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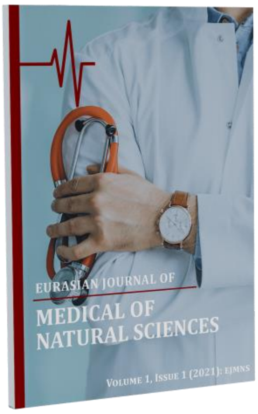

FUNCTIONAL ENDOSCOPIC SINUS SURGERY (FESS) IN CHRONIC RHINOSINUSITIS: ADVANCES, TECHNIQUES, COMPLICATIONS, AND MULTIDISCIPLINARY MANAGEMENT"

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ABSTRACT

This article provides a comprehensive overview of Functional Endoscopic Sinus Surgery (FESS) as a primary treatment for chronic rhinosinusitis (CRS) and its expanding role in managing various sinonasal and skull base pathologies. It explores the clinical significance of FESS, the indications, contraindications, and stepwise surgical techniques. Key insights into the anatomy, equipment requirements, and common complications, such as orbital and skull-base injuries, are discussed. The article emphasizes the importance of multidisciplinary collaboration with specialists, including neurosurgeons, oncologists, and ophthalmologists, as well as the essential role of postoperative care in preventing recurrence and improving patient outcomes. By combining advanced imaging, navigation, and careful surgical technique, FESS offers improved safety and efficacy for patients with CRS and related conditions.

Continuing Education Activity

Endoscopic sinus surgery (ESS) has evolved rapidly alongside technological advancements, expanding its applications far beyond its initial use in chronic rhinosinusitis (CRS). Today, ESS is indicated not only for CRS but also for pituitary tumors, skull base defects, sinonasal tumors, and complications of acute rhinosinusitis, among other conditions. A systematic approach that addresses all sinuses leads to successful outcomes in CRS cases and establishes a clear and safe pathway for addressing areas beyond the sinuses. This activity covers the anatomy and indications for ESS and emphasizes the role of the interprofessional team in managing patients undergoing this procedure.

Objectives:

1. Identify the indications for endoscopic sinus surgery.
2. Distinguish among various ESS techniques and their specific applications.
3. Evaluate potential complications associated with endoscopic sinus surgery.

Introduction

Endoscopic sinus surgery (ESS) has advanced tremendously since its early applications. Endoscopic examination of the sinuses was introduced in 1902, but ESS did not become routine until the 1970s. Throughout much of the 20th century, sinus pathologies were managed using external approaches with a headlight 333. From the 1970s onward, ESS techniques have consistently evolved with advancements in surgical instrumentation, imaging, simulation, and navigation technologies.

The principles of sinus surgery are rooted in Messerklinger's research on mucociliary clearance and its role in sinusitis pathogenesis. The primary goals of functional ESS (FESS) for sinusitis include widening sinus ostia, restoring sinus ventilation, improving mucociliary transport, and enhancing delivery routes for topical treatments. Although FESS aims may seem straightforward, anatomical variability and the range of diseases addressed in each procedure present ongoing challenges for surgeons. Thorough preoperative planning is essential to achieve optimal results and minimize complications.

ESS has become the gold standard for managing chronic rhinosinusitis (CRS). Technological advancements have continued to expand the procedure's applications beyond rhinosinusitis, now encompassing the management of sinus tumors and other pathologies extending beyond the sinuses.

Anatomy and Physiology

A comprehensive understanding of nasal and paranasal anatomy is fundamental to safe and effective ESS. Significant anatomical variations exist among individuals and even between sides, making preoperative imaging studies, like CT scans, essential.

The external nose comprises the nasal bones, upper lateral cartilages, and lower lateral cartilages. Internally, the nasal structure is divided into two cavities by the septum, with each cavity featuring a medial wall, lateral wall, and vertical septum. The nasal cavity roof includes the crista galli, cribriform plates, and the sphenoid body, while the floor is formed by the palatine processes of the maxilla and palatine bones.

The septum has both bony and cartilaginous components, with the anterior septum formed by septal cartilage. The perpendicular plate of the ethmoid lies postero-superiorly, and the vomer postero-inferiorly. Blood supply to the septum includes the sphenopalatine, ethmoidal, superior labial, and palatine arteries. Little's area, or Kiesselbach's plexus, is a highly vascularized region prone to anterior epistaxis.

The lateral nasal wall contains bony outgrowths known as turbinates, typically three or four per side. The superior, middle, and occasionally supreme turbinates arise from the ethmoid bone, while the inferior turbinate originates from a separate bone. Turbinates, covered by mucosa, play crucial roles in filtering, humidifying, and regulating airflow.

Beneath each turbinate is a nasal passage called a meatus. The inferior meatus receives drainage from the nasolacrimal duct through Hasner's valve. The middle meatus, the primary drainage passage for the frontal, maxillary, and anterior ethmoid sinuses, is anatomically complex. The uncinate process, a projection from the ethmoid bone, defines part of the middle meatus and attaches to various structures. The hiatus semilunaris, the space between the ethmoid bulla and the uncinate process, is the main drainage site for sinus secretions into the nasal cavity.

The ethmoid sinuses are bordered by the lamina papyracea laterally and the fovea ethmoidalis superiorly. The basal lamella divides these sinuses into anterior and posterior cells, with anterior cells draining into the middle meatus and posterior cells draining into the sphenoethmoidal recess. The largest ethmoid cell, the ethmoidal bulla, lies posterior to the hiatus semilunaris.

The maxillary sinuses lie between the orbital floor above and the alveolar processes of the maxilla below. Their drainage ostium is located on the superior medial wall, usually opening into the posterior third of the ethmoid infundibulum. In about 43% of cases, an accessory maxillary ostium is also present. The primary blood supply comes from branches of the maxillary and facial arteries.

The sphenoid sinuses are positioned within the sphenoid bone and separated by a septum. The sphenoid ostium drains into the sphenoethmoidal recess within the superior meatus. Surrounding the sphenoid sinuses are key structures such as the internal carotid arteries, cavernous sinuses, and several cranial nerves, making anatomical precision crucial during ESS. Occasionally, Onodi cells, located superolaterally, are associated with the optic nerve.

The frontal sinuses, located between the tables of the frontal bone, drain through the frontal recess. The frontal recess drainage path varies depending on the uncinate attachment. Recent anatomical classifications categorize frontal sinus cells into anterior, posterior, and medial cells based on their position.

In summary, a thorough knowledge of nasal and paranasal anatomy is essential for successful ESS and the prevention of complications. Detailed preoperative imaging and anatomical awareness enable surgeons to manage complex cases effectively, extend indications beyond sinusitis, and improve patient outcomes.

Indications

Since the advent of functional endoscopic sinus surgery (FESS), the range of indications for this procedure has steadily broadened. Advances in endoscope technology, cameras, surgical instruments, and navigation systems have opened new possibilities, allowing endoscopic access to structures beyond the sinuses, such as the skull base, optic nerve, cavernous sinus, pituitary gland, orbit, and pterygopalatine fossa.

The primary and most common indication for FESS remains chronic rhinosinusitis (CRS), an inflammatory condition of the paranasal sinuses. Rhinosinusitis is classified based on the duration of inflammation:

- **Acute rhinosinusitis**: less than 4 weeks
- **Subacute rhinosinusitis**: between 4 and 12 weeks
- **Chronic rhinosinusitis**: longer than 12 weeks

These sinus conditions are among the most frequently encountered by healthcare providers and contribute significantly to healthcare costs, with chronic rhinosinusitis alone accounting for an estimated $8.3 billion in annual healthcare expenditures in the United States.

CRS also substantially impacts patients' quality of life, both emotionally and physically. Diagnosis should be based on patient-reported symptoms and objective findings from physical examination, anterior rhinoscopy, nasal endoscopy, or CT scans. According to clinical practice guidelines, initial treatment for CRS involves saline irrigation and/or topical intranasal steroids. If medical therapy proves insufficient, FESS is considered the next step, though there is no universal consensus on the criteria for maximal medical therapy or optimal timing for surgery. FESS has demonstrated a significant benefit in improving the quality of life for patients with CRS.

Beyond CRS, FESS is instrumental in managing complicated cases of acute rhinosinusitis (ARS), particularly those with extracranial and intracranial complications as classified by Chandler's criteria. Complications range in severity from pre-septal cellulitis to cavernous sinus thrombosis. FESS is indicated in cases of preseptal and orbital cellulitis with visual impairment or increased intraocular pressure, especially when medical treatment is insufficient.

For cases involving subperiosteal abscesses (SPA) larger than 1 cm or orbital abscesses (OA), FESS enables abscess drainage, sinus clearance, and culture collection to guide targeted antibiotic therapy.

Due to the proximity of the ethmoid sinuses to the orbit, FESS can also be used for trans-nasal access to specific orbital pathologies, providing an incision-free alternative. Indications include decompression of the orbit or optic canal in cases of Graves disease or posttraumatic optic neuropathy, management of lesions in the medial orbital apex or extraconal space, benign sinonasal tumors encroaching on the orbit medially, and fractures of the medial orbital wall.

FESS has become the preferred approach for additional conditions, including mucoceles, invasive and non-invasive fungal sinusitis, silent sinus syndrome, pituitary tumors, cerebrospinal fluid leaks, benign and malignant sinonasal tumors, and lesions of the ventral skull base, petrous apex, or pterygomaxillary fossa. In cases of nasal or paranasal malignancies extending into the anterior skull base, expanded FESS plays a critical role.

Navigation-assisted endoscopic sinus surgery has become highly valued in rhinology, providing intraoperative guidance based on preoperative imaging. Image-guided tracking enables a more precise dissection, improved visualization of tumor margins for achieving negative borders, and a lower risk of complications.

Indications for using navigation systems in FESS include:

- Revision sinus surgery
- Distorted sinonasal anatomy
- Benign or malignant sinonasal tumors
- Cerebrospinal fluid leak repairs, skull base defects, or lesions
- Pathologies near critical structures such as the optic nerve, orbit, carotid artery, or skull base
- Diseases affecting the frontal, sphenoid, or ethmoid sinuses
- Extensive polyposis

These advanced applications continue to expand the therapeutic scope of FESS, enabling safer and more effective management of complex sinonasal and skull base pathologies.

Contraindications

Contraindications for Functional Endoscopic Sinus Surgery (FESS) include patients who cannot undergo general or local anesthesia due to general health contraindications.

Specific contraindications for purely endoscopic surgery include lesions or pathologies extending into the palate, skin or soft tissues, areas lateral to or above the orbit, lateral recesses of the frontal sinus, or cases with advanced intracranial involvement. In such cases, where there is significant extension, a combined endoscopic and open approach may be required.

Equipment

The necessary equipment for the operating room includes a television monitor, navigation system (if utilized), camera, and a comprehensive sinus endoscopy tray with various instruments. These include curettes, down-biters, backbiters, elevators, ball-tip probes, through-cutting instruments, Kerrison rongeurs, giraffe instruments, sinus forceps with different angles, punch instruments, and endoscopes (0-, 30-, 45-, and 70-degree scopes, including reverse scopes). A powered debrider with straight and angled blades is also essential.

Personnel

The FESS procedure requires an otolaryngologist as the primary surgeon, along with a scrub technician, nurse, and anesthesiologist. For transsphenoidal approaches to access pituitary tumors or removal of tumors with intracranial extension, a neurosurgeon is typically present to assist the otolaryngologist.

Preparation

The patient is positioned on the operating table, oriented toward the television monitor, with the head elevated in a reverse Trendelenburg position. The endotracheal tube is secured at the corner of the patient's mouth on the left side.

The patient's eyes are shielded with a transparent cover, or partially covered, ensuring the medial portion remains accessible for the surgeon to monitor for any signs of swelling that may indicate orbital hematoma.

Both nasal cavities are initially packed with oxymetazoline-soaked cotton for decongestion, and the patient is then draped.

When navigation is being used, preoperative imaging should be uploaded to the navigation system. The tracking system must be registered and its accuracy confirmed before beginning the procedure.

Technique or Treatment

A detailed nasal endoscopy is performed initially using a 0- or 30-degree endoscope. The lateral nasal wall near the uncinate process and the axilla of the middle turbinate are infiltrated with 1% lidocaine with 1:100,000 epinephrine using a 3 ml syringe and 27-gauge needle. Oxymetazoline-soaked cotton pledgets are then placed in the middle meatus, though some surgeons opt for a 4% cocaine solution.

Typically, surgery begins on the side with the most significant disease or the side that is more accessible in cases of septal deviation.

Excision of Concha Bullosa

If a concha bullosa (air-filled cell) is present within the middle turbinate, it is excised first to improve access to the lateral nasal wall. An incision is made on the anterior part of the middle turbinate with a sharp sickle knife, and the lateral section of the turbinate is removed.

Uncinectomy

The middle turbinate is carefully medialized using a Freer elevator to reach the uncinate process. Uncinectomy may be performed in a retrograde fashion, where the uncinate is identified and separated from the lamina papyracea using a ball-tip probe. A backbiter is used to incise the uncinate inferiorly to prevent injury to the medial orbital wall. Blakesley forceps are then used to grasp and remove the free edge of the uncinate, with the remaining uncinate process being removed using biting instruments or a powered debrider until the maxillary ostium becomes visible.

Alternatively, uncinectomy can be performed by making an incision in the uncinate process with a sickle knife or the sharp edge of a Freer elevator.

Maxillary Antrostomy

Once the uncinate is removed, the natural ostium of the maxillary sinus is visualized. This ostium is elliptical and located in the lower portion of the infundibulum. It is critical to differentiate the natural ostium from any accessory ostium. The natural opening to the maxillary sinus is confirmed using a ball-tip probe and best viewed with a 30- or 45-degree endoscope. Once confirmed, the natural ostium is enlarged using through-cutting instruments, punch forceps, and a powered debrider, with the ostium being expanded posteriorly and inferiorly to avoid injury to the orbit superiorly and the nasolacrimal duct anteriorly.

Ethmoidectomy

Ethmoidectomy is performed with a 0- or 30-degree endoscope. The first cell encountered within the ethmoid sinus is the ethmoid bulla. This large cell is opened medially and inferiorly with a powered debrider, curette, or punch forceps, or it can be removed retrogradely from the retrobullar space. The lamina papyracea is identified, and it is advised to preserve its mucosa. Dissection is carried posteriorly until the basal lamella is reached and penetrated. The posterior ethmoid cells, located behind the basal lamella, are dissected medially between the middle and superior turbinates and laterally along the lamina papyracea. Once the skull base is identified posteriorly at the face of the sphenoid, the dissection continues superiorly from posterior to anterior, with septations removed as the dissection progresses forward. A 45-degree endoscope may be used when dissecting superior cells.

It is essential to identify any dehiscence in the lamina papyracea, locate the ethmoid artery, and ensure visualization of the skull base (either directly or via navigation, if available) before dissecting superiorly. Care should also be taken not to dissect medial to the superior attachment of the middle turbinate to avoid breaching the fovea ethmoidalis.

Sphenoidotomy

The sphenoid ostium can be accessed either transnasally, medial to the middle turbinate, or transethmoidally, lateral to the middle turbinate. When accessed transethmoidally, the sphenoid ostium is located in the inferomedial portion of the posterior ethmoid. Occasionally, the inferior part of the superior turbinate is removed to improve visualization of the sphenoethmoidal recess and the sphenoid ostium. The ostium is identified by gently guiding a probe along the face of the sphenoid; the probe will slide into the ostium upon reaching it. Once identified, the ostium is enlarged inferiorly with Kerrison rongeurs or curettes, and the sphenoidotomy is further widened with a powered debrider. If sphenoethmoidal cells are present, navigation should be used to locate these cells, their septations, the skull base, and nearby structures like the optic nerve and carotid artery, noting any dehiscence in these structures.

Frontal Sinusotomy

The frontal sinus is typically addressed last to prevent bleeding in the frontal recess area from obscuring visualization of posterior and inferior cells. Given its complex anatomy, navigation is especially beneficial for approaching the frontal recess. A 45- or 70-degree scope is used for better visualization. The posterior wall of the agger nasi cells, which obstructs the frontal sinus outflow, is carefully examined and relieved if necessary. The superior attachment of the uncinate process plays a key role: if attached to the middle turbinate, the frontal sinus drains into the infundibulum, necessitating removal of the superior part of the uncinate to access the frontal recess. A registered frontal probe aids in locating the frontal recess, and curved curettes and frontal giraffe instruments are used to remove septations, dissect frontal cells, and widen the frontal recess.

Throughout all steps, preserving the mucosa reduces the risk of postoperative scarring and osteogenesis. Maintaining the middle turbinate's vertical and horizontal attachments prevents destabilization, which could lead to lateralization, scarring, and sinus drainage obstruction. If destabilization occurs, options to prevent lateralization include removing the anterior turbinate portion, suturing the turbinate to the septum, or placing nasal packing in the middle meatus to keep it medially positioned.

At the conclusion of the procedure, any remaining bony septations are removed, and hemostasis is achieved. A dissolvable nasal pack may be placed in the middle meatus as a spacer.

Complications

The proximity of the sinuses to critical structures is a primary source of complications during endoscopic sinus surgery (ESS).

Orbital Injury

The maxillary and ethmoid sinuses border the orbit inferiorly and medially. During an uncinectomy, it is important to keep the dissection low and to identify and carefully medialize the uncinate process away from the orbital wall. In maxillary antrostomy, the ostium should be identified inferiorly, using the inferior orbital wall as a landmark. On CT scans, the lamina papyracea should be examined closely for any dehiscence that might lead to an orbital wall breach during ethmoidectomy. Identifying sphenoethmoidal cells, as well as checking for dehiscence of the optic nerve and carotid artery, is crucial. If a breach of the lamina papyracea occurs, resulting in bleeding, the periorbita should be inspected, and if orbital fat is exposed, ophthalmology should be consulted intraoperatively to measure intraocular pressure. If elevated, eye massage, mannitol administration, and IV dexamethasone may be performed. More aggressive intervention, such as canthotomy/cantholysis, is indicated if intraocular pressure exceeds 40 mmHg in an anesthetized patient or if an awake patient experiences retro-orbital pain, a cherry-red macula, or a Marcus-Gunn pupil. Once the canthotomy is performed, the bleeding vessel should be identified, and hemostasis achieved to prevent optic nerve compression and ischemia.

Skull-Base Injury and Cerebrospinal Fluid (CSF) Leaks

Preoperative CT is critical for assessing the slope of the skull base, sinus height, thickness, and any potential dehiscence. The length of the lateral lamella varies, with the Keros classification assessing depth and associated risk of injury:

- **Keros type I**: 1 to 3 mm deep
- **Keros type II**: 4 to 7 mm deep
- **Keros type III**: 8 to 16 mm deep

The risk of injury increases with deeper lamella (higher Keros type), with the cribriform plate and lateral lamella being common sites of injury. CSF leaks can occur intraoperatively or postoperatively. If a CSF leak is identified intraoperatively, the exact site should be located for immediate repair, as delays increase infection risk and hospital stay. For small defects (<2 mm), overlay autogenous mucosal grafts are used. Middle turbinate composite grafts are used for defects 2-6 mm, while defects over 6 mm require a multilayered reconstruction with cartilage or bone, sometimes with fibrin glue. Allogenic materials or vascularized flaps may be used based on defect size and location. Post-surgery, deep extubation minimizes Valsalva maneuvers and intracranial pressure, and a CT scan can rule out pneumocephalus and intracranial bleeding. A postoperative CSF leak is diagnosed using Beta transferrin, intrathecal fluorescein, and imaging.

Epistaxis

Mild bleeding for a few days postoperatively is typical, but severe bleeding requires intervention. Stabilizing the patient and securing the airway are essential in cases of significant bleeding. The source of bleeding is identified through nasal examination. Management options include topical vasoconstrictors, resorbable or non-resorbable packing, and cautery (silver nitrate or electrocautery). For severe, recurrent bleeding, surgical arterial ligation or endovascular embolization may be needed. Knowledge of nasal blood supply anatomy is essential, especially regarding the sphenopalatine artery, which enters the nasal cavity through the sphenopalatine foramen near the posterior end of the middle turbinate and can be ligated in cases of severe posterior epistaxis.

Disease Recurrence

In FESS for CRS, recurrence or persistence is a risk. Inadequate maxillary antrostomy or failure to sufficiently enlarge the natural ostium may cause mucus recirculation through the accessory ostium. Lateralization of the middle turbinates can block sinus drainage, while insufficient postoperative cleaning and management may result in synechiae formation, leading to nasal obstruction. Excessive mucosa removal, bone exposure, and failure to eliminate bony septations can also contribute to rhinosinusitis recurrence.

Clinical Significance

Functional endoscopic sinus surgery (FESS) is the most frequently performed procedure for managing chronic rhinosinusitis (CRS). With advancements in fine instrumentation and high-resolution imaging, rhinologists can now perform more detailed and comprehensive sinus dissections. However, successful FESS requires more than advanced tools and imaging. Rhinologists must have a thorough understanding of sinus anatomy and remain mindful of both minor and major complications. Safe surgery involves adhering to each step of FESS and identifying consistent anatomical landmarks at every stage of the procedure.

Enhancing Healthcare Team Outcomes

FESS continues to evolve with advancements in imaging, instrumentation, and navigation, offering enhanced resolution and more detailed visualization. These developments have expanded FESS applications into intracranial and oncological cases. The multidisciplinary team required for these procedures may include rhinologists, neurosurgeons, oncologists, endocrinologists, pulmonologists, ophthalmologists, and allergy specialists, depending on the pathology and its extent.

A careful, step-by-step technique guided by anatomical landmarks helps the surgeon avoid complications and ensures a safer procedure. For patients with CRS, the primary intraoperative goals are to restore sinus patency while preserving mucosa and to avoid injury to adjacent structures.

Postoperative care is just as crucial as the surgical technique for reducing the risk of CRS recurrence. Medical therapy often includes nasal rinsing, topical or oral corticosteroids, and antibiotics to mitigate inflammation and prevent recurrence. The role of postoperative debridement in decreasing the risk of disease recurrence and adhesion formation is still debated and typically depends on the surgeon's preference, the level of inflammation, and the extent of the surgery.

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