Chapter 50: Anatomy

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The clinical significance of the paranasal sinuses is well known to anyone who has suffered from acute or chronic sinusitis. The functional significance of the sinuses has, however, eluded physiologists and physicians alike since the sinuses were first described some 1800 years ago. Blanton and Biggs (1969) reviewed several theories related to the function of the sinuses and concluded that most are conjecture. These theories claim that sinuses (1) impart resonance to the voice, (2) humidify and warm the inspired air, (3) increase the area of the olfactory membrane, (4) absorb shock applied to the head, (5) secrete mucus for keeping the nasal chambers moist, (6) provide thermal insulation for the brain, (7) contribute to facial growth, (8) represent vestigial structures, and (9) lighten the bones of the skull. No substantive laboratory studies document any of these hypothetic sinus functions. However, the sinuses do seem to form a collapsible framework to help protect the brain from frontal blunt trauma.

Each of the four pairs of sinuses is named after the skull bones in which it is located: maxillary, ethmoid, frontal, and sphenoid. During the development of a sinus, however, pneumatization may involve adjacent bones - for example, the maxillary sinuses invading the zygomatic bones, or the ethmoid complex invading the frontal, sphenoid, and maxillary bones. The size of the sinuses depends particularly on the age of the individual, especially until late puberty; the sinuses may be asymmetric in the same individual.

The sinuses are similar in the sense that they all contain air and are lined by the typical respiratory mucosa composed of ciliated, pseudostratified columnar, epithelial cells. Interspersed among the columnar cells are goblet-type mucous cells. Because the mucosa is attached directly to bone, it is frequently referred to as a *mucoperiosteum.* Although it is

somewhat thinner, the mucoperiosteum of the sinuses is continuous with that of the nasal cavities through the various ostia of the sinuses.

To facilitate discussion, each sinus is described separately, including descriptions of its development, anatomic relationships, blood supply, and innervation.

Maxillary Sinuses

Development

The maxillary sinus begins as a bud in the lateral wall of the ethmoid portion of the nasal capsule in approximately the third month of fetal life. At the base of the middle concha, the developing uncinate process of the ethmoid projects medially, forming a groove between it and the lateral nasal wall - the infundibulum (Van Alyea, 1951), or uncibullous groove (Libersa et al, 1981). This is the site of the original maxillary sinus cell or bud. Enlargement of this cell occurs slowly throughout fetal life, and the size of the sinus at birth is estimated at 6 to 8 cm^3 (Schaeffer, 1920). By 4 to 5 months after birth, the maxillary sinus can be readily seen radiographically, in a standard anteroposterior view, as a triangular area medial to the infraorbital foramen. After birth, growth of the maxillary sinus continues rapidly until about 3 years of age, and then slowly progresses until the seventh year (Fig. 50-1). At this time another acceleration in growth occurs until about the age of 12 years. By then pneumatization has extended laterally as far as the lateral wall of the orbit and inferiorly to the point where the floor of the sinus is level with the floor of the nasal cavity. Thereafter, modest enlargement occurs until the adult size is attained in the late teens (Caffey, 1967; Maresh, 1940; Schaeffer, 1920; Torrigiani, 1914). However, it is important to note that much of the growth occurring after the twelfth year is related to an invasion of the alveolar process following the eruption of the secondary dentition. Thus in the adult the floor of the maxillary sinus is usually 4 to 5 mm inferior to the floor of the nasal cavity (Van Alyea, 1951).

The maxillary sinus occupies the body of the maxilla and is approximately 15 mL in volume. The average dimensions are 34 mm anteroposteriorly, 25 mm transversely, and 33 mm in height (Schaeffer, 1920; Van Alyea, 1951). When viewed from above in a transverse section, the sinus appears triangular, with its base formed by the lateral wall of the nasal cavity and its apex projecting into the zygomatic process. The anterior wall corresponds to the facial surface of the maxilla and the posterior wall to the infratemporal surface of the maxilla. Its roof is the orbital surface of the maxilla, which is about twice as wide as the floor, formed by the alveolar process of the maxilla. The limits of the maxillary floor are usually marked anteriorly by the first bicuspid and posteriorly by a small recess posterior to the roots of the third molar. Recesses within the sinus occur variably and when present are described as *zygomatic, palatine, anterior* (to the nasolacrimal duct), and *alveolar.*

The maxillary ostium is located within the infundibulum of the middle meatus, with accessory ostia occurring in 25% to 30% of individuals (Schaeffer, 1920; Van Alyea, 1951). Its shape and size vary from a small, narrow slit to a large, oval opening, depending on the anatomy of the ethmoid bulla and uncincate process of the ethmoid bone (Figs. 50-2 and 50-3). Its average diameter is 2 to 4 mm. Embryology thus mandates that the ostium be within the infundibulum usually where it passes under the bulla ethmoidalis (see Fig. 50-4).
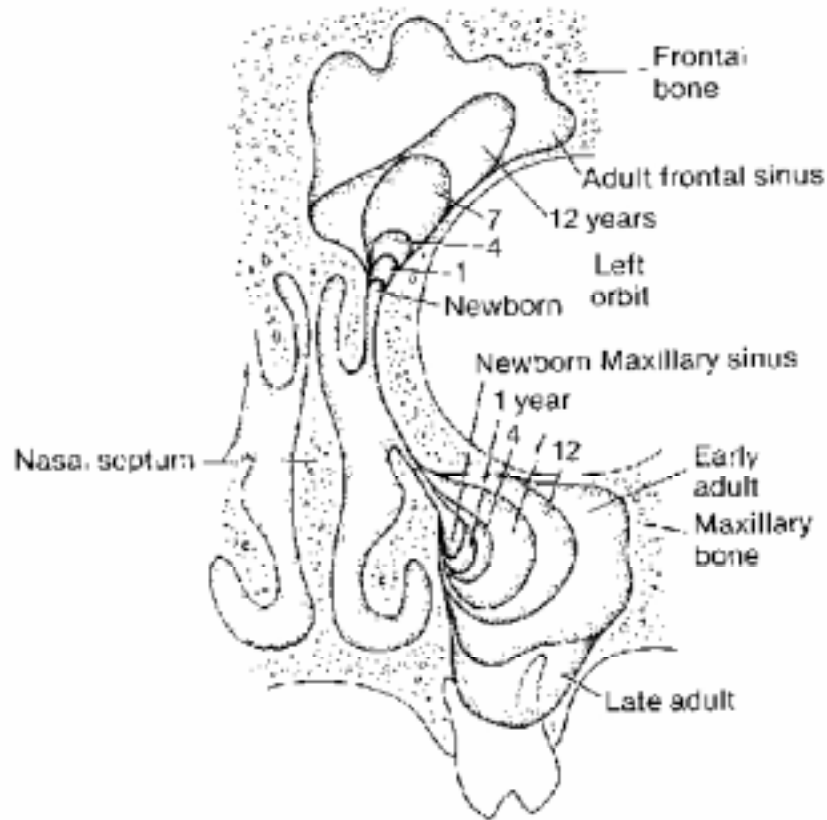
Figure 1 Developmental stages of maxillary frontal sinuses.

Because of these bony limitations, it is impossible to enlarge the opening without fracturing bone. Inferior to the uncinate process the medial wall of the maxillary sinus is usually membranous, consisting only of a reduplication of the mucosae of the sinus and lateral nasal wall, the so-called fontanella. This may also be site of an accessory maxillary ostium.

Blood supply

The major blood supply of the maxillary sinus is via branches of the maxillary artery although the facial artery may make a small contribution. Distribution of the maxillary arterial branches is essentially topographic and includes the infraorbital, greater palatine, posterosuperior, and anterosuperior alveolar arteries and the lateral nasal branches of the sphenopalatine artery.

Venous drainage may occur anteriorly via the anterior facial vein into the jugular vein or posteriorly via tributaries of the maxillary vein, which parallel the branches of the maxillary artery. After the maxillary vein joins the superficial temporal vein in the substance of the parotid, they form the retromandibular vein, emptying into the jugular system. However, in the region of the infratemporal fossa, the maxillary vein communicates with the pterygoid venous plexus, an abundant plexus of veins intertwining the pterygoid muscles, which in turn has anastomoses with the dural sinuses through the skull base. These vessels are responsible for the spread of infection from the maxillary sinus to the interior of the cranium and the resulting meningitis or phlebitis.

Innervation

Innervation of the mucosa of the maxillary sinus is via several branches of the maxillary nerve. These include the greater palatine, posterolateral nasal, and all of the superior alveolar branches of the infraorbital nerve. In addition to the sensation these nerves carry, the mucous glands within the mucosa also have an efferent function. The sphenopalatine ganglion in the pterygopalatine fossa contributes post-ganglionic parasympathetic, secretomotor fibers. The parasympathetic fibers originate in the intermediary branch of the seventh cranial nerve (CN VII) and are carried to the pterygopalatine fossa via the greater petrosal nerve and the nerve of the pterygoid canal.
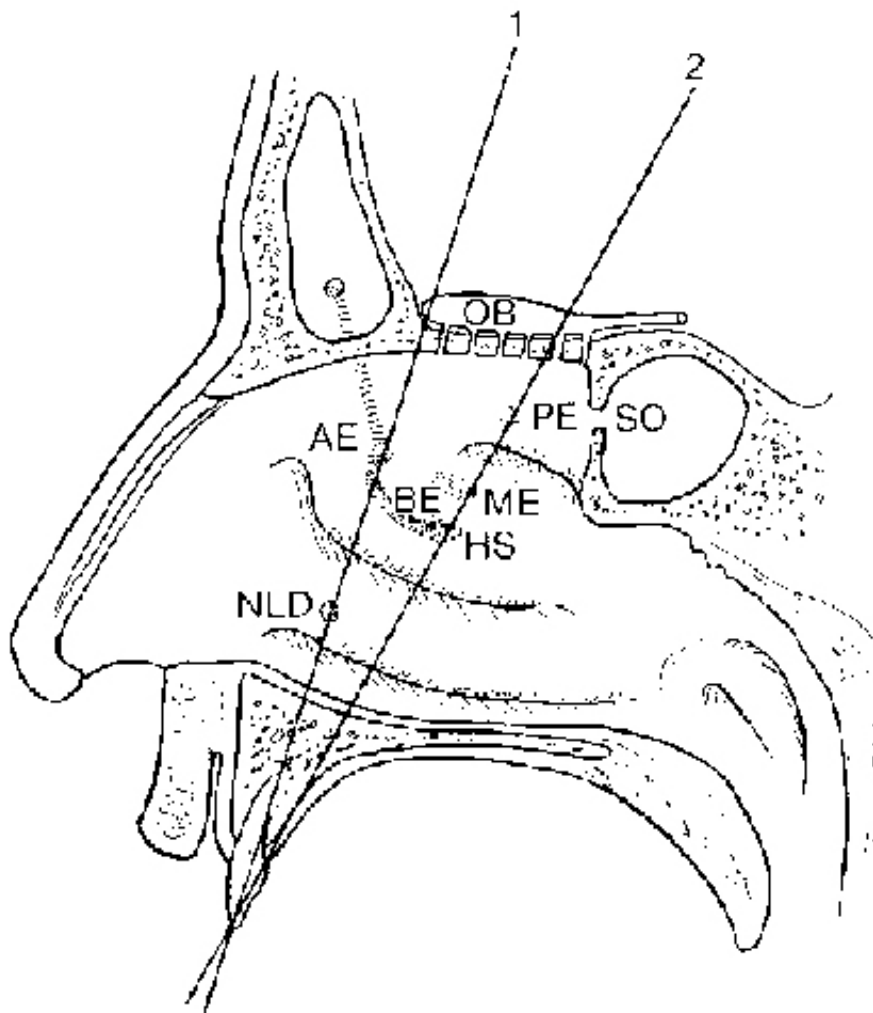

Figure 2 Sagittal section of head, illustrating position of ostia of paranasal sinuses and sectioning planes of Fig. 50-3.

Ethmoid Sinuses

Development

In the third fetal month, anterior and middle ethmoid cells begin as evaginations of the

lateral nasal wall in the region of the middle meatus (Fig. 50-4). Shortly afterward, posterior cells evaginate the nasal mucosa in the superior meatus and progressively enlarge throughout fetal life (Libersa et al, 1981; Van Alyea, 1951). At birth the size of the anteromiddle group is approximately 5 mm high, 2 mm long, and 2 mm wide, and the posterior group is 5 mm high, 4 mm long, and 2 mm wide (Schaeffer, 1920). The ethmoid and maxillary sinuses are the only sinuses that are large enough at birth to be clinically significant in rhinosinusitis.

Radiographically the ethmoid sinuses are more difficult to visualize at birth than the maxillary sinuses. If reasonably well developed, however, the ethmoids can be visualized in radiographic films of infants at 1 year (Shapiro and Janzen, 1960). In their early state of development, the ethmoid cells tend to be spherical but are flattened as they attain maximal development and encroach on the walls of adjacent cells. By the age of 12 years the ethmoids have almost reached their adult size (24 mm high, 23 mm long, and 11 mm wide for the anteromiddle group, and 21 mm high, 21 mm long, and 12 mm wide for the posterior sinus group) (Van Alyea, 1951).

Anatomy

Usually 2 to 8 anterior and middle ethmoid cells, and 1 to 8 posterior cells exist. Because of the compactness of the region and the inconsistency in the site of the various ostia, the anatomy of the ethmoid labyrinth is often confusing. The key to understanding the relationships of the anterior and middle ethmoid air cells is the infundibulum of the middle meatus. To paraphrase Myerson (1932), the infundibulum constitutes a crescentic depression, trough, furrow, groove, or channel caused by the proximity of the ethmoid bulla and the uncinate process. The opening of this depression or groove is the hiatus semilunaris (see Fig. 50-2). Fundamentally, anterior ethmoid cells are defined as those whose ostia open in relation to the infundibulum; middle or bullous ethmoid cells are those opening either above, on, or under the bulla. Posterior ethmoid cells have their ostia in the superior meatus.

Anterior ethmoid cells can be further subclassified as: agger nasi cells, terminal cells, suprainfundibular cells, and inferior cells (Van Alyea, 1951). The agger nasi cell is notable because it occurs in about 80% of individuals. It occupies the lateral nasal wall anterosuperior to the hiatus semilunaris and forms an elevated area of bone in the anterior part of the middle meatus. Its ostium (or ostia, when it is composed of two cells) opens into the superior part of the infundibulum.

Although the limit of the ethmoid labyrinth is thought to be the ethmoid bone, ethmoid cells may encroach on any of the adjacent bones: the nasal and lacrimal bones anteriorly, the sphenoid posteriorly, the maxilla inferiorly, and the orbital plate of the frontal bone superiorly. The smooth, thin, lateral wall of the ethmoid labyrinth is the lamina papyracea, which also defines the medial wall of the orbit.
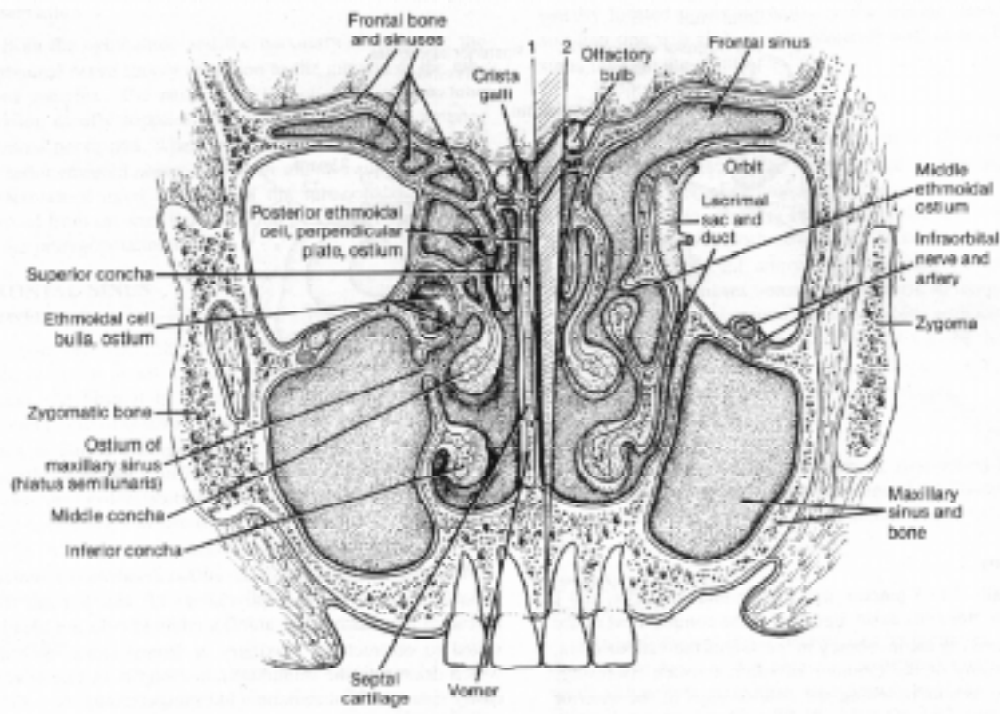
Figure 3 Coronal section of head to illustrate relationship of ostia to nasal conchae and meati.

A thorough knowledge of the ethmoid sinuses is essential to understanding the pathophysiology of infection and the spread of neoplasms. The anterior ethmoid cells are ideally suited to obstruct the maxillary or frontal sinus, both of which drain into the infundibulum. Neoplasms can spread easily through the thin bone within the ethmoid.

The lateral, superior, and posterior boundaries are well-defined structures and should be familiar to the sinus surgeon. The lamina papyracea is in approximately the same parasagittal plane as the natural ostium of the maxillary sinus. The fovea ethmoidalis may be nearly flat or steeply sloped. This can be determined with coronal CT scans. The posterior boundary, the sphenoid, should be readily recognizable by its large size and smooth walls, which are usually made of dense bone.

Blood supply

Like the other paranasal sinuses, which receive their principal blood supply from the maxillary artery, the ethmoid sinuses receive blood from the nasal branches of the sphenopalatine artery. However, they also are supplied by the anterior and posterior ethmoidal arteries derived from the ophthalmic artery. Thus the ethmoid sinuses receive blood from both the internal and external carotid vessels. The ethmoidal arteries enter their respective areas by piercing the frontal bone either at or slightly superior to the frontoethmoid suture.

Venous drainage may also follow two routes: either into the nose via the nasal veins that are tributaries of the maxillary or via ethmoidal veins that drain into the ophthalmic veins, which are tributaries of the cavernous sinus. The latter pathway is responsible for cavernous sinus thrombosis following ethmoid sinusitis.

Innervation

Both the ophthalmic and the maxillary divisions of the trigeminal nerve supply sensation to the mucosa of the ethmoid complex. The nasociliary branch of the ophthalmic division usually supplies the anterior cells via the anterior ethmoid nerve and, when present, the posterior cells by a posterior ethmoid nerve. The latter are also supplied by the posterolateral nasal branches of the sphenopalatine nerve derived from the maxillary division of the trigeminal nerve in the pterygopalatine fossa.

Frontal Sinus

Development

Developmentally the frontal sinus begins in the ethmoid portion of the nasal capsule in the region of the frontal recess. At birth it is indistinguishable from the anterior ethmoid cells. Postnatal growth is slow, and at 1 year the sinus is barely perceptible anatomically (see Fig. 50-4). Usually after the fourth year the frontal sinus begins to invade the vertical portion of the frontal bone; in most children over 6 years of age it can be demonstrated radiographically. Although quite large in a child of 12, its size still increases significantly until the late teens (Maresh, 1940; Torrigiani, 1914; Van Alyea, 1951).

Anatomy

The size of the frontal sinus in the adult has been described as measuring 28 mm in height, 24 mm in width, and 20 mm in depth (anteroposteriorly) (Schaeffer, 1920). Size varies substantially among individuals as does asymmetry between left and right sides in the same individual. Although the frontal sinus is usually considered a pyramidal structure in the vertical part of the frontal bone, it may appear in other forms. In some cases no invasion of the squamous part of the frontal bone occurs; instead, pneumatization occurs posteriorly into the orbital plate of the frontal bone to form a supraorbital cell (Van Alyea, 1951). Other individuals may have both frontal and supraorbital cells, with part of the supraorbital cell extending superiorly and parallel to the frontal cell. This can be an important point in surgical drainage, since these spaces have distinct boundaries and separate openings into the nasal cavity and therefore require that the common wall between them be removed or that separate drains be placed into each of the sinuses.

Normally the frontal sinus opens into the anterior part of the middle meatus (see Fig. 50-2) or frontal recess in a little over half of the cases studied, and directly into the anterior part of the infundibulum in the remaining individuals (Kasper, 1936; Schaeffer, 1916). The natural ostium of the frontal sinus can be found at the superior-anterior end of the infundibulum. This is located directly posterior to the anterior attachment of the middle turbinate to the lateral nasal wall. If the frontal recess cells in this area are carefully removed, the ostium will come into view. The ostium is usually located posteromedially in the frontal sinus floor, so often one will also see the posterior wall of the frontal sinus through the ostium.

Blood supply

The frontal sinus is supplied by the supraorbital and supratrochlear arteries derived from

the ophthalmic artery, a branch of the internal carotid artery. The normal blood flow in the ophthalmic artery is out of the orbit and onto the forehead via the supraorbital vessels. In occlusive disease of the internal carotid artery, the flow may be reversed because of anastomoses between the superficial temporal (a branch of the external carotid) and supraorbital arteries within the scalp. Venous drainage is primarily via the superior ophthalmic vein posteriorly through the superior orbital fissure into the cavernous sinus.

Innervation

Sensory innervation of the mucosa is supplied by the supraorbital and supratrochlear branches of the frontal nerve derived from the ophthalmic division of the trigeminal nerve.

Sphenoid Sinus

Development

Although the sphenoid sinuses can be identified in sections of the fetus at 4 months, at birth the sinus remains small and is little more than an evagination of the spheno-ethmoid recess (see Fig. 50-1). After the fifth year, invasion of the sphenoid bone is more rapid, and by the age of 7, the sinus has extended posteriorly to the level of the sella turcica. By the late teens most of the sphenoid has been aerated to the dorsum sellae, although further enlargement into the basisphenoid may occur in the adult (Torrigiani, 1914).

Anatomy

The average size of the sphenoid sinus in the adult, as measured by Van Alyea (1951), is 20 mm in height, 23 mm in length, and 17 mm in width. Frequently there is asymmetry between the two sides because the intersinus septum is not a flat midline structure but is bowed or twisted. An interesting aspect of the adult anatomy relates to the degree of pneumatization of the sphenoid bone: when bone erosion is maximal, structures adjacent to the sinus tend to be sculpted in relief on the interior walls of the sinus. Structures such as the optic nerve, internal carotid artery, (vidian) nerve of the pterygoid canal, maxillary nerve, and sphenopalatine ganglion may thus appear as impressions indenting the walls of the sinus. These relationships can present potential hazards when surgical instruments are used, since the bony wall may be exceptionally thin or absent. One should be particularly careful when removing soft tissue from within the sphenoid sinus; this should be done only when essential.

The sphenoid sinus opens into the sphenoethmoid recess above the superior concha. On average the ostium measures 2 mm x 3 mm and lies 10 mm above the floor of the sinus (Van Alyea, 1951).

Blood supply

The blood supply of the sphenoid sinus arrives via branches of both the internal and external carotid arteries. From the region of the orbit, the posterior ethmoidal branch of the ophthalmic artery may contribute vessels to the roof of the sphenoid sinus after entering the posterior ethmoid cells. The floor of the sinus receives blood from the sphenopalatine branches of the maxillary artery.
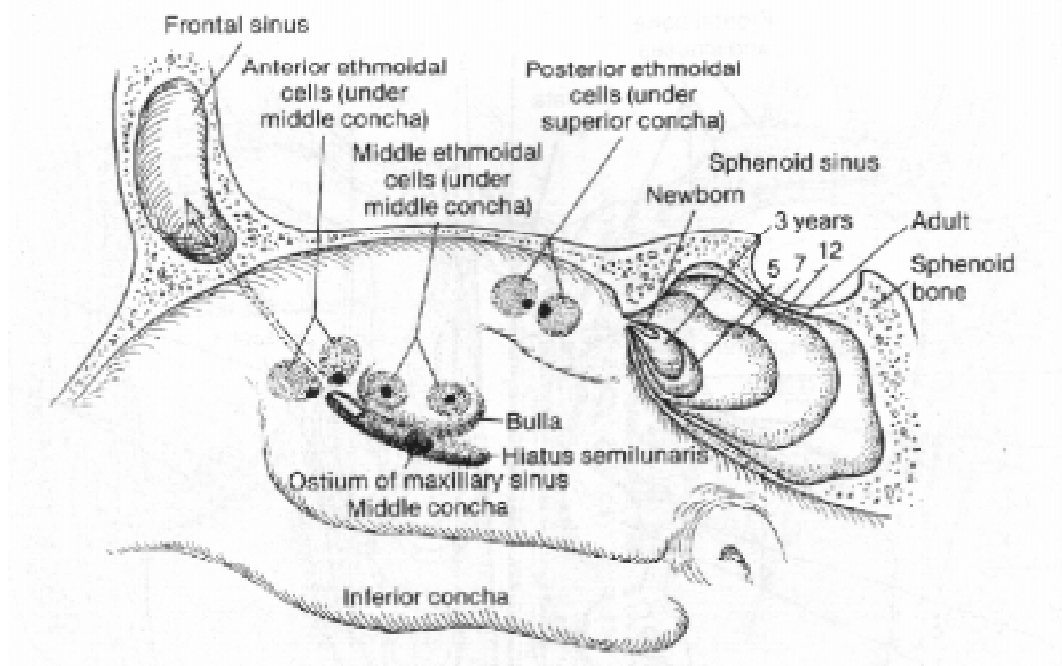
Figure 4 Developmental stages of ethmoid and sphenoid sinus.

The venous drainage of the sinus follows the pattern of the nasopharynx and nasal cavity. It drains into the maxillary vein and pterygoid venous plexus.

Innervation

Both the first and second divisions of the trigeminal nerve supply the mucosa of the sphenoid sinus. The posterior ethmoid nerve from the nasociliary branch of the ophthalmic division supplies the superior portion, and the sphenopalatine branches of the maxillary division supply the floor of the sinus.