Chapter 35: Anatomy

Daniel O. Graney, Shan R. Baker

Nasal Pyramid

The nose is a pyramidal structure with its apex projecting anteriorly and its base attached to the facial skeleton. The superior part of the base, consisting of the nasal bones, is raised and projects more anteriorly than the inferior part, creating the *bony vault* of the nose. In contrast, the more anterior part of the apex is formed by cartilage and is called the *cartilaginous vault.* The analogy to a pyramid can be misleading because it implies a quadrilateral base: the base of the nose is actually pear shaped and is named the *piriform aperture.* Furthermore, in the usual concept of a pyramid the base is at the bottom and, until one mentally rotates the image sideways, some confusion may occur. Nevertheless, the concept is useful and has been used extensively for a number of years, especially in the clinical literature. Hinderer (1971) has described the nasal pyramid as consisting of four parts: the bony pyramid, the cartilaginous vault, the lobule, and the nasal septum.

Bony pyramid

If one traces the outline of the piriform aperture on a dried skull specimen, all of the parts distal to this outline are clearly the mobile parts of the nose. Beginning at the anterior nasal spine in the midline, the outline of the piriform aperture follows posterolaterally along the floor of the nasal cavity and then ascends the edge of the nasal notch on the anterior surface of the maxilla. Up to that point the plane of the maxillary bone is coronal, but there, the medial edge of the maxillary bone begins to rotate anteriorly until it projects into the sagittal plane that forms the frontal process of the maxilla. Rotation of the frontal process brings it into alignment with the surface of the nasal bone and completes the outline of the piriform aperture. The projecting frontal processes of the maxillae and the paired nasal bones thus form the bony vault. An important clinical corollary of this is useful to the otolaryngologist - head and neck surgeon when placing the lateral osteotomy to mobilize the bony pyramid. The osteotomy must be placed on the projecting frontal process, rather than on the flat coronal plane on the maxilla, to keep from entering the nasolacrimal canal.

The superior border of the nasal bones form a suture with the frontal bone and is also an important point of support for the bony vault because of the buttress formed by the underlying nasal spine of the frontal bone. Also buttressing the nasal bones in the midsagittal plane is the perpendicular plate of the ethmoid bone. The midline point at which the nasal bones meet the frontal bone is termed the *nasion.* The inferior point of the midline suture between the nasal bones where they meet the upper lateral cartilages is the *rhinion.*

Cartilaginous vault

The cartilaginous vault consists of the upper lateral cartilages and the adjacent portion of the cartilaginous nasal septum. The details of the septum are discussed in the later section on nasal cavities.

The upper lateral nasal cartilages attach to the undersurface (deep surface) of the nasal bones and extend inferiorly (caudally) to form the cartilaginous portion of the dorsum of the nose (Fig. 35-1). Straatsma and Straatsma (1951) describe the amount of overlap as varying between a minimum of 2 mm and a maximum of 15 mm. Laterally the cartilages have a modest attachment to the frontal process of the maxilla. In the midline, the upper lateral cartilages fuse or adhere to the cartilaginous portion of the nasal septum. The articulation between the caudal edge of the upper lateral cartilage and the lower lateral cartilage is of interest both anatomically and clinically. Anatomically, considerable debate exists regarding the precise arrangement of the articulation. Clinically the articulation is the site of the intercartilaginous incision during rhinoplasty.

Two studies of this region are particularly worthwhile because they employed histologic as well as dissection techniques. Drumheller (1973) and Dion et al (1978) all confirm the variability of the anatomy from specimen to specimen as well as from side to side (Fig. 35-1). In 52% of 46 sides examined, Dion et al found the articulation between the edges of the upper and lower lateral cartilages to be of an interlocked-scroll type. In this classification the edge of the upper lateral cartilage turns laterally and superiorly and appears concave when viewed from the lateral aspect. In contrast, the convex surface of the lower lateral cartilage turns medially and caudally to interlock with the upper lateral cartilage. The authors point out that in patients with this form of articulation, an intercartilaginous incision is actually intracartilaginous. Other variations noted by these authors (Fig. 35-1) were classified as: 17% end to end; 20% overlapiing (similar to interlocking but with less curling of the edges); and 11% opposed (edge of the lower lateral cartilage is deep to the edge of the upper lateral cartilage).

Lobule

The nasal lobule includes the tip, lower lateral cartilages, alae, vestibular regions, and columella. Each lower lateral cartilage is shaped approximately in the form of an inverted U and consists of a medial and lateral crus. The crura underlying the skin of the vestibule thus contribute to the dome of the vestibule by providing the skeletal support for it. The width of the vestibular dome and any irregularity in it is usually reflective of the underlying anatomy of the lower lateral cartilage.

The meical crus enters the skin of the columella, where it artculates loosely with the medial crus of the opposite side. Posterior to the columella the vestibule's skin forms the membranous portion of the nasal septum and prevents fusion of the crura with the cartilaginous part of the nasal septum. Within the nares the skin of the vestibule abruptly changes at the limen vestibuli from a stratified nonkeratinizing type to the typical respiratory ciliated columnar epithelium.

Nasal Muscles

The nasal muscles include the procerus, nasalis (including both transverse and alar parts), levator labii superioris alaeque nasi, depressor septi, and the anterior and posterior dilator naris (Fig. 35-2). Whereas the procerus (along with the action of the forehead muscles) elevates the skin over the dorsum of the nose, the nasalis acts as a compressor of the naris. Dilatation of the nostrils is accomplished by the dilators and the levator labii superioris alaeque part of the quadratus labii. Individuals with a well-developed depressor septi draw the nasal tip downward when smiling widely. Such individuals should have this muscle transected during rhinoplasty to help prevent migration of the nasal tip downward postoperatively, a common cause of "polly beak" deformity following rhinoplasty.

Nasal Cavities

The key to the nasal cavities is the underlying bony framework. Beyond the soft tissue of the nose the nasal cavities begin at the piriform aperture, as just described, and end at the posterior choanae. Other limiting boundaries of the nasal cavities are the roof, floor, septal wall, and lateral wall.

Roof

The roof of the nasal cavity is formed anteriorly by the nasal bones, the nasal spine of the frontal bone, and the floor of the frontal sinus (Fig. 35-3). In its more horizontal midpart, the roof is formed by the cribriform plate of the ethmoid bone. Posteriorly the roof slopes down to the posterior choana along the anterior wall of the sphenoid sinus and the body of the sphenoid bone.

The cribriform plate is very thin and is penetrated by olfactory filaments carrying the meninges along with them. The subarachnoid space and endocranial cavity are intimately associated with the bone, making them particularly vulnerable during nasal and ethmoid surgery.

Floor

Approximately three fourths of the floor of the nasal cavity is formed by the palatal process of the maxillary bone. Posteriorly the remaining part is formed by the horizontal process of the palatine bone.

Nasal septum

The principal parts of the nasal septum are the vomer, perpendicular plate of the ethmoid bone, and quadrilateral cartilage. Additional bony reinforcements to the septum are the nasal crest and the anterior nasal spine formed by the midline fusion of the palatal processes of the maxillae. The membranous septum and columella divide the anterior part of the nasal cavities. The septum is seldom located completely in the midline, having deflections of varying degrees on all or portions of the bony or cartilaginous partitions. There may be expression from the septum into the nasal passage, particularly at the junction of the quadrilateral cartilage with the nasal crest. These "spurs" may be large enough to partially obstruct the nasal passage.

Lateral wall

The lateral wall of the nasal cavity is formed by the contribution of several bones: the nasal surface of the maxilla, inferior concha, superior and middle conchae of the ethmoid bone, and perpendicular plate of the palatine bone (Fig. 35-3). The horizontally aligne conchae each form a passage, or meatus, between the lateral nasal wall and the scroll-like edge of the medially projecting concha. Each meatus is named after the concha that forms its roof. In addition, a number of important landmarks are located in relation to the meatus as well as the openings of the paranasal sinuses and the nasolacrimal duct. Posterosuperior to the superior concha is the space known as the sphenoethmoid recess, which is the drainage site of the sphenoid sinus (Fig. 35-4).

Inferior to the superior concha in the superior meatus, there are usually one or two openings for the posterior ethmoid air cells.

The posterior end of the middle concha points to the opening of the sphenopalatine foramen in the upper part of the vertical plate of the palatine bone. The sphenopalatine foramen actually represents a gap in the fusion between the sphenoid, palatine, and ethmoid bones rather than a specific opening in one of the bones. As described later, it transmits a neurovascular bundle to the nasal mucosa and is thus an important landmark for topical anesthetic administration or other clinical procedures.

The most complex of the three meatus lies deep to the middle concha. Elevation of the middle concha usually reveals a rounded prominence, the ethmoid bulla, which overlies a slitlike opening - the hiatus semilunaris (Fig. 35-5). One to three openings on the surface of the bulla represent the drainage sites of the middle an anterior ethmoid cells. The hiatus semilunaris is in fact the opening of the maxillary sinus. Inferiorly the bony margin of the hiatus semilunaris is formed by the unciform process of the ethmoid bone; therefore enlarging the hiatus semilunaris to place a drainage cannula is impossible without fracturing either the bulla or the unciform process. However, one should note that inferior to the unciform process to the level of the inferior concha there is no bony wall limiting the medial part of the maxillary sinus (Fig. 35-3). This nonbony area is approximately circular (1 to 2 cm in diameter) and is closed only by a fibrous membrane, which is, in turn, covered only by the nasal mucosa.

In the anterosuperior portion of the middle meatus, the middle concha narrows into the infundibulum, where an opening can be found for the frontal sinus. The proximity of the openings of the frontal sinus, as well as the anterior and middle ethmoid sinuses to the hiatus semilunaris, facilitates the spread of a sinusitis condition by allowing a purulent discharge from these sinuses to be carried into the maxillary sinus.

The key landmark in performing an intranasal ethmoidectomy is the middle concha. The anterior and middle ethmoid air cells lies inferior to this concha and drain into the middle meatus, whereas the posterior ethmoid cells lie above the middle concha and drain into the superior meatus. The anterior and middle ethmoid cells can be surgically exenterated without disturbnig the concha. The posterior cells are removed through the surgical defect created by the anterior ethmoidectomy. In addition to marking the location of the ethmoid air cells, the attachment of the middle concha is a guide to other structures that the surgeon must be concerned about when performing an intranasal ethmoidectomy. The anterior attachment lies 1 cm inferior to the cribriform plate and 1 cm medial to the lamina papyracea. The posterior end of the concha marks the posterior limit of the ethmoid pneumatization and is 1 cm inferior and medial to the optic nerve.

No sinuses empty into the inferior meatus, but that meatus is the site of the nasolacrimal duct's drainage. The opening of the nasolacrimal duct is located in the anterosuperior portion of the meatus at the point that the inferior concha contacts the lateral wall of the nasal cavity. Because the inferior meatus is a common point of entry when placing a troacar during irrigation of a maxillary sinus, the nasolacrimal duct is at risk for injury. Similarly, in performing a Caldwell-Luc antrostomy, if bone is removed too far anteriorly, there is potential for damaging the duct, resulting in epiphora.

Blood Supply of the Nasal Cavities

The blood supply of the nasal cavity is basically derived from two sources: the ophthalmic artery, a branch of the internal carotid system, and the maxillary artery, a branch of the external carotid system (Fig. 35-6). In the orbital cavity the ophthalmic artery gives off an anterior and posterior ethmoid artery. Each artery pierces the bone on the medial wall of the orbit at the point where the lamina papyracea of the ethmoid bone articulates with the orbital portion of the frontal bone (frontoethmoid suture). There the vessels enter the ethmoid sinuses to supply the mucosa and to send important branches to the attic of the nasal cavity. The posterior ethmoid artery is distributed mainly to the region of the superior concha, whereas the anterior ethmoid supplies the more anterosuperior aspect of the nasal mucosa. In some patients these vessels require ligation to control nasal hemorrhage, so the exact locations of the anterior and posterior ethmoid foramina are of surgical interest. Kirchner et al (1961) note that the anterior ethmoid foramen was 14 to 22 mm posterior to the maxillolacrimal suture in 84% of the 80 orbits they studied. The location of the posterior ethmoid foramen was more variable, but could be found 3 to 13 mm posterior to the anterior ethmoid foramen in 86% of the observed specimens. In most cases the foramina were found either on the line of the frontoethmoid suture or slightly superior to it. The anterior and posterior ethmoid arteries are the most important surgical landmarks when performing an external ethmoidectomy. These branches penetrate from the orbit into the ethmoidal sinuses at the level of the fovea ethmoidalis, thus delineating the superior extent, or roof, of the ethmoid sinuses. Above these arteries is the floor of the anterior cranial cavity; below them, the ethmoid air cells. The posterior ethmoid artery is also a landmark for the optic nerve. This nerve lies approximately 1 cm posterior to and on the same level as the vascular structure.

The terminal branch of the maxillary artery in the pterygopalatine fossa is the sphenopalatine artery. This artery can be ligated to control nasal hemorrhage through a transantral approach to the pterygopalatine fossa. The artery enters the nasal cavity through the sphenopalatine foramen, where it supplies the mucosa on both the lateral wall and septum (Fig. 35-6). From the sphenopalatine foramen branches course on the lateral wall over the posterior surfaces of both the middle and inferior meatus. A septal branch of the sphenopalatine artery ascends from the sphenopalatine foramen to the roof of the nasal cavity, follows the contour of the sphenoid bone to the nasal septum, and then courses anteriorly and inferiorly on the septum along the path of the vomer. Because the septal branch is located in the mucosa covering the face of the sphenoid sinus, this mucosa should be reflected inferiorly before the sinus is entered surgically, so as not to transect the artery.

As the vomer meets the nasal crest on the nasal floor, foramina on each side of the nasal crest merge with each other to form a single canal in the anterior maxillary palate. The canal opens onto the hard palate posterior to the central incisors; it is called the *incisive* *foramen.* Branches of the septal sphenopalatine arteries enter the incisive foramen from both sies of the nasal cavity and emerge as a plexus of vessels on the anterior aspect of the palate in the oral cavity.

The anterosuperior portion of the septum is also supplied by the anterior ethmoidal artery descending from the roof of the nasal cavity. The vestibule of the nose is supplied by the terminal branches of the arteries just mentioned as well as by nasal branches of the superior labial artery in the upper lip derived from the facial artery. The anterior portion of the nasal cavity, particularly the septum, is thus an important site of anastomosis between vessels from several sources, namely ophthalmic, from the internal carotid system, and the maxillary and facial, from the external carotid system. Anastomosing vessels on the anterior septum, reportedly a common site of nosebleed, have been termed Kiesselbach's, or Little's, area.

Because of the various and sometimes confusing names applied to the vessels of the nose, thinking of the source of the vessels is easier than thinking of the individual names. In this simplified view there are two sources; either the ethmoial arteries in the attic of the nose or the sphenopalatine arteries arising posteriorly at the sphenopalatine foramen from the maxillary artery.

Venous Drainage of the Nasal Cavities

The venous drainage of the nasal cavities follows the basic arterial pattern. Veins in the roof of the nasal cavity follow the ethmoidal veins into the orbital cavity, where they become tributaries of the ophthalmic veins. These usually course posteriorly into the cavernous sinuses and become part of the drainage pattern of the dural venous sinuses. The posterior portion of the nasal cavity drains via the sphenopalatine vessels into the pterygopalatine fossa and subsequently into the pterygoid venous plexus within the infratemporal fossa. The anterior portion of the nasal cavity drains into the anterior facial vein, which is a tributary of either the external or internal jugular vein. Both the pterygoid venous plexus and the ethmoidal veins have communication with the dural venous sinuses. For these reasons it is obvious that infections in the attic of the nose or nasal sinuses may spread to the adjacent orbital tissues or intracranial cavity with disastrous clinical sequelae.

Innervation of the Nasal Mucosa

A thorough discussion of the innervation of the nasal mucosa requires specific knowledge of the osteology of the pterygopalatine fossa and the distribution of the branches of the trigeminal nerve's maxillary division. The true fibers of the maxillary nerve, which are those entering the pons in the root of the trigeminal nerve, conduct only general sensory input (touch, pain, and temperature) from the nasal, palatal, and oral mucosae and skin of the cheek. However, the terminal branches of the maxillary nerve also carry special sensory taste fibers and postganglionic, parasympathetic, secretomotor fibers. These fibers (taste and parasympathetic) join the maxillary nerve in the pterygopalatine fossa and are distributed with the various branches of the maxillary nerve from the pterygopalatine fossa to taste buds or mucous glands in the oral or nasal mucosa. Because of the anatomic detail involved in discussing the pathways of these nerves, the subject is divided into five sections: (1) osteology of the pterygopalatine fossa, (2) maxillary division of the trigeminal nerve, (3) ophthalmic division of the trigeminal nerve, (4) parasympathetic innervation of the nasal mucosa, and (5) sympathetic innervation of the nasal mucosa.

Osteology of the pterygopalatine fossa

The following is written in a manner such that if the reader has a skull and a pipe cleaner or broom straw available, the descriptions can be followed on the specimen to clarify the complicated three-dimensional relationships of this area. The pterygopalatine fossa can be located easily on a skull specimen by removing the mandible and looking at the interval between the tuberosity of the maxilla and the pterygoid process of the sphenoid bone (Fig. 35-7). These structures form the anterior and posterior walls, respectively, of the fossa. The opening into the fossa on its lateral aspect is called the *pterygomaxillary fissure;* medially the wall of the fossa is formed by the vertical plate of the palatine bone and the sphenopalatine foramen located at the superior border of the palatine plate. If a probe is inserted into the fossa through the pterygomaxillary fissure, it exits the fossa via the sphenopalatine foramen and occupies the nasal cavity posterior to the middle concha (see Fig. 35-3). The roof of the pterygopalatine fossa is open essentially because of the inferior orbital fissure, although the greater wing of the sphenoid bone projects anteriorly into this region. Because the bony walls of the fossa are somewhat inclined, the floor of the fossa is like the apex of a cone and represents the fusion of the walls. However, the fusion is incomplete and provides an opening in the floor, leading into a canal in the palatine bone - the greater palatine canal - that terminates on the palate as the greater palatine foramen (Fig. 35-8). A lesser palatine canal, also from the floor of the fossa, traverses the pyramidal process of the palatine bone and opens slightly posterior to the greater palatine foramen; it is called the *lesser palatine foramen.*

If a skull is sectioned coronally in the exact plane of the pterygopalatine fossa, it is possible to view the anatomy of the posterior wall of the fossa. The same view can be obtained by examining the anterior surface of an isolated sphenoid bone (Fig. 35-9). When viewe in this manner, two foramina can be seen in the body of the sphenoid at the root of the pterygoid process; the foramen rotundum and the forament of the pterygoid canal. A probe inserted into the foramen rotundum leads immediately into the middle cranial fossa, whereas a probe inserted into the pterygoid canal must transverse the entire depth of the body of the sphenoid bone before it exits the canal at the skull base near the foramen lacerum.

Maxillary branch of the trigeminal nerve

The maxillary division is derived from the semilunar ganglion and exits the middle cranial fossa via the foramen rotundum. It enters the roof of the pterygopalatine fossa, traverses the inferior orbital fissure, and occupies the floor of the orbit before it comes to lie in the infraorbital groove (Fig. 35-10). Following the infraorbital groove it traverses the infraorbital canal of the maxilla and finally exists the canal via the infraorbital foramen. The nerve terminates in the skin of the face as three named branches: (1) a palpebral branch supplying the skin of the lower lid, (2) an external nasal branch supplying skin of the lateral aspect of the bridge of the nose and both the external and internal surfaces of the ala, and (3) a labial branch supplying the skin of the upper lip, the labial mucosa on the internal surface of the lip, and the labial gingiva associated with the incisors and canine teeth. The entire maxillary division may be anesthetized to perform nasal and paranasal sinus surgery by injecting a small quantity of the anesthetic agent near the vicinity of the foramen rotundum in the pterygopalatine fossa. Needle access to the fossa is accomplished through either the greater palatine foramen or the pterygopalatine fissue, via the notch of the mandible between the coronoid process and the ramus.

Dental branches

Beginning in the pterygopalatine fossa, a number of branches arise from the maxillary division as it courses through the midface. The posterosuperior alveolar nerve arises from the maxillary nerve in the pterygopalatine fossa and exits via the pterygomaxillary fissure. The nerve penetrates the posterior wall of the maxilla as two or more filaments; it supplies the roots of the posterior teeth, including the molars and bicuspids. In addition, it supplies the buccal gingiva associated with these teeth.

After the maxillary nerve enters the infraorbital canal, a middle superior alveolar nerve is given off, which may share with the posterosuperior alveolar nerve in the innervation of the bicuspids. Slightly distal to this point is an anterosuperior alveolar nerve, which supplies the remaining teeth in the maxillary arch, namely, the incisors and canines (Fig. 35-10).

Palatine branches

In the pterygopalatine fossa a palatine branch descends vertically from the maxillary nerve, passing through the floor of the pterygopalatine fossa, branching at the greater and lesser palatine canals, and forming the greater and lesser palatine nerves (Fig. 35-11). These nerves supply the palatal mucosa and gingiva from the region of the molar teeth anteriorly, to the area adjacent to the first bicuspid.

Nasal branches

A large medial branch of the maxillary nerve arises in the pterygopalatine fossa and enters the nasal cavity through the sphenopalatine foramen where it divides and contributes branches to the mucosa on both the lateral and septal walls of the nasal cavity. The branch on the lateral wall forms several small nerves in the mucosa, calle the *posterolateral nasal nerves* (Fig. 35-12). These nerves course anteriorly in the mucosa over the middle and inferior conchae. The branch to the nasal septum leaves the sphenopalatine nerve at the foramen and follows the contour of the sphenoid bone along the roof of the nasal cavity before turning inferiorly to reach the septum. On the septum the nerve is called the *nasopalatine nerve;* it continues anteriorly as a major nerve in the mucosa, supplying branches to the septal area. Near the anterior end of the vomer the nerve enters a bony canal on the nasal floor, traverses the premaxillary palate, and exits via the incisive foramen. On the anterior aspect of the palate, the nerve supplies the mucosa and gingiva posterior to the incisor teeth (Fig. 35-11).

Nasal branches of the ophthalmic division of the trigeminal nerve

In addition to the branches of the maxillary nerve, branches from the first division of the trigeminal nerve supply portions of the nasal mucosa. After the ophthalmic division of the trigeminal nerve enters the orbital cavity, it gives off several branches, among which is the nasociliary nerve. The nasociliary nerve crosses to the medial aspect of the orbit and gives off the anterior and posterior ethmoidal nerves. These nerves, accompanied by their respective vessels, enter the anterior and posterior ethmoid foramina at the frontoethmoid suture, as described before. The nerves supply the mucosa of the ethmoid sinuses, send a small twig to the dura in the anterior cranial fossa, and enter the roof of the nasal cavity. The posterior ethmoid supplies only a small area of the mucosa near the superior concha on the lateral wall and a corresponding area on the nasal septum (Fig. 35-12). After entering the attic of the nasal cavity, the anterior ethmoid nerve sends branches to the mucosa of the septum and lateral nasal wall. The nerve follows the posterior surface of the nasal bone anteriorly, as the *internal nasal nerve*, until it reaches the articulation with the upper lateral cartilage. At this point it passes between the nasal bone and the upper lateral cartilage to occupy the surface of the cartilage. Here the nerve is called the *external nasal nerve.* It provides cutaneous innervation to the skin over the dorsum and tip of the nose. Trauma to the external nasal nerve of the anterior ethmoidal undoubtedly results in hypesthesia over the dorsum after rhinoplasty.

Autonomic innervation of nasal mucosa

As already noted, an understanding of the maxillary nerve branches is important not only because of the general sensory innervation they provide, but because they also serve as conduits for the distribution of parasympathetic secretomotor fibers to the nasal, palatal, and oral mucosae.

The autonomic innervation of nasal mucosa, both parasympathetic and sympathetic, does not follow a direct path to the glands of the nasal mucosa. The parasympathetic fibers begin with the seventh cranial nerve (CN VII, the facial), but istally they use branches of the trigeminal nerve for their distribution to the individual glands. Similarly sympathetic fibers beginning in the spinal cord have a distinct path until they reach the superior cervical ganglion. From the ganglion, postganglionic fibers may appear as diffuse plexuses on the surface of blood vessels or with branches of the trigeminal system.

Autonomic innervation, whether parasympathetic or sympathetic, requires two neurons from the central nervous system (brainstem or spinal cord) to the effector organ. In contrast, innervation of skeletal muscle requires only one neuron from the central nervous system to the motor end-plate. Thus in the autonomic pathway a ganglion, eirther parasympathetic or sympathetic, always intervenes between the central nervous system and the effector organ.

Parasympathetic innervation

Parasympathetic innervation of the nasal mucosa begins in the superior salivary nucleus, which is located in the brainstem at the junction between the pons and the medulla (see Fig. 35-10). Secretomotor fibers exit the brainstem at this point via the intermediary nerve. This nerve exists briefly as an inependent nerve, between the brainstem and the internal auditory meatus. Within the auditory meatus its fibers join with the motor fibers of CN VII. At the anterior end of the internal acoustic canal, CN VII makes a sharp bend (genu) to follow the medial wall of the middle ear cavity. The genu of CN VII is also the site of the geniculate ganglion. Although the secretomotor fibers traverse the geniculate ganglion, they do not synapse at this site because the geniculate ganglion is a sensory ganglion for other CN VII fibers. Traversing the ganglion, the fibers form an anterior branch from the ganglion, named the *greater petrosal nerve,* which penetrates the roof of the temporal bone and enters the middle cranial cavity.

On the petrous bone the greater petrosal nerve courses medially, descending on the petrous pyramid until it reaches the surface of the internal carotid artery within the foramen lacerum. The nerve continues on the lateral wall of the carotid artery until it reaches the junction between the temporal and sphenoid bones. The fibers enter the pterygoid canal of the sphenoid bone, traveling anteriorly until they exit from the canal into the pterygopalatine fossa. Crossing the fossa, the preganglionic, parasympathetic, secretomotor fibers enter the sphenopalatine ganglion to synapse with neurons, which ultimately distribute postganglionic fibers to the glands of the nasal mucosa.

Although these parasympathetic fibers begin within CN VII, after leaving the geniculate ganglion they are termed the *greater petrosal nerve* until they reach the pterygoid canal. Because these fibers are joined by sympathetic fibers (deep petrosal fibers) while they are in the pterygoid canal, the combined mixture of fibers is known as the *nerve of the pterygoid canal,* or the *vidian nerve.* The final distribution of these fibers is along the various branches of the maxillary division of the trigeminal nerve. The vidian nerve is sometimes surgically divided to reduce rhinorrhea. The vidian neurectomy is accomplished via a transantral approach to the pterygopalatine fossa, giving access to the pterygoid canal.

After synapsing in the sphenopalatine ganglion, postganglionic fibers course medially through the sphenopalatine foramen and follow sphenopalatine branches of the maxillary nerve, supplying both the lateral wall and septum of the nasal cavity. Thus the posterior lateral nasal nerve and the nasopalatine nerve contain not only general sensory fibers from the nasal mucosa but both parasympathetic secretomotor fibers (to the mucous glands within the nasal mucosa) and sympathetic fibers (to the blood vessels. Similarly, the nasopalatine nerve on the nasal septum, after exiting the incisive foramen, also carries secretomotor fibers to mucous glands on the anterior portion of the palate.

The posterior parts of the hard and soft palates receive secretomotor fibers from the sphenopalatine ganglion, which follow the greater and lesser palatine nerves, respectively.

So far, three types of functional neural components have been discussed within the branches of the maxillary nerve: (1) general sensory fibers from the mucosa itself that travel back to the semilunar ganglion of the trigeminal nerve and project to the sensory nuclei of the trigeminal nerve; (2) parasympathetic secretomotor fibers; and (3) sympathetic vasomotor fibers. A fourth group of fibers carries taste from the region of the palate via the greater and lesser palatine nerves. Taste fibers do not return with the maxillary nerve; instea, they join the nerve of the pterygoid canal. In effect, they follow the pathway of the parasympathetic secretomotor fibers in a retrograde manner and eventually enter the intermediary nerve. This is accomplished by traveling posteriorly through the pterygoid canal and ascending the greater petrosal nerve to the geniculate ganglion. The taste fibers have their cell bodies within the geniculate ganglion, with central processes that project via the intermediary nerve back to the brainstem, where they make synaptic connections in the nucleus solitarius.

Although taste fibers in the palatine nerves may be few in number, they have clinical significance in Ramsay Hunt's syndrome (herpes oticus). In addition to presenting vesicles in the external acoustic meatus, patients with this syndrome may occasionally also have vesicles distributed over the region of the hard and soft palates.

Sympathetic innervation

Sympathetic fibers begin in the intermediolateral cell column of the spinal cord in the region of T-1. Traveling via the ventral roots of the spinal cord, the fibers enter the first thoracic spinal nerve. From the spinal nerve the fibers enter the first thoracic sympathetic ganglion via a white communicating ramus. The fibers do not synapse in the ganglion but ascend in the sympathetic chain to the level of the superior cervical sympathetic ganglion. This is the site of synapse and relay of postganglionic sympathetic fibers to various parts of the head, and in particular the nasal mucosa.

A large number of postganglionic fibers ascend from the superior cervical ganglion, forming the internal carotid nerve, which accompanies the internal carotid artery into the skull. After traversing the carotid canal, some of the fibers, termed *deep petrosal fibers*, leave the carotid at the posterior boundary of the sphenoid bone and enter the pterygoid canal, joining the greater petrosal nerve (see Fig. 35-10). The combination of fibers from the greater petrosal and deep petrosal nerves forms the nerve of the pterygoid canal, described previously. When the postganglionic fibers reach the pterygopalatine fossa, they do not synapse in the sphenopalatine ganglion because they are already postganglionic fibers and the sphenopalatine ganglion is a parasympathetic ganglion. The distribution of these fibers is not known precisely, but most are distributed as vasomotor fibers to the blood vessels of the nasal and oral mucosae via branches of the maxillary nerve.

Parasympathetic Innervation of the Lacrimal Gland

It may seem inappropriate to include the lacrimal gland in the chapter on nasal cavities, but the lacrimal gland shares its innervation pathway with the gland of the nasal and palatal mucosae. Interruption of these fibers - whether by disease, trauma, or surgical intervention, as in the case of vidian nerve neurectomy for vasomotor rhinitis - also interferes with lacrimal secretion and may require the patient to use artificial tears.

Lacrimal secretion is usually described as being of two types: basic and reflex (Reeh et al, 1981). The basic secretion contributes to a precorneal film containing a mixture of mucin and oils derived from glands in the lid and conjunctiva. Basic secretion rates are relatively constant but tend to diminish slightly with age. The oily component of the basic secretion is important in maintaining a low evaporative rate of the lacrimal secretions.

Reflex secretions are caused by direct stimulation of the lacrimal gland by parasympathetic fibers of CN VII. The afferent limb of this reflex is stimulated by several afferent mechanisms: via nasociliary branches of the ophthalmic division of the trigeminal nerve when the conjunctiva or cornea is irritated; via the optic nerve and caused by light (reflex secretion is nil in darkness or during sleep); or via cortical or hypothalamic centers in varying emotional states.

The pathway of postganglionic parasympathetic fibers to the lacrimal gland is the zygomatic branch of the maxillary nerve. Before the maxillary nerve enters the infraorbital groove, it gives off the zygomatic branch, which abruptly divides into the zygomaticotemporal and zygomaticofacial branches (Fig. 35-13). The zygomaticofacial nerve crosses the lateral portion of the orbital floor and enters the malar bone, exiting via the zygomaticofacial foramen onto the skin of the face. It provides cutaneous sensation over the malar bone. The zygomaticotemporal nerve ascends in the orbit on the lateral wall, usually penetrating the bone near the lacrimal gland, and ascends the lateral surface of the skull to become a cutaneous nerve of the scalp.

Parasympathetic fibers to the lacrimal gland are also contained in the nerve of the pterygoid canal. After synapsing in the sphenopalatine ganglion, the postganglionic fibers join the maxillary nerve and follow the zygomatic branch of it to the zygomaticotemporal nerve. Just before the point at which the zygomaticotemporal nerve leaves the orbit, the postganglionic secretomotor fibers leave the nerve and enter the substance of the lacrimal glan (Fig. 35-13). Although a vidian nerve neurectomy is usually performed via a modified Caldwell-Luc approach, the relationship of the posterior wall of the maxillary sinus is well illustrated in Fig. 35-13. The position of the opening of the pterygoid canal is always medial and inferior to the maxillary nerve and the foramen rotundum. Interestingly, it is also just medial to the sphenopalatine foramen, where it can be entered by an intranasal approach with a long, supple needle.