Cone Beam Computed Tomography for the Nasal Cavity and Paranasal Sinuses

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KEYWORDS
- Paranasal sinuses • CBCT • Anatomic variant • Sinus pathology

KEY POINTS
- The paranasal sinuses are 4 paired airspaces that border the nasal cavity. The functions of the nasal cavity and paranasal sinuses include decreasing the weight of the skull, heating and humidifying inspired air, resonance in speech, regulation of intranasal pressure, and increasing surface area for olfaction.
- The paranasal sinuses have also been described as crumple zones or areas that absorb the energy from trauma and protect vital structures in the skull.
- Dental professionals are most familiar with the maxillary sinuses as viewed 2-D imaging (eg, periapical, panoramic projections). With the increasing implementation of 3-D imaging, however, specifically cone beam computed tomography (CBCT), there is a high probability that much or all of the paranasal sinuses and nasal cavity are captured in a scan.

NASAL CAVITY

The nasal cavity is bounded inferiorly by the hard palate, laterally by the medial walls of the right and left maxillary sinus, and superiorly by the nasal, ethmoid, and sphenoid bones. The primary components of the lateral walls of the nasal cavity are the inferior middle and superior conchae (also termed, turbinates). These structures protrude into the nasal cavity and act as baffles to help warm/cool, filter, and humidify inspired air. Another function of the nasal cavity is the sense of smell. The spaces between the conchae are referred to as meatuses. The inferior meatus is located beneath the inferior concha and is the site for drainage of the nasolacrimal duct. The middle meatus is the site of drainage for the frontal, anterior ethmoid, and maxillary sinuses. There is also a communication from the middle meatus to the maxillary sinus through an opening, called the ostium. The superior meatus communicates with the posterior ethmoid and sphenoid sinuses through the sphenoethmoidal recess (Fig. 1).

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The anterior portion of the nasal septum is composed of cartilage. The posterior nasal septum is bony. The arterial blood supply for the nasal cavity comes from the internal maxillary artery (branch of the external carotid artery) and the anterior and posterior ethmoidal arteries (branches of the internal carotid artery). The vascularity of the nasal cavity accounts for the volume and intensity of bleeding when the region is injured. The nasal cavity is innervated by the olfactory (CN I), ophthalmic, and maxillary branches of the trigeminal (CN V) and facial (CN VII) nerves.

ANATOMIC VARIANTS—NASAL CAVITY

Deviated Nasal Septum

The deviated nasal septum is a common finding within the nasal cavity and occurs when the nasal septum is displaced toward one side of the nasal cavity. Deviated nasal septum may be congenital or due to trauma. The deviation may be mild with no symptoms or sequelae. When a deviation is severe, however, the flow of air through the nasal cavity is redirected and may manifest as nasal obstruction, noisy breathing during sleep, and/or epistaxis. Severe deviations can result in hypoplasia of the ipsilateral turbinates and/or hyperplasia of the contralateral turbinates (Fig. 2). The nasal septum may also exhibit pneumatization. This is of little clinical significance unless it obstructs nasal airflow or surgical access to the paranasal sinuses.

Concha Bullosa

Concha bullosa or pneumatization of the concha is seen in from 14% to 53.6% of the population (Fig. 3). Concha bullosa are grouped according to the location of the pneumatization and are classified as lamellar, bulbous, or extensive. Concha bullosa are most commonly seen in the middle turbinate and may be unilateral or bilateral. Unilateral concha bullosa are frequently associated with a deviated nasal septum. A vast majority of concha bullosa are asymptomatic. There is ongoing debate regarding the association of concha bullosa with sinus disease, with the current view that concha bullosa are associated with sinus disease when they block or impinge on the ostiomeatal complex.
Paradoxic turbinates refer to a convex curvature on the lateral, rather than medial side of the turbinate, and is seen in 4% to 27% of the population.\textsuperscript{5–7} Paradoxic turbinates may predispose patients to unilateral sinusitis if they block the middle meatus.\textsuperscript{7}

**Paranasal Sinuses**

**Frontal Sinus**

The frontal sinuses are located within the frontal bone on either side of the midline superior to the orbits. The floor of the frontal sinus is bordered by the orbital portion of the frontal bone. The posterior wall separates the dura of the frontal lobe from the lining mucosa. The frontal sinuses extend to the most anterior aspect of the middle meatus and drain through the nasofrontal duct, which can, in turn, drain into either the frontal recess or ethmoid infundibulum (Fig. 4). The ostia of the frontal sinuses are positioned approximately two-thirds up the posterior medial walls. This positioning makes complete clearing of the sinus after infection difficult. The middle meatal branch of the sphenopalatine and anterior ethmoid arteries provide the arterial supply to the frontal

**Fig. 2.** Coronal view of nasal cavity and maxillary sinuses. White arrow, hypoplastic middle turbinate; dashed white arrow, a hypoplastic right inferior turbinate. The nasal septum is deviated and the turbinates opposite the hypoplastic turbinates are enlarged.

**Paradoxic Turbinate**

Paradoxic curvature of the middle turbinate refers to a convex curvature on the lateral, rather than medial side of the turbinate, and is seen in 4% to 27% of the population.\textsuperscript{5–7} Paradoxic turbinates may predispose patients to unilateral sinusitis if they block the middle meatus.\textsuperscript{7}

**Fig. 3.** Coronal view of maxillary sinuses. EB, ethmoid bulla; MT, mucosal thickening; dashed white arrow, a soft tissue polyp on the medial wall of the left maxillary sinus; white arrow, concha bullosa.
sinuses. The venous drainage of the frontal sinuses is through valveless transosseous channels that communicate with both the orbit and cranial vault. Branches of V1 and V2 innervate the frontal sinus mucosa. The frontal sinuses are usually paired but are often asymmetric and exhibit the greatest amount of developmental variation. These variations range from complete agenesis to pneumatization of the frontal bone.

**Ethmoid Sinuses (Ethmoid Air Cells)**

The ethmoid sinuses, or ethmoid labyrinth, are contained within the ethmoid bone. The ethmoid sinus is divided into anterior and posterior components due to the separate drainage of these components. The anterior ethmoid sinus drains into the middle meatus. The posterior ethmoids drain into the sphenoethmoidal recess (Fig. 5). The

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**Fig. 4.** Frontal sinus. (A) Coronal view of frontal sinus. DS, deviated nasal septum. (B) Sagittal view of frontal/ethmoid sinuses. Asterisk, frontal sinus; white arrow, frontoethmoidal recess. (C) Axial view of frontal sinus.

**Fig. 5.** Ethmoid sinus. (A) Sagittal view of frontal/ethmoid sinuses. Asterisk, frontoethmoidal recess; dashed white arrow, frontal sinus; white arrow, drainage of the anterior ethmoid sinuses. (B) Sagittal view of ethmoid/sphenoid sinuses. Dashed white arrow, drainage of the posterior ethmoid sinuses; white arrow, sphenoid sinus.
lateral borders are the lamina papyracea of the orbit. The medial border of the anterior ethmoid sinuses is the middle turbinate. The medial border of the posterior ethmoid sinuses is the superior turbinate. The roof of the ethmoid sinuses is called the fovea ethmoidalis. The ethmoid roof is immediately adjacent to the cribiform plate and is often the point of entry of the anterior cranial fossa during endoscopic surgery. The anterior ethmoid sinuses are supplied by the sphenopalatine and anterior ethmoid arteries. The posterior ethmoid sinus is supplied by the superior conchal branch of the sphenopalatine artery and the posterior ethmoid artery. The posterior ethmoid sinus is innervated by the superior nasal branches of V2 and anterior ethmoid branch of V1.

There are several ethmoid air cells that serve as anatomic markers. The largest and most prominent air cell in the anterior ethmoid sinus is referred to as the ethmoid bulla. The agger nasi cells are the most anterior of the anterior ethmoid air cells and are found anterior and superior to the middle turbinate. The agger nasi cell is the landmark through which the frontoethmoidal recess is entered during endoscopic surgery. Haller cells are found along the inferior border of the orbits. The Haller cells can be of clinical significance if they enlarge to the point where they impinge on the ethmoid infundibulum. The Onodi cells are derived from the posterior ethmoids and represent pneumatization of air cells lateral and superior to the sphenoid sinus.

The Ostialmedal Complex

The ostialmedal complex is not a discrete anatomic entity. Ostialmedal complex refers to a collection of middle meatal structures and consists of the uncinate process, ethmoid infundibulum, and anterior ethmoid cells. It also represents the final common pathway of drainage for the frontal, anterior ethmoid, and maxillary sinuses. The uncinate process is a sickle or hook-shaped bone of the lateral nasal wall. Anteriorly, the uncinate process attaches to the lacrimal bone; inferiorly, the uncinate process attaches to the ethmoidal process of the inferior turbinate. The posterior margin sits in the hiatus semilunaris inferioris. Superiorly, the uncinate process may attach to the middle turbinate, lamina papyracea, and/or the skull base. The ethmoid infundibulum is a space bordered laterally by the bony orbit and medially by the uncinate process. The maxillary sinus drains into this space.

Sphenoid Sinus

The sphenoid sinus is found in the sphenoid bone. The pituitary fossa sits superior to the sinus along with the olfactory nerves and optic chiasm. The pterygoid canal often courses beneath the mucosa along the floor of the sinus. The cavernous portion of the internal carotid artery runs along the lateral wall of the sphenoid sinus. The ostium of the sphenoid sinus is positioned in the center of the anterior wall of the sinus toward the superior aspect of the sinus. The sphenoid sinus drains into the sphenenoethmoidal recess (Fig. 6). Branches of the sphenopalatine and nasopalatine arteries provide the arterial blood supply of the sphenoid sinus. The sphenoid sinus is innervated by the posterior ethmoid branch of V1 and the posterior superior nasal branches of V2. Pneumatization is a common anatomic variant of the sphenoid sinus. Pneumatization can occur in the lateral or superior direction and involve the greater and lesser winds of the sphenoid bone as well as the pterygoid processes and anterior clinoid process. This pneumatization increases the size of the air space but more importantly thins the bone and, given the proximity of numerous vital structures, can increase the risk of surgical misadventures (Fig. 12). Onodi cells from the posterior ethmoids can also extend superior and lateral to the sphenoid sinus further thinning the bone.
Maxillary Sinus

The maxillary sinuses are the largest of the paranasal sinuses and the most familiar to dental professionals. The maxillary sinus is viewed in images that are used daily (eg, periapical, panoramic projections). The maxillary sinuses are contained within the maxilla. The roof of the maxillary sinus is the orbital floor. The infraorbital canal traverses the roof of the maxillary sinus. The floor of the maxillary sinuses closely approximates the roots of the posterior maxillary teeth. The ostium of the maxillary sinus is located in the medial wall and drains into the ethmoid infundibulum (Fig. 7). The nasolacrimal ducts pass adjacent to the maxillary sinuses and drain into the inferior meatus. The ethmoid arteries and middle meatal branch of the sphenopalatine artery provide the arterial blood supply for the maxillary sinus.2 The maxillary sinus is innervated by branches of the infraorbital and branches of the posterior superior nasal nerves. Anatomic variants of the maxillary sinuses include pneumatization, septations, and accessory ostia.

PATHOLOGY

Nasal Obstruction

The most common form of nasal obstruction is hyperplasia of the turbinates. This can be caused by chronic inflammation and infection. Many times, nasal obstructions can,

Fig. 6. Sphenoid sinus. AN, agger nasi cell; FE, frontoethmoidal recess; SP, sphenoid sinus.

Maxillary Sinus

Fig. 7. Maxillary sinus. (A) Coronal view of maxillary sinuses. Dashed white arrow, mild mucosal thickening along the floor of the right maxillary sinus; white arrow, Haller cell. The right and left ostiomeatal complexes are patent. (B) Coronal view of maxillary sinuses. DS, deviated nasal septum; EB, ethmoid bulla; dashed white arrow, mild mucosal thickening adjacent to periapical radiolucency associated with tooth #14.
in turn, obstruct the flow of air into the paranasal sinuses. Other causes of nasal obstruction are nasal polyps; antrochoanal polyps; benign tumors, such as osteoma, papilloma, or angiofibroma; rhinoliths (Fig. 8); foreign bodies (Fig. 9); and malignant tumors (most commonly squamous cell carcinoma).\textsuperscript{14,15} Rhinoliths are calcifications of endogenous materials, such as pus, epithelial cells, or bone or exogenous materials–foreign bodies.\textsuperscript{16,17} The long-standing presence of either rhinoliths or foreign bodies can cause ipsilateral hypoplasia of the turbinates.

**Hyperplastic Turbinates**

Hyperplastic turbinates are thought to be the result of chronic inflammatory conditions, such as allergic rhinitis. The increase in turbinate size may be due to either soft tissue or bony enlargement. Hyperplastic turbinates are of clinical significance when they impinge on airflow through the nasal cavity and into the paranasal sinuses (Fig. 10).

**Nasal Polyps**

Nasal polyps are aggregates of soft tissue that arise within the nasal cavity. The tissue enlargement is not neoplastic but is most likely the result of chronic inflammation/infection of the nasal mucosa. When nasal polyps are small they have minimal clinical significance. Large polyps can produce obstruction of the nasal airway and block

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**Fig. 8.** Rhinolith; sagittal views showing irregularly shaped radiopacity in the nasal cavity.

**Fig. 9.** Foreign body. (A) Coronal view of metallic foreign body in left nasal fossa; small antral pseudocysts are present along the lateral walls of the right and left maxillary sinuses. (B) Axial view of metallic foreign body in left nasal cavity. The metallic object is a watch battery.
Fig. 10. Hyperplastic/hypoplastic turbinates coronal view of nasal cavity and maxillary sinuses; white arrow indicates a hypoplastic inferior turbinate; dashed white arrow indicates a hyperplastic inferior turbinate. The nasal septum is deviated toward the hypoplastic turbinate.

Fig. 11. Polyp coronal view of polyp on the roof of the left maxillary sinus.

Fig. 12. Antrochoanal polyps. (A) Coronal view of maxillary sinuses; antrochoanal polyp extending from the right maxillary sinus into the nasal cavity (white arrow). (B) Axial view of antrochoanal polyp in right maxillary sinus/nasal cavity.
sinus ostia. The radiographic appearance of a nasal polyp is a homogeneous relative radiopacity that arises in an air space. Polyps can also appear in the maxillary sinuses (Fig. 11).

**Antrochoanal Polyps**

Antrochoanal polyps arise in the maxillary sinus and extrude through the ostiomeatal complex into the nasal cavity. Antrochoanal polyps have a similar radiographic appearance as nasal polyps. The extension from the maxillary sinus differentiates the antrochoanal polyp from the nasal polyp (see Fig. 12). Antrochoanal polyps are more commonly seen in children and are usually unilateral. Obstruction of the maxillary ostium is the most common complication of the antrochoanal polyp.

**Papilloma**

Papillomas can arise from the epithelium within the nasal cavity and are considered true neoplasms. The radiographic appearance of a nasal papilloma is a unilateral, irregularly shaped relative radiopacity. A subtype of nasal papilloma is termed, *inverted papilloma*.\(^{14,15,18}\) The inverted descriptor refers to the histopathology rather than the clinical or radiographic presentation. A small percentage of these inverted polyps can undergo malignant transformation into squamous cell carcinoma. In addition to the soft tissue radiopacity, these entities may cause some bony resorption as they enlarge. An infrequent finding is hyperostosis of the bone adjacent to the base of the inverted papilla.

**Juvenile Nasal Angiofibroma**

The juvenile nasal angiofibroma (JNA) is a tumor of fibrous connective tissue with a propensity for brisk bleeding. JNA is seen almost exclusively in males in the second decade. JNA presents as a fast-growing soft tissue mass that originates from the area of the posterior aspect of the middle turbinate. JNA can produce bony destruction. One of the classic radiographic findings is bowing of the posterior bony wall of the maxillary sinus.\(^{19}\)

**Cleft Palate**

Palatal clefts can extend into the nasal cavity and appear as discontinuities of the nasal floor. Additionally, the morphology of the nose and the nasal cavity can be altered due to the palatal cleft. Deviated nasal septum and nasal asymmetry are commonly seen with cleft palate (Fig. 13).

![Fig. 13. Cleft palate coronal view of cleft palate involving the floor of the nasal cavity.](image-url)
Malignant Tumors of the Nasal Cavity

Malignant tumors arising in the nasal cavity are rare; however, due to proximity, malignancies that originate in the paranasal sinuses often invade the nasal cavity. Squamous cell carcinoma is the most common malignant tumor found in the nasal cavity. The radiographic appearance of a squamous cell carcinoma in the nasal cavity is nonspecific but includes a relative radiopacity with evidence of bony destruction of normal bony structures.

The olfactory neuroblastoma is a rare malignancy found in the nasal cavity. The olfactory neuroblastoma is somewhat unique in that the tumor traverses the cribriform plate with a portion of the tumor in the intracranial fossa and a portion that extends into the nasal cavity. The most characteristic radiographic finding is that of a dumbbell-shaped mass extending across the cribriform plate. CT shows speckled calcifications and bone erosion of the lamina papyracea, cribriform plate, and/or the fovea ethmoidalis.

Fig. 14. Pneumatization. (A) Coronal view of pneumatization of the frontal sinus. (B) Coronal view of pneumatization of the sphenoid sinus.

Fig. 15. Sinus hypoplasia. (A) Coronal view of maxillary sinuses displaying hypoplastic left maxillary sinus. (B) Coronal view of maxillary sinuses showing hypoplasia of the right and left maxillary sinuses; the airspace of the right maxillary sinus is obliterated; mild mucosal thickening is present in the left maxillary sinus. CB, concha bullosa.
PATHOLOGY OF THE PARANASAL SINUSES

Disorders of Size

The paranasal sinuses may become larger airspaces due to pneumatization (Fig. 14) but it is much more common for the paranasal sinuses to be hypoplastic or even absent (Fig. 15). Sinus hypoplasia can affect any of the paranasal sinuses. Sinus hypoplasia may be developmental or secondary to blockage of sinus drainage. Sinus aplasia is rare and usually involves the frontal sinus.

Acute/Chronic Sinusitis

Acute sinusitis can affect any of the paranasal sinuses. Radiographic appearance of acute sinusitis includes fluid level, mucosal thickening and bubbles within the fluid.

Fig. 16. Acute/chronic sinusitis. (A) Midsagittal view of mucosal thickening in the frontal and ethmoid sinuses; small antral pseudocyst is present in the sphenoid sinus. (B) Coronal views demonstrating mucosal thickening in the sphenoid sinuses. (C) Coronal view demonstrating mucosal thickening and antrochoanal polyp in the right maxillary sinus and severe circumferential mucosal thickening present in the left maxillary sinus. (D) Coronal view showing mild circumferential mucosal thickening in the right maxillary sinus and circumferential mucosal thickening with antrolithiasis in the left maxillary sinus. The white arrow indicates an antrolith. (E) Cross-sectional view of left maxillary sinus with fluid level and aeration.
CBCT does not provide sufficient contrast to differentiate between fluid level and mucosal thickening. Consequently, clinicians should look for cues to help differentiate the 2 entities. For example, the presence of bubbles or horizontal flattening of the entity in the sinus is indicative of a fluid level. If the entity appears on the walls of the sinus, this is most likely mucosal thickening. Mucosal thickening can be found in patients with chronic sinusitis as well. A radiographic finding that is suggestive of chronic sinusitis is sclerosis of the wall of the affected sinus. Sometimes these thickened sclerotic walls are termed, hyperostotic. Acute and chronic sinusitis can have similar radiographic presentations (Fig. 16). These entities are differentiated by the duration of symptomatology rather than radiographic appearance.

**Dental Disease and Mucosal Thickening in the Maxillary Sinus**

Many studies have attempted to explore the relationship between dental disease in the posterior maxillary posterior teeth and antral mucosal response in the adjacent

![Fig. 17. Antral mucosal response to odontogenic infection. (A) Cross-sectional and sagittal views of apical periodontitis extending into the maxillary sinus cavity. (B) Sagittal views of tooth #3 demonstrating apical periodontitis associated with the mesiobuccal root of #3 with antral mucosal thickening present immediately adjacent to the tooth in the right maxillary sinus.](image)
maxillary sinus. Unfortunately, most of these studies are retrospective in nature so it is difficult to determine if the dental disease produced the mucosal changes or if the mucosal thickening and dental disease are epiphenomenon. Dental diseases implicated in mucosal thickening include chronic periodontitis and apical periodontitis. The mucosal thickening attributed to chronic periodontitis exhibits uniform height adjacent to the affected teeth. When apical periodontitis affects a maxillary posterior tooth, there can be localized mucosal thickening, or, if a periapical radiolucency is present, the mucosal thickening follows the contour of the radiolucency (Fig. 17). The appearance of periapical radiolucency/mucosal thickening is referred to as a periapical halo. Communication between the maxillary sinus and the oral cavity is a common complication of maxillary posterior tooth extraction and is discussed later.

**Antral Pseudocyst**

The antral pseudocyst or mucous retention cyst (or phenomenon) is a common pathologic finding in the paranasal sinuses. The antral pseudocyst is an accumulation of fluid within the lining mucosa without an epithelial lining (Fig. 18). Antral pseudocysts do not produce erosion or sclerosis of the adjacent bone and are generally asymptomatic. The classic radiographic description is a well-defined, dome-shaped relative radiopacity that arises from the floor of the sinus. Antral pseudocysts can also arise from the lateral wall of the sinus. Antral pseudocysts are most commonly found in the maxillary sinuses but can appear in the frontal and sphenoid sinuses.9 No treatment is required unless the antral pseudocyst enlarges to the point where it fills the antrum and herniates into the nasal cavity.

**Fig. 18.** Antral pseudocyst. (A) Coronal view demonstrating an antral pseudocyst in the left frontal sinus. (B) Sagittal view of large antral pseudocyst in the right maxillary sinus; note the severe periodontitis in the right maxillary posterior sextant. (C) The dashed white arrow indicates a supernumerary tooth; the white arrow identifies the sphenoeinthoidal recess.
**Sinus Mucocele**

A sinus mucocele is a fluid-filled epithelial-lined cyst. The mucocele is most commonly seen in the frontal and ethmoid sinuses but have been reported in the sphenoid and maxillary sinuses. Mucoceles are thought to arise from blockage of normal drainage of the sinus. Mucoceles can be secondarily infected and tend to exhibit faster enlargement when infected. Mucoceles are expansile and can produce bony erosion and extension into surrounding structures. The orbit is often affected by the soft tissue extension of the mucocele given the proximity to the frontal and ethmoidal sinuses. Patients with mucocele do not report typical sinus-related symptoms but symptoms related to orbital swelling and visual changes. Surgical intervention is required to manage a mucocele.

**Antrolith**

An antrolith is a calcified mass within the antrum of the sinus. Antroliths are most commonly found in the maxillary sinus but can be found in the frontal sinus. The nidus of calcification may be extrinsic (foreign body) or intrinsic (stagnant secretions or fungus ball). Most antroliths are small and asymptomatic. The radiographic description of the antrolith is a well-defined, irregularly shaped radiopacity found either superior to mucosal lining or contained within thickened antral mucosa (Fig. 19). Most antroliths are small and asymptomatic and reported as an incidental finding. Fungal balls are also known as mycetomas and are uncommon manifestations of a fungal sinus infection. Fungal balls appear as relative radiopacities within the antrum. These radiopacities may contain punctate calcifications. Other radiographic signs include thickened mucosal lining, sclerosis of the sinus walls, and, rarely, focal erosions secondary to pressure necrosis.

**Osteoma**

Osteoma is a benign tumor of bone. Osteomas within the paranasal sinuses are found in up to 3% of sinus imaging studies. A vast majority of paranasal sinus osteomas are found in the frontal and ethmoid sinuses. Radiographically, osteomas present as well-defined radiopacities of variable density, varying from very dense (similar in density to cortical bone) to less dense with a ground-glass appearance. They are

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**Fig. 19.** Antrolith sagittal view of right maxillary sinus; the white arrow identifies an antrolith.
seen either with the sinus antrum or less commonly as an exophytic mass growing out of a sinus. Paranasal sinus osteomas arise from the bony borders of the sinuses. A vast majority of paranasal sinus osteomas are found in the frontal and ethmoid sinuses (Fig. 20). Most osteomas are small and require no treatment other than periodic observation. If a patient presents with sinus symptomatology and an osteoma is thought to be the cause of the symptoms (eg, block normal sinus drainage), however, then surgical removal is indicated.

Papilloma

Papillomas are most frequently reported in the nasal cavity but can arise within the paranasal sinuses. Papillomas have been reported in the maxillary, ethmoid, and sphenoid sinuses. These tumors present as exophytic soft tissue masses but can cause bony destruction. As with other papillomas found throughout the body, human papilloma virus subtypes have been identified in sinonasal papillomas.15

Odontogenic Cysts and Tumors

Most odontogenic cysts and tumors found in the maxillary sinuses arise from the tooth-bearing regions of the maxilla. Because the maxillary sinus is an airspace, it is not surprising that cysts and tumors could easily expand into the air space. The most common odontogenic cyst seen in the maxillary sinus is the periapical cyst associated with a necrotic pulp (Fig. 21).26,27 These cysts extend into the antrum of the

Fig. 20. Osteoma. (A) Axial view of osteoma in the frontal sinus. (B) Sagittal views of osteoma in the ethmoid sinus.

Fig. 21. Apical periodontal cyst cross-sectional views of apical periodontal cyst and attendant antral mucosal thickening in the right maxillary sinus.
sinus and are often associated with antral mucosal thickening and can appear as a periapical halo.

The dentigerous cyst (Fig. 22), keratocystic odontogenic tumor (Fig. 23), and ameloblastoma are most commonly seen in the posterior mandible but have been reported in the maxillary sinus. These entities generally present as well-defined pericoronal

![Fig. 22. Dentigerous cyst. (A) Cross-sectional views of dentigerous cyst associated with unerupted tooth #1. (B) Sagittal views of dentigerous cyst associated with tooth #1.](image-url)
Radiolucencies associated with unerupted teeth that expand into the maxillary sinus. These lesions are expansile and can cause resorption of adjacent teeth. The odontogenic myxoma is a rare benign mesenchymal tumor that is usually found in the posterior mandible but has been reported in the maxillary sinus. The odontogenic myxoma can appear as either a unilocular or multilocular radiolucency that can be expansile or can cause thinning or perforation of cortical bone. Fine septae can often be seen in the radiographic images of the odontogenic myxoma. The odontogenic myxoma has a fairly high recurrence rate. The recurrence rate may be related to conservative initial treatment of the tumor.

Central Ossifying Fibroma

The central ossifying fibroma is considered to be a neoplasm but shares many characteristics of the benign fibro-osseous lesions. It is typically asymptomatic until they enlarge to the point where a facial deformity is noted. Central cemento-ossifying fibromas are typically well defined, solitary radiolucencies containing varying amounts of radiopaque foci. They maintain a round shape, expand the surrounding cortical bone with no cortical invasion and may cause divergence of adjacent teeth. As with other odontogenic tumors, the most frequent location for the central ossifying fibroma is the posterior mandible. Central ossifying fibromas have been reported in the maxillary, sphenoid, and ethmoid sinuses (Fig. 24). The expanded tumors may involve the nasal septum, infraorbital foramen, and orbital floor.
ODONTOGENIC MYXOMA

Malignant neoplasms of the paranasal sinuses are most frequently found in the maxillary sinuses followed by the ethmoid sinuses. Epithelial neoplasms are the most common malignant tumor types found in the nasal cavity and paranasal sinuses. Of these, squamous cell carcinoma is the most common malignancy found in the paranasal sinuses. Adenoid cystic carcinoma (salivary gland origin) and variants of adenocarcinoma comprise 10% to 15% of the nonsquamous cell epithelial neoplasms. Lymphomas constitute approximate 5% of paranasal sinus malignancies. Malignant melanoma presents in less than 1% of neoplasms in this region. The radiographic appearance of malignant neoplasms in the paranasal sinuses is nonspecific but includes relative radiopacity of the tumor with obliteration of the airspace, thinning/erosion/perforation of the cortical outlines of the sinuses, and expansion into local structures (Fig. 25).

Trauma

The nasal fracture is the most common facial fracture. The zygomaticomaxillary complex (ZMC) fracture is the second most common facial fracture. The ZMC fracture is seen much more frequently in men between the ages of 20 and 30. The mechanism of injury includes motor vehicle accidents, sporting injuries, and personal altercation. There is a great deal of variation in the distribution of bony involvement in ZMC...
Fig. 25. Malignant tumor. (A) Coronal view of right maxillary sinus demonstrating obliteration of the airspace, expansion into the nasal fossa and perforation of the hard palate; the right inferior and middle turbinates have been destroyed; the medial and lateral walls of the right maxillary sinus are perforated. (B) Axial view of right maxillary sinus showing palatal perforation and soft tissue extension into the right cheek area.

Fig. 26. ZMC fracture. (A) Axial view showing fracture of the lateral and posterior walls of the right maxillary sinus and obliteration of the right maxillary sinus airspace; the asterisk indicates the soft tissue swelling in the area. The white arrow indicates the fracture of the posterior wall of the maxillary sinus. The dashed arrow indicates the fracture of the anterior wall of the maxillary sinus. (B) Coronal view demonstrating fracture of the lateral wall of the right maxillary sinus and fluid level in the right maxillary sinus. (C) Axial view showing displaced fracture of the zygomaticotemporal process, deviated nasal septum, and mucosal thickening in the ethmoid sinuses.
fractures. It is common to see the anterior and/or lateral wall of the maxillary sinus involved. The radiographic appearance includes discontinuity of the bony contours of the sinus and alteration of normal sinus morphology as well as fluid level (Fig. 26).

Orbital blowout fractures usually result from blunt trauma to the eye. The floor of the orbit fractures and allows the body of the inferior rectus to herniate into the maxillary sinus (Fig. 27). Clinical features include enophthalmos, orbital emphysema, and upward gaze.

The Le Fort I fracture includes the lateral walls of the maxillary sinuses (Fig. 28). Le Fort fractures may be the result of trauma or orthognathic surgery. The frontal sinus is resilient to injury. Frontal sinus fractures can result, however, from high-velocity impacts, such as motor vehicle accidents and assaults. Because of the location, mechanism of injury, and proximity to vital structures, the potential for intracranial injuries, bony deformities, and late mucocele formation is high.

Oroantral Communication/Oroantral Fistula

The oroantral communication (OAC) is a pathologic communication between the oral cavity and the maxillary sinus. This kind of communication arises mainly after
extraction of posterior maxillary teeth due to the close anatomic relationship between the root and the floor of the sinus (Fig. 29). An OAC may occur after implant placement, excision of maxillary cysts, benign or malignant tumors, or trauma. The OAC is differentiated from an oroantral fistula by the presence of epithelial lining between the sinus antrum and the oral cavity. If this epithelial interface is not removed, spontaneous closure may be delayed or prevented. Closing this communication is important to

Fig. 29. PAC/fistula. (A) Cross-sectional views of PAC after tooth extraction. The sinus airspace is obliterated with either mucosal thickening or fluid level. (B) Sagittal views of right maxillary sinus following tooth extraction. The floor of the right maxillary sinus is discontinuous; mucosal thickening is evident along the floor of the right maxillary sinus. Small radiopacities consistent with bone fragments are evident in the area of the recent extractions.

Fig. 30. Surgical intervention. (A) Coronal view of right and left maxillary sinuses; the dashed white arrows indicate bilateral nasal antrostomies; the white arrows show turbino-plasties of the right and left inferior turbinates. (B) Coronal view showing right uncinectomy (dashed white arrow) and fluid level in the left maxillary sinus (white arrow).
avoid contamination that could lead to bacterial infection, impaired healing, and chronic sinusitis. Radiographic findings include sinus floor discontinuity, focal alveolar atrophy, and opacification of the sinus antrum. The OAC and oroantral fistula cannot be radiographically differentiated.

Fig. 31. Sinus grafting. (A) Cross-sectional and sagittal views of left maxillary sinus with grafting material. The more radiopaque section of the grafting material most likely represents a portion of the lateral wall of the left maxillary sinus. (B) Cross-sectional and sagittal views of left maxillary sinus with grafting material. A periapical radiolucency is associated with tooth #14; the airspace of the left maxillary sinus is opacified. The radiographic appearance is consistent with a secondarily infected graft.
Surgical Intervention

Surgery to improve the flow of air through the nasal cavity and into the paranasal sinuses is a frequent occurrence. The most common procedure is the correction of a septal deviation or septoplasty. Hyperplastic turbinates are reshaped to improve airflow. The reshaping of turbinates is referred to as **turbinoplasty**. When the communication between the nasal cavity and the paranasal sinuses is blocked, several procedures are performed to improve this communication. Nasal antrostomy increases the size of the ostiomeatal complex. Uncinectomy removes or reshapes the uncinate process (Fig. 30). A majority of sinus surgeries are performed through the nasal cavity using a flexible endoscope. These procedures are referred to as **functional endoscopic sinus surgery**.51

Sinus augmentation surgery is often performed by clinicians. The classic approach is referred to as the lateral window and involves removal of a portion of the cortical plate and insertion of grafting material inferior to the sinus membrane. The radiographic appearance of the lateral window approach includes a discontinuity of the cortical bone as well as the presence of radiopaque grafting material. Transcrestal procedures are minimally invasive and may or may not be associated with the presence of grafting material. This minimally invasive technique is difficult to detect using CBCT (Fig. 31).

The use of CBCT has provided clinicians with an immense quantity of radiographic information regarding the nasal cavity and paranasal sinuses that was not available with conventional 2-D imaging. This article has provided an overview of normal anatomy and anatomic variants as well as commonly encountered pathology found within the paranasal sinuses.

REFERENCES


