2. Endoscopic Anatomy of the Paranasal Sinuses

Anatomical textbooks and atlases offer very accurate descriptions of the structure and topography of the nose and the paranasal sinuses, but the details have been worked out from macroscopic sections on cadaver dissections. However, the intranasal surgeon must be able to orientate himself looking through straight or angled endoscopes. He must develop a three-dimensional mental image allowing him to know exactly where he is, where the ducts and the danger points lie, and what structures are closely related. Endoscopic topographical anatomy is presented by a discussion of the important regions of the nasal cavity. Three-dimensional anatomy is presented by tomograms and an illustrated dissection of the paranasal sinuses based on photographs and line diagrams.

The Nasal cavity and its Endoscopic Landmarks

The medial nasal wall, the nasal septum, is simple and smooth, unlike the highly complex lateral nasal wall, the area of interest for the endoscopic surgeon. The ducts and ostia, covered by the nasal turbinates, form the entrances to the paranasal sinuses. The size and position of the lateral nasal wall vary widely, dictated by the paranasal sinuses. The following endoscopic views should be mentally projected onto the complex of the lateral nasal wall. When the endoscope, usually the 25° telescope, is introduced into the nostril, it impinges immediately on the vibrissae of the nasal vestibule obstructing the view of the nasal valve; therefore these hair should be trimmed before an endoscopic procedure. The nasal valve is formed by the floor of the nose, the septum and the lower edge of the upper lateral cartilage tilted inwards. Anteriorly the septum and the floor of the nose usually has ridges on both sides arising from the pre-maxilla. The slit-like opening could hinder a view during intranasal surgery, so that preliminary septal correction can be useful; the necessary access may also be widened by a nasal speculum.

Immediately behind the nasal valve lies the second narrow point: the anterior end of the inferior turbinate takes up two-third of the field of vision, and divides the inspiratory airstream into an upper and a lower pathway.

The field of vision can be improved by vigorous decongestion of the mucosa by pledgets soaked in 1/1000 adrenalin solution. However, the bone of the anterior end of the turbinate may be large and obstruct the view, requiring limited resection. The body of the turbinate consists of the rigid turbinate bone and erectile tissue covering its medial surface. The lateral wall of the turbinate is shaped like a gutter, so that the border between the mucosal surfaces is tilted externally. The inferior meatus lies lateral to the inferior turbinate: its lateral wall is the lowest part of the lateral nasal wall. The line of insertion of the turbinate bone is concave downwards, and lacks any particular landmark. Its bony wall is thinnest at the center, just below the apex of the curve, and antral puncture is most easily carried out at this point. The anterior insertion of the inferior turbinate may lie only 2-3 mm above the floor of the nose, so that an endoscope may only be introduced with difficulty beneath the inferior meatus, leaving little space for an accompanying instrument. A vertical incision through the mucosa and bone may then be needed at this point to allow the turbinate to be displaced medially and upwards.
The lacrimal canal opens immediately behind and about 2 mm below the insertion of the turbinate. Its slit-like opening into the anterosuperior part of the inferior meatus must be strictly avoided when creating an inferior meatal antrostomy using the punch. Endoscopic exposure of the lacrimal sac and canal is considerably helped by identification of its nasal ostium.

Extending superiorly from the nasal vestibule, the next structure to come into view is the agger nasi, a smooth bony swelling lying in front of the anterior insertion of the middle turbinate. It may be pneumatized and thin walled, and contain the agger nasi cells; more often it has a thick bony wall. Lateral to the agger nasi lies the outflow tract of the frontal sinus, the frontonasal duct. This is normally approached from the semilunar hiatus via the ethmoidal infundibulum, but after ethmoidectomy and clearance of the infundibulum it is entered directly from the nasal cavity. Identification of the agger nasi from the nasal introitus is therefore important. The agger nasi is also an important landmark for endoscopic exposure of the nasolacrimal canal: the canal lies to the lateral nasal wall at the same level as the agger nasi or 1-2 mm in front of it. It runs parallel to the agger, after running medially under some ethmoidal cells. This proximity explains why the lacrimal canal is in danger in the region around the ethmoid cells in massive polyposis with bony erosion. The frontal sinus, the nasolacrimal duct and the agger nasi lie in roughly the same frontal plane.

Passage of the endoscope into the common nasal meatus beyond the narrow area at the anterior end of the inferior turbinate is often hindered further by a ridge on the lower edge of the nasal septum. This is formed by the premaxilla and the palatal ridge of the maxilla onto which impinges the lower edge of the septal cartilage. An accessory (Huschke’s) cartilage also lies at this point (Zuckerkandl). More superiorly the septum again restricts vision of the nasal roof: an apparent upper septal deviation is actually a widening of the septum, the tuberculum septi (Zuckerkandl). It is present on both sides and histologically it is formed by rudimentary erectile tissue. In addition, a widening of the bony septum may be hidden beneath it. The CT scan shows its relation to the base of the skull. It is almost impossible to remove without damaging the mucosa; if it is well developed and is obstructing drainage it may have a very unfavorable influence on the healing of the ethmoid gutter after ethmoidectomy. Synechiae often form in this area where the septum is wide after rough extraction of nasal polyps.

Further back, the endoscope impinges on another obstruction, the oblique ascending septal ridge formed by the edge of the vomer and the end of the quadrilateral cartilage extending backwards. It may even impinge upon the middle turbinate and protrude into the middle meatus affecting the airstream. To bring the nasal choana into view the endoscope must be passed beneath the ascending septal ridge rather than over it. The mucosa along the ridge is usually atrophic and vulnerable to the passage of the endoscope.

The lower posterior nasal region and the choanae can almost always be inspected with a 0° or 25° rigid or flexible telescope passed along the floor of the nose. In adults the choanae are 1.5 to 2.0 cm high, and form an important landmark.

The posterior end of the inferior turbinate projects into the lower part of the posterior nasal choana from the lateral side, occupying up to half its height. It is often hypertrophic, resembling a mulberry, and then can considerably narrow the choana. The posterior insertion
of the middle turbinate lies in the upper third of the choana, just in front of its anterior edge. This point of attachment forms a landmark for the front wall of the sphenoid sinus: a thin point in the bony wall of the anterior sphenoidal sinus can be found and perforated lying a little more than 1 cm above and 0.5 cm medially. This point can also be palpated 1 cm above the dome of the choana paramedially. The sphenoidal ostium lies higher and somewhat more medial. It is seldom suitable for access to the sphenoidal sinus. The posterior third of the middle turbinate lies in the same sagittal plane as the lateral wall of the sphenoid sinus. The posterior end of the inferior turbinate and the ostium of the Eustachian tube lie at the same level, and in the same sagittal plane, but separated by the choana.

The middle meatus is the most important region for endoscopic nasal examination: it is the normal entrance to the ethmoid, frontal and maxillary sinuses, and also provides a portal for their surgical exposure. It can only be seen properly after displacing the middle turbinate medially. The middle meatus extends over two-thirds of the length of the lateral nasal wall between the cut edge of the middle turbinate and the upper edge of the inferior turbinate. After removal of the soft tissues, the bony specimen shows the relationship in the middle meatus: the ethmoid process ascending from the turbinate bone divides the membranous part of the lateral nasal wall into an anterior and a posterior fontanelle. Usually a small spicule of bone runs toward it from the uncinate process. The endoscopic view in the cadaver shows the ethmoid bulla, forming the lower limit of the ethmoid cell system, and the lateral boundary of the middle turbinate. The bulla also forms the upper edge of the semilunar hiatus. The most anterior ethmoid cells, the maxillary sinus and the frontal sinus drain into the hiatus; the frontal sinus opens into the ethmoid infundibulum, the most anterior, upward-pointing and deeply etched prolongation of the hiatus. The hiatus and the infundibulum are usually not visible with the endoscope, so that the primary maxillary ostium cannot be inspected.

Between the curved, anteriorly projecting, uncinate process and the insertion of the inferior turbinate lies a smooth strip of the lateral wall of the middle nasal meatus, 2-4 mm high. This area is part bony and part membranous, the latter being formed by the fontanelles, and it often contains an opening into the maxillary sinus, the secondary ostium. The relationships of the middle meatus to the ethmoid sinuses, the maxillary and frontal sinuses, and particularly to the orbit must be studied with great care before beginning intranasal surgery. These are particularly well shown by a series of frontal CT scans.

The middle turbinate is of central importance in endoscopic surgery: its body is integrated into the ethmoid cell system so that ethmoid disease extends into the middle turbinate, but not into the inferior turbinate. The medial lamella of the middle turbinate is inserted anteriorly into the skull base: it conducts fibers from the olfactory nerve, is covered with olfactory mucosa, and thus forms part of the olfactory region. In contrast the posterior part of the turbinate is anchored relatively loosely to the ethmoid bone, and only its posterior edge is attached to the lateral nasal wall. As a result good exposure of the posterolateral ethmoid cells can only be achieved by partial resection of the middle turbinate. The junction of the part attached to the skull base and the dependent ethmoid bone lies at the posterior edge of the cribriform plate. It can be easily recognized during intranasal endoscopy, and is thus an important landmark.
In front of this junction the middle turbinate carries olfactory fibers, so that destruction of the bony base of the turbinate carries the danger of tearing these fibers leading to a CSF fistula. Behind this junction, on the other hand, the ethmoid roof may be exposed as far as the septum without the danger of a CSF fistula.

The superior nasal meatus is difficult to inspect, particularly if the septum is widened or deviated. In front, it contains the olfactory cleft, a narrow slit extending superiorly between the middle turbinate and the nasal septum to the roof of the nose, and covered on both sides by olfactory mucosa. Posteriorly, the superior nasal meatus is narrowed by the downward-sloping anterior wall of the sphenoid sinus. The superior meatus is similarly narrowed if a supreme nasal turbinate is present, although the latter is usually recognizable only as a smooth swelling. The natural sphenoid ostium often cannot be recognized at endoscopy, but can occasionally be seen after displacing the middle turbinate laterally, although this may be difficult if the bone is hard.

A CT Scan Study of the Spatial Arrangement of the Paranasal Sinuses

An important prerequisite for safe endoscopic surgery within the paranasal sinuses is a clear three-dimensional mental picture of their spatial relationships to each other and to the neighboring maxilla, orbit, sphenoid sinus and anterior cranial fossa. This knowledge allows the surgeon to avoid the danger areas while taking full advantage of the endoscopic technique, and gives him the confidence to continue the procedure rather than abandoning it prematurely because of groundless anxieties. The layout of the cell system can best be learnt step-by-step from a series of high resolution CT scans. However, even the most recent three-dimensional reconstructions of CT scan sections do not substitute for a stratigraphic comparison of CT scans and anatomical sections of the skull base as an optimal basis for exploration of these intercommunicating hollow spaces within the anterior skull base.

Vertical Coronal Sections

Examination of coronal CT scans begins anteriorly at the root of the nose. The plane is tilted 10-20° backwards from above downwards, depending on the type of the apparatus and on the patient’s ability to extend the head while lying prone. The frontal sinus comes into view first. Its extension superiorly and laterally varies between subjects, and the sinus is seldom symmetrical on the two sides. Extensive supraorbital niches indicate that an intranasal procedure will not reach the periphery of the sinus without an additional external approach.

The interfrontal septum is seldom in the midline and usually lies lateral to the nasal septum, an important fact in transnasal frontal sinusotomy. The outflow tract of the frontal sinus (the frontal infundibulum) tapers inferiorly. It is often directed slightly posteriorly, and runs under the forward convexity of the posterior wall of the frontal sinus. The transition to a true duct or opening into an anterior ethmoid cell may lie very deeply. Superomedial to this point, the nasal roof is formed by the anterior edge of the olfactory cleft, and the crista galli is at its greatest extent at this point. Often the frontonasal duct impinges tightly on the orbital wall, whereas medial to it lie even smaller cell tracts which cannot be inspected.
The anterior ethmoid cells are very variable in shape. Sometimes they project into the frontal sinus; rarely supraorbital ethmoidal cells may also run laterally and above the frontal sinus so that the orbit has a doubly pneumatized upper layer. The prebullar cell system is divided up even more precisely (Terrier, 1987) as follows:

- uncinate cells with upper, anterior (agger) and posterior cells,
- anterior and posterior meatal cells.

Classically the upper uncinate cell opens into the frontal sinus, but the frontal sinus may also drain via the meatal cell. Bagatella and Guirado (1983) name these cell groups as follows:

- pre-infundibular cells (0-1 cell) with the agger nasi cell,
- lateral infundibular cells (0-2 cells),
- post-infundibular cells (0-2 cells).

The varying development of these cells is the cause of the differences in the outflow tract of the frontal sinus.

The nasal septum can always be recognized easily on CT scans. Its height increases from anteriorly to the middle, reaches its maximum beneath the crista galli where it contacts the base of the skull in the midline and then decreases towards the choana, to not quite half of its original size. The anterior soft tissue widening of the septum lying close to the anterior end of the inferior turbinate can always be recognized, and its varying cartilaginous and bony construction can be recognized over its entire length as far as the vomer.

The interfrontal septum in front and the intersphenoidal septum behind do not always lie in the same plane as the nasal septum. This is important information in transeptal sphenoidotomy. The asymmetrical insertion of the septum into the palate, and the varying level of the floor of the nose can also be seen easily on CT scans.

The lateral nasal wall must be examined systematically. Below it is typically convex, corresponding to the concavity of the medial antral wall, and above concave corresponding with the lateral ethmoid wall. The edge is convex into the nose and concave into the orbit. This relationship is usually constant between sides and between subjects, giving the surgeon confidence during sphenoidal-ethmoidal operation. Whereas the lateral wall of the ethmoid and nasal cavity thus forms a lazy S in frontal section, the continuation of the lateral ethmoid wall into the roof of the maxillary cavity forms a continuous curve without a step, an important point during intranasal maxillary operations and middle meatal antrostomy.

The point of intersection of the lateral nasal contour with the orbitomaxillary arch is an important landmark: 1 to 3 mm beneath it lies the primary maxillary ostium. This outflow tract often runs very close to the orbit, almost exactly in the same frontal plane in which the medial lamella of the middle turbinate swings away from the base of the skull to insert into the ethmoid. This point represents the posterior end of the olfactory cleft.

Whereas the point of intersection of the roof of the maxilla with the lateral wall of the nose or of the ethmoids lies about halfway up the nose at the center it inclines upwards due
to the tapering of the orbit, until it breaks up in the root of the pterygoid process. Further posteriorly to the lateral wall of the ethmoid is continuous with the lateral wall of the sphenoid cavity without a step. This slightly bulging but smooth transition between the lateral sphenoid and ethmoid wall can be easily recognized on axial CT scans. This detailed knowledge of anatomy facilitates complete removal of cells during intranasal ethmoidosphenoid operations.

The shape of the maxillary cavity changes from anterior to posterior. In front it is triangular, in the middle kidney-shaped, and posteriorly it resembles a large almond with rounded contours. Familiarity with its upper (ethmoid) and lower (alveolar and palatine) recesses is important since they must be reached by instruments introduced through an inferior or middle meatal antrostomy.

Before intranasal procedures, particularly revision surgery, it is worthwhile estimating the relationship of the inferior turbinate to the nasal and maxillary cavities on serial three-dimensional sections. The extent of the obstruction of the common and inferior meatus by the turbinate bone is clear, although its absolute size varies with the nasal cycle. The turbinate extends along the entire length of the lateral nasal wall as far as the posterior choana, two-thirds of which can be obstructed by the thick posterior end of the turbinate.

The varying height of the inferior meatus and of the groove that it forms in the turbinate are particularly marked in frontal sections. Usually the free edge of the turbinate is tilted externally. The turbinate bone may also be curved externally but sometimes it forms only a narrow ridge in the center of the turbinate. A limited turbinectomy may be needed in some cases.

The middle turbinate is a key structure in intranasal surgery. Beneath and immediately lateral to it in the middle meatus lie the most important outflow tract of the paranasal sinuses, the ostia and the ducts for the frontal, maxillary and anterior ethmoid sinuses. Its shape is very variable: sometimes it is high and narrow with few or no cells, on other occasions it is plump and permeated by many cells which are difficult to assign either to the turbinate or the ethmoid, as the two merge with each other. Anteriorly, the medial lamella of the middle turbinate always extends to the dome of the nose, thus forming the lateral wall of the olfactory cleft, but posteriorly it deviates from the roof of the nose, curves more deeply and inserts into the ethmoid. Above it the superior turbinate lies in the posterior half of the nose; alternatively the ethmoid cells reach this point. The point at which the middle turbinate deviates from the anterior skull base is thus an important landmark which must be identified during ethmoidectomy, otherwise the medial surface of the turbinate can be torn off by a rough technique, damaging the olfactory fibers and producing a CSF fistula.

The posterior attachment of the middle turbinate can be readily identified on a CT scan, lying on the lateral nasal wall just in front of the floor of the sphenoid sinus, at the point where the wall becomes thicker due to the base of the pterygoid process.

The superior turbinate is often overlooked by the surgeon, and it may be represented only by a slight swelling, in which case the superior meatus is difficult to define. However, the superior turbinate is often well developed and can be confused with the medial turbinate on rapid examination. The CT scan illustrates its slender structure and its suspension from the
dome of the nose at the point where the medial turbinate is running more deeply to insert into the ethmoid, at the level of the posterior edge of the crista galli. Occasionally a supreme turbinate is also present.

Understanding of the three-dimensional structure of the ethmoid is mandatory for the intranasal surgeon. The main features are constant, but the individual shape of the ethmoid varies so much that it is scarcely worthwhile identifying or naming individual cells. The most important landmarks are the following:

- the semilunar hiatus and its rostral prolongation, the ethmoid infundibulum,
- the uncinate process,
- the ethmoid bulla forming the foundation wall of the anterior ethmoid cells,
- the posterior wall of the bulla forming the anterior boundary (basal lamella) of the posterior ethmoid cells,
- the middle turbinate,
- the olfactory region, particularly its anterior and posterior limits,
- the agger nasi,
- the frontonasal duct or its equivalent in the form of ethmoid duct cells,
- the primary maxillary ostium.

The endoscopic image of the semilunar hiatus has already been described above. Its gutter is moon shaped, curving forwards and upwards, and is usually only visible on a CT scan if 2 mm slices at 2 mm intervals are used. Posteriorly it is 1-2 mm high, but anterosuperiorly it often forms a 3 mm deep ethmoid infundibulum. Posteriorly it extends a good 3 mm in a trough shape. The canal between the infundibulum and the antral cavity in the sections in the figures: it is not a true ostium but rather a tunnel several millimeters long.

The inferior wall of the hiatus is formed by the uncinate process whose thickness and height vary. During middle meatal antrostomy it forms a barrier, at least in the posterior half of the middle meatus, and must often be removed to allow an antrostomy to be created large enough to permit manipulations within the antral cavity.

The ethmoid bulla projects in an inferomedial direction over the semilunar hiatus. Several ethmoidal cells of varying size lie above the hiatus and drain into it, and are thus classified as anterior ethmoid cells. However, they do not form the lateral boundary because ethmoid cells are present lateral to the bullar cells and lateral to the semilunar hiatus. This fact is easily overlooked during overtimorous removal of the bulla anteriorly, so that complete ethmoidectomy is better achieved by concentrating on the lateral nasal wall as a landmark. The length of the bulla varies between 4 and 8 mm. At its posterior edge there is said to be a bony wall running obliquely in an anterosuperior direction, the basal lamella of the middle turbinate, or the floor of the posterior ethmoid cells. However, in practice this party wall is often not found, so that the posterior ethmoid cells are also opened during anterior ethmoidectomy.

Defining a boundary between the intraconchal cells of the middle turbinate, the bulla cells, and the posterior ethmoid cells is of theoretical rather than practical importance. Complete removal of this boundary zone can easily damage the medial lamella of the middle turbinate resulting in damage to the olfactory region. The turbinate cells (most anterior medial
ethmoidal cells) can be easily seen lying under the lateral olfactory region in the sections in the figure. Their removal must therefore greatly weaken the anterior suspension of the middle turbinate.

Endoscopic identification of the relation of the anterior ethmoid cells to the frontal sinus is vital. This boundary zone often varies between the two sides, and particularly between different subjects; ethmoid cells sometimes penetrate far laterally. It is impossible to expose this area without resecting the agger nasi. Anteriorly at this point can be seen the medial boundary of the ethmoids formed by the lamella inserting into the skull base. The frontonasal duct can occasionally be recognized on sagittal sections, but not in frontal projections. The figures illustrate the distance from the semilunar hiatus of small ethmoid cells surrounding the duct. It is easier to distinguish the posterior ethmoid cells from the sphenoid sinus. It is usually possible to recognize the party wall easily on a CT scan by following the lateral ethmoid and nasal wall, and taking the end of the middle turbinate as a landmark. This point will not be mistaken either by endoscopy or under the microscope if the surgeon sticks to the posterior end of the middle turbinate as a landmark. Occasionally an Onodi cell extending laterally under the optic nerve may render orientation difficult, and careless radical removal with the sharp punch may endanger the optic nerve.

A CT scan of the sphenoid sinus may demonstrate the wide variations of size between the two sides and individual recesses extending deeply into the pterygoid process. A pronounced inferolateral recess can be found in about one-third of all subjects, lying immediately adjacent to the bone over the nerve of the pterygoid canal and the maxillary nerve. The floor of the sphenoidal sinus has no significant structures except bone, and the only complication of excessive resection is bleeding from branches of the sphenopalatine artery: in contrast, the lateral wall of the sinus carries the optic nerve, the internal carotid artery and the cavernous sinus. Its position relative to the sinus cavity can be readily seen on CT scan. A well developed superolateral recess between the optic nerve and the internal carotid artery is found in about 20% of sphenoid sinuses.

Before undertaking his first endoscopic ethmoid operation on patients, the surgeon must be intimately aware of the shape of the anterior base of the skull, as it appears on intranasal exposure. The CT scan is helpful, because it shows clearly the danger zones during intranasal manipulations. Anteriorly the dome of the nose projects towards the nasal bone, but the septum does not yet meet the skull base. Even the plane in which the anterior end of the middle turbinate arises from the agger nasi is not free from danger because the frontal sinus lies above the septum (the frontal section in the figure is not absolutely perpendicular). There is no dura lying anterior to the frontonasal duct, so that the bone in front of the duct can be resected.

However, the base of the skull reaches its deepest point behind the frontonasal duct: at this point begins the olfactory fossa. This boundary is marked by the anterior edge of the crista galli lying immediately upon the septum. The depth of the olfactory groove varies widely between different subjects, and between the two sides in the same subject. Furthermore, its width increases as it extends posteriorly. The cribriform plate is perforated by olfactory fibers, and it usually lies obliquely rather than horizontally, so that the skull base and its overlying dura can lie medial to the upper ethmoid cells. The roof of the ethmoids may sometimes present a dangerous construction; the olfactory region is always dangerous!
Behind it the slope flattens out and the sphenoid plane projects over the posterior ethmoid cells as a thick horizontal plate.

**Horizontal Axial Sections**

Axial slices are less informative than coronal, because they do not always clearly demonstrate the relative positions to the endoscopist as he enters the nose from the nostril. The endoscopist orientates himself to vertical landmarks, and the horizontal sections are less helpful. Also the skull base may be confused with opaque cells. Furthermore, asymmetry of the sections produces a greater effect on axial than on coronal tomograms. The value of axial tomograms is that they outline continuous contours such as the lateral nasal wall or the lateral wall of the sphenoid sinus. They may be very useful in the identification of recesses or of pathological expansion by mucoceles or tumors. As an example, the figure highlights the optic canal projecting from the lateral wall of the sphenoid sinus: removal of bone with the punch to expose the lateral recess would have devastating results.

The examination begins above and continues downwards. The upper part of the frontal recess and the cavity of the frontal sinus are clearly seen in the first sections. As the infundibulum of the frontal sinus is usually not demonstrated, the anterior ethmoid cells are reached quite abruptly, although it is usually not clear whether the air spaces extending laterally are small supraorbital ethmoid cells or whether they belong to the frontal sinus. The uniformity of the ethmoid compartment can be easily seen in the center of the ethmoid. All ethmoid sections and the shape and properties of the sphenoid sinus are best assessed in this position. Cells extending laterally are only seen in sections below the level of the floor of the orbit: At this point the lumen of the antral cavity on a horizontal CT scan shows a typical rhomboid outline. The nasolacrimal duct is usually well seen in the neighboring cuts. These sections are also suitable for demonstrating circumscribed changes of the middle nasal meatus.

The deepest sections show clearly the relation of the walls of the antral cavity to the facial soft tissues, to the retromaxillary space and to the alveolar process of the upper jaw.

**Typical Operative Steps on a Cadaver**

We have now completed the endoscopic view of the nasal cavity supplemented by CT scans allowing the surgeon to build up a three-dimensional image of the paranasal sinuses. An illustration of several typical operative steps on an anatomical dissection now follows. The steps should be studied before being performed on patients, and if possible should be practice on a skull. A safe topographic perspective and a feeling for bimanual endoscopic dissection in the confined spaces closely related to the orbital cavity and the anterior cranial fossa should be developed.

We begin with various dissections of the lateral nasal wall, and practice inspection with the microscope and angled telescopes.
Dissection of the Lateral Nasal Wall in Eight Steps

W. Hosemann

First Step

The nasal septum has been completely resected. In the center of the exposed lateral nasal wall lies the medial surface of one ethmoid bounded by a middle and a superior nasal turbinate. Below lies the independent inferior turbinate. In the midline, the saw cut passes through the opposite sphenoid cavity, providing a view of the intersphenoid septum.

In just under two-thirds of cases a supreme nasal meatus is present. The ethmoid is 4-5 cm long, 2.5-3.0 cm high, 1.5 cm wide posteriorly and 0.8 cm wide anteriorly. Its volume of 8-10 cm³ is occupied by as many as fifteen ethmoidal cells. On the lateronasal wall in the fetus lie up to six isolated swellings (main turbinates) lying behind each other as an uncinate mass resembling the free edge of the later middle turbinate. Posteriorly these fetal main turbinates merge completely, whereas anteriorly the medial ethmoidal wall of the adult arises from the dome of the swelling. However, from four to five remnants of the main and accessory fetal turbinates can be recognized in the ethmoid labyrinth. These are the basal lamellae:

- basal lamella 1: uncinate process (remnant of a nasal turbinate),
- basal lamella 2: lamella of the ethmoid bulla (remnant of a nasal turbinate),
- basal lamella 3: basal lamella of the middle nasal turbinate,
- basal lamella 4: basal lamella of the superior turbinate,
- basal lamella 5: basal lamella of the supreme turbinate.

The third lamella, the basal lamella of the middle turbinate, is the best developed and the most important. In a lateral view of the dissection it lies obliquely, behind the ethmoid bulla, uniting the medial part of the middle turbinate to the lamina papyracea and the roof of the ethmoid. It often appears very marked on axial CT scans: it can be found on CT scans at the anterior point of contact of the maxillary sinus and the ethmoids from which it deviates at a right angle. This basal lamella divides the ethmoid anatomically into an anterior and a posterior part. The cells of the posterior ethmoid are large but few in number: the anterior cells are smaller but more numerous. However, there is no constant relationship of the size of the anterior to the posterior ethmoid. The compartments between the basal lamellae show an individual variation of invasion and expansion of the ethmoid cells, so that the lamellae may be displaced or deformed. For example, the posterior ethmoid may be narrowed by a pushed-back basal lamella due to an enlarged anterior cell compartment. Posterior ethmoid cells may in this case encroach upon the anterosuperior sphenoid cavity: The reverse relationship is also possible. The basal lamella of the middle turbinate forms a functional landmark: the mucociliary apparatus of the anterior ethmoids discharges its secretion into the middle meatus, whereas the posterior ethmoids and the sphenoid cavity drain via the superior or supreme nasal meatus.
Second Step

The anterior and posterior ethmoid cells come into view after uncovering the medial ethmoid wall. Palpation with a fine probe provides additional information about the position of the ostium of the cells (determining their developmental origin) and the sinus.

In this dissection the cell complex of the ethmoid bulla is voluminous, consisting of two cells with a wide connection. The ostium of the bulla cells usually lies posteriorly. The inferior turbinate has been fenestrated so that the ostium of the nasolacrimal duct can be seen. A star marks the site of puncture of the antral cavity for endoscopy of the antral cavity, using a flexible or rigid telescope.

A detailed classification of the cells into subgroups within the compartments determined by the basal lamellae is not always possible because of the marked variation of the ethmoid cells. Furthermore, there is variation in the literature about the classification and the anatomical nomenclature.

The following terms may be defined:

The **semilunar hiatus** is a gap in the shape of a half moon up to 3 mm wide, between the ethmoid bulla and the upper free edge of the uncinate process. The hiatus is thus a cleft which opens into the ethmoid infundibulum.

The **ethmoid infundibulum** is the gutter lying between the ethmoid bulla and the uncinate process.

The **frontal infundibulum** is the upper end of the frontal outflow tract (the frontonasal duct or the ostium) lying within the frontal sinus.

The **frontal recess** is a space within the anterior ethmoids. It lies in a plane which is an anterosuperior continuation of the direction of the semilunar hiatus. It can reach the base of the skull between the lateral nasal wall and the middle turbinate. It is bounded in front by the agger nasi, and behind by bony swellings in the region of the ethmoid bulla, for example.

The **maxillary ostium** is more a tunnel than a simple opening; it may be straight or curved and lies between the ethmoid bulla, the uncinate process and the orbital plates of the maxillary and the ethmoid bones. It unites the antral cavity with the ethmoid infundibulum.

If the **frontonasal duct** forms a true duct, the term **frontal ostium** indicates both the opening into the lumen of the frontal sinus and that into the nasal cavity or the ethmoid.

Third Step

Removal of the edge of the middle turbinate provides a free view of the secondary ostium of the antral cavity in the region of the posterior fontanelle, but the uncinate process and the projecting bulla cells still obstruct the view of the maxillary ostium.
The term *fontanelles* indicates those parts of the medial wall of the antral cavity in the middle meatus consisting of membrane only with no bony support. The anterior fontanelle lies beneath the uncinate process and in front of the ethmoid process of the inferior turbinate; the posterior fontanelle extends between the uncinate process and the palatal bone. About one-quarter of specimens demonstrate secondary accessory ostia of the antral cavity through these membranes, especially posteriorly.

**Fourth Step**

Removal of the walls of the bulla renders the maxillary ostium visible. The ethmoid infundibulum continues anterosuperiorly giving off ethmoid cells in the direction of the agger nasi. The anterosuperior part of the frontal recess is marked by a broken line. The most anterior of the posterior ethmoid cells extends anteriorly into the resected body of the middle turbinate.

In about three-quarters of cases the maxillary ostium opens into the posterior third of the ethmoid infundibulum. However, due to the varying width of the uncinate process the maxillary ostium can be assessed without endoscopy in less than 10% of cases.

The anterior ethmoid cells, delineated as infundibular cells, arise from the ethmoid infundibulum. In particular, a cell extending towards the agger nasi is found in 80% of cases. The ethmoid infundibulum itself often ends blindly above as the terminal recess, or in a further infundibular cell, the terminal cell.

The frontal recess demonstrates characteristic frontal accessory turbinates on its lateral wall during the course of its development. Local cells of the frontal recess develop in about 50% of cases from the intervening frontal grooves which may be up to four in number; furthermore, the frontal sinus is pneumatized from this point in up to 60% of cases. The frontal sinus arises by direct extension of the ethmoidal infundibulum in only 5% of cases, and it is much more often pneumatized via the intermediate stage of infundibular cells.

The free part of the middle turbinate can conceal an air-filled hollow space due to a pronounced inrolling of its free edge laterally and superiorly. This hollow turbinate sinus drains into the middle meatus. On the other hand posterior ethmoid cells lying behind the basal lamella or anterior ethmoid cells arising from the frontal recess can pneumatize the body of the turbinate to form a bullous turbinate ("concha bullosa"). Either cavity (a bullous conchal sinus or a concha bullosa) may become diseased separately, but in both cases the principle of surgical treatment is resection of the lateral part of the wall of the cavity (turbinate).

**Fifth Step**

The outflow tract of the frontal sinus is demonstrated by pushing a probe from within the sinus inferiorly. The duct opens into the frontal recess independently of the ethmoid infundibulum. The bulla cells have been partially removed, and part of the lamina papyracea is shown. The inferior meatal antrostomy has been suitably extended for an adequate distance from the ostium of the nasolacrimal duct. The lacrimal duct can be seen in the anterolateral
nasal wall extending in an anterosuperior direction from the ostium. The duct of the frontal sinus and any supraorbital cells can be palpated with a probe.

The ethmoid bulla is the most constant ethmoid cell in shape. It almost always reaches the lateral boundary of the ethmoids, thus filling their entire width. An anterior bulge in the floor of the frontal sinus produced by an anterior ethmoid cell is termed a frontal bulla. It is found in 10% of cases, but is in reality only a particularly well developed cell lying in the floor of the frontal sinus, whereas smaller cells are found here in 50% of specimens. Duplication of the frontal sinus and its duct is found in 8% of cases. The varying anatomy of the floor of the frontal sinus can be assessed during surgery by rigid 70° endoscopes.

One anomaly is a recess of the middle nasal meatus extending into the antral cavity. The lateral nasal wall fuses at this point with the orbital process of the maxillary bone for some distance. In this way a part of the orbit extends into the nasal cavity, demanding care during the creation of a middle mental antrostomy.

In about 20% of specimens from one to four ethmoid cells extend into the orbital roof.

Sixth Step

The anterior ethmoid cells and the greater part of the uncinate process have been removed. The basal lamella of the middle turbinate divides the resected area from the preserved posterior ethmoid. The medial wall of the maxillary antrum is preserved in the region of the middle nasal meatus; it encloses the natural maxillary ostium, the accessory ostium with its membranous fontanelles and bony wall consisting of the uncinate process, and the ethmoid process of the inferior turbinate. The nasolacrimal duct is shown with its medial wall removed. The bulge due to the anterior ethmoid artery lies in the roof of the ethmoids. The intersphenoidal septum has been removed providing a free view into the left sphenoid cavity. A posterior ethmoid cell projects above the sphenoid sinus. A probe is passed into the ostia of the posterior ethmoid cells and the sphenoid sinus.

The volume of one sphenoid sinus varies widely between 0 and 14 cm³. In 10% of cases the posterior ethmoid cells invade the sphenoid sinus. The sphenoid ostium lies in the upper half of the anterior wall in the sphenoethmoid recess. The ration of the breadth of the nasal part of the anterior wall of the sphenoid sinus to that of the ethmoid part is 3:5.

The bulge of the anterior ethmoid artery runs close to the line of attachment of the second or third basal lamella along the anterior skull base. Small defects in the bone of the ethmoid roof can be shown in 10% of cases.

The nasolacrimal duct lies in a similar angle to the frontonasal duct (about 110° to the Frankfurt horizontal).
Seventh Step

The ethmoid cell lying over the anterior part of the sphenoid sinus has been uncapped; it encloses the optic nerve and is known as an Onodi cell. The internal carotid artery projects from the lateral wall of the sphenoid sinus.

The term Onodi cell is used to describe any posterior ethmoid cell related to the optic nerve. The bone surrounding the nerve is usually 0.5 mm thick, but is dehiscent in 4% of cases. Those cells which completely enclose the optic nerve are of particular importance. Onodi cells are found in 10% of cases, but an optic nerve lying freely within such a cell is less common.

Haller's cell is an ethmoid cell which arises by splitting of the medial part of the floor of the orbit, and should thus be classified as an ethmoid cell penetrating the anterior or posterior orbital floor. Haller's cells overlooked during surgery can be a source of persistent mucopurulent secretion, but can be demonstrated easily by endoscopy.

Eighth Step

Wide removal of the posterior ethmoids, the lamina papyracea and the orbital periosteum brings the rectus muscles of the orbit into view. The sphenopalatine foramen has been dissected. The optic nerve can be followed by removing its bony wall; the greater petrosal (Vidian) and maxillary nerves are followed similarly. The lateral wall of the sphenoid sinus is resected, providing a view of the slit internal carotid artery and the cavernous sinus. The pituitary gland has been divided.

The sphenopalatine foramen usually lies just behind the posterior end of the middle turbinate.

The internal carotid artery bulges into the lateral wall of the sphenoid sinus in more than half the specimens. In two-thirds of cases the optic and maxillary nerves are also outlined. The sphenoid sinus may have wide recesses, firstly a superolateral recess between the optic nerve and the internal carotid artery in 25% of cases, secondly an inferolateral recess running towards the pterygoid process or the greater wing of the sphenoid bone in 25% of cases.

Inferior Meatal Antrostomy

The shape of the antral cavity has already been described. Its height varies with the floor of the orbit: it is higher anteriorly and posteriorly than in the middle, and it is higher medially than laterally where it tapers off to form the zygomatic recess. It has a roof, an anterior, a posterior and a medial wall. The first three are smooth, flat and convex, but the medial wall is complex. The lacrimal duct produces a vertical bulge in the anterior third. In front of that the prelacrimal recess leads upwards, whereas behind it the maxillary ostium lies above a small horizontal bulge. The maxillary sinus ostium lies very close to the roof of the antral cavity; its antral opening varies widely in shape.
An inferior meatal antrostomy can be created without an endoscope. The inferior turbinate is displaced by a Killian's speculum, and the lateral nasal wall is perforated by a sharp dissector in the middle third of the exposed inferior nasal meatus. The dissector is angled outwards, and used to lever the piece of bone into the nose, where it is removed with forceps. An endoscope can be introduced to inspect the antral cavity after smoothing the edges of the defect. An opening 3 x 5 mm is enough for transnasal antroscopy. The antrostomy can be enlarged with forward- or backward-cutting punches; a diameter of 6-12 mm usually suffices. The antrostomy can be extended inferiorly and anteriorly to allow introduction of instruments into the antral cavity.

Orientation within the antral cavity is not always simple. The posterior wall is relatively easy to inspect using a forward-viewing telescope, but a wide-angled 70° telescope is needed to inspect the anterior wall and the prelacrimial recess lying anterosuperiorly. A prominent landmark is the zygomatic recess, the most lateral recess. From this point a flat groove can be followed as it runs upwards and medially to form the boundary between the posterior wall and roof of the antral cavity. The junction between the roof and anterior wall is usually smooth. The surgeon learns to recognize the typical contours usually bilaterally symmetrical in order to preserve the thin wall of the orbit during sharp dissection. The anterior wall of the antral cavity slopes outwards, and tapers inferiorly.

The bony canal of the infraorbital nerve may form a sagittal bulge running anteriorly in the roof of the antral cavity providing a valuable landmark. It must not be confused with mucosal bands which often run from the medial to the lateral walls of the antral cavity under its roof.

The entire medial wall of the antrum can only be inspected satisfactorily through an infraturbinate portal using a telescope with an angle of at least 70°. Since disease very often begins medially and at the ostium, it is always necessary to check the medial wall, including the ethmoid recess.

Rotation of the endoscope illuminates the lowest antral recesses, the alveolar recess and a palatine recess if present. Often these recesses are partially walled off from each other or the main antral cavity by bony septa.

Safe surgery depends on familiarity with the topographical anatomy of the danger areas, and this facility must be developed by practice on the skull. Firstly, the nasolacrimal canal is demonstrated by extending the inferior meatal antrostomy anteriorly until the nasolacrimal ostium is exposed. Then the anterior end of the inferior turbinate is removed with a scalpel, demonstrating the position of the ostium relative to the insertion of the inferior turbinate.

The posterior relations can be demonstrated by cutting off the inferior turbinate completely from the lateral nasal wall using the large nasal scissors. The posterior edge of the antrostomy is now extended backwards using a punch under endoscopic vision until nothing more remains. The proximity of the sphenoid sinus and the exit of the sphenopalatine artery can now be recognized and impressed on the memory.
Piecemeal resection of the uncinate process and of the lateral ethmoid cells finally demonstrates the construction of this part of the medial wall of the antral cavity. This step leads to practice of middle meatal antrostomy.

If a dissected skull is available it is useful to punch out the anterior antral wall at the same time, to be able to monitor the endoscopic field of vision through the inferior meatus by the naked eye anteriorly.

**Middle Meatal Antrostomy**

Once the surgeon is familiar with infraturbinate endoscopy of the antrum, middle meatal antroscopy using a 70° telescope is not difficult.

There are two possible methods of middle meatal antrostomy: firstly exposure via the semilunar hiatus, the ethmoid infundibulum, and the primary maxillary ostium, and secondly through the lateral nasal wall beneath the uncinate process. The following description is concerned solely with the second, more usual, method of access.

Typically the antrostomy is created immediately above the insertion of the inferior turbinate. A 45° upward-cutting Blakesley punch is used to perforate the wall; it must be introduced horizontally along the upper edge of the turbinate, to the center of its long axis. This point is also marked by the lower part of the semilunar hiatus which can usually be recognized endoscopically anteriorly as a very well marked channel running anterosuperiorly between the uncinate process and the ethmoid bulla. Normally a circumscribed antrostomy with a diameter of about 8 mm suffices to drain the antrum; in this case only the membranous wall (the fontanelle) is resected. A hole as small as 5 x 5 mm may suffice for simple endoscopy, but for more extensive procedures within the antrum the antrostomy must be enlarged by resection of the uncinate process, and be extended to the wall of the orbit above (see Chapter 6). The figure shows, in an anatomical frontal section, the position of the lateral nasal wall which is to be fenestrated relative to the maxillary ostium, the turbinate bone and the orbital wall. It also emphasized how the endoscopic view using a 70° telescope through the middle meatal antrostomy always falls first on the posterior antral wall. The other antral walls must then be viewed with telescopes of appropriate angles.

The figures show the position of the middle meatal antrostomy relative to the four main surfaces of the antrum. The alveolar recess is the most difficult area to inspect, since the view from above is often obstructed by a convex projection of the medial antral wall. In contrast, examination of the upper part of the antrum is easy, and the anterior and posterior walls can be seen better than by the infraturbinal access because the view is not obstructed by the inferior turbinate. The surgeon should now practice introducing a curved instrument into all recesses to develop familiarity with orderly inspection of the antral cavity, and purposeful endoscopic manipulations within it. If a dissected skull is available an additional portal through the canine fossa is useful to allow the endoscopic maneuvers to be monitored.
Anterior Ethmoidectomy

Familiarity with the topographical anatomy of the ethmoids is essential for understanding the pathogenesis of chronic sinusitis, and for safe surgery in this dangerous area. The steps of a typical operation are now described on a dissected skull. These steps need not be followed slavishly in the order given during an operation; the surgeon should rather be guided by the wide individual variation of the pneumatization of the ethmoids.

Step I: Middle Meatus: Opening of the Semilunar Hiatus

Using a forward-viewing telescope (usually with an angle of vision of 25°) the first structure to come into view is the middle turbinate projecting medially. The sharp edge of the uncinate process curving anteriorly and upwards forms the lower edge of the semilunar hiatus, and the ethmoid bulla its upper edge. The ethmoid cells and the maxillary ostium opening within it cannot be seen initially. However, a secondary antral ostium in the anterior or posterior fontanelle is often visible below the uncinate process. Superiorly a transverse bony bar can be seen closing off the hiatus in front. The cells opening into the hiatus can be demonstrated by removing the lower edge of the hiatus, the upper edge of the uncinate process, using a sharp fissure knife and slender forceps. The ethmoid tunnel running under (occasionally over) the bar of bone described above, and towards the frontal duct now comes into view above and anteriorly. Several ostia do not open into the narrow groove of the hiatus (called the inferior semilunar hiatus of Hajek), but they communicate with the middle nasal meatus via a superior semilunar hiatus. This superior semilunar hiatus (Gruenwald) runs in a curve parallel to the lower semilunar hiatus above the ethmoid bulla. It also opens into the middle meatus, and it drains part of the anterior or middle ethmoid cells, particularly the bulla cells, and may expand superiorly and laterally to form a lateral sinus (Gruenwald).

Because of the wide variation in pneumatization of the ethmoids it is usually futile to define a "typical" arrangement of ethmoid cells: in practice the pathology of the lesion is more important. However, one must always try to remove as many cell walls as necessary from the inferior semilunar hiatus in an anterosuperior direction until the ethmoid infundibulum is reached. This dissection can be termed ethmoid infundibulotomy (Stammberger).

Step II: Opening of the Ethmoid Bulla

The lower wall of the bulla can now be removed using a sharp elevator and a narrow-pointed ethmoid punch. The anterior and middle ethmoid cells are thus partially opened. It is true that the cell septa are arranged according to a specific plan, but the individual arrangement is so variable that uniform nomenclature is not possible. The cells are serially opened, and the party walls removed precisely until the position of the cell tunnel running to the frontal and antral cavities is visible, and the pathology can be assessed. The figure shows the junction of the bulla cells and those of the middle turbinate.
Step III: Clearance of the Anterior Ethmoid

A telescope with an angle of not less than 70° is used for optical control of dissection of the anterior ethmoidal cells. In this phase of dissection on the cadaver it is possible to preserve the middle turbinate completely, but this cannot be achieved in all cases of chronic ethmoid polyposis. The turbinate, or the medial bony ethmoid lamella, bounds the cleared ethmoid compartment medially, and the lamina papyracea separates it from the orbit laterally. Both boundaries are exposed by stepwise semi-sharp resection of the cell septa using the smallest Blakesley punch or double forceps, under endoscopic control. The roof of the ethmoids above is often concealed by an upper layer of shallow ethmoid cells. The canal of the anterior ethmoid artery forming a shallow budge running across the roof of the ethmoids should be identified carefully.

Step IV: Resection of the Agger Nasi, and Frontal Sinusotomy from below

It is usually not possible to expose the most anterior ethmoid cells and the connecting ducts to the frontal cavity by endoscopy without opening up the nasal cavity in front by removing the overhanging bone of the agger nasi. However, once 3-6 mm of this obstructing bony ridge has been removed with a cutting punch, the entire ethmoid comes into view. The superolateral cell recesses can now be inspected, the medial lamella of the middle turbinate up to its union with the base of the skull identified, and the frontonasal duct inspected.

If a frontonasal duct is absent, but the radiographs have shown a frontal cavity to be present, then frontal sinusotomy is carried out with a sharp, curved curette or with a diamond burr from the nasoethmoidal cavity under endoscopic control. In both cases the direction of dissection runs from the skull base anteriorly: initially a dark, transparent, party wall usually lying 3-8 mm in front of the easily recognizable bulge of the anterior ethmoid artery is identified, and perforated carefully. It is occasionally difficult to be sure whether the delicate membrane lying behind it is dura or mucosa, but the experienced endoscopic eye can usually distinguish the two. The figure shows a limited frontal sinusotomy. Continuity of the roof of the ethmoid with the convex curve of the posterior wall of the frontal sinus is a definite landmark for successful exposure of the frontal sinus. For practice, the floor of the frontal sinus can now be removed extensively, removing the anterior circumference of the small sinusotomy using sharp curettes.

Mastery of anterior ethmoidectomy and the creation of a sufficiently wide access to the frontal sinus is of decisive importance in the surgical treatment of severe polypoid pansinusitis. The ethmoid narrows anteriorly, and it is this area which determines healing or recurrence, and where the tendency to formation of scar tissue, and the danger of injury to the olfactory cleft is highest. Practice of correct manipulations under endoscopic control is therefore particularly important for this area of dissection.

The surgeon must assure himself on the dissected skull that all the cells have been removed, by going one step further and dissecting more widely in the surrounding area. The following are recommended:

- removal of the middle turbinate entirely in stages, and study of its attachment to the base of the skull,
- identifying the anterior ethmoid artery and exposing the surrounding dura,
- removal of the lamina papyracea to demonstrate the spatial relationships with the orbit,
- removal of further bone from the agger nasi until the nasolacrimal canal and lacrimal sac are completely exposed,
- opening the floor of the frontal sinus completely from below, and inspecting the posterior wall of the frontal sinus and its recesses.

**Posterior Ethmoidectomy**

A bony party wall between the anterior and posterior ethmoid cells formed by a continuous basal lamella cannot always be recognized as is indicated in anatomical texts. Therefore the surgeon cannot always build up a mental image through the endoscope of separate anterior ethmoid cells draining into the middle meatus and posterior cells opening into the superior meatus. Dissection backwards from the bulla, preferably using a narrow ethmoid punch after removing the anterior ethmoid cells, brings the picture about to be described into view after resection of the posterior ethmoid cells. Examination can be carried out with the naked eye, but more effectively with the straight telescope or the operating microscope.

Laterally the ethmoid compartment has now reached its greatest extent, because its external wall, that is the medial wall of the orbit, runs laterally to form the orbital apex. Room can also be gained medially by dividing the middle turbinate from the skull base. Its upper insertion lies further laterally at the center of the ethmoids (that is the posterior end of the cribiform plate) and runs deeply to insert into the ethmoid and reach the lateral nasal wall more posteriorly, where its posterior point of attachment lies at the level of the floor of the sphenoid sinus.

If the ethmoid is well pneumatized, tracks of cells may run laterally alongside the inferior turbinate (paraturbinal cells), either posteroinferiorly into the pterygoid process, or in a posterolateral and superior direction as Onodi cells beneath or lateral to the canal for the optic nerve. They are all of great importance in complete ethmoidectomy.

**Exposure of the Sphenoid Sinus**

Smooth and safe surgery on the ethmoidosphenoidal complex depends on thorough understanding of the topography of the sphenoid sinus and its relations. During total ethmoidectomy, a partial resection of the posterior ethmoid is carried out first, with subsequent broad fenestration of the sphenoid sinus. After this maneuver, a complete posteroanterior exenteration of the ethmoid follows. Exposure of a sphenoid sinus following complete ethmoidectomy on a cadaver is described here. The figure shows an endoscopic view through the nose after complete ethmoidectomy, with the anterior wall of the sphenoid still intact and with its natural ostium lying superiorly. The mental picture of topographical relationships gained from CT scans should be projected onto this situation, and the distance from the orbital wall, the optic nerve, the anterior cranial fossa and the carotid canal, should be remembered. It is also worthwhile considering the expected position of the sphenopalatine fissure and both the canalis rotundus and the canalis pterygoideus.
The anterior wall of the sphenoid sinus is fenestrated and removed completely with a punch. All walls of the sphenoid sinus are illuminated using a forward-viewing or a 30° telescope, and the preoperative concept of the topography of the structures named above is compared with the endoscopic view which is now available. The distortion of the image due to the wideangled telescope should be remembered: close objects are magnified whereas distant objects appear too small.

If the sphenoid ostium cannot be found, and the view of the posterior ethmoid is narrow and obstructed by the middle turbinate, the posterior third of the middle turbinate should be resected with scissors. The most posterior ethmoid cells can be removed easily and the transparent sphenoid wall can be seen and perforated with a probe or with a fine closed ethmoid punch. In the author's experience, the cavity will always be found if the site of perforation lies about 1 cm above the roof of the posterior nasal choana. The entire anterior wall of the sinus is now removed with a 90° punch, allowing the sphenoid cavity to be examined with the straight telescope or with an operating microscope.

The roof of the sphenoid cavity sloping obliquely downwards and backwards is marked by the bulging wall over the pituitary. The sphenoid septum seldom lies in the midline, and often is not strictly sagittal. The lateral wall may be largely formed by the projections produced by the canals of the optic nerve and the carotid artery. Sphenoid recess extending laterally and inferiorly can be of great importance in complete clearance of the sphenoid sinus. The floor of the sphenoid sinus also varies. Usually the bone is too hard to allow removal with the punch. Arterial bleeding from the bony branches of the sphenopalatine artery indicates the level of the floor of the sphenoid sinus.

During endoscopic procedures within the sphenoid cavity, for example for treatment of a CSF fistula or for removal of papillomas, the bone of the lateral wall, roof or posterior wall must on occasion be thinned, using endoscopically monitored diamond burrs. Knowledge of the topographical relationship of the structures in the wall to the anterior and middle skull base, and the contents of the neighboring cranial fossa is very important. The distance between the anterior wall of the sphenoid sinus and the optic canal, the carotid canal and the pituitary gland, demand particular care but attention should also be drawn to the relative fragility of the posterior wall of the sphenoid sinus and the proximity of large basal blood vessels.