The Role of Imaging in Pediatric Sinonasal Pathology

Alireza Khatami*, Matthew Bromwich**, Elka Miller*, Michael Vassilyadi ***, Amer AlAref*, Julie Hurteau-Miller*

*Children’s Hospital of Eastern Ontario, Department of Diagnostic Imaging.
**Children’s Hospital of Eastern Ontario, Department of Head and Neck surgery.
*** Children’s Hospital of Eastern Ontario, Department of Neurosurgery.
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Alireza Khatami*, Matthew Bromwich**, Elka Miller*, Michael Vassilyadi ***, Amer AlAref*, Julie Hurteau-Miller*

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Objectives

Illustrate the normal pattern of development and anatomy of the sinonasal cavities in children
Demonstrate the imaging features of common non-traumatic sinonasal pathology in children
Highlight findings with clinical and surgical relevance

Legend

What the radiologist should look for
What the surgeon wants to know
Paranasal sinuses form as diverticula from the walls of the nasal cavities. The original openings of the diverticula persist as the ostia of the sinuses.

- **Ethmoid:** present at birth
- **Maxillary:** rudimentary at birth
- **Sphenoid sinus:** between 7 months-2 years
- **Frontal sinus:** between 2-8 years

Sinuses reach their full size after puberty.

**Cribriform plate** begin to ossify between 2-8 months. The **perpendicular plate of ethmoid and crista galli** begins to ossify between 4 and 11 months. Ossification is completed by age 3.

Awareness of the normal ossification sequence of midline facial structures may help avoid misdiagnosis of frontoethmoidal defect.
ANATOMY OF SINONASAL CAVITIES

ETHMOID SINUSES

Anterior and posterior ethmoids

Asymmetric or low ethmoid roof increases surgical risk of dural fistula or anterior ethmoidal artery injury

Anterior ethmoids drain into hiatus semilunaris and middle meatus

Posterior ethmoids drain into sphenoethmoidal recess and superior meatus

Deep olfactory fossa increases the risk of intra-op anterior cranial fossa perforation and dural fistula

Anterior ethmoidal artery may run in a bony canal along the supero-medial border of the orbits seen as small “bony beak”

Asymmetric and low ethmoid roof increases surgical risk of dural fistula or anterior ethmoidal artery injury
ANATOMY OF SINONASAL CAVITIES

ANATOMICAL VARIANTS OF THE ETHMOID SINUSES

Extension of ethmoid air cells into adjacent structures creates common normal variants:

1. Concha bullosa
cell in middle turbinates

2. Agger nasi cell
cell anterior to middle turbinate, under the frontal sinus

3. Haller cell
Extension of ethmoid air cell along roof of maxillary sinus

4. Onodi cell
Cell postero-lateral to sphenoid in close relation with optic nerve

5. Fronto ethmoidal cell
Type I - single cell above agger nasi
Type II - collection of cells above agger nasi
Type III - single large cell into frontal sinus

Large Haller cell may impinge on OMC
ANATOMY OF SINONASAL CAVITIES

MAXILLARY SINUSES

Osteomeatal complex **OMC**: Final common pathway for drainage/ventilation of maxillary, frontal and anterior ethmoidal sinuses

OMC:
- **uncinate process**: thin bone leaflet, runs anterior to posterior
- **hiatus semilunaris**: space between ethmoid bulla and uncinated process
- **infundibulum**: tunnel between uncinate process and bulla
- **maxillary ostium**: opening to infundibulum
- **ethmoid bulla**: most dominant ethmoid cell, may encroach on OMC
- **middle meatus**: space under the middle turbinate

Knowledge of site of attachment of the middle turbinates may prevent intra-op injuries

Middle turbinate attachment may vary:
1. cribriform plate
2. lamina papyracea
3. lateral wall
4. ethmoid bulla

Infundibulum: long and narrow infundibulum can pose problem in locating the maxillary ostium

Middle turbinate attachment at cribriforme plate and pneumatised Lamella Bullosa
ANATOMY OF SINONASAL CAVITIES

SPHENOID SINUSES

Pneumatisation varies
Rarely symmetrical
Close proximity to important structures:
- foramen rotundum
- foramen spinosum
- Carotid artery
- optic nerve
- sella

Drainage:
- into sphenethmoidal recess
- medial to superior turbinate

Bony dehiscence over carotid or optic nerve

FRONTAL SINUSES

- Frontal infundibulum - funnel shaped tunnel draining into hiatus semilunaris (middle meatus) via frontal ostium in the most dependent portion of the frontal sinuses
- Agger nasi - may be large and obstruct the infundibulum frontal
- Ethmoid bulla - most dominant ethmoid cell
- Middle meatus - space under the middle turbinate
- Hiatus semilunaris - space between ethmoid bulla and uncinate process

Large agger nasi, frontoethmoidal cell or ethmoid bulla may obstruct the infundibulum
IMAGING OF SINONASAL CAVITIES

Opacification / mucous membrane thickening = physiologic until 6 years
Uncomplicated sinusitis = clinical diagnosis = no imaging required

X-RAYS
Very limited utility
Poor sensitivity and specificity
May be used to confirm or exclude intranasal foreign body

CT SCAN
Excellent anatomic detail, indicated in:
- Complications of acute sinusitis
- Recurrent / chronic infection not responding to treatment
- Evaluation of OMC and Surgical planning
- Bony tumours / destruction
- Facial trauma
- Neonatal nasal obstruction

CT Radiation exposure
Low dose sinus CT: 0.6mSv
3 views sinus x-rays:
  - Head CT: 1-2mSv
  - Chest x-rays: 0.1mSv
  - Chest CT: 7mSv
  - Natural background: 3mSv/year

MRI
Superior soft tissue contrast
Help differentiate neoplasm from inflammation
Indications: Intracranial complications of sinusitis
Sinonasal tumours

Coronal images are mainstay of sinonasal imaging
CONGENITAL ANOMALIES

NEONATAL NASAL OBSTRUCTION

1- Choanal atresia  Most common nasal congenital anomaly
30% : purely bony
70% : mixed (bony + membranous)

5 day-old girl, difficulty breathing

Unilateral bony choanal atresia

Criteria for Choanal atresia
Medial bowing of lateral nasal wall
Thick vomer
> 2.4mm
Narrow Choanae
< 3.4mm

Bilateral mixed choanal atresia

2- Nasal piriform aperture stenosis  Rare congenital anomaly

3 day-old boy, dysmorphic features, cyanosis while feeding

in normal infant, anterior aperture has triangular shape

Normal infant

MRI indicated for possible holoprosencephaly, hypopituitarism, absent olfactor bulbs

narrowing anterior pyriform aperture of less 11mm

medial bowing and overgrowth of medial nasal process of the maxilla

Bilateral mixed choanal atresia

Normal infant

in normal infant, anterior aperture has triangular shape

bony ridge undersurface of hard palate and "box" shaped anterior aperture

Normal infant

bony ridge undersurface of hard palate and "box" shaped anterior aperture

Normal infant

hypoplastic hard palate with small cleft

solitary median incisor

triangular shaped hard palate

solitary median incisor
CONGENITAL ANOMALIES

CONGENITAL MASSES

1- Dermoid Cyst
   9 month-old girl hard nasal lump

   DDx of a medial canthal mass in infants:
   - Dacryocystocele
     Obstruction of nasolacrimal duct
     Extending to inferior meatus
   - Nasal Glioma
     Glial heterotopia (not a tumor)
     Usually along nasal ridge
     Disconnected from brain
   - Infantile Hemangioma
     Benign vascular mass
     Proliferative and involuting phases
     Frequently head/neck region

   C+CT
   well defined non-enhancing nodule

2- Nasal Dermal Sinus and Dermoid
   11-year-old male with non tender mass on the nose

   > 3 year old, large foramen cecum or abnormal crista galli on CT suggest intracranial extension
   sinus tract from tip of the nose to base of crista galli, no intracranial extension

   < 3 year old, MRI is more sensitive
   foramen cecum is not enlarged

   hyperintense on T1 suggest fat content Dermoid

Before surgery of any nasal lump:
Investigation for possible intracranial connection

well defined hyperechoic nodule adjacent to cranial suture
CONGENITAL ANOMALIES

CONGENITAL MASSES

3- Cephalocele – Basal (Spheno-pharyngeal)

*Newborn, facial dysmorphism and nasal obstruction*

Congenital herniation of meninges and brain tissue through a skull defect:

1- Occipital 75%
2- Sincipital 15%
   - Fronto-ethmoidal
   - Naso-ethmoidal
   - Naso-orbital
3- Basal 10%

- Stretching deformity of the third ventricle and hypothalamic pituitary axis
- Cephalocele herniating through large craniopharyngeal canal defect with absence of the presphenoid ossification center
- Corpus callosum agenesis
- Cystic central nasopharyngeal mass
- Coloboma

CT and MRI usually necessary for pre-op evaluation
INFLAMMATORY DISEASES

PREDISPOSING FACTORS

1- Structural

12 year girl, chronic pansinusitis and nasal congestion – Atelectatic uncinate process, nasal septum deviation

- Normal right uncinate process
- Uncinate process is adherent to lamina papyracea and obstructs the infundibulum
- Maxillary sinus hypoplasia increase the intra-op risk of orbital injury

2- Mucociliary dysfunction

10 year boy with Kartagener and chronic nasal congestion - Nasal polyposis and chronic sinusitis

- Expanded nasal fossa, sinus and ostium by polyposis
- Bony thinning

Polyposis

Hyperdense centrally with hypodense peripheral rim may help differentiate from tumor

Polyposis is infrequent in children unless an underlying predisposing condition (cystic fibrosis, Kartagener)
INFLAMMATORY DISEASES

ACUTE AND CHRONIC SINUSITIS

1- Acute Sinusitis   AS
Difficult to differentiate viral rhinosinusitis VS bacterial sinusitis
Imaging not helpful in differentiating the two conditions
Non-complicated AS is a clinical diagnosis (no imaging required)
Definition: Upper respiratory infection with purulent discharge > 10 days
Resolving completely with treatment < 30 days

2- Chronic sinusitis   CS
Definition: Paranasal sinus inflammation > 90 days
Usually in child > 5 year
Usually associated with predisposing factors
  Recurrent URI
  Mucociliary deficiency, CF (seen in nearly 100% of children with CF)
  Allergy
  GERD

3- Polyposis   Rare under 5 year
  > 5 year, mostly limited to children with CF, CS, mucociliary dysfuncyion, allergy, asthma

11 year old with allergy, asthma and chronic nasal congestion – Polyposis and allergic fungal sinusitis

Symptoms of sinusitis
  Cough
  Purulent nasal discharge
  Headaches
  Facial pain
  Urge to throat clearing
  Malodorous breath
  Sleep deprivation
  General malaise

- Complete maxillary, nasal and ethmoid opacity with expansion and thinning of turbinates and septa
- Hyperdense secretions from fungal infection
INFLAMMATORY DISEASES
FUNGAL SINUSITIS

4 subtypes:

1- Acute Invasive Fungal Sinusitis
   - Mostly in immunocompromised
   - Mucormycosis and aspergillosis
   - Rapidly progressive
   - Bone destruction, orbital and intra-cranial extension

2- Chronic Invasive Fungal Sinusitis
   - Mostly in immunocompetent
   - Associated with chronic sinusitis

3- Allergic Fungal Sinusitis
   - In young atopic patients with asthma
   - Associated with polyposis
   - Frequently pansinusitis

4- Fungal Ball
   - In non-atopic and immunocompetent
   - Rare
   - Associated with chronic sinusitis
   - Usually isolated to maxilla or sphenoid
   - 60% have punctate calcifications

Regardless of subtype, fungal infections are frequently:
- **Hyperdense on CT**
- **Hypointense on T2 and T1**
- From mineral content and low free water

15 year boy pre B ALL relapse painful right eye movement
within few days, patient developed right proptosis and severe headaches

Inflammation of the orbit and intracranial abscess

“Dark T2 signal” should not be confused with an aerated sinus

Rapid orbital and intracranial extension

**Acute Invasive Fungal disease**
**Mucormycosis**

Hyperdensity filling right ethmoid

With this story, fungal infection should be suspected

New brain edema, surrounding intracranial abscess

Hypointense “signal void” signal in right ethmoid

Rapid orbital and intra-cranial extension

Cor CT

Cor T1 gado

Cor T2
INFLAMMATORY DISEASES

SINUSITIS COMPLICATIONS

1- Subperiosteal abscess
   Most common intra-orbital complication in children
   6-year-old boy with left orbital cellulitis

   Orbital complications are frequently from ethmoid sinusitis

   Ethmoid sinusitis with sub-periosteal intraorbital extraconal abscess

2- Osteomyelitis and Pott's Puffy tumor
   15 year boy, 3 weeks of facial and orbital swelling, headaches

   To find subtle osteomyelitis, pay special attention to the bone adjacent to the area of most soft tissue swelling

   Adjacent Sub-galeal abscess with restricted diffusion

   MRI can show early phase of osteomyelitis: bone edema and enhancement

   If suspecting sinusitis complications, an enhanced CT scan should be performed to avoid unnecessary radiation of an unenhanced CT
INFLAMMATORY DISEASES
SINUSITIS COMPLICATIONS

3- Intracranial abscess
12-year-old, headaches and fever

4- Subdural Empyema
9-year-old boy, hemiparesis and neurological deterioration following sinusitis

5- Cavernous sinus thrombosis
12 year old, 2 weeks of headaches and mild fever, new right ptosis
INFLAMMATORY DISEASES

SINUSITIS COMPLICATIONS

6- Pyomyositis
16-year boy, right eye pain and slight proptosis

- Sphenoid sinusitis
- Extensive edema in the temporal and infra temporal muscles and soft tissue: Pyomyositis

7- Infectious optic neuritis
16 year girl treated for sinusitis, poor response, new decreased right eye vision

- Epidural empyema along planum sphenoidal
- Thinning of ethmoid roof
- Planum sphenoidale empyema extending into sella and abutting chiasma
- Swelling of the chiasm

Optic neuritis

Coronal images are your best friends
MASSES

BENIGN BONY LESIONS

1- Ossifying Fibroma
15 year old with symptoms of chronic sinusitis

2- Fibrous Dysplasia
14-year-old girl, headache

Osteoma
Common
Usually incidental finding
Frequently frontal sinus
Sclerotic well defined lesion
If multiple: Gardner’s syndrome

Uncommon fibro-osseous tumor
Usually asymptomatic
May be expansile
Usually unilateral and monostotic

well defined sclerotic “target lesion” of the right maxilla

ground glass skull lesion filling the frontal sinus

diagnostic ground glass maxillary lesion

homogenous hypointense T1 and T2

homogenous enhancement

expansile ground glass maxillary lesion

Uncommon fibro-osseous tumor
Usually asymptomatic
May be expansile
Usually unilateral and monostotic
MASSES
BENIGN BONY LESIONS

3- Osteoblastoma
16-year-old boy, left proptosis and decreased left visual acuity

- Expansile lesion of frontal and ethmoid bone with thin peripheral bony rim with thick ground glass component
- Multicystic with multiple air/fluid levels
- Homogenous enhancement of the thick component and thin septations

Skull osteoblastoma: very rare
Usually spine and long bones
Expansile, well defined lytic lesion
DDX: Aneurysmal Bone Cyst
Skull involvement is also rare
Expansile and multicystic appearance

4- Odontogenic Keratocyst
9 year old with swelling lower left cheek

- Unerupted tooth
- Expansile left maxillary lytic lesion with incomplete thin bony rim displacing an unerupted tooth

Dental origin should be suspected in any lesion at the inferior aspect of maxillary sinuses
**MASSES**

**BENIGN LESIONS**

1- **Cysts**

- **Retention cyst**
  - Frequent = result from obstruction of submucosal mucinous gland
  - Not inflammatory
  - Homogenous fluid density and signal
  - Non-enhancing

- **Mucocele**
  - Infrequent, mostly seen with CF
  - Result from sinus obstruction
  - Frontal 60%, ethmoid 30%
  - Sinus expansion, bone thinning

16 year girl, 6 months of nasal congestion and orbital pressure

- **Dome shaped**
- **Well defined**
- **Inferior aspect of sinus** – **Retention cyst**

2- **Antrochoanal polyp**

- **16 year girl, 6 months of nasal congestion and orbital pressure**

- **Polyp - hypodense mass**
  - from maxillary antrum protruding into nasal cavity

- **Polyp - bright T2 and low T1**

- **Polyp - non-enhancing**
  - Inflamed mucosa - enhance

- **Dense secretion on CT**
  - Hypointense on T2 from secondary fungal infection

- **Hyperintense T1 secretion from proteinacous content**

- **Enlarged maxillary ostium**

Antrochoanal polyp from maxillary antrum differs from inflammatory polyp: tend to be more fibrotic

Seen in teenagers and young adults
3- Antrochoanal polyp with secondary mucocele

16 year old girl with right facial pain and long standing nasal congestion

The chronic obstruction from the antrochoanal mass caused a secondary mucocele.

In this case, the cerebriform type of enhancement of the mass is more suggestive of Inverted Papilloma.

MRI best for:
- differentiating mass vs. secretion / fluid
- localising the mass with more precision
MASSES
MALIGNANCIES INVOLVING THE PARANASAL SINUSES

1- Rhabdomyosarcoma
17-year-old boy, right proptosis

- Ethmoid mass extending in the right orbit
- Bone destruction
- Homogenous slightly hypointense T1
- Homogenous intermediate T2
- Homogenous enhancement

Most benign or inflammatory lesions are hyperintense T2, sinonasal malignancies are intermediate T2 because of their high cellularity.

2- Burkitt Lymphoma
6 year boy, bilateral cervical adenitis, progressive upper airway obstruction and voice hoarseness

- Large soft tissue mass with bony destruction
- Large homogenous intermediate T2 mass
- Restricted diffusion

DWI
ADC
CONCLUSIONS

1- IMAGING MODALITIES

XRAYS
Not indicated for sinusitis < 6 years old
Limited value even > 6 years old

CT SCAN
Sinusitis complications
Chronic sinusitis
Pre-op evaluation

MRI
Intracranial complications of sinusitis
Sinonasal masses

CT and MRI are complementary in mapping neoplasm

Good communication between the radiologist, clinician and surgeon is most important!
2- PEDIATRIC SINONASAL PATHOLOGY

Conclusions

Nasal mass
Intracranial extension should be excluded before surgery

Chronic Sinusitis and Polyposis
Mostly associated with CF, asthma, mucociliary dysfunction

Fungal infection
Seen in immunocompromised and immunocompetent
Tendency to have high density on CT and T2 “signal void”
Acute Invasive Fungal Sinusitis has high rate of orbital and intracranial extension

Complications of sinusitis
Better detected in coronal plane

Paranasal malignancies
Usually have T2 intermediate signal, while inflammatory process has T2 hypersignal

Benign bony lesions
Can cause deformity and opacification of paranasal sinuses