anterior than in the posterior ethmoid.

Strictly speaking, anterior ethmoidectomy can be carried out in two ways; neither one nor the other should be preferred, but the one appropriate to the extent of the disease, or a combination of the procedures, should be chosen.
An initial middle meatal antrostomy has proven to be a particularly safe procedure; an antrostomy is often indicated per se because the antral cavity is frequently involved. The antrostomy is created by resection of the posterior fontanelle, and possibly of the lower edge of the uncinate process beneath the semilunar hiatus. The neighboring anterosuperior and medial bone can now be punched out from the opening thus created, with the orbital wall under direct vision, until the ethmoid infundibulum is exposed entirely. The remaining cells of the bulla and the anterior ethmoid cells can be opened a cell at a time using the angled telescope until the anterior ethmoid compartment is reduced to one common cavity covered by mucosa. Its borders - the lamina papyracea, the skull base and the boundary with the frontal sinus - are reached relatively safely in this way. In the author's clinic, injury to the orbital periosteum has now become extremely rare, even if the bony dividing wall is absent.

In order to achieve better exposure of the anterior ethmoid cells it is often necessary to remove bone around the agger nasi with a punch, since it overhangs and obstructs the view. If the frontal duct is still not visible after exposure of the most anterior cells under the agger, its position is determined by careful probing and its lumen exposed by removal of overlying polyps. Dissection should never be carried in front of the small mound of bone where the anterior end of the middle turbinate meets the agger nasi, since the olfactory cleft and the base of the skull begin above or in front of this point.

The middle turbinate may be left entirely intact at infundibulotomy or anterior ethmoidectomy for circumscribed ethmoiditis. Although disease of individual cells may require the cells to be opened and the lateral part of the turbinate to be removed, its medial surface should be completely preserved.

The second method of anterior ethmoidectomy is based on that originally described by Halle (1915), and later developed into an endoscopic procedure by Messerklinger (1987) and Stammberger (1985), in which the anterior ethmoid is entered through the semilunar hiatus and the ethmoid bulla. After exposing the semilunar hiatus and the ethmoid infundibulum, and opening the bulla widely the ethmoid system is opened cell-by-cell without fenestrating the antral cavity anew. This method conforms to physiological and pathological principles. In practice the end result in hyperplastic ethmoiditis requiring surgery is often the same as in the above resection technique because the boundary with the antral cavity beneath the uncinate process is also opened by systematic removal of cells.

The second approach via the ethmoid infundibulum is more dangerous than the first, because the orbital wall often runs only 2-3 mm from the infundibulum, and can thus be damaged by careless blind dissections using a sharp sickle knife or similar instrument, whereas the primary middle meatal antrostomy exposes the antral roof and thus the orbital wall immediately, so that they are constantly under vision and are therefore safe during removal of the uncinate process and the neighboring ethmoid cells with the punch.

Posterior Ethmoidectomy

A partial posterior ethmoidectomy is seldom indicated for chronic ethmoiditis because this disease spreads via the middle meatus, mainly affects the anterior ethmoids and is seldom limited to the posterior compartment. However, this operation is often indicated to expose the
sphenoid sinus. There are no disadvantages arising from a wide upper nasal cavity after posterior extension of the ethmoidectomy. Septal correction is advisable to improve the view.

The operation begins with a hiatotomy to allow the cells to be opened systematically rather than randomly. After resection of the posterior half of the upper edge of the uncinate process and opening of the posterior bulla cell, the basal lamella of the middle turbinate is usually encountered dividing the anterior from the posterior ethmoid compartment. It is perforated carefully, the posterior ethmoid cells removed stepwise, and the anterior wall of the sphenoid sinus and its ostium exposed. If dissection is continued on the anterior wall of the sphenoid sinus through the ethmoids, the insertion of the superior turbinate to the anterior wall of the sphenoid cavity often obstructs a free view of the sphenoid ostium. Mosher (1929) pointed out that the insertion of the superior turbinate to the anterior wall of the sphenoid sinus normally divided the wall into a medial part opening into the superior nasal meatus and a lateral part bordering the ethmoid in a ratio of 1:2. The above dissection of the posterior ethmoids can usually be carried out without difficulty, with total preservation of the middle turbinate provided that the ethmoid has not been destroyed by polyposis or undergone necrosis and provided that the ethmoid does not extend far laterally at its posterior end. In these circumstances the following variation is recommended:

The view into the posterior ethmoids is greatly facilitated and the security of the operation considerably improved by resection of the posterior third of the middle turbinate, by a cut curving backwards and upwards using the curved turbinectomy scissors, a counter incision at the end of the turbinate and removal of the divided end of the turbinate. The posterior insertion of the middle turbinate is then clearly exposed, forming a landmark leading to the sphenoid ostium. At the same time the posterior ethmoid cells are also exposed; they are removed by breaking down the party walls with ethmoid forceps, or with a forward-cutting punch directed carefully towards the anterior wall of the sphenoid sinus, until the latter is freely exposed.

Simultaneous opening of the sphenoid sinus is achieved by pushing a slender closed ethmoid forceps into the sphenoid ostium, and the widening the defect of the anterior wall by opening up the forceps. If the ostium cannot be found the anterior wall is carefully perforated after determining the correct point from the appropriate landmarks (see Chapter 2 on Endoscopic Anatomy). This initial opening can then be extended using a 45° or 90° punch until the anterior wall of the sphenoid sinus is completely removed. Bleeding from the branches of the sphenopalatine artery can be controlled by the curved bipolar coagulation. The roof and lateral wall of the sphenoid sinus are now exposed as landmarks to allow a posterior ethmoidectomy to be carried out safely: prolongation of the sphenoid roof anteriorly meets the ethmoid roof at the same level, and with only slight curvature of the surface. The removal of all cells can now be checked exactly and safely using a bone punch with a blunt head without danger to the base of the skull.

The lateral wall of the sphenoid sinus also marks very accurately the contour of the lateral wall of the ethmoid compartment, as the series of CT scans shows, running forwards in a smooth gentle curve towards the orbit (see Chapter 2 on Endoscopic Anatomy). It is relatively thick unlike the thin party walls of the ethmoid cells, so that careful dissection precludes injury to the orbit or the optic nerve.
The canal for the optic nerve may lie almost free in the lateral part of the sphenoid cavity but the author has always found it to have a bony cover. Passage of the optic nerve through an ethmoid cell running very far laterally and superiorly is rare, but should be mentioned.

The anterior extent of removal of the posterior ethmoids for posterior ethmoiditis depends on individual findings. If the middle ethmoid cells are also affected, an infundibulotomy is recommended to secure drainage from the remaining anterior cells.

Posterior ethmoidectomy is seldom carried out in isolation, but is usually combined with anterior ethmoidectomy to allow removal to diseased posterior ethmoid cells. It begins with penetration of the basal lamella which has previously been exposed through the bulla, and proceeds from in front backwards.

Complete Ethmoidectomy with Opening of the Sphenoid, Frontal and Antral Cavities

Complete ethmoidectomy is supposed to be one of the most dangerous operations in this area. The literature and discussions at conferences show that various techniques are used for reasons of safety. Radical removal of all the mucosa is said to be better carried out through an external facial incision, but if complete clearance is not indicated many surgeons prefer transmaxillary access after an incision in the oral vestibule. Finally it appears that most authors only choose a strictly intranasal procedure if limited cell clearance is desired. These differences apply more or less to the present day (for example, Naumann, 1987). On the other hand the purpose of surgery with preservation of mucosa, independent of the route of access, is the creation of a unilocular ethmoid cavity with no party walls from which mucosal polyps can be removed with preservation of the mucosal surfaces of the external walls.

Anteroposterior Exposure

This exposure can be achieved with an intranasal technique, either using a classical transbulla procedure described by Halle, or the method beginning in the infundibulum described by Messerklinger and Stammberger. An infundibulotomy is the followed by clearance of the bulla and the anterior ethmoid cells. Next, the posterior ethmoids are opened from the basal lamella, and cleared cell-by-cell in an anteroposterior direction. Stammberger (1985) does not insist on the obligatory opening of the sphenoid and frontal cavities, and he also rejects resection of the middle turbinate.

Posteroanterior Exposure

A description of the technique of intranasal complete ethmoidectomy developed since 1975 in the author's clinic now follows. Unlike previous methods it is based on retrograde exposure of the ethmoids, beginning at the sphenoid sinus and working in a posteroanterior direction along the base of the skull. This has been developed into a standard technique giving a clear exposure which is therefore free of complications, and which also give reliable results. It is indicated for severe diffuse polyposis of the ethmoids: it is usually combined with septoplasty and opening of the sphenoid, frontal and antral cavities (pansinus operation).
The main prerequisite for the safety of the procedure is an optimal view of the surgical field. It is true that a large part of the procedure can be carried out under direct vision through the nostril using a long nasal speculum, but for the deeper regions optical magnification is necessary, using the operating microscope where forward vision suffices, and the angled telescope to see around corners. The author usually uses a 70° angled telescope with an irrigation-suction handpiece.

The second principle is complete opening of the cells to guarantee healing of the chronic mucosal inflammation. Remaining cells are often the point of origin of persistent disease. These two aspects therefore led us to develop complete ethmoidectomy, in which an entirely visible ethmoid compartment is created with no remaining narrow areas and no remaining cells. The resulting wide upper nose was a new and surprising experience, that did not lead to drying of the regenerating mucosa nor to the development of ozena. Thus the middle turbinate can be removed partially or sub-totally with no ill effects.

Polyps filling the nasal cavity are removed with forceps or snares after intensive decongestion of the mucosa with adrenalin-soaked pledgets, providing a reliable view of the shape and position of the often markedly atrophic or polypoid middle turbinate.

Opening of the sphenoids begins with a posterior partial resection of the middle turbinate. An incision curved concavely upwards is made with the turbinectomy scissors curved on the flat so that the posterior part of the turbinate inserting into the ethmoid is reduced in size. The loose posterior turbinate stump can be removed with a No 3 ethmoid forceps through the curved incision and through a counter incision at the end of the turbinate. The incision curving obliquely downwards gently straddles the lateral ethmoid and encompasses about one-third to one-quarter of the free body of the turbinate. Bleeding from the sphenopalatine artery is controlled by bipolar coagulation and compression with a pledget.

The posterior ethmoid labyrinth is opened by posterior, limited removal of the free body of the middle turbinate. The figure shows some cells with their party walls. Polypoid mucosal edema, tenacious mucus or pus often ooze out in cases of polypoid ethmoiditis. The tangle of cell walls and polyps is removed carefully using a large Blakesley No 3 forceps; the instrument must always be directed posteriorly.

At a point from 1 to 2 cm above the upper edge of the posterior nasal choana there is no danger of perforation of the base of the skull because the surgeon encounters the thick anterior wall of the sphenoid sinus or the rigid plate of the sphenoid plane if he goes too high.

The lateral boundary of the posterior ethmoid demands care: occasionally the canal of the optic nerve may form a visible bulge or can even be surrounded by an extensive Onodi cell so that it lies almost completely within this cell. However, the optic nerve is safe from injury if the forceps are not directed laterally during this first phase of removal of the posterior ethmoid cells, but are introduced towards the anterior wall of the sphenoid sinus in the midline, parallel to the septum.

It is advisable not to expose the posterior ethmoid cells as far as the ethmoid roof directly at this point, but firstly to expose and remove the anterior wall of the sphenoid sinus,
to avoid dissection towards the base of the skull. The level of the roof of the ethmoid sinuses can be deduced from the direction of the easily visible roof of the sphenoid so that resection of the posterior ethmoid cells with a punch can now proceed safely in a posteroanterior direction. The blunt end of the punch cannot perforate the anterior cranial fossa even if excess pressure is exercised.

First of all, however, some remarks must be made about exposure of the sphenoid cavity behind an unusually well developed ethmoid. The surgeon who is familiar with the anatomical landmarks can open the sphenoid cavity without difficulty once the presence and shape of the cavity have been confirmed by radiography, preferably CT scans.

The anterior wall of the sphenoid sinus is easily exposed by careful removal of the posterior ethmoid cells after resection of the posterior end of the middle turbinate. It is easy to find a thin point using a suction tube, and to break into the sphenoid at this point using gentle pressure.

In other cases the closed pointed Blakesley’s (No 1 or 2) forceps can be used to find the ostium and to enlarge it by opening the blade. The position of the sphenoid ostium can be deduced from the relation between the posterior insertion of the middle turbinate and the choana. A point about 5 mm above and 3 mm medial to the attachment of the inferior turbinate usually lies in front of the sphenoid cavity, and at this point the ostium or a semi-transparent bony area can be found marking the underlying cavity. Another easy method of finding the point of opening is to introduce a suction tube 10-12 mm above the apex of the choana, then to pass it slowly in a medial direction and finally to push gently in the midline. The wall gives suddenly, and the suction tube then lies within the sphenoid cavity. The Blakesley's forceps is now introduced closed and pulled out again in the open position, producing an opening of sufficient width through which the 45° or 90° forceps can be introduced for complete removal of the anterior wall of the sphenoid sinus. Arterial bleeding from the edge of the resection, usually inferolaterally, is dealt with by coagulation or packing.

The patient's eyes and his circulation deserve special attention during all procedures in the posterior part of the ethmoids and the sphenoid cavity. The pupil should be repeatedly inspected to ensure that it is constricted and reacts to light. A reflex mydriasis indicates a functional lesion of vision that resolves spontaneously. The operation should be suspended and an ophthalmologist asked to inspect the optic fundi to exclude ischemia of the central artery, indicating thrombosis or even a lesion of the optic nerve. Also an exploratory transethmoid opening of the orbital cavity by resection of the lamina papyracea and longitudinal incision of the orbital periosteum may be indicated in the search for a hematoma either outside or inside the orbital periosteum due to damage to an ethmoid artery which then retracts into the orbit. In the worst cases a transfacial or transfrontal orbitotomy must be carried out. The author has seen reflex transitory mydriasis on two occasions during ethmoid operations; they both resolved without sequelae within 30 minutes.

Reflex increase in pulse rate and blood pressure during resection of bone in the posterior ethmoid and sphenoid sinus region is quite common. They are harmless but in high-risk patients require attention from the anesthesiologist.
Complete exposure of the posterior ethmoids is not always simple. The cell septa are punched out, beginning on the roof of the cavity of the sphenoid sinus and remaining in the same level along the base of the skull in a posteroanterior direction. They are removed with their abnormal contents such as polyps, cysts or pus. Great attention must be paid to complete removal of bony spurs and party walls which encourage the retention of secretions. This removal of the posterior ethmoid cells can often be carried out under direct vision. However, all the cells of the posterior ethmoid, including any lateral processes must be removed so that optical control using an angled telescope is necessary. Others prefer routine use of the operating microscope (Teatini, 1982, Draf, 1980). The bony party walls should be removed, using sharp punch or forceps, and the cell contents cleared, but the outer wall of the ethmoids should remain covered by mucosa. Unfortunately the mucosa covering the roof and the lateral wall of the ethmoid is often not completely preserved because it is torn by blunt instruments.

Once the posterior ethmoid is opened and hemostasis has been achieved with pledgets soaked in adrenalin, an outstanding view is obtained, facilitating removal of the anterior ethmoid. Before undertaking the next step the topography should be checked again by looking for the upper end of the curved incision through the posterior part of the middle turbinate. This point marks the anterior point of removal of the resected end of the turbinate, and also the posterior point of the main part of the middle turbinate still attached to the base of the skull. The posterior end of the attachment of the medial lamella of the turbinate to the base of the skull is an important landmark indicating the posterior edge of the cribiform plate. The mucosa extending up to this point in the gutter between the nasal septum and the middle turbinate forms the olfactory region and must be preserved at all costs. Olfactory fibers run rostral to this landmark and also within the medial surface of the turbinate; if they are torn, the dural sheaths are split causing a CSF leak.

In contrast, the ethmoid cells behind the insertion of the middle turbinate into the roof of the ethmoid, are roofed by the firm bone of the sphenoid plane, excluding inadvertent perforation with the forceps or punch.

**Management of the Middle Turbinate**

The middle turbinate is an integral part of the ethmoid cell system forming both a key and an obstruction to complete ethmoidectomy. It may be poorly or well pneumatized, or even expanded due to excessive pneumatization forming a bullous turbinate. If it is affected by polyoid ethmoiditis it must be cleared, producing a cavitation of the turbinate. After scrupulous removal of the cells from the turbinate, sometimes little remains other than a membranous floating medial lamella. In other cases the turbinate is narrow and compact so that it need not be cleared. Often one turbinate obstructs the view of a narrow ethmoid, particularly if the septum is broad. For these reasons, and in the interests of healing and safety, a partial removal of the turbinate should be seriously considered, but sacrifice of tissue should be minimal to prevent unnecessary loss of olfactory mucosa. Objections to resection based on the worsening of the airstream or drying of the nasal mucosa are groundless, even after sub-total resection.

Initially the author carried out a generous resection of the turbinate both for reasons of safety and to allow thorough removal of the cells (Wigand, 1981), but now practices conservative turbinate resection to preserve the sense of smell. The posterior third is resected
to expose the posterior ethmoids in most cases of complete ethmoidectomy for massive polyposis, so that the posterior ethmoids and the sphenoid cavity may be exposed completely, but the main part of the body of the turbinate is preserved. In particular, great care should be exercised to preserve the medial lamella of the turbinate. The extent of anterior partial resection of the turbinate is determined individually by its shape.

If the pneumatization of the turbinate is pronounced (concha bullosa) an initial longitudinal incision with a size 15 scalpel, a fissure knife or bone scissors is worthwhile. In this way the medial surface with its fine bony lamella is preserved while the body of the turbinate and its cells can be recognized in steps. If the turbinate is less well pneumatized in its free part but cells are well developed in the upper part then postero-anterior clearance of the middle and anterior ethmoid cells usually suffices.

If the middle turbinate is even better pneumatized with cells extending into its inferior segment close to its edge then all polyps must be removed from the cells of the middle turbinate complex. Its medial lamella then hangs from a narrow base only, and is even more unstable if the agger nasi is punched out lateral to the anterior area of attachment of the bone to uncover the most anterior ethmoid cells, the agger nasi cells and the frontal duct. In this situation it may be appropriate to cut back as much as fifty percent of the turbinate through a longitudinal curved incision with no regard for damage to the olfactory function. Personal observations show that normal olfaction is often preserved even if the middle turbinate is lost up to its fixed base. It appears that remnants of the turbinate along with the olfactory area of the septum are able to provide a sense of smell.

A large floating medial lamella of the turbinate can later cause "turbinate flutter" during respiration, and the large wound surface can adhere to the lateral ethmoidal wall. A drop of blood at this narrow point is enough to cause the adhesion. This situation can be managed successfully by folding the floating lamella of the turbinate over to prevent both turbinate flutter and unnecessary loss of valuable olfactory mucosa. The mucous membrane is folded over to reach the roof of the ethmoid and is fixed with fibrin glue. This type of reconstruction has three advantages: stabilization of the fluttering remnant of the turbinate, patency of the olfactory cleft, and minimizing of the wound surfaces. The frontal duct must not be obstructed by parts of the turbinate.

Dissection of the olfactory cleft requires special attention. One of the main symptoms of chronic sinusitis is loss of the sense of smell, usually due to mechanical obstruction of the olfactory cleft. The sense of smell may return rapidly or gradually after the operation, provided that enough Olfactory epithelium remains following restitution of aeration and drainage. It is doubtful whether the olfactory epithelium is capable of regeneration by surface expansion. Therefore great care must be taken, even during minor procedures such as polypectomy, to preserve mucosa on the upper third of the medial lamella of the middle turbinate and on the corresponding surface of the septum, to lacerate as little mucosa as possible and to preserve bone. If ulceration in this region can be prevented, for example by extremely careful diathermy removal of polyps and adhesions under endoscopic control, the prospects of recovery of the sense of smell are good. Unfortunately, repeated extractions of nasal polyps in the doctor's office without correction of the septum and without clear operating conditions often lead to a superficial defect of the turbinate and septum with
resulting synechiae of the upper nasal cavity. Many of these patients go through life with no sense of smell.

The middle turbinate may have to be split initially, it may have to be partially resected or it may be left untouched. Which of these is done determines whether dissection of the turbinate allows clearance of the posterior ethmoids or exposure of the middle and anterior ethmoid cells.

**Removal of the Middle and Anterior Ethmoid Cells**

Then the honeycomb of cells and polyps is removed lateral to the medial lamella of the turbinate preserving the stump of the middle turbinate (which may already have been exposed) or the retained body of the turbinate. The cells are removed with the punch, or opened with a sharp upward-curved forceps and cleared up to the base of the skull. It is useless to plan a previously determined route of removal of named cells tracts. All cells lying between the body of the middle turbinate or its medial lamella and the lateral ethmoid wall (the lamina papyracea) should be broken down gently and removed. The ethmoid gallery is thus cleared between the middle turbinate and the orbital wall as far as the overhang of the agger nasi. An angled telescope must be brought into use at this point for the further rostral part of the procedure. Once again the necessity for care around the point of insertion of the middle turbinate to the skull base is emphasized: a row of olfactory fibers runs through the skull base onto its medial lamella and these can be damaged. Firm resistance during breaking down the party walls of the ethmoid cells or removal of polypoid mucosa may indicate that an olfactory fiber has been grasped in the instrument. Energetic tearing is always to be avoided as ethmoid cells and their mucosa can almost always be removed without force. A particularly dangerous dural tear may also be signalled by the oozing of dark venous blood.

A small CNS leak indicates tearing of an olfactory fiber. The operation should be abandoned, and the fistula closed as follows: firstly it is inspected very carefully with the endoscope, and the integrity of the neighboring bone tested by careful probing with a fine elevator. Mucosal remnants are removed from a surrounding area of 2-3 mm with a small double forceps. An oval mucosal flap is now harvested from the free edge of the inferior turbinate, carefully smoothed on its internal surface, freed of bone, but not overly thinned. This free mucosal graft is fixed over the fistula with a wide overlap using fibrin glue after hemostasis has been achieved. The procedure ends with an endoscopic check and packing, using two layers of moist gelfoam left in place for more than 2 weeks. Under this lies a layer of packing of gauze strips soaked in aureomycin exerting slight upward pressure; it too should be left in place for at least 10 days. The defect should heal within 4 weeks. Small perforations of the anterior base of the skull due to other causes can be managed in a similar manner.

Removal of the most anterior ethmoid cells under direct vision or using the endoscope requires resection of the agger nasi. This procedure also plays a key role in opening of the frontal sinus and in the prevention of recurrent polyps and cicatricial stenosis, but it destabilizes the middle turbinate whose anterior edge merges into the agger nasi. One jaw of a 90° upward-cutting punch is passed under the bony overhang uniting the most anterior part of the medial lamella and the middle turbinate with the lateral ethmoid wall. Under it open the agger nasi cells forming part of the most anterior ethmoid cell system, and which are usually affected by diffuse polyposis. This step can easily be done during ethmoidectomy.
without endoscopic control, but if it is omitted loculated sinuses remain, hindering free
drainage from the frontal sinus. On the other hand too aggressive resection of the agger nasi
can damage the lacrimal canal running within it.

Complete exposure of the most anterior ethmoid cells demands the help of the 70°
telescope. The first step is control of the lateral wall of the ethmoid that is tapering both in
height and breadth as it runs anteriorly. A specially designed, blunt, 45° upward-cutting
ethmoidal forceps is valuable for this step: it must always be introduced parallel to the lamina
papyracea. The bony septa inserting perpendicularly into the lamina papyracea can be broken
down and the surface smoothed safely by closing its jaws.

The most anterosuperior part of the ethmoid system is often relatively acellular, and
it varies widely in form. Also, a slender upper track of cells sometimes running forwards over
the larger cells along the base of the skull can escape the naked eye. Endoscopic inspection
is therefore necessary to pick up these small niches and clefts, and to inspect the recesses
bulging laterally into the orbit.

Complete removal of mucosal polyps from the lateral anterior ethmoid cell systems
is particularly important in massive polyposis, because recurrence can easily arise from
remnants which are readily overlooked at this point. Small paraturbinate cells or recesses of
the ethmoid are occasionally found during antrostomy even lying lateral to the insertion of
the middle turbinate, and they can be the source of recurrence.

With the angular telescope it is always easy to see the transverse bar housing the
ethmoid artery in the anterior part of the ethmoid roof. This bulge is an important landmark
forming the boundary between the danger area of the ethmoid containing olfactory fibers, and
the ascending part of the ethmoid roof or the posterior wall of the frontal infundibulum lying
a few millimeters in front of the bar. The two are usually separated by only one cell. If the
artery has been damaged with the punch, the bleeding can be controlled quite easily using
bipolar coagulation, but the arterial stump can retract into the orbit causing a massive extra-
or subperiosteal hematoma, leading to exophthalmos or even blindness caused by compression
of the optic nerve. Swelling or hematoma of the eyelids are harmless; they are treated by ice
packs, but immotility of the eyeball, mydriasis or an absent light reflex demand the
emergency measures already described.

If the orbital periosteum is breached allowing orbital fat to enter the nasal cavity, the
protruding tissue is replaced and possibly scarified using bipolar coagulation. This procedure
should of course be used only for small defects. For added safety a small piece of lyophilized
dura can be fixed over the defect with fibrin glue.

The above description of complete ethmoidectomy applies to polypoid pansinusitis,
the most frequent indication. In consequence, it must be emphasized that free drainage of the
frontal duct should also be secured. In most cases the ostium of the nasofrontal duct, or even
a wide frontal infundibulum, opens up automatically after removal of the most anterior party
walls of the ethmoids. If the duct will accept a curved size 17, or even better a size 18,
suction tube, then further procedures can be omitted. The frontal sinus will heal provided that
the duct is kept patent by careful aftercare. A narrow frontonasal duct may be adequate in the
absence of disease. If it is inadequate to guarantee permanent aeration of the frontal sinus an intranasal frontal sinusotomy should be carried out. In most cases widening of the narrow but visible frontal ducts by curettage directed anteriorly suffices. In other cases a wide connection to the frontal sinus is created by resection of the dividing wall between the most anterior ethmoid cells and the frontal infundibulum.

In massive polypoid pansinusitis it has proved appropriate to follow intranasal endoscopic pansinus operations by the appropriate antral procedure, once the ethmoid compartment has been attended to. Manipulation of sharp-angled instruments within the antrum via the middle meatus is considerably easier once the middle turbinate and the agger nasi have been partially resected. The severity of the disease of the maxillary mucosa does not always mirror that of the ethmoids, so that a middle meatal antrostomy, possibly even with preservation of the primary maxillary ostium, may suffice despite the need for a complete ethmoidectomy. However, in many cases the antral mucosa, too, is severely diseased with numerous polyps and thick retention cysts requiring wide resection. In this case a small window is inadequate, and the medial meatal antrostomy should be extended over the entire uncinate process, and the shape of the window must be adapted to the needs of manipulation of instruments on the floor of the antrum. Occasionally it may even be necessary to create a second, inferior, meatal antrostomy.

Anterior extension of a middle meatal antrostomy and particularly of an inferior meatal antrostomy can expose and damage the lacrimal canal, although this accident is often without sequelae.

At the end of the pansinus operation the nasal cavity and the ethmoid compartment are packed loosely for 2 days, and a breathing tube is left in place.

**Revision Operations on the Ethmoid**

If the patient has had a previous partial or complete ethmoidectomy by either the intranasal, external or transmaxillary route, a second procedure is more difficult due to scarring of the bony framework, and sheets of scar tissue within the cells rendering orientation and safe surgery much more difficult. Sadly, revision operations are quite often necessary but are difficult to carry out by the intranasal route if the patient has previously undergone a transfrontal procedure in which the cell tracts in the fronto-ethmoidal junction have been destroyed. Similarly a functional antro-ethmoidal procedure with mucosal preservation is often difficult and disappointing after a previous Caldwell-Luc transoral procedure because the cavities are no longer lined with mucosa capable of regeneration. There is therefore a danger of creation of lining of scar tissue arising from granulation tissue sprouting from the wound surfaces.

However, in such cases clinical examination and imaging may suggest that removal of mucosal scars or opening of loculated residual cells are indicated and an intranasal revision procedure should be tried before re-exposing the ethmoids through an external facial incision. The systematic series of steps described above is advisable: that is the examination of the posterior ethmoid and the sphenoid sinus, inspection of the ethmoid roof posteroanteriorly along the now visible base of the skull, re-exposure of the most anterior part of the ethmoid region as far as the opening of the frontal sinus, and revision of the antrostomy.
The main reasons for secondary obstruction of the frontal sinus include firstly, scar tissue obliteration of the narrow ethmoid gutter between the insertion of the middle turbinate and the lamina papyracea, and secondly prior inadequate excision of the agger nasi. The symptoms include frontal headache, a feeling of pressure in the medial canthus, and the symptoms of sinusitis and recurrent bronchitis in addition. There is no golden rule for sharp dissection and removal of the sheets of scar tissue and synechiae. The choice of sharp instruments such as double forceps, curettes, pointed punches, etc, must be determined by the experience of the surgeon and the local situation. It must always be borne in mind that removal of tissue creates a wound surface which will form further scar tissue, unlike the first operation which preserves at least some of the mucosa. In recent years the author has preferred the argon laser or diathermy for revision surgery, and has found that excessive granulations to recurrent scar tissue are less common, particularly after laser coagulation of cicatricial bands in the antrostomy opening. In contrast the introduction of spacers such as silicon tubes or sheet has not so far proved of value.

Ethmoidectomy in Children

Like antral operations in infancy, ethmoidectomy in children demands a conservative policy. Complete ethmoidectomy at this age is as technically possible as in the adult, and the smaller dimensions are no hindrance if fine instruments are used. The indications are limited, however, by the necessity for simultaneous mobilization of the septum which is possible but not without problems, and by intolerance to endoscopic aftercare.

If partial or complete ethmoidectomy is indicated for severe bronchial asthma, mucoviscidosis, etc, good pediatric support must be ensured, and the parents must understand that the prognosis is dubious, and that one or more endoscopic examinations under general anesthesia will be required during follow-up.

The technique follows that already described for adults, but the prospect of recovery of hyperplastic polypoid or cystic lesions is better than in adults. Therefore the author would always first of all try a minor procedure limited to the middle meatus: polyps narrowing the nasal lumen or choana should be removed carefully without damaging the mucosa of the turbinates or nasal walls. The middle turbinate is displaced, the middle meatus is exposed, and an extremely careful exenteration undertaken. A hiatotomy alone or a limited infundibulotomy, with or without middle meatal antrostomy, can suffice, or at least gain an interval of up to 3 years after which time an ethmoidectomy may be carried out. The danger of synechiae is particularly high because of the small dimensions of the ethmoids. The author is particularly opposed to the sloppy technique of indiscriminate breaking down of the ethmoidal cells.

Applications

Chronic Ethmoiditis

The decision to carry out an ethmoidal operation for chronic sinusitis must always be weighed carefully.
The indications for surgery for mucosal hyperplasia of the ethmoids demonstrated by tomography or CT scans, and particularly for endoscopically confirmed polyposis include:

- failed conservative treatment of nasal obstruction, mucosal swelling, headache, postnasal drip, dysosmia, pharyngitis and laryngitis,
- recurrent episodes of sinobronchitis complicated of bronchospasm or even established asthma; in recent years ethmoidectomy has proved to be useful for severe inflammation of the bronchial mucosa in mucoviscidosis;
- secondary ear disease such as tubal catarrh, chronic otitis media, particularly as a prelude to tympanoplasty, but also for fluctuating, progressive and otherwise unexplained sensorineural deafness,
- an inflammatory focus associated with a proved chronic ethmoiditis.

An endoscopic ethmoidectomy is contraindicated:

- if operative complications or an inadequate procedure are likely due to the surgeon's lack of experience; no operation at all is better than an unsuitable operation,
- if the patient cannot tolerate endoscopic aftercare, which is particularly true of children, oversensitive and frail patients. If the pediatrician or the internist has referred the patient for clearance of a septic focus, aftercare may require repeated general anesthesia.

The planning of the operation is determined mainly by the findings on CT scan, which may suggest partial removal of the anterior ethmoid cells or demand complete ethmoidectomy, particularly for anatomical anomalies such as aberrant cells, a low-lying ethmoid plate, etc. When talking to the patient before operation the surgeon should always keep his options open, and explain that external incision may be found to be necessary during the operation. This is particularly true of unilateral ethmoiditis which is unusual and which must always be suspected of concealing an inverted papilloma or even a carcinoma. In the author's material unilateral polyposis of the nasal cavity was found in 8.5% of cases whereas unilateral ethmoiditis was disclosed by radiology in only 3.3%.

The operative technique for chronic inflammation follows the guidelines already described. The view may be made worse by brisk bleeding from a highly inflamed mucosa, by arterial hypertension, by scar tissue due to a previous operation or by a septum which has been previously subjected to an inadequate operation. Repeated removal of nasal polyps is very unfavorable for the healing of the ethmoid and olfactory cleft, and damage to the septal mucosa all too often leads to adhesions between the septum and the middle turbinate. Local hemostasis using adrenalin or cocaine is very useful. Thick plates of scar tissue lying close to the dura or the orbit can occasionally indicate that the limits of operability by the intranasal route have been reached. If it is still possible to obtain a straight view into the sinus the use of an operating microscope may be helpful.

Complications of Inflammatory Disease

The categorical statement in textbooks and surgical atlases that external radical frontal and ethmoid operations are required for rhinogenic complications deserves revision.
An increasing proportion of patients with inflammatory complications of ethmoiditis requiring drainage of pus, or relief of an infective focus, can be treated by intranasal ethmoidectomy. The indications include pyoceles arising from the anterior ethmoid cells, inflammation extending to the lacrimal pathways, and subperiosteal orbital cellulitis or abscess. Osteitis of the maxilla, too, can be treated effectively by this method. The most important principle is complete endoscopic removal of the diseased ethmoid cells, wide marsupialization of a pyocele from within, or generous slitting of the orbital periosteum of the endoscopically visible and palpable swelling of the medial wall of the orbit. Careful drainage of the orbit with slender drains can even be achieved in this manner.

The CT scan in the figure shows expansion of the left antroethmoidal region by a large pyocele displacing the orbital contents upward and laterally and causing double vision. It arose from mucosa entrapped at a transoral radical antrostomy with partial transmaxillary ethmoidectomy 12 years previously. The inferior meatal antrostomy had closed by scar tissue. Simple marsupialization of the mucocele into the middle meatus and exenteration of the remaining neighboring ethmoid cells led to healing of the antral lumen and the orbital contents within a few weeks. The vision returned to normal and the pain resolved immediately after release of the pressure. The figure shows a CT scan taken later, and the other figure shows the noninflamed antral mucosa through the large, newly created middle meatal antrostomy.

Ethmoid inflammation spreading to the orbit is a particularly suitable indication for complete intranasal ethmoidectomy. A deep-seated orbital abscess, shown by imaging, requires a wide orbitotomy via an external facial or frontal approach, whereas an abscess in the ethmoid area can be drained intranasally. Even osteitis arising from the ethmoid and presenting externally, and meningitis in the absence of an abscess can be healed by endoscopic ethmoidectomy supplemented by antibiotics and intensive postoperative care.

**Ethmoid Tumors**

Benign ethmoid tumors and early localized malignant tumors can be controlled by an intranasal ethmoid procedure under endoscopic vision. An attempt at complete removal by this route is justifiable if the limits of the tumor have been defined by tomography and invasion through the roof of the ethmoids has been excluded. Specimens should be taken for histology from the wound edges to ensure complete excision of papillomas and small carcinomas. However, if the roof of the ethmoids, the septum or the orbital periosteum are invaded, an extensive external procedure must be undertaken. For large squamous carcinomas, adenoid cystic carcinomas or esthesioneuroblastomas, intranasal access may play a part in providing an inferior counter access in a combined transfrontal neurosurgical-rhinological procedure, whereas an intranasal operation alone is not to be recommended for this group.

The exposure of an *ethmoid osteoma* is very simple. Since the ethmoid cells are usually not infected, only limited resection is needed, and in particular the medial wall of the middle turbinate should be completely preserved. The tumor is completely exposed by opening the ethmoid bulla, and by piecemeal removal of the overlying cells. If it is large or wedged by lateral processes, it can be broken up *in situ* with the diamond burr before removing it. Even an osteoma with a wide intraorbital extension can be removed in this way.
The wound surface can be relied upon to re-epithelialize spontaneously because the healthy mucosa is mostly preserved.

Other benign tumors of the ethmoids are unusual, the commonest being a neurinoma. Its point of origin cannot always be defined because this tumor is often quite large before it is diagnosed due to the non-specific symptoms. If the tumor is shown by CT scan to be limited and biopsy confirms its benign nature, intranasal endoscopic removal via a limited ethmoid resection can be successful. The figure shows an example of a well demarcated neurinoma that was permanently controlled by subtotal resection of the middle turbinate with exenteration of the neighboring ethmoids. The differential diagnosis includes fibroma and adenoma. These must not be confused with a meningocele of the ethmoid requiring an external incision because of the accompanying defect of the base of the skull. Lymphomas are usually treated by a combination of chemotherapy and radiotherapy.

Inverted papillomas and small carcinomas arising from the middle meatus can be controlled by complete resection of the middle turbinate. Tissue from the neighboring cells must be submitted for histology to confirm complete excision. Ethmoid papillomas can be equally well controlled by an intranasal procedure as by the external route. Often they arise at the maxillo-ethmoid junctional zone and extent to the antrum. Even with the endoscope it is not always possible to know whether the polypoid tissue is of a nonspecific inflammatory nature or neoplastic, so that a generous ethmoid resection should be carried out with painstaking geometrical removal of tissue followed by histological examination of several identified specimens. In addition to removing the mucosa completely in suspect areas, the bone should be removed with the diamond burr, using a drill with a slender shaft under endoscopic control. If the tumor extends into the antral cavity an inferior meatal antrostomy or an antrostomy through the canine fossa has proved valuable for the introduction of the drill. The drill is monitored with an endoscope introduced through the middle meatus. Cooling with physiological saline solution is difficult if the drill lacks an attached nozzle. Healing of the bone may take several months, and must be followed by endoscopy. The danger of histological misdiagnosis is very great for tumors of the nose and sinuses. Chondrosarcomas, rhabdomyosarcomas, esthesioneuroblastomas and malignant vascular tumors often demand extensive special investigation. Since they frequently extend beyond the limits of the ethmoid, they are usually not suitable for an intranasal operation.

**Ethmoidectomy for Access**

Intranasal endoscopic ethmoidectomy is being used with increasing frequency for access to the pituitary gland, the sphenoid sinus, the optic nerves, the lacrimal pathways and the frontal sinus. Wide experience with ethmoidectomy for chronic sinusitis is necessary before embarking upon this development in base-of-skull surgery. An experienced surgeon should be able to undertake the exposure for these specific procedures using this elegant and atraumatic technique, with the help of a microscope and an angled telescope, without reducing the efficacy of the procedure.
Internal Dacryocystorhinostomy*

M. Weidenbecher

* Intranasal endoscopic dacryocystorhinostomy has become established as a routine in the eye and ear clinics in Erlangen. The author is particularly grateful to Prof Dr G. O. H. Naumann, Director of the Ophthalmological Clinic of the University of Erlangen-Nürnberg for sympathetic and fruitful cooperation.

Only a few years after Toti (1904) described external dacryocystotomy through the medial canthus, West (1911) and Polyak (1913) published a procedure for intranasal opening of the lacrimal sac. At present this operation is usually carried out by the rhinologist, with the help of an endoscope or the microscope. Compared with the external method it has two advantages: good cosmesis because there is no incision in the medial canthus, and preservation of the lacrimal apparatus. Restricted vision is a potential disadvantage, but is easily overcome with experience.

Indications for Internal Dacryocystorhinostomy

This intranasal procedure is suitable for:
- intrasaccal and postsaccal stenosis of the lacrimal ducts,
- reoperation after Toti’s procedure.

Etiology of Stenosis of the Lacrimal Ducts

Narrowing of the lacrimal pathways can be caused by:
- recurrent inflammation of the ducts,
- repeated probing of the ducts,
- transmaxillary and, rarely, intranasal operations on the antrum,
- trauma to the base of the skull (impaling injuries, fractures of the lacrimal bone, Le Fort-II- and III-fractures,
- rhinoplasty,
- telecobalt irradiation causing fibrosis of the lacrimal ducts,
- tumors of the nasal cavity.

Operative Technique

The operation can be carried out under either general endotracheal or local anesthesia. Visualization is improved by decongestion of the nasal turbinates and resection of a high septal deviation. A vertical mucosal incision is made with a fissure knife about 1.5 cm long over the frontal process of the maxilla, above the anterior end of the inferior turbinate, in front of the anterior end of the middle turbinate, and about 1 cm behind the piriform aperture. A second incision is made parallel to this lying 2 cm further posteriorly. The mucosa is raised using an elevator and excised with a small curved conchotomy scissors. Irregular edges are straightened with the conchotome. A 15 x 20 mm mucosal defect is thus created on the lateral nasal wall. A septal chisel is used to create a 8 x 16 mm defect in the frontal process of the
maxilla lying over the lacrimal sac. Since the upper edge of the lacrimal fossa is closely related to the anterior ethmoid cells, the latter may be inadvertently opened, and must then be carefully removed. An assistant introduces a probe through the inferior lacrimal punctum, and pushes the medial wall of the lacrimal sac into the nasal lumen using the probe. Using a specially curved sickle knife as employed in ear surgery, with an irrigation-suction telescope in his left hand, the surgeon cuts the medial wall of the lacrimal sac in its entire extent. Draf (1982) has described the formation of flaps from the edges of the lacrimal sac; these flaps are then reflected and fixed with fibrin glue. However, the author regards these flaps as being unnecessary, and in any case they are usually not practicable because of the restricted field. The excellent illumination of the surgical field provided by the endoscope allows precise surgery to be carried out so that the entire medial surface of the sac can be resected, thus largely preventing re-stenosis. It is advisable to intubate both canaliculae into the nasal cavity for 6 weeks to guarantee a good result. Further irrigation of the lacrimal ducts during this period is unnecessary. Loose nasal packing for 2 days reduces the risk of postoperative bleeding.

The results of this operation should not be assessed for at least a year, but personal experience and the literature show that the results are at least as good as those achieved by an external procedure, and are satisfactory in 75-80% of cases.

**Operations on the Frontal Sinus**

**Indications**

- recurrent empyema of the frontal sinus,
- chronic frontal sinusitis,
- partial operations for diffuse hyperplastic pansinusitis,
- muco- and pyoceles,
- biopsy,
- small benign tumors,
- foreign bodies.

**Principles**

The goal of the operation is the removal of circumscribed pathological changes with preservation of mucosa and thus of mucociliary transport, and without extensive destruction of the bony walls of the sinus. The following are available:

- endoscopic, limited opening of the frontal sinus from below (widening of the fronto-ethmoidal junction zone),

- endoscopic monitoring of intracavity manipulations through an external bore hole,

- a limited external frontal sinus procedure using the endoscope and plastic repair of the small defect in the anterior wall of the frontal sinus, with preservation of the bony framework. If necessary a mucocele is marsupialized
and tumors are reduced in size within the cavity before removal. Treatment of complications by conservative surgery is still developing, and demands intensive postoperative care.

Operative Technique

Preliminary Observations

The restricted access to the often extensive and recessed frontal sinus limits intranasal sinus surgery. Whereas the view into all recesses may be satisfactory for diagnostic purposes, many therapeutic manipulations are ill advised because the necessary instruments cannot be monitored endoscopically.

However, much can be achieved, contrary to what might be expected, including the generous transnasal fenestration of the floor of the frontal sinus which suffices for the treatment of most cases of sinusitis when combined with circumscribed dissection of the frontal infundibulum. Many other problems such as stenosis, foreign bodies and occasionally mucopyoceles, can be tackled if this procedure is combined with a small transfrontal portal to allow the introduction of an endoscope or instruments. When choosing between a transfacial or intranasal procedure the safety of the patient is more important than avoiding a facial scar.

Exposure of the Frontal Infundibulum

The prerequisite for endoscopic exposure of the frontal sinus from the nose is removal of the anterior part of the ethmoid area as far as the base of the skull. If the most anterior ethmoid cells have been opened intranasally during an anterior ethmoidectomy the blunt probe usually glides smoothly into the frontal infundibulum. The use of force and of pointed bougies is dangerous. An endoscope with an angled telescope should be used to expose the anterior ethmoid.

Bony overhangs, coarse mucosal tags and polyps interfering with the view into the frontal duct should be removed under vision. These obstacles are often not present, so that removal of the most anterior cells leads directly into the frontal sinus. In those cases with a well developed cell system, the frontal duct can be easily widened to a diameter of 4-5 mm by removing small remaining septa with the punch. This step improves the prospects of healing of chronic sinusitis and prevents obstruction by scar tissue. If a curved suction tube 4 mm in diameter passes without resistance the frontal duct will usually be found to be wide enough. The resulting opening suffices for suction of thickened secretion and for the removal of polyps or cysts with the curved forceps. Further procedures are unnecessary even if the mucosa is thickened and humped because of the excellent recuperative capacity of the frontal sinus mucosa.

Care must be exercised when tearing off mucosal tags, because resulting reparative granulation tissue can lead to the formation of cicatricial stenosis. On no account must the mucosa around the entire circumference be damaged because this leads to a ring of scar tissue.
If the endoscope does not enter the frontal sinus and the anterior ethmoid cells apparently end blindly, or if only a narrow nasofrontal duct is visible, fenestration of the floor of the frontal sinus may be indicated, but the author usually omits this extension of the procedure if the ethmoiditis is not extensive, and radiography has shown good aeration of the frontal sinus with no mucosal swelling. On the other hand sinusotomy should be carried out for massive polyposis with an absent view into the frontal sinus indicating a disorder of drainage and aeration of the sinus. It is likewise indicated for the fenestration of frontal mucoceles.

**Intranasal Frontal Sinusotomy**

Two concepts are important:

1. If the nasofrontal duct has a visible diameter of only 1-2 mm, and appears incapable of ensuring satisfactory drainage for extensive polyposis of the frontal sinus, it should be widened to form a broad duct extending as far as the frontal infundibulum. This procedure corresponds to the concept of isthmus surgery. Although the surgeon is now aware of the direction of dissection, widening of the duct is often more difficult than perforation of the cells by the second method about to be described because the cells are usually small and few in number.

   Sharp forceps are usually inadequate for the often hard bone, and in this case the diamond burr should be used to resect the bone on one side in an anterior direction (but not in a circular manner) in front of the nasofrontal duct. Since ideal angled diamond burrs have not yet been developed the arch of bone hanging down from the agger nasi must be straightened, and the anterior wall of the duct itself must be drilled gradually. One finger of the left hand holding a long speculum should be placed on the medial canthus to detect perforation of the bone in this area immediately, and thus prevent damage to the lacrimal ducts. An assistant irrigates the drill with cool saline solution which is sucked out of the nasopharynx with a curved tube.

   If a circular lesion of the mucosa has been produced, and the newly created window does not appear to be wide enough, then a spacer should retained for from 2 to 3 weeks to prevent stenosis. The frontal duct may appear to be patent during the first weeks to be followed by cicatricial stenosis some weeks later.

2. Sometimes the search for the frontal duct with the endoscope proves fruitless. However, if radiographs have shown the presence of a developed frontal sinus, a careful endoscopic examination should be carried out. This maneuver is particularly delicate and demanding because inadvertent perforation of the anterior skull base is life threatening.

   The surgeon should orientate himself by the transverse bar formed by the anterior ethmoid artery, and proceed forward from there. At the same time the midpoint between the medial lamella of the middle turbinate and the surface of the already exposed lateral ethmoid wall should be estimated. Anteriorly the ethmoid may be relatively narrow. If the anterior wall of the already dissected ethmoid if now freed of its mucosa in the direction indicated, the frontal sinus can be seen shining through the most anterior ethmoid cells. Sometimes careful curettage with the curved House ear curette helps. This instrument is also particularly
useful for breaking and elevating the thin bony edges to look for the pathway to the frontal infundibulum. If the point of the instrument is never directed towards the dura, damage is impossible even if the instrument has taken a false pathway behind the posterior wall of the frontal sinus. Unfortunately a highly angled diamond burr with which the bone could be removed safely has not yet been developed. After all the cells walls have been removed and the mucosa has been perforated (taking care not to confuse it with dura) the newly created passage is widened using forceps or a punch, but the mucosa should be removed from the anterior and lateral surfaces only.

The following are suitable landmarks for fenestration via the most anterior ethmoid cells:

- the bulge formed by the anterior ethmoid artery,
- the medial lamella of the middle turbinate at its central insertion into the ethmoid roof after removal of the agger nasi,
- the orbital wall.

Inspection with the endoscope in an anterosuperior direction towards the base of the skull reveals the prominent bar formed by the anterior ethmoid artery forming the posterior limit of the sinusotomy. One or two flat cell recesses still lie between it and the site of the nasofrontal duct anteriorly at a distance of at least 2-4 mm.

The medial lamella of the middle turbinate and its insertion into the ethmoid roof form a landmark of inestimable value, because they mark the lateral limit of the cribiform plate. The surgeon must at all costs stay lateral to it when looking for the entrance to the frontal cavity and he has to stay medial to the orbital wall, which after its exposure is another guideline. The curettage may be directed anteriorly halfway between the middle turbinate and the orbital wall. The use of force inevitably leads to perforation of the base of the skull. However, it should always be possible to expose the radiologically defined frontal sinus without visualization of a nasofrontal duct by adhering to the landmarks already mentioned.

Endoscopic Operation on the Frontal Sinus with Two Access Ports

If the frontal sinus is affected by diffuse polyposis the first procedure should be restricted to securing the frontal duct. Only if inspection from below shows obstruction of the frontal infundibulum by polyps is it necessary, or indeed possible, to remove them. Small curved forceps which reach far into the frontal sinus are useful. If the ostium is too narrow it should be widened, usually by the procedures described above.

However, a more vigorous expansion is sometimes necessary because of hard bone or because of an obstinate tendency to stenosis. In these cases supplementary procedures such as the use of the diamond burr or laser excision of scar tissue are necessary. The two portal procedure has proved to be useful. The drill is monitored and irrigated through a transfrontal observation window immediately above the floor of the frontal sinus. The author has used this procedure several times with good results, but it is necessary to take into account inevitable scar tissue retraction of the new ostium, and to overcorrect by extending the hole by twice as much as necessary. The figure shows the end result from below of a frontal sinusotomy
widened in this way, that lead to healing of a long-standing frontal sinusitis after removal of polyps from within the sinus.

The histological type of a soft tissue tumor of the frontal sinus, and the best route for its removal may be determined by an endoscopic biopsy. Beck's trephine is the simplest and most direct method in most cases. If radiographic opacity of the anterior ethmoids demands that a sinusitis be distinguished from a tumor, then an anterior ethmoidectomy may be combined with endoscopic biopsy of the frontal sinus from below. In this way retention cysts, for example, can be recognized and removed at the same procedure, and a metastasis undergoing central necrosis be excluded.

**Limited External Frontal Sinus Operation under Endoscopic Control**

Intranasal endoscopy is not suitable for the removal of polyps, foreign bodies or benign tumors from the upper recess of the frontal sinus, because the view and scope for manipulation are unsatisfactory. Mucopyoceles and osteitis in the superior compartments are even less suitable for this procedure. However, methods are constantly being sought to achieve the goal of restitutions of an aerated frontal sinus draining securely into the nose and lined with mucosa, thus avoiding an external radical procedure. A previous operation or the extent of the disease may preclude an osteoplastic procedure.

In such circumstances the frontal sinus can be opened with the usual incision in the eyebrows. Bone is removed locally, preserving bone struts, in a similar manner to preservation of the bridge in ear surgery. Endoscopic manipulations can then be carried out successfully in the angles and recesses with limited external access. The advantage is the widespread preservation of the mucosa and the bony superstructure. The access holes in the floor and anterior wall of the frontal sinus are covered with periosteum or lyophilized dura. The operation must of course include exenteration of the anterior ethmoids, and wide frontal sinusotomy into the nose. The procedure was developed to exploit the given circumstances during revision of classical frontal sinus operations, with a pre-existing often small sinusotomy.

The figure illustrates an endoscopic procedure for a mucocele with widening of the frontal access to the nose, and with a view through a circumscribed external window of the lower third of the frontal sinus. A small bony defect was already present at this point. The internal drainage could be secured in this manner with minimal loss of mucosa. The two small bony defects in the anterior wall of the frontal infundibulum were covered with lyophilized dura. The widened frontal duct was stented for several weeks with a polyethylene tube.

In other patients with large supraorbital mucoceles causing extensive resorption of the anterior wall of the frontal sinus the bony anterior wall was reconstructed with simultaneous intranasal endoscopic resection of the frontal infundibulum and the diseased ethmoids without sacrificing mucosa. This is a good example of developing functional frontal sinus surgery using endoscopic control.

The principle of minimal opening of the frontal sinus allowing preservation of its bony walls can be used to advantage for foreign bodies and tumors. The author uses the endoscope during an external operation on the frontal sinus to extract a foreign body, based on the
following concepts: (1) The patient's own bone forms a more stable support for the facial soft tissues than foreign material. (2) Several small mucosal defects are more likely to regenerate and restore the mucociliary transport necessary for the self-cleaning of the mucosa than one large defect. A small hole suffices for the observation tube, allowing the use of angled telescopes of varying degrees. One or two further holes allow the introduction of instruments for the extraction of the foreign body or for drilling of a frontal osteoma to reduce it in size in situ.

**Operations on the Sphenoid Sinus**

**Indications**
- empyema,
- removal of polyps,
- removal of small benign tumors,
- removal of foreign bodies,
- biopsy,
- decompression of the optic nerve,
- resection of the vidian nerve.

**Principles**

The sphenoid sinus is exposed by removal of its anterior wall. Securing of the sphenopalatine artery ensures a bloodless field. The posterior edge of the nasal septum should be preserved. Manipulations on the roof and lateral wall should be carried out only under microscopic or endoscopic control. Sphenoid sinus surgery should never be carried out without previous tomography.

**Operative Technique**

The *exposure of the sphenoid sinus* by finding its anterior wall after removal of the posterior ethmoid cells has already been considered in detail in the section on ethmoid operations. Sphenoid sinus surgery is often regarded as being particularly dangerous and attended by severe complications. However, mistakes are usually based on inadequate preoperative investigation, lack of adequate instruments such as the endoscope and the operating microscope, and inadequate hemostasis. However, if these three prerequisites are satisfied and the surgeon is fully familiar with the endoscopic anatomy of the posterior ethmoid, then there is no particular difficulty or danger in finding the sphenoid sinus. Thus disease of the sphenoid itself can be treated by surgery, and the sphenoid sinus can be used for access to related structures.

The sphenoid sinus is often unsymmetrical, and its deep recesses can only be inspected by an angled telescope.

**Applications**

The *extraction of polyps* from the sphenoid sinus has already been dealt with in the section on pansinus operations. Intranasal endoscopy can achieve permanently successful
results in the removal of *inverted papillomas* from the antrum and ethmoids. It can be equally successful for this lesions with the sphenoid sinus. External access does not create better conditions for radical removal of papillomas, but it is the perfect exposure of the operative field with optical magnification that prevents a recurrence: intranasal access is just as good or even better for the use of the endoscope and the operating microscope. After removal of the suspect tissue with the double forceps under endoscopic control the underlying bone is drilled down with the diamond burr, again under visual control, using a long, slender handpiece. If the appropriate equipment is not available then wide exposure via the external access is of course indicated.

The transnasal removal of *benign tumors* and the *extraction of foreign bodies* from the sphenoid cavity present no difficulties using the techniques already described, but are seldom used. *Biopsy of tumors* is quite often indicated, but if the tumor proves to be malignant it usually cannot be removed surgically.

Resection of the *vidian nerve* is recommended for the treatment of nasal polyps and vasomotor rhinitis. The exposure of the nerve begins with opening of the sphenoid sinus under the operating microscope. The indications are controversial, and the author has no personal experience of Golding-Wood's technique of vadian neurectomy nor of intranasal transethmoidosphenoidal *decompression of the optic nerve*.

Strict indications are laid down in the author's clinic for decompression of the optic nerve by slitting its sheath in patients with an orbital fracture. Transorbitoethmoid access to the optic nerve has so far been preferred, but an intranasal transethmoid microdissection of the orbital apex and the canal of the optic nerve may be considered in exceptional cases with no fracture of the orbit or the ethmoids, but with loss of vision due to head injuries. A CT scan provides details about the direction of dissection with the diamond burl.

**Operations on the Anterior Base of the Skull, including the Roof of the Ethmoids and the Wall of the Sphenoid Sinus**

**Indications**

- removal of foreign bodies,
- debridement,
- closure of a small CSF leak,
- biopsy and localized removal of tissue,
- combined neurosurgical and rhinological procedures.

**Principles**

Ethmoidectomy provides a limited, direct endoscopic view of the lower surface of the anterior skull base. Very accurate and effective dissection and reconstruction may be carried out with slender instruments, burrs and tissue glue on the ethmoid roof and the walls of the sphenoid sinus.
Operative Technique

The anterior part of the anterior skull base is formed by the posterior wall of the frontal sinus and the roof of the orbit. In the middle lies the roof of the ethmoid, and posteriorly the sphenoid plane and the roof of the sphenoid sinus. The exposure of the ethmoid and sphenoid roof described with the intranasal endoscopic technique in the previous section, related only to dissection of the anterior skull base from below. The posterior wall of the frontal sinus is suitable for only very limited endoscopic manipulations, but the lateral and posterior walls of the sphenoid sinus are well within the reach of endoscopy.

Endoscopy of the anterior base of the skull is indicated for lesions of the anterior and middle ethmoid roof especially the cribriform plate, and for the walls of the sphenoid sinus, whereas lesions of the sphenoid plane requiring attention are unusual. For this reason anterior ethmoidectomy is the method of choice for access to the base of the skull, followed by posterior ethmoidectomy with opening of the sphenoid sinus. Individual circumstances will decide which of these is used for exposure of the base of the skull. Particular procedures do not need to be described further at this point. Ethmoidectomy in these circumstances naturally includes the radical removal of the mucosa as far as this is necessary.

For an ethmoidal-dural fistula, confirmed by CT scan, an approach via the middle meatus (preserving the middle turbinate) the ethmoid infundibulum and the ethmoid bulla is indicated. In the absence of polyposis this dissection can be very precise. If a fracture line crossing the olfactory cleft causing a CSF leak is expected, surgery should begin with a partial resection of the middle turbinate so that the base of the skull can be inspected endoscopically in the midline along the medial lamella of the middle turbinate without obstruction by the body of the middle turbinate. If an iatrogenic CSF leak after a previous ethmoid operation requires closure, the surgery must be adapted to the prevailing situation beginning with systematic removal of scar tissue, and gradual exposure of the bony base of the skull by removal of any remaining cells.

In a case of CSF leak after a septal operation, the repair begins with separation of the two layers of the septum up to the base of the skull. The the problem is tackled from the exposed defect with resection of olfactory mucosa followed by exenteration of the ethmoids up to this point. Most cases require complete ethmoidectomy to obtain a maximal view of the base of the skull.

There are no guidelines yet available in this still-developing endoscopic surgery of the anterior base of the skull to help in deciding whether the ethmoid should be exposed from in front or behind. Whichever is chosen, it is important always to preserve the physiological drainage of the ethmoid compartments or the sphenoid sinus which might be preserved during limited ethmoidectomy.

Procedures such as the removal of an impacted foreign body, the closure of a fistula or the removal of a tumor will not be described here in detail. The principles and the instruments are detailed on the section on sphenoid and ethmoid operations.
Applications

The anterior base of the skull is a relatively firm party wall between the paranasal sinuses and the anterior cranial fossa that resists foreign bodies penetrating from below, so that they often remain impacted under or in it. Foreign bodies include glass splinters and pieces of metal which become impacted during road traffic accidents, pieces of plastic and wood, and air gun pellets. These may be removed successfully by the intranasal route provided the base of the skull has not been pierced. Since the entry portal is often very small and normally requires only localized attention, an external operation is usually unnecessary. The projectile can usually be localized and the degree of injury assessed by radiography. A bullet in the wall of the sphenoid sinus can often be revealed by posterior ethmoidectomy to expose the sphenoid sinus, allowing the foreign body to be removed or freed after drilling the surrounding bone. A defect in the base of the skull must be looked for, and if necessary debrided. Postoperative treatment is the same as that for secondary healing after ethmoidectomy if the dura is not injured.

The immediate repair of a CSF fistula caused by injury of olfactory fibers in the anterior and middle ethmoid roof has already been described under total ethmoidectomy. The technique has proved to be reliable and has therefore been developed as the standard procedure for traumatic and idiopathic dural fistulae of other types and sites. The decision between a wide external rhinological procedure, a transfrontal neurosurgical exposure of the anterior skull base or an intranasal endoscopic access for closure of a CSF fistula today should not depend on generally accepted guidelines. Traditions, a surgeon's previous training and the instruments available often carry too much weight in the decision. The advantages of intranasal debridement of a localized fracture of the base of the skull and closure of a dural defect include preservation of bony support of the floor of the frontal sinus, avoidance of division of the supraorbital nerve, and prevention of the permanent dysosmia characteristic of the neurosurgical procedure.

The technique is not difficult if the surgeon is familiar with bimanual endoscopy. After removal of as much of the middle turbinate as necessary, the ethmoid cells are cleared up to the base of the skull. Once the fistula has been found the neighboring mucosa is removed delicately from the edge over a distance of 2-4 mm using fine curved double forceps. If the fistula reaches the nasal septum, removal of the mucosa must encompass this area. A similar procedure is followed in the roof of the sphenoid sinus. Here the conditions for closing the defect are considerably more favorable, as even large defects of the base of the skull in this area can be managed by intranasal endoscopy. The entire sphenoid sinus mucosa is removed and the cavity filled with a large piece of fascia lata, or muscle and periosteum. Additional packing with fibrin foam encourages adhesion of the connective tissue to the bone so that tissue glue is not needed.

However, tissue glue does have a place in the closure of a fistula in the roof of the ethmoid. In the absence of a counter resistance the graft must support itself by adhesion until it becomes incorporated. Thus the use of tissue glue and packing of the upper part of the nose for at least 10 days are very important. Transposition of a soft tissue flap under the denuded bony edges of a defect is very successful after wide external transfacial exposure of the posterior wall of the frontal sinus in the management of large fistulae at that point, but is scarcely practicable for small ethmoid fistulae managed by the endoscopic route.
After careful demarcation of the defect, a graft is fitted carefully over the fistula and the surrounding bone edges, and is fixed with tissue glue. A mucosal flap taken from the free edge of the inferior turbinate has proved to be very useful. Its manipulations and control with nasal forceps and an elevator is not particularly difficult but demands prior hemostasis and very careful use of the suction. The site of the graft must be checked carefully by endoscopy. The edges are then covered with a further layer of tissue glue: once this is dry the nose is packed with material such as fibrin foam which is removed at the earliest from 2 to 3 weeks later. Indeed it can be left until it is rejected spontaneously. The nasal packing of vaseline gauze introduced beneath this contact packing can be removed as soon as 10 days after the operation. Since healing of the transplanted tissue to the bone requires several weeks, reoperation should not be immediately embarked upon for a slight CSF leak in the first postoperative weeks. In this event it may be necessary to adjust the nasal packing, place the patient with the head in the upright position and drain off CSF by a lumbar drainage.

The endoscopic technique just described for closure of small CSF leaks has proved valuable for the care of spontaneous CSF rhinorrhea. The defect is usually found around the cribriform plate, particularly at its posterior edge, or in the roof of the sphenoid sinus, apparently at points of congenital weakness of the wall or of previously formed bony defects. A complete neurological work-up is indicated. In one case of spontaneous recurrent CSF rhinorrhea, we found a large acoustic neuroma with no further lesions of the anterior skull base.

Intranasal endoscopic exposure of the anterior skull base using a similar technique to that for closure of small CSF fistulae is suitable for debridement. Limited endoscopic exposure of the ethmoid and skull base is the procedure of choice for destruction of structural support, cell septa and lamellae found during a procedure for a fracture of the middle third of the face and of the anterior skull base, where the differential diagnosis of an opacity shown by precise imaging include sinusitis, an organized hematoma or a meningocele.

The advantages of endoscopic biopsy, localized removal of tumor and nontraumatic, very precise aftercare have already been mentioned. Invasion of the skull base by a tumor mandates the inclusion of endoscopy in the diagnosis, treatment and follow-up. Tissue diagnosis, marginal biopsies, removal of residual tumor, and the palliation of inoperable disease need only be mentioned at this point. However, the curative procedure for inverting papillomas which has been developed in the Erlangen Clinic needs emphasis. This intranasal, endoscopic technique embraces ethmoidectomy and sphenoid sinusotomy for tumors invading the walls of the sphenoid and skull base. Endoscopic follow-up and biopsy has on several occasions indicated the necessity for a revision operation or retreatment with irradiation.

The example of an ossifying nasopharyngeal fibroma shows that occasionally even a large benign tumor can be controlled by intranasal endoscopy. An initially explorative procedure could be extended to a completely successful removal because the tumor was well demarcated and was avascular.

Thanks to increasing cooperation in the search for the optimal solutions for patients with difficult problems* we have recently carried out several neurosurgical-rhinological combined operations incorporating intranasal endoscopic techniques. The contributions to this developing field include the following:
- Histological specimens have been obtained on several occasions by localized exploration of the base of the skull for supra- and intrasphenoid tumors and orbital tumors infiltrating into the skull base.

- In some cases the nasal procedure was carried out from below at a different sitting either before or after a neurosurgical procedure to resect and reconstruct a large part of the base of the skull. Occasionally a combined procedure is carried out at the same time.

- Combined neurosurgical-intranasal resection of large tumors of the anterior skull base using the operating microscope, via a unilateral or bifrontal approach offers greater advantages because of the very wide exposure of the anterior cranial fossa so that a good margin can be obtained round an invasive ethmoid carcinoma or esthesioneuroblastoma. In this procedure the rhinologic excises the ethmoid bloc, the sphenoid sinus and the nasal septum. The use of the microscope with an angled telescope can be very useful for inspection of all the concealed recesses such as the edges of the maxillary sinus.

- Intranasal endoscopic closure of CSF leaks has also proved very useful in these combined procedures allowing late defects in the dural closure to be repaired. It has also been used successfully for a few cases of CSF rhinorhea after transethmoid operations on the pituitary gland.

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