FESS AND WHAT THE RADIOLOGIST NEEDS TO KNOW

Introduction:

• Advances made in FESS (functional endoscopic sinus surgery) requires a thorough pre-op understanding of patients sino-nasal anatomy by ENT surgeon
• CT scanning and subsequent evaluation of the patients anatomy with special attention to anatomical variants that may predispose to complications during surgery are important to reduce morbidity and mortality
• OMU and the ethmoid sinus in particular are intimately associated and the anatomy of both must be thoroughly understood to accurately interpret CT scans
• Normal variants predisposing to complications during FESS should be understood
• Imaging evaluation of patients presenting with complications of FESS

NORMAL ANATOMY:

Nasal septum

• Nasal septum extends the entire length of the nose and is comprised of a hard and soft part
  • **Hard portion:** perpendicular plate of ethmoid (sup) (posterior) vomer (post-inf) septal cartilage
  • **Soft mobile septum:** medial crus of alar cartilage (anterior) skin and soft tissue

Anatomy of lateral wall of the nose

• 3 Turbinates project from lateral nasal wall, i.e. superior, middle and inferior turbinates (concha).

• As each turbinate curls inferolaterally, 3 distinct air channels are formed in the AP dimension, i.e superior, middle and inferior meati respectively.
Various ostia drain into the meati

**Superior turbinate and meatus**

- Part of ethmoid bone
- Smallest turbinate, overlies the superior meatus
- Posterior ethmoidal air cells drain into superior meatus via multiple ostia
- Sphenoid-ethmoidal recess lies on postero-superior aspect of superior turbinate, between the anterior wall of the sphenoid sinus and the posterior wall of the ethmoid air cells.
- Easily seen on axials; on coronals more difficult - usually seen where sup turbinate ends posteriorly
- Sphenoethmoidal recess drains the sphenoid sinus through the sphenoid ostium
Middle turbinate and meatus

- Middle turbinate (ethmoid bone) overlies the middle meatus, which is the most important anatomic area in the lateral wall of the nose.
- Superiorly attached to lateral aspect of the cribriform plate; between cribiform plate and fovea ethmoidalis.
- Lateral attachment, called the basal lamella, attaches to the thin lamina papyracea of the lateral ethmoidal wall.
  Posteriorly, the basal lamella curves superiorly to become coronally orientated. This coronal part, separates the anterior and middle from the posterior ethmoidal air cells.
- Pneumatization of the middle turbinate occurs as a normal variant and is called concha bullosa.

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BASAL LAMELLA (long white arrow)
  - attachment of middle turbinate to the lamina papyracea (black arrowhead)

B = Bulla ethmoidalis

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Drainage to the middle meatus:

1. Bulla ethmoidalis – a prominent anterior ethmoid air cell, located posteriorly in the middle meatus. Receives drainage from front and middle group of ethmoid air cells and drain into ethmoid infundibulum/middle meatus

2. Hiatus semilunaris – just inferior to bulla ethmoidalis. Anteriorly, it receives drainage from anterior ethmoidal air cells. Posteriorly, it receives drainage of the maxillary sinus via the maxillary sinus ostium.

3. Frontal recess / nasofrontal duct – defined as bony walls that lead to and communicate with frontal sinus. Frontal sinus drains via frontal recess and nasofrontal duct into middle meatus.

**Inferior turbinate and meatus**

- Largest of the 3 nasal turbinates.

Receives only the nasolacrimal duct in its posterior aspect
Ostiomeatal unit

- It refers to the common drainage pathway of the anterior sinuses (frontal, maxillary, ant and middle ethmoid sinuses)
- The ostiomeatal unit is in the centre of interest in the lateral wall of the nose since the development of FESS, since it is though to be the key in the pathogenesis of chronic sinusitis

OMU is comprised of the:
- ethmoid infundibulum
- uncinate process
- ethmoid bulla
- hiatus semilunaris
ETHMOID INFUNDIBULUM

- Funnel-shaped tube on CT between the inf-med border orbit / ethmoid bulla sup-lat; uncinate process medially; maxillary sinus inferiorly; hiatus semilunaris superiorly
- Maxillary sinus ostium opens into floor of ethmoid infundibulum
- Receives drainage from ant and middle ethmoid air cells via ethmoid bulla
- Continues superiorly as nasofrontal duct into frontal sinus (50%)

UNCINATE PROCESS

- Crescent or hook shaped bony prominence; part of ethmoid bone
- Runs along the inferior margin of the hiatus semilunaris.
- Forms the medial bony wall of the ethmoid infundibulum
- It arises anteriorly from the posterior margin of the nasolacrimal duct
- Uncinate process may be pneumatized
- Attached inferiorly to the inferior turbinate (seen on post scans)
Uncinate process has variable superior attachments which influence frontal sinus drainage pattern:

1. Skull base frontal sinus opens into ethmoid
2. Middle turbinate infundibulum
3. Lamina papyracea
   - closes the ethmoid infundibulum superiorly and forms a blind ending pouch – recessus terminalis.
• Frontal recess and ethmoid infundibulum becomes separated; frontal recess now drains separately into middle meatus medial to the ethmoid infundibulum

ETHMOID BULLA

• A prominent single anterior ethmoid air cell
• Good anatomical landmark
• Located on the lateral wall of the middle meatus
• Medial to the lamina papyracea
• On coronal CT seen superior to ethmoid infundibulum into which it drains
• Superiorly it may fuse with the skull base
• Post it may fuse with the basal lamella. In case of no fusion, a space is created between the ethmoid bulla and basal lamella called the sinus lateralis
• Sinus lateralis opens medially into middle meatus
• Projects inferomedially over the hiatus semilunaris in a rounded fashion
• Variation in degree of pneumatization – failure to pneumatize called torus ethmoidales. Excessive pneumatization results in a giant bulla

UNCINATE PROCESS VARIANT:
Attaches superiorly to the lamina papyracea with frontal recess now draining directly into middle meatus
HIATUS SEMILUNARIS

- Accommodates multiple anterior ethmoidal ostia, as well as single maxillary ostium, to form final common pathway for draining of these sinuses into middle meatus

Boundaries:
Sup: bulla ethmoidalis
Inf: uncinate process
Lat: bony orbit
Med: middle meatus

Patterns of obstruction

Depending on which drainage pathways are involved, different patterns of obstruction are recognised in sinonasal disease:

1. **Maxillary infundibular pattern**
   - Ipsilateral maxillary sinus involvement only
   - Due to diseased maxillary sinus ostium

2. **Nasofrontal duct pattern**
   - Ipsilateral frontal sinus involvement
• Due to obstruction of nasofrontal duct / frontal recess

3. OMU pattern
• Opacification of the middle meatus
• Secondary inflammatory change in maxillary, ant and middle ethmoid, and frontal sinus

4. Sphenoethmoidal recess pattern
• Sphenoid and ipsilateral post ethmoid sinus involvement
• Due to obstruction at level of spheno-ethmoidal recess

5. Sinonasal polyposis
• Inflammatory polyps fills the nasal cavity and sinuses bilaterally – see mixture of previously mentioned patterns

6. Sporadic pattern
• Random inflammatory changes

Ethmoid sinus
• Key sinus in FESS is the ethmoid sinus; knowledge of its anatomy is essential for understanding pathological processes and in prevention of surgical complications.

“If the ethmoid were placed in any other part of the body it would be an insignificant and harmless collection of bony cells. In the place where nature has put it, it has major relationships so that diseases and surgery of the labyrinth often leads to tragedy. Any surgery in this region should be simple but has proven one of the easiest ways to kill a patient”
MOSHER 1929

• Ethmoid bone delicate and complex; articulates with 13 other bones
• Divided into 4 parts: cribriform plate
 perpendicular plate (part of bony nasal septum)
 2 laterally located ethmoid labyrinths

Cribriform plate
• 2-3 mm wide plate
• each has approximately 20 foramina – transmit olfactory nerve fibres
• forms ant part of roof of nose

Ethmoid labyrinth
• each side consist of 3-18 highly variable thin-walled air cells
• in disarticulated bone – air cells open superiorly - closed by fovea ethmoidalis of frontal bone (lat to cribriform plate)
• air cells arranged in ant, middle and post groups
• 3 air cell groups included in ant group

1. Frontal recess cells - most anteriorly
   extends ant-sup toward frontal bone
   frontal sinus develop from these
2. Infundibular air cells – gives rise to agger nasi cells (extramural air cell)
3. Bulla air cells / bulla ethmoidalis – part of OMU

Late pneumatization of the ethmoid sinus lead to normal variants / extramural air cells:

1. Agger nasi cells
   • extension of pneumatization of ant ethmoid air cells into frontal process of the maxilla / lacrimal bone
   • Located ant and inf to frontal recess
   • Forms ant part of floor of frontal sinus
   • Closeness to frontal recess make them excellent surgical landmarks – often opened to view nasofrontal duct
   • Drain into ethmoid infundibulum

2. Concha bullosa
   • Pneumatization of middle turbinate from middle ethmoid air cells
   • 34 % incidence
   • May cause obstruction of ethmoid infundibulum

3. Haller cell
   • Air cell located below ethmoid bulla, along roof of maxillary sinus and below lowest point of lamina papyracea
   • If large may obstruct maxillary sinus ostium

4. Onodi cell
   • Post-lat extension of post ethmoid air cell to surround optic nerve
Functional endoscopic sinus surgery (FESS)

- FESS is based on the belief that the OMU is the key area in the development of chronic sinus disease
- Changes in nasal mucosa in vicinity of OMU may interfere with mucociliary drainage and ventilation of the maxillary, ethmoid and frontal sinuses

Indications for FESS

1. Patients in whom non-invasive therapy fails
   Ideally patients with repeated bouts of bacterial sinusitus in whom antibiotics only provide temporary relief

- * concha bullosa
- H - Bilateral Haller cells
2. Chronic hyperplastic rhinosinusitis (extensive disease throughout paranasal sinuses) or polyps
3. Mucocele
4. Peri-orbital cellulitis secondary to ethmoiditis

**Role of radiologist in FESS**
1. Should be familiar with principles of FESS
2. Should carefully evaluate the paranasal sinuses, with particular attention to the ethmoid bone and OMU
3. Should be familiar with normal variations that predispose to complications of FESS
4. Should ensure correct patient preparation and correct technique of CT evaluation

**Technique of FESS**
1. FESS attempts to restore normal sinus drainage via an intranasal fiberoptic endoscope
2. Extent of surgery depends on the pattern of obstruction identified on CT scans
3. Involves minimal resection of sinus walls and mucosa
4. Success rate is comparable to that of older more invasive techniques

**CT Technique for evaluation of OMU / sinuses**
1. Coronal CT preferred – simulates plane seen by endoscopist
   • patient prone with neck hyperextended
   • 3mm slice increments
2. Axial plane (5mm slices) allows better evaluation of
   • Ant and post walls of frontal sinuses
   • Relationship between post ethmoid and sphenoid sinuses
   • Relationship of optic nerve to post ethmoid and sphenoid sinuses
2. Wide window widths (4000H/750H), ?soft tissue settings - advantages - mucosal debris, microcalcifications, incidental findings in globe and orbit

**Complications of FESS**
• Complications vary from minor and temporary to that causing permanent injury and even death.
Anatomical variants predispose certain structures to injury during FESS
Radiologist can minimise risk for complications by recognising normal variants and alerting surgeon

COMPLICATIONS:
- Recurrent inflammatory disease
- Orbital injuries
- Hemorrhage
- CSF leak
- Intracranial complications

Recurrent inflammatory disease
- Factors predisposing to poor symptom relief after FESS:
  1. Diffuse sinonasal polyposis
  2. Asthma
  3. Prior surgery
  4. Tenacious sinus secretions

Complications of FESS can predispose to recurrent infection:
1. Synchiae/adhesions - b/t lat nasal wall + lat aspect middle turbinate; thus causing inadequate drainage through stenotic middle meatus
2. Closure of natural sinus ostia - common in sinonasal polyposis
3. Incomplete ethmoidectomy

Orbital complications:
These include:
- Orbital edema, hematoma of lower eyelid and orbital emphysema due to violation of lamina papyracea
- Epiphora - injury to nasolacrimal duct - located just ant to maxillary sinus ostium
- Diplopia - d.t. extra-ocular muscle injury
  most commonly MR, SR and SO which are injured/transected during ethmoidectomy
- Blindness - Acute intra-orbital hematoma with resultant pressure on optic nerve leading to ischaemia (ant ethmoid artery
• Blindness can also be result of direct optic nerve injury (rare)
• Post-op orbital abcess – can lead to cavernous sinus thrombosis

CONSIDERATIONS ON PRE-OP CT:
1. Lamina papyracea integrity – LP a thin bone separating orbit from ethmoid sinus
   May be dehiscent after previous sinus surgery or previous blow out fracture
   Dehiscence may lead to proptosis of peri-orbital fat which can be mistaken for mucocele and thus be resected
2. Onodi cell – posterior ethmoid air cell which extends post-lat to surround the optic nerve – if entered may injure ON
3. Extensive sphenoid sinus pneumatization
   • increased risk of optic nerve injury if ACP pneumatized
2. Dehiscence of bony covering of the optic nerve
   • 4 – 24% incidence
Post-op evaluation of suspected orbital complications

- Post-operative evaluation should be conducted in both coronal and axial planes; usually unenhanced only

**GUIDELINES FOR EVALUATION:**

- Retrobulbar or extraconal hematoma, proptosis, distorted peri-orbital fat, orbital emphysema and protrusion of peri-orbital fat into ethmoid should alert radiologist to possibility of disruption of the lamina papyracea.
- Optic nerve should be traced in its entirety

**Hemorrhage**

- Usually the result of injury to IMA branches or ant ethmoidal arteries
- Where ant ethmoid arteries enter ACF, the cribiform plate offers little resistance
- May have direct injury to ICA

**PRE-OP - VARIATIONS PREDISPOSING TO INJURY**

- ICA bulging medially into sphenoid sinus (65-75%)
- Dehiscence of bony wall separating ICA from sphenoid sinus (4-8%)
• Deviated sphenoid septum - often the lateral insertion corresponds to position of ICA; if septum avulsed during surgery, may lead to ICA injury

**POST-OP EVALUATION**

1. ICA injury usually controlled intra-operatively
2. Emergency angiogram to be performed immediately post-op with temporary occlusion of artery - if tolerated without neurological deficit, then to proceed to permanent balloon embolisation

**CSF Leak**

• Usually observed intra-op, but can present from d1 to 2 years post-op
• Rhinorhea usually the presenting symptom
• Often the result of injury to the middle turbinate's delicate attachment to the skull base
• Usual sites for leakage: cribriform plate, post ethmoid roof, fovea ethmoidalis, skull base above ant roof of sphenoid sinus
PRE-OP EVALUATION
1. Evaluate the above mentioned areas for dehiscence/thinning patients at increased risk if previous facial or skull base trauma; or previous sinus surgery
2. Low fovea ethmoidalis
3. Shallow olfactory fossa
4. Supra-orbital extension of ethmoid air cells

POST-OP EVALUATION OF CSF LEAK
• Unenhanced CT scan in coronal (3mm) and axial (5mm) plane
• If any dehiscence seen - assumed to be the site of leakage
• If no defect is seen - then proceed to perform CT cisternography after injection of 5 ml of LOCM into lumbar SAS

Intracranial complications
• Extremely rare
• Not usually the result of anatomical variants
• Documented complications include:
  intracerebral hematomas
  cerebritis/abcess
  encephaloceles
  injury to ACA/ACoA and their branches
  pneumocephalus

CONCLUSION:
• FESS and its complications has made it increasingly critical for the radiologist to have a thorough understanding of sinonasal anatomy
• In particular, one needs to be aware of the many normal variants of especially the OMU and the ethmoid sinus.
• It is the role of the radiologist to alert the surgeon of variants that could put the patient at increased risk of complications during surgery.
• As a team, the radiologist and ENT surgeon should aim to optimise the benefits of FESS while minimising its risks