10 Endoscopic Nasal and Paranasal Sinus Surgery

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10.1 Introduction

The endoscopic sinus surgery (ESS) has greatly evolved over the past few decades. It was originally started with the attempt at nasal endoscopy in 1901 by Hirschman by using a modified cystoscope to assess the nasal cavity [1]. Following that, Reichert introduced a 7 mm endoscope through an oro-antral fistula, and this was regarded as the first endoscopic procedure [1]. Later on, in 1925, the term 'sinuscopy' was coined by Maltz. The turning point in nasoendoscopy was when Hopkins introduced the rod optic endoscope system together with the inventions of a fibre-optic gastroscope and zoom camera lens [1]. Subsequently, Messerklinger utilized this innovation and performed a cadaveric study on mucociliary clearance [1]. From his observation, the mucociliary clearance in the paranasal sinuses was draining towards their respective natural ostium. Then, Stammberger and Kennedy popularized the philosophy of widening the natural ostium of the diseased paranasal sinuses [2]. Following that onwards, with the advancement in the instrumentation and technological progress, the use of the endoscopic technique is extended to other procedures such as endoscopic dacryocystorhinostomy, orbital/optic nerve decompression, and anterior skull base surgery via transsphenoidal route.

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10.2 Surgical Anatomy

It is of utmost importance to thoroughly know and understand the surgical landmarks involved during the endoscopic sinus surgery for surgical planning to achieve complete clearance of the disease and to avoid complications. The nose is divided internally into two nasal cavities by the nasal septum. The nasal septum is composed of membranous, cartilaginous, and bony components as shown in Fig. 10.1 [3].

The membranous component consists of connective tissues located between the columella and the caudal part of the cartilaginous septum. The cartilaginous septum is comprised of septal cartilage or also known as quadrilateral cartilage. On the other hand, the bony septum is composed of superiorly the perpendicular plate of the ethmoid bone and inferiorly the vomer, crest of maxilla bone, and crest of palatine bone. The Little's area is located at the anterior part of the nasal septum and supplied by branches from the anterior ethmoid artery, sphenopalatine artery, greater palatine artery, and superior labial artery, which anastomose forming the Kiesselbach's plexus. This region is the commonest site of anterior epistaxis as it is very rich in capillary loops and

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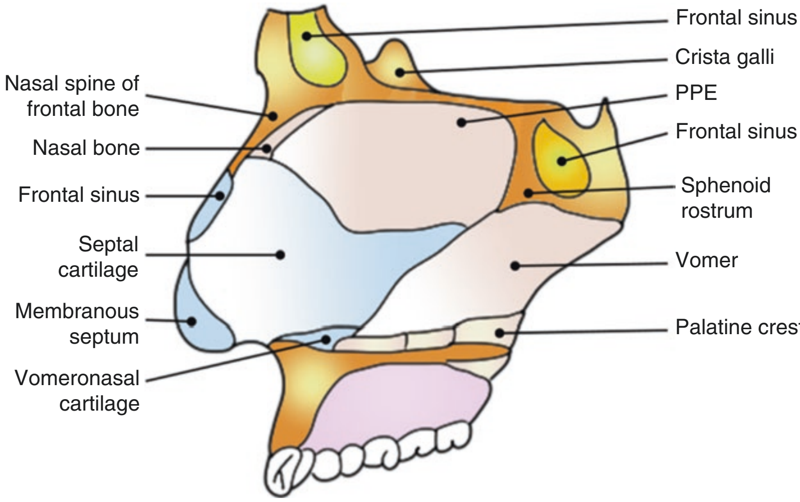

Fig. 10.1 Components of nasal septum

Fig. 10.2 Coronal view of the CT scan of the paranasal sinuses showed some degree of bony septal deviation to the right. The septal deviation in this case is not in contact with the mucosa of the structures in the lateral wall of the nose

susceptible to injury such as digital trauma. The nasal septum deviation may cause narrowing of the nasal airway passage leading to some degree of nasal blockage for the patient (Fig. 10.2).

Along the lateral nasal wall, there are 3–4 types of turbinates, namely inferior turbinate, middle turbinate, superior turbinate, and supreme turbinate occasionally. These turbinates play some role in the regulation of the inhaled nasal airflow, humidification, and filtration. The nasal passage inferior to each turbinate is called the meatus. The nasolacrimal duct drains into the inferior meatus via some mucosal folds named Hasner's valve, which is about 1 cm posterior to the caudal end of the inferior turbinate. The middle meatus is a complex region whereby it acts as a common drainage from the maxillary sinus, anterior ethmoid sinus, and frontal sinus. Meanwhile, the posterior ethmoid air cells drain into sphenoethmoidal recess of the superior meatus.

From anterior to posterior, there are a series of 4–5 bony partitions or lamellae separating the ethmoid sinuses, namely uncinate process (first lamella), bulla ethmoidalis (second lamella), ground or basal lamella of the middle turbinate (third lamella), superior turbinate (fourth lamella), and occasionally supreme turbinate (fifth lamella) [4]. The basal lamella of middle turbinate marks the division between anterior and posterior ethmoid sinuses. Posterior ethmoid air cells are fewer in number but larger in size compared to anterior ethmoid air cells. The uncinate process is a boomerang-shaped bone that runs from anterosuperior to posteroinferior direction. Superiorly, it can attach to the lamina papyracea (85% of cases), middle turbinate, or skull base (both account for 15% of cases). Interestingly, in more than 50% of cases, it has multiple

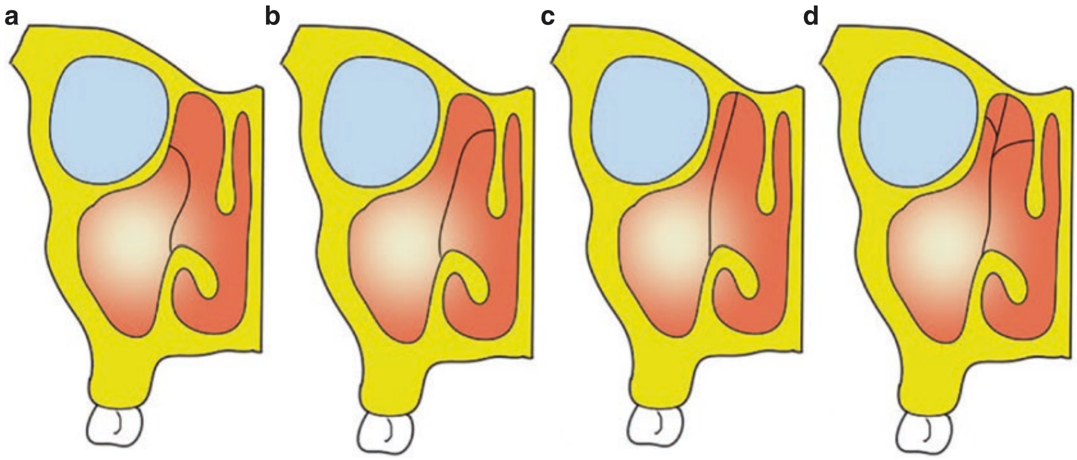

Fig. 10.3 Different attachment of uncinate process: (**a**) single attachment to lamina papyracea, (**b**) middle turbinate, (**c**) skull base, or (**d**) multiple attachment

attachments in the nasal cavity. Figure 10.3 shows different attachment of the uncinate process in the nasal cavity [3].

The uncinate process has a horizontal and a vertical component, whereby the latter is closely related to the frontal recess. When the uncinate process attaches to the lamina papyracea, the frontal recess will drain medially to the uncinate process into the middle meatus, and vice versa; if the uncinate process attaches to the middle turbinate or skull base, then the drainage pathway of the frontal recess will be lateral to the uncinate process, hence draining into the ethmoid infundibulum. The ethmoid infundibulum is a three-dimensional space located lateral to the uncinate process. Bulla ethmoidalis is the largest and the most prominent anterior ethmoid air cell on the lateral nasal wall. It is bounded anteriorly by the frontal recess and uncinate process, posteriorly by the basal lamella of the middle turbinate, medially by the lamina papyracea, and laterally by the middle turbinate.

The outflow tract of the frontal sinus resembles an hourglass appearance in the sagittal plane. The wider upper part of the hourglass (floor of the frontal sinus) drains into the wider lower part (frontal recess) via the narrowest segment in the middle (frontal ostium). Frontal recess is bounded anteriorly by the agger nasi cell, posteriorly by the bulla ethmoidalis and supra bulla air cells, laterally by lamina papyracea, and medially by the middle turbinate. Agger nasi cell is the most anterior ethmoid air cell. If it enlarges, it can encroach the frontal recess resulting in a narrower frontal recess drainage pathway. Besides that, the size of the drainage pathway of frontal recess is also determined by other cells. According to the International Frontal Sinus Anatomy Classification, there are three types of cells related to the frontal recess [5]:

1. Anterior cells (push the drainage pathway of frontal sinus medially, posteriorly, or posteromedially): agger nasi cell, supra agger cell, and supra agger frontal cell
2. Posterior cells (push the drainage pathway anteriorly): supra bulla cell, supra bulla frontal cell, supraorbital ethmoid cell
3. Medial cells (push the drainage pathway laterally): frontal septal cells

The maxillary sinus is bounded by orbital floor superiorly, alveolar process inferiorly, facial surface of the maxilla anteriorly, infratemporal fossa posteriorly, and lateral wall of nasal cavity medially. The infraorbital nerve runs in the roof of maxillary sinus to exit via infraorbital foramen at the anterior surface of maxilla. About 14% of cases have a dehiscent infraorbital canal, which may increase the risk of nerve injury intraoperatively [4]. The natural maxillary sinus ostium opens into the posterior third of the ethmoid infundibulum on the superior part of the medial wall of the maxillary sinus. On the other hand, the accessory sinus ostium can be found in either anterior or posterior nasal fontanelle. It is important to differentiate between the true and the accessory sinus ostium so that we can enlarge the true ostium and restore the drainage pathway of the maxillary sinus. Occasionally, the anterior ethmoid air cells can expand laterally into the maxillary sinus, known as infraorbital ethmoid cells or Haller cells.

Sphenoid sinus ostium can be found within 1 cm behind the posteroinferior end of the superior turbinate, and most of the time the sphenoid ostium (SO) is medial to it [6]. Besides that, the roof of the maxillary sinus can be used as a reference point when looking for the SO. A horizontal imaginary line is drawn at the level of the roof of the maxillary sinus to the nasal septum [7], and the SO is usually within 1 cm medial to the nasal septum [6]. Posterior choana can also be one of the landmarks for SO as the SO is located about 1.5 cm above the posterior choana. Sphenoid sinuses are surrounded by important neurovascular structures, namely internal carotid arteries (ICA), optic nerves, cavernous sinuses, and other nerves such as oculomotor, trochlear, maxillary, vidian, and abducens nerves. Bony canal dehiscence for ICA and optic nerve were found to be in approximately 25% and 6% of cases, respectively [8]. Onodi cells or sphenoethmoidal cells, which are located at the superolateral part of sphenoid sinuses, can also be seen occasionally.

10.3 Indications

The term 'functional' in functional endoscopic sinus surgery (FESS) refers to the restoration of the function of the sinonasal cavity, i.e. trying to preserve as much mucosa as possible. The most common indication for FESS is for chronic rhinosinusitis with or without polyp when maximal medical therapy has failed. The goals for this procedure are to remove the diseased sinonasal mucosa, allow adequate sinus drainage and ventilation, facilitate topical drug deliverance, and facilitate the surveillance of disease recurrence post-operatively.

Other indications include:

- Sphenopalatine artery ligation
- Orbital/optic nerve decompression
- Mucocele
- Invasive and non-invasive fungal rhinosinusitis
- Benign and malignant sinonasal tumour
- Cerebrospinal fluid leaks
- Lesions involving pituitary fossa, petrous apex, and pterygomaxillary fossa

10.4 Preoperative Evaluation and Surgical Preparation

Optimizing the surgical field in patients prior to endoscopic sinus surgery increases the chances for a safe and efficient surgery. Preoperative medical management, anaesthetic choice, patient positioning, and topical vasoconstrictors are methods currently used to mitigate cumbersome bleeding during surgery. Decreased bleeding improves the quality of the optical cavity, thereby enhancing visualization of nearby critical structures.

10.4.1 Patient Preparation

Before we proceed with endoscopic sinus surgery, one of the most crucial aspects that we need to deal with is stabilizing the patient's current medical condition. We need to optimize patient health, especially for those who had diabetes and hypertension. Early referral to physician for blood sugar monitoring and blood pressure control is mandatory.

The patient was also advised to stop smoking for at least 1 month before the surgery. A study on smoking habits in endoscopic sinus surgery found an association between exposure to cigarette smoke and potentially severe surgical site infections in the 30-day post-operative period after ESS [9].

All the blood-thinning products such as garlic and ginkgo biloba need to be stopped. Blood thinner medication such as aspirin also needs to be withheld before surgery.

10.4.2 Informed Consent

Informed consent is also another important issue that needs to be highlighted before we proceed with the surgery. A good, informed consent should include several important issues:

- Thorough explanation about the disease
- Indication for endoscopic sinus surgery
- Patient's expectation and surgeon's expectation
- The procedure itself in general
- Complication of the surgery
- Post-operative care

10.4.3 Preoperative Planning/Evaluation

Prior to the surgery, the nasal anatomy is re-evaluated, and any significant abnormalities are noted. It is helpful to repeat the nasal endoscopy to detect the presence of reactive nasal mucosa identified by marked congestion, sneezing, and hypersecretion during diagnostic endoscopy despite maximum medical therapy. In this situation, if the oedematous mucosa is not treated preoperatively, bleeding will be increased intraoperatively.

It is essential that the patient's CT scan be re-reviewed again prior to the surgery. Preoperative planning requires careful evaluation and conceptualization of the anatomy based upon the preoperative CT scan. This requires a systematic review of the CT scan so as to provide not only an understanding of the anatomy of the skull base and the medial wall of orbit, but also the surgeon's conceptualization of the frontal sinus drainage pathway and the relevant anatomy of the ethmoid pneumatization.

A checklist of anatomic landmark and variants should be reviewed (Table 10.1), including the presence of Onodi (sphenoethmoidal) cell and integrity of the ethmoid. The vertical height of the ethmoid sinus as well as the slope of the roof of the ethmoid should also be carefully assessed.

Table 10.1 Systematic CT scan review

		Yes/No
Patient ID	Is this the correct CT scan for the patient?	
Previous surgery	Has the patient had another sinus surgery before?	
Anterior ethmoid root	Slope, height	
	Keros classification	
	Anterior ethmoidal artery course	
	Any asymmetries	
Medial wall of orbit	Uncinate; superior attachment	
	Middle turbinate; attachment	
	Concha bullosa	
Posterior ethmoid	Vertical height	
	Dehiscence lamina papyracea	
Sphenoid sinus	Sphenoethmoidal cells	
	Pneumatization	
	Intersinus septa	
	Dehiscence carotid artery	
Frontal recess/sinus	Frontal sinus drainage pathway	
	Frontal cell	
	Agger nasi	

Failure to recognize a sloping pattern of skull base will end up the surgeon entering the cranial cavity.

When evaluating the frontal sinus for preparation of endoscopic frontal sinusotomy, the surgeon needs to conceptualize the frontal sinus drainage pathway and the adjacent cells as they will be encountered intraoperatively. Failure to do so will lead to a more disastrous problem postoperatively. It may be helpful if the surgeon can draw the drainage pathway in relation to middle turbinate, ethmoid bulla, agger nasi, supraorbital cells, and uncinate process. The presence of any septal deformity is important to be addressed also.

As the CT scan is reviewed, sphenoid skull base, bony optic and carotid canal, size and pneumatization pattern of the sphenoid sinus, integrity of the bony medial wall of orbit in case of dehiscence of lamina papyracea, and orbital apex should also be addressed. Careful attention is also paid to the position of anterior ethmoidal artery and veins as these may lead to torrential bleeding intraoperatively if not recognized prior to it.

It is best to view the CT scan in all planes, coronal images, sagittal images, and axial images. Even though most of these landmarks can be recognized on coronal images, the axial and sagittal images can provide important supplemental anatomic perspective. For example, axial images are best viewed for sphenoid ostium and sagittal images of the sphenoid can easily demonstrate Onodi cells.

MRI becomes important when there is opacification adjacent to the erosion of the skull base or when there is tumour. Besides that, presence of midline pulsatile mass seen during nasoendoscopy should warn the otorhinolaryngologists of the possibility of meningoencephalocele. MR allows the identification of meningoencephalocele and their differentiation from other tumours or inflammatory disease.

10.4.4 Preoperative Measure to Reduce Intraoperative Bleeding

10.4.4.1 Antibiotic

In patients with acute infection, reducing the inflammation with antibiotic will help to reduce intraoperative bleeding. However, in a case where there is no acute infection, the use of antibiotic preoperatively is controversial as it is considered as one of the regimes in maximal medical therapy for chronic rhinosinusitis. Most surgeons do not advocate starting antibiotic prior to the surgery. Usage of antibiotic usually depends on intraoperative findings of the patients [10].

10.4.4.2 Systemic Corticosteroid

The use of preoperative systemic corticosteroids in endoscopic sinus surgery (ESS) has been a topic of debate among otolaryngologists for many years now. Until recently, most of the evidence to support its use in ESS was largely anecdotal and based on expert opinion. In the presence of reactive mucosa or polyposis, the use of systemic corticosteroid preoperatively is controversial. Most of the surgeons prefer the usage of steroid during the initial part of therapy as one of the regimes in maximal medical therapy for CRS where the inflammatory loads are still not in control.

A systematic review and meta-analysis on the preoperative use of local and/or systemic corticosteroids in FESS concluded that it had significantly reduced blood loss, shortened operative time, and improved surgical field quality [11]. Studies are limited on the intraoperative use of corticosteroids to reduce post-operative pain. Post-operative corticosteroids improve post-operative endoscopic scores in CRS and recurrence rates in cases of CRSwNP. In their review on the usage of systemic steroid, Carlton and Chiu [12] had pointed out that there are known risks of administration of systemic corticosteroids, and clinicians must take these into account when evaluating an individual patient. In view of the adverse effect of systemic steroid, Harvey et al. (2018) suggested the usage of steroid irrigation post-operatively in the setting of diffuse or patchy CRS disease, compared to simple nasal spray in postsurgical patients [13].

10.4.4.3 Topical Decongestants

Usage of topical oxymetazoline has been advocated as one of the measures to reduce bleeding intraoperatively as it has also been a common practice among otolaryngologists. The justification is that alpha-receptor agonist can help to reduce bleeding during surgery if used before the operation. However, simple decongestants like oxymetazoline are not ideal for pre-op decongestion as these are partial, mainly alpha-1 agonist, and while they do have an effect in causing vasoconstriction on the arteriole side, they are less or not effective on the venous side. Furthermore, they are competitive agonists at the same receptors that adrenaline works at. So why use these partial agonists when they can only compete with adrenaline and diminish the effects of adrenaline, which is going to be part of our topical preparation and infiltration intraoperatively?

10.4.4.4 Adrenaline

It stimulates both alpha-1 and -2 receptors. Furthermore, the degree of vasoconstriction is dose dependent. Adrenaline can accurately achieve optimal local vasoconstriction while minimizing the systemic effects. Topical vasoconstriction of adrenaline via gauze or cotton pledges with a concentration of 1:1000 in children or 1:2000 in at-risk patients has been demonstrated to be safe [14].

10.4.4.5 Moffett's Solution

In our centre, we advocate the use of Moffett's solution as topical decongestion and local anaesthetic prior to endoscopic sinus surgery. It is a combination of cocaine, adrenaline, bicarbonate, and 0.9% sodium chloride, which was first described by Major A.J. Moffett of the Royal Army Medical Corps in 1941 [15]. The combination of cocaine and adrenaline synergistically acts on both alpha-1 and alpha-2 adrenoreceptors in nasal vasculature. When applied topically to the nasal mucosa, it produces profound vasoconstriction and anaesthesia, reducing blood loss and improving visualization in the operative field for sinonasal surgery [16]. The solution consists of a mixture of 2 mL of 10% cocaine solution (200 mg), 1 mL of 1:1000 adrenaline, 2 mL of sodium bicarbonate, and 5 mL of 0.9% sodium chloride solution, 10 mL in total with 5 mL applied to each side.

10.4.5 Anaesthesia

Endoscopic sinus surgery can be performed satisfactorily under either local anaesthesia with sedation or general anaesthesia. With the advancement in anaesthetic drugs, less blood loss was encountered in endoscopic sinus surgery. Hypotensive anaesthesia has been used to reduce bleeding intraoperatively. The mean arterial pressure (MAP) is aimed to be in between 50 and 70 mmHg. To have a good surgical field in endoscopic sinus surgery, it usually relies on good vasoconstriction and good clotting mechanism. This is when the term hypotensive anaesthesia is coined. Neither vessel ligation nor extensive diathermy is needed once a clear surgical field is achieved.

Surgical field improves with bradycardia anaesthesia [17]. With this finding, bradycardia anaesthesia is achieved by using total intravenous anaesthesia (TIVA) with either propofol or remifentanil. Meta-analysis study on total intravenous anaesthesia (TIVA) vs. inhalational anaesthesia indicates that TIVA has the potential to confer superior surgical field visibility and reduce intraoperative blood loss compared to inhalational anaesthesia in ESS [18]. TIVA has been demonstrated to be associated with less blood from prior inhalational agents [19].

10.4.6 Positioning of Patient

The reverse Trendelenburg position (RTP), a head-up, feet-down tilt varying from 10° to 30°, is also commonly used during ESS [20]. The RTP reduces venous return and cardiac output by retaining blood in the lower parts of the body. The 15° RTP improves the endoscopic field of view and reduces blood loss during ESS [21].

10.4.7 Image-Guided System (IGS)

Image-guided systems (IGS) have gained widespread use in endoscopic sinus surgery (ESS) and have been thoroughly analysed. The use of IGS in ESS and anterior skull base surgery is predicated on the notion that its ability to aid in anatomic identification during surgery will lead to fewer complications and improved surgical outcomes. Based on the best available evidence in the literature, the use of IGS has not clearly been shown to decrease surgical complications or improve surgical outcomes [22].

Level 2A evidence from systematic reviews suggests that in certain cases IGS may be associated with decreased major and total surgical complications, though the potential for bias and confounding exists in these conclusions. The choice to use IGS in any endoscopic procedure remains best determined by the operating surgeon based on factors including case complexity and surgeon comfort [23].

10.5 Operative Techniques

10.5.1 Endoscopic Sinus Surgery

After topical decongestion with Moffett's solution, by using a 0° Hopkins telescope, a local infiltration with Scandonest 2% (adrenaline 0.001% and mepivacaine HCl 2%) is placed at the body and axilla of the middle turbinates, and lateral wall of the nasal cavity as shown in Fig. 10.4. Then, the middle turbinate is 'relaxed' by gently medializing it with utmost precaution to avoid injury to the lateral lamella of the cribriform plate (Fig. 10.5). In a case of a bulky concha bullosa or paradoxical middle turbinate, surgical access is widened by resection of the lateral part of the middle turbinate. Again, care is to be taken to have a clean sharp cutting edge and avoid unnecessary mucosal injury surrounding this area to prevent synechia formation (Fig. 10.6).

10.5.1.1 Uncinectomy

The free edge of the uncinate process is identified and probed in an upward-downward direction and teased out anteromedially. There are two approaches for uncinectomy: antegrade and retrograde approach. We prefer to use a retrograde approach as the antegrade approach may increase

Fig. 10.4 Positioning of patient in reverse Trendelenburg position

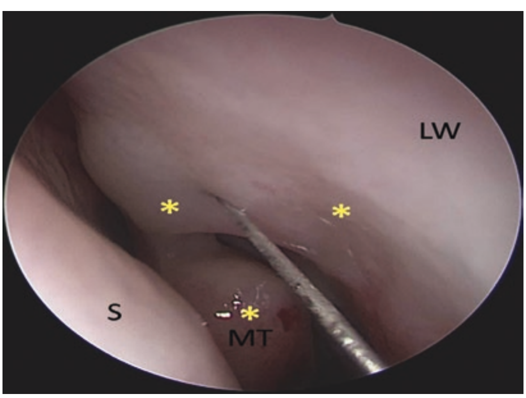

Fig. 10.5 Injection sites for the local anaesthesia (*marked with asterisks* *). Axilla and body of left middle turbinate (MT), lateral wall of nasal cavity (LW). Septum, S

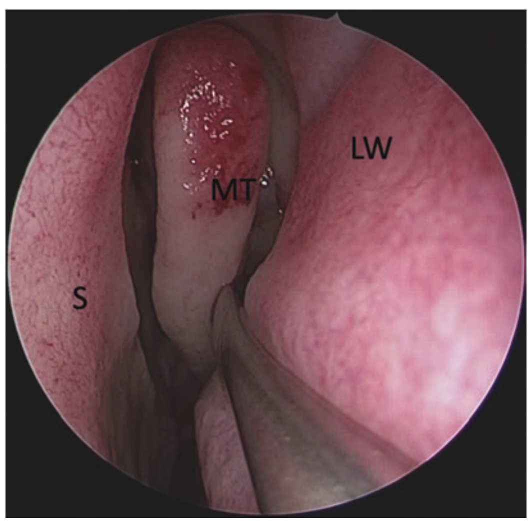

Fig. 10.6 Relaxation of the left middle turbinate (MT) by gently medializing it from inferoposterior to inferomedial direction. Septum (S) and Lateral wall (LW) of the nasal cavity

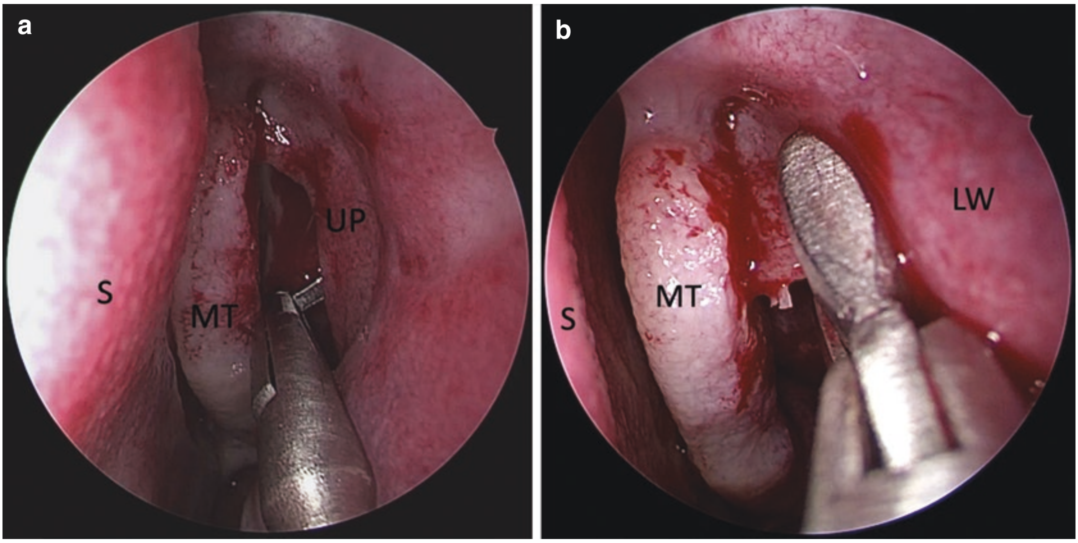

Fig. 10.7 Left uncinate process (UP) was removed by using (**a**) a backbiting forceps and (**b**) an upturned through-cutting Blakesley forceps. Septum, S; middle turbinate, MT; and lateral wall of nasal cavity, LW

the risk of penetrating the lacrimal sac or breaching lamina papyracea, especially in the case of an atelectatic uncinate process, hence injuring the orbit. By using a retrograde approach, both vertical and horizontal parts of the uncinate process are removed by cutting with a backbiting forceps at the middle of the vertical component of the uncinate process, whereby usually 2–3 bites are needed (Fig. 10.7). Then the rest of the uncinate process can be removed with the backbiter forceps angled 45° cutting in upwards direction or using an upturned through-cutting Blakesley forceps or a microdebrider to trim it.

10.5.1.2 Middle Meatal Antrostomy (MMA)

The true maxillary sinus ostium is usually visualized after uncinectomy. Sometimes, mucus or mucopus discharge with some debris can be seen flowing out of the sinus ostium when the medial wall of the maxillary sinus is pressed. It can also be identified by using a right-angled ball-tipped probe, curved curette, or sinus suction tube. Then the posterior fontanelle is removed with a straight Blakesley forceps and a backbiting forceps as shown in Fig. 10.8. The MMA can also be performed by using a microdebrider. If a Haller cell is encountered, the inferomedial part of the Haller cell is removed first and the dissection continued until the surgeon can engage where the posterior wall and roof of the maxillary sinus are. Careful dissection is necessary to avoid injury to the orbit. Palpation of the eye globe helps to guide

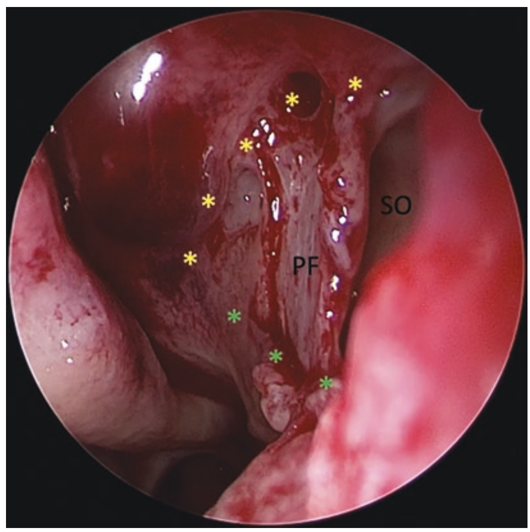

Fig. 10.8 Left middle meatal antrostomy performed by removing the posterior fontanelle (PF), using a straight Blakesley forceps in a backward direction (along the yellow asterisks) and a backbiting forceps in a forward direction (along the green asterisks). True left maxillary sinus ostium (SO)

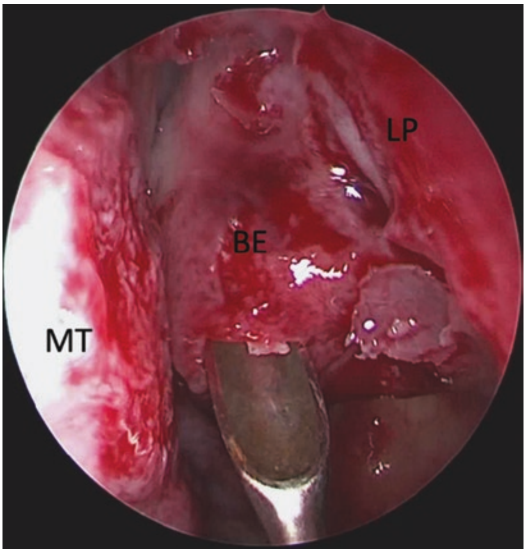

Fig. 10.9 Left bulla ethmoidalis (BE) was opened with a straight curette at the inferomedial part of the bulla. *MT* middle turbinate, *LP* lamina papyracea

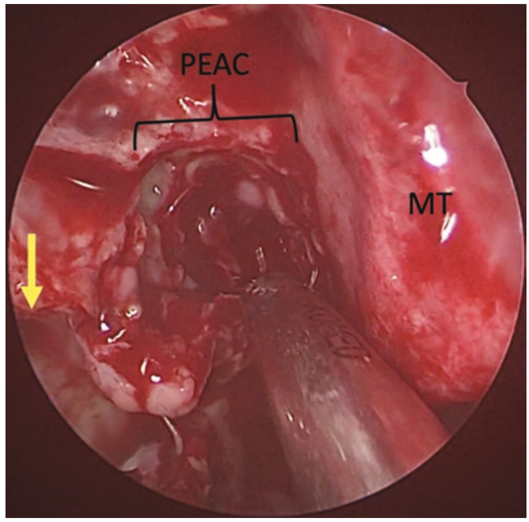

Fig. 10.10 After penetrating the basal lamella of right middle turbinate (MT), posterior ethmoidectomy was performed by using a microdebrider. *PEAC* posterior ethmoid air cells. The roof of right maxillary sinus is shown by the *yellow arrow*

the surgeon if the lamina papyracea has been breached.

10.5.1.3 Ethmoidal Bullectomy

The bulla ethmoidalis is identified, and a straight curette is used to open the inferomedial part of the bulla as seen in Fig. 10.9. Then the rest of the bulla is removed by using a straight through-cutting Blakesley forceps and a microdebrider. In a case of anterior ESS or mini-ESS, uncinectomy and opening of the anterior face of the bulla are done with retention of 3–4 mm mucosa from the edge of the anterior and inferior part of the bulla [5]. If proceeding to posterior ethmoidectomy, all the anterior wall of the bulla is removed to gain better access.

10.5.1.4 Posterior Ethmoidectomy

After uncapping the bulla, the posterior ethmoid sinus region is entered by opening up the basal lamella of the middle turbinate with a straight curette, ball probe, or straight Blakesley forceps at its inferior and medial part, at the same level with the roof of the maxillary sinus. Then the posterior ethmoid air cells are removed with a straight through-cutting Blakesley forceps, a straight curette, or a microdebrider (Fig. 10.10). Keep in mind that the base of the skull runs in a downward sloping fashion as it goes more posteriorly. The base of the skull is also recognized by its pale ivory-coloured mucosa.

10.5.1.5 Sphenoidotomy

During the posterior ethmoidectomy, landmarks of the sphenoid sinus ostium are identified, i.e. the superior turbinate, the roof of maxillary sinus, and the posterior choana, which have been discussed earlier in the 'surgical anatomy section'. The sphenoid sinus ostium can be identified by either transnasal or transethmoid approach. In a transethmoid approach, once the basal lamella is breached, the superior turbinate is identified. The sphenoid ostium is more clearly visualized when one-third up to half of the inferior part of the superior turbinate is removed with a straight through-cutting Blakesley forceps or microdebrider (Fig. 10.11). It is most of the time medial to the superior turbinate. The ostium can be enlarged adequately by removing part of the anterior face of the sphenoid sinus with a Kerrison punch or microdebrider. The maximum border for removal of the anterior face of the sphenoid will be the base of the skull superiorly, the floor

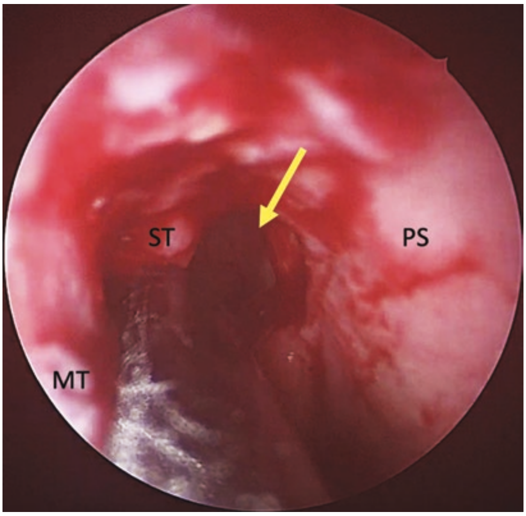

Fig. 10.11 Right sphenoid sinus ostium is shown by the yellow arrow. The right superior turbinate (ST) was trimmed with a microdebrider. Posterior nasal septum, PS and right middle turbinate, MT

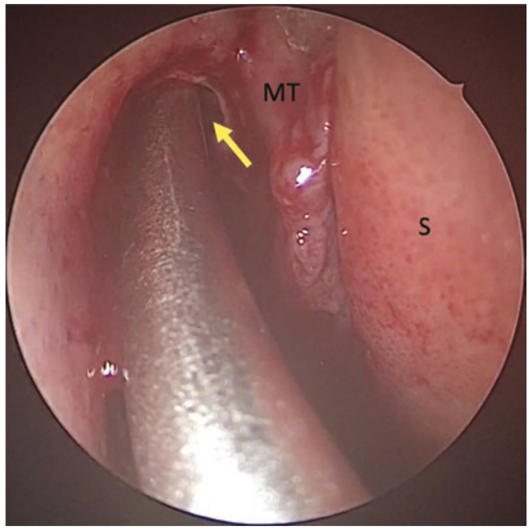

Fig. 10.12 A long curved sinus suction tube was inserted into the right frontal recess as shown by the *yellow arrow*. Right polypoidal middle turbinate, MT, and septum, S

of the sphenoid sinus inferiorly, the posterior part of the nasal septum medially, and the lamina papyracea laterally. Important neurovascular structures such as internal carotid artery and optic nerve should be kept in mind during the dissection, especially when Onodi cell is encountered. The optic nerve may lie freely within the Onodi cell; hence, extra precaution is needed.

10.5.1.6 Frontal Sinusotomy

The frontal sinus is usually addressed last due to its complex anatomy, and that bleeding from the frontal sinus work may drip down obscuring the surgical field when working more posteriorly. A 45° or 70° Hopkins telescope can be used for a better visualization during the dissection. The frontal recess can be identified by probing with a frontal seeker or sinus suction tube (Fig. 10.12).

The cells obstructing the frontal sinus outflow should be studied thoroughly preoperatively and removed carefully. A navigation system with a registered frontal probe will be helpful in this frontal sinus work. The obstructed cells can be removed using a curved curette, Stammberger upward-cutting forceps, or frontal giraffe forceps to widen the frontal recess. Endonasal frontal sinusotomy can be classified into Draf I–III (Table 10.2).

Table 10.2 Types of frontal sinusotomy according to Draf [24]

Type	Extent of surgery
I	Anterior ethmoidectomy with drainage of the frontal recess without touching the frontal sinus outflow tract
IIa	Removal of ethmoid cells protruding into the frontal sinus, creating an opening between the middle turbinate medially and lamina papyracea laterally
IIb	Removal of the floor of frontal sinus between the nasal septum medially and lamina papyracea laterally
III	Bilateral Draf type II drainage with removal of the superior part of nasal septum and lower part of intersinus septum

The Draf type I is achieved by clearing the anterior ethmoid cells without manipulation of frontal sinus outflow. The Draf IIa–b are usually performed in case of mucocoele or complication of acute rhinosinusitis. Endoscopic modified Lothrop procedure or Draf III is commonly reserved for revision cases or resection of anterior skull base tumours [24].

Endoscopic sinus surgery has come a long way since its maiden application in the late 1800s. It was first introduced as a procedure to be applied to organs 'down-south' examining the urinary tract and the bladder. That was the first time the word *endoscope* was used. Nowadays, endoscopic sinus surgery (ESS) is almost synonymous with rhinology as more surgeons are adapting well with ESS in their practice. The technique in ESS is fine-tuned as time progresses, where surgeons learn and modify steps in ESS to improve the outcome. The number of otorhinolaryngology head and neck surgery (ORL-HNS) surgeons has increased as well as the number of ESS procedures. With that said, one must consider the learning curve of these surgeons in expecting the possibility of ESS complications.

Like all surgical procedures, the risk and possibility of complications will have to be addressed. Besides the importance of explaining before surgery the indications and the basic steps of the ESS to the patient, the risk and complications must also be explained in detail so that patients will understand and be aware of all the issues before the surgery. Equally important is that the surgeon himself/herself must understand the risk and complication thoroughly if not more than the patient must as well as how to avoid and solve if one encounters such complications. Complications in ESS can be categorized into minor and major complications, by location, procedure, and timing of the procedure, i.e. intraoperative vs. post-operative. Recognising and anticipating complications is as important as preventing and managing them. Below are the complications and suggestions on how to manage them.

10.6 Intraoperative Complication

Intraoperative complications during ESS can be further divided into intranasal, intraorbital, and intracranial.

10.6.1 Intranasal Complications

10.6.1.1 Haemorrhage from Mucosa

The nasal airway is a vascular area, with its main supply coming from two main arteries, which are the internal and the external carotid arteries (ICA and ECA). The ICA branches into the ophthalmic artery, which then supplies the anterior and the posterior ethmoid arteries. The branches of ECA, i.e. the facial and the internal maxillary arteries, supply the rest of the nasal airway.

Bleeding from the mucosal surface of the nasal airway while doing ESS is sometimes unavoidable but only to be considered cumbersome when it hinders the view in ESS. According to Rem et al. (2011), about 0.8% and 5% of the minor bleeding were perioperative and post-operative haemorrhages, respectively [25]. It can be localized or diffuse. The bleeding can be procedure, surgical, or patient related. It usually occurs in circumstances such as the following:

1. Multiple or inappropriate instruments used in ESS which when in contact with the surrounding structure will cause injury and bleeding.
2. Inflamed mucosa in active diseases such as chronic rhinosinusitis with or without nasal polyposis: Therefore, the pre- and intraoperative preparation is important to avoid diffuse mucosal bleeding [26, 27].

Statistics

1. Epistaxis requiring intervention is 0.6–1.6%, whereas major haemorrhage that requires transfusion is 0.76% [28, 29].
2. Endoscopic sinus surgery is affected by diffuse bleeding in about 5% of cases, and about 1.4% of the procedures are cancelled [27, 30].
3. Two percentage of bleeding complications occur during and post operation, and only 0.2% of cases need transfusion [31, 32].
4. Post-operative haemorrhage following endoscopic nasal sinus surgery occurs in 2.7% of patients [33].

Prevention

Preoperative measures

1. Preoperative systemic steroid (e.g. 30–60 mg/day prednisone for 7–14 days before surgery) can reduce bleeding, therefore reducing the duration of surgery.
2. Position the patient in a reverse Trendelenburg, i.e. lifting the head and the upper part of the patient's body for about 10–20° can be successful in reducing intraoperative bleeding [34, 35].

Prevention
Intraoperative measures
1. Appropriate instruments for each procedure, i.e. sharp through-cutting forceps for thin bony removal and sharp soft-tissue cutting (Blakesley forceps) to remove or mobilize polyps or tissue. Polyps or tissue should be cut not pulled when using the tissue-cutting forceps, to avoid excessive mucosal bleed [36].
2. When inserting a sharp instrument, it is advisable that the scope follows the instrument. The instrument should be in front of the scope so that you can see the instrument as it is manoeuvred through the nasal cavity. This way you avoid injury to the surrounding mucosa and thus unnecessary bleeding.
3. Study has shown that local injection of vasoconstrictors, i.e. epinephrine, has no significant benefit over topical vasoconstrictors [37]. However, Fokkens et al. reported that preoperative injections of local anaesthetic (1:80,000 adrenaline) and vasoconstrictor into the greater palatine canal effectively reduce intraoperative bleeding in ESS [34]. Topical vasoconstrictors suggested include the following:
(a) 1:2000 adrenaline has been shown to have better haemostatic effect over much lower concentrations [34]. The risk of optic nerve damage and blindness after the application of local adrenaline has been reported in 0.05% [38].
(b) Oxymetazoline 0.05% or epinephrine 1:2000 may be used for children [39].
4. EPOS 2020 concluded that there is a level I evidence that the usage of propofol in achieving hypotension improved surgical field, but it is less superior when compared to the usage of alpha-2-adrenergic agonists. Fokkens et al. show that total intravenous anaesthetic (TIVA) is more superior to inhalation anaesthetic (IA) in reducing blood loss, hence improving the surgical field [34]. The recommended pulse rate is 60 min^{-1} [40].
5. Using warm saline of up to 50 °C to irrigate the surgical area has significantly reduced blood loss and duration of surgery, therefore enhancing the visibility of the surgical site and improving the outcome of functional endoscopic sinus surgery and septorhinoplasty [41]. Irrigating with hot saline improves the view of the surgical field in FESS after 2 h of operating time [42]. Solares et al. showed that rinsing the surgical field with 40 °C water is also helpful [26].
6. The use of tranexamic acid: Kim et al. showed that the operative time and the intraoperative time were statistically lower in the tranexamic group, and it shows no significant effect on thrombotic events compared to placebo [43]. Similar findings by El Shah et al. were shown when intravenous tranexamic acid was given to the patient [44]. The suggested dosage is IV tranexamic acid 10 mg/kg diluted in 100 mL saline administered during 10-min infusion [44, 45].

10.6.1.2 Arterial Injury

The arteries that are commonly dreaded in ESS are the sphenoidal artery and its branches, the anterior ethmoidal artery, and finally the internal carotid artery.

10.6.1.2.1 Sphenopalatine Artery

The commonly injured artery would be the sphenoidal artery at its branches. It emerges from the sphenopalatine foramen, which is identified by elevating a mucoperiosteal flap and identifying the crista ethmoidalis, at the posterior aspect of the middle meatus within the superior meatus [46]. It branches into posterior septal branch (PS) supplying the anterior wall of the sphenoid sinus and the septum, and to the lateral wall via posterior lateral nasal branch (PLN) [47] (Figs. 10.13 and 10.14, Table 10.3).

Prevention
• Identify the bleeding source and secure it via cauterization and surgical clip. Rarely, extension is done laterally at the posterior wall of the maxillary sinus if the SPA is retracted laterally.

10.6.1.2.2 Anterior Ethmoidal Artery (AEA)

Besides causing significant bleeding during surgery, a complete transection of the AEA may result in retraction of the lateral stump end into the orbit causing orbital haematoma, which is a major complication.

The anterior ethmoidal artery (AEA) is supplied by the ophthalmic artery, which is the branch of the

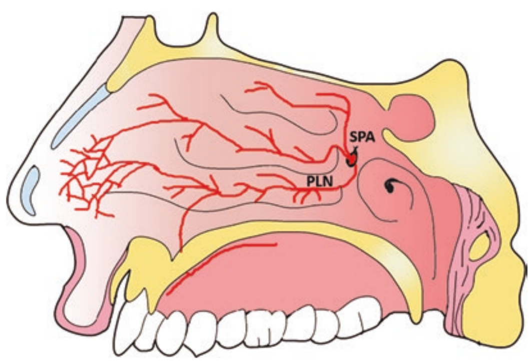

Fig. 10.13 Illustration showing the posterior lateral nasal wall and the branches of the sphenopalatine artery (SPA). *PLN* posterior lateral nasal branch

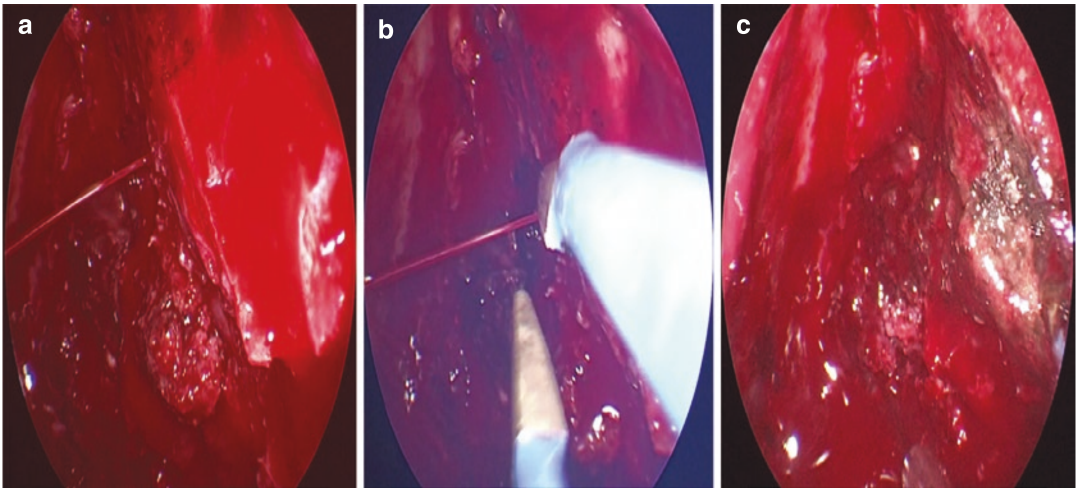

Fig. 10.14 Bipolar cauterization of a bleeding sphenoid artery (SPA). (**a**) Bleeding (sputter) from sphenoid artery. (**b**) Bipolar cauterization used to stop the SPA bleed. (**c**) Charred area post cauterization

Table 10.3 Procedures that may injure the SPA and its branches

Branches	Procedure
PLN	Bleeding due to aggressive debridement of the posterior Fontanelle during posterior extension of the medial maxillary antrostomy
PS	In transnasal sphenoidal approach, i.e. pituitary surgery. Widening of the sphenoid ostium inferiorly will cause bleeding from the PS branch of the SPA
Branches of SPA at the SPF	Several ostia may be present at the SPF 13% [48]. Bleeding may occur while locating the SPF due to the branches that emerge from extra ostia

internal carotid artery. From the orbit, it traverses medially through the lamina papyracea and enters the anterior ethmoid sinus. The artery may be identified endoscopically running along the skull base, i.e. the roof of the ethmoidal sinuses, just posterior to the anterior face of the bulla ethmoidalis. It then pierces through the lateral wall of the olfactory recess. In-between its lateral entrance and medial exit is the area of vulnerability for AEA.

Floreani et al., in their cadaveric studies, showed that 20% of AEA that runs in a bony mesentery was able to be clipped effectively [49]. Another important anatomy feature of AEA is that the blood flow through the anterior ethmoid artery comes from a posterolateral to an antero-medial direction, at 60° angle [35] (Fig. 10.15).

In the majority of cases, the AEA can be adequately cauterized using endoscopic bipolar instruments, thus avoiding transmitting the electrical current to the skull base and orbit.

Prevention
1. Preoperative imaging Identification of the position of the AEA through imaging is important to determine if AEA is ‘hanging’ in the ethmoid roof or within the bony mesentery. AEA can be best seen as a pinch or ‘nipple’ between the medial rectus and superior oblique muscles in the coronal view of the computed tomography (CT) scan (Fig. 10.16). 2. Instrument precaution Always have in view whatever you want to cut. Usage of powered instrument, i.e. microdebrider, must be with extra precaution. Once unsure, gentle usage of upturned tissue-cutting forceps is advisable.

10.6.1.2.3 Posterior Ethmoidal Artery (PEA)

The posterior ethmoidal artery is a branch of the ophthalmic artery and runs symmetrical, and it is much smaller than the AEA. The bone overlying it, in most cases, is approximately 60% dehiscence. PEA is most commonly injured during sphenoid sinus surgery or during posterior ethmoidectomy [40]. If bleeding occurs due to injury to the PEA, a bipolar cautery is a preferable measure to control the bleeding, thus avoiding transmitting of the electrical current to the

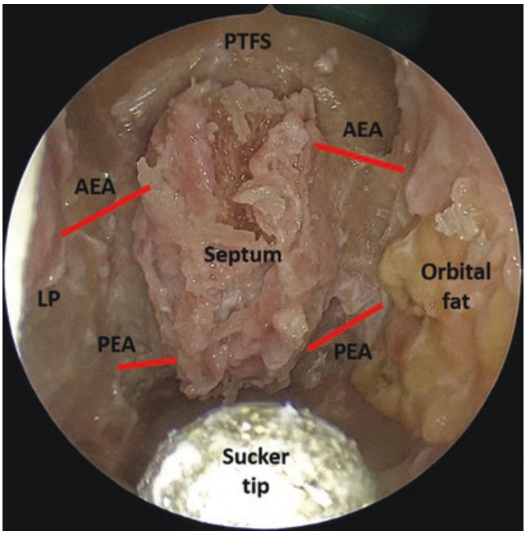

Fig. 10.15 Cadaveric dissection illustrating the anatomy of the anterior skull base following partial resection of both middle turbinates and nasal septum. The lateral margins are the lamina papyracea (LP). *AEA* anterior ethmoidal artery which runs from posterolateral to anteromedial, *PEA* posterior ethmoidal artery (*red line*)

Fig. 10.16 Anterior ethmoidal artery exiting the orbit into the nasal cavity: 'nipple sign'

skull base and orbit when using a monopolar cautery.

10.6.1.2.4 Internal Carotid Artery (ICA)

The injury to the ICA is very rare, and the exact incidence of the injuries in ESS is unknown.

Fig. 10.17 CT scan coronal section showing the carotid artery relation to the lateral wall

Dalziel (2006) reported that 0.3% of ICA injuries occurred in ESS of diffuse CRS cases and 1% in pituitary surgery [32, 50]. Hosemann et al. showed that approximately 0.3–0.9% of ICA injuries occurred in sinoneurosurgical procedures with a mortality rate of 17% [40].

The ICA can be seen indented on the lateral wall of the sphenoid sinus and is reported to be dehiscent in 75% of cases. Welch et al. also reported that 1% of intersinus (sphenoid) septum is inserted at the bone overlying the ICA [51]. Therefore, it is of utmost importance, especially for the beginners, to take extra precautions when removing the intersinus septum so that it will not break at the lateral attachment. A through-cutting bone forceps may be used to remove the bone, and try not to twist or rotate the intersinus septum so that the bone segment will not pierce the ICA. Staying medially and inferiorly is the best option, so as to avoid going too laterally in the sphenoid sinus, thus increasing the risk of penetrating the ICA (Fig. 10.17).

Powered drills should be used with precautions, but if one is unsure do resort to using through-cutting forceps.

If one is unfortunate enough to have injured the ICA, a summary of recommended steps should be followed (Fig. 10.18).

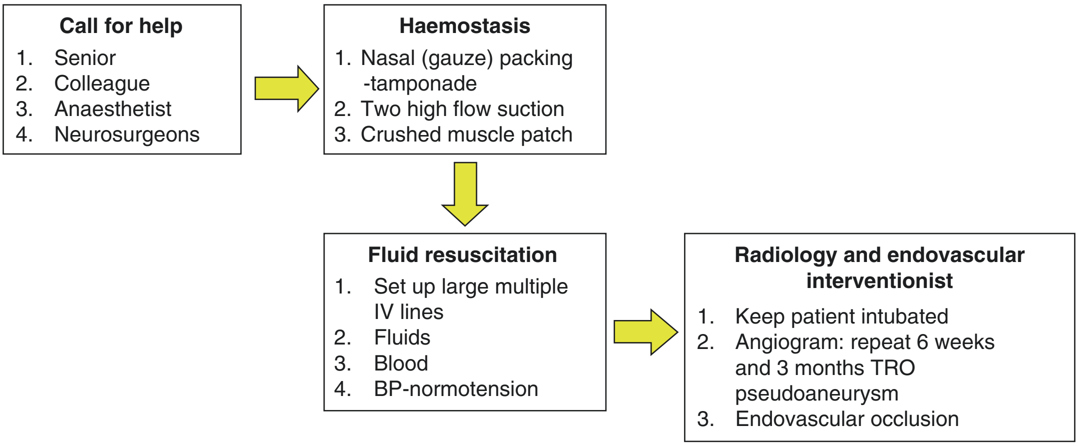

Fig. 10.18 Summary of management of ICA injury

The steps include the following:

Call for Help

Here, *too many cooks spoil the broth* does not apply. The presence of a senior surgeon or a second set of hands will help in overcoming the complication. The assistance from the anaesthetist is vital in resuscitating the patient by keeping the blood pressure under control, i.e. the systolic pressure, thus maintaining a sufficient cerebral blood flow from the contralateral ICA. Give a heads-up to the neurosurgeons and the interventional radiologist about the case, where the latter will assess the location and the extent of the vascular injury.

Secure the Bleeding

The surgeon needs to immediately halt the bleeding with nasal and pharyngeal packing, i.e. with gauze [52]. The idea here is not to panic; thigh packing in a calmly and orderly fashion will ensure that the gauze counts are correct and the location of packing is precise. Multiple IV lines should be established as well as several suctions should be prepared. Initiation of an aggressive fluid resuscitation and emergency blood transfusion should begin to help maintain cerebral perfusion.

Having said that, a tight packing may cause stenosis, partial occlusion or even complete occlusion of the affected ICA [53]. Examples of packing agents [54–56] that have been suggested and discussed in the literature include:

1. Teflon (Medox Medical, Oakland, NJ) and methyl methacrylate patch
2. Fibrin glue
3. Gelfoam (Pfizer, New York City, NY)
4. Oxidized cellulose packing thrombin-gelatin matrix
5. Oxygel
6. Glue and muslin gauze

In 2011, Valentine et al. compared the haemostatic and biocompatible haemostats' efficacy in an animal model of carotid bleeding using various absorbables such as oxidized cellulose, thrombin-gelatin matrix, and a crushed muscle patch and concluded that crushed muscle succeeded in gaining the optimum haemostasis regardless of the type of vascular injury, i.e. linear, stellate, or punch injuries. The long-term complications of crushed muscle patch also maintain the patency of the vessels with low risk of pseudoaneurysm [55].

Muscles that can be harvested are [52, 57–59]:

(a) Quadriceps muscle
(b) Sternocleidomastoid muscle
(c) Thigh muscle
(d) Temporalis muscle
(e) Nasopharyngeal muscle-longus capitis muscle

The suggested measurement for the muscle is about 1.5 by 1.5 cm. It should be crushed, usually between two metal kidney dishes [52]. Two surgeons with a four-hand technique would be preferable. While the second surgeon is diverting the bleeding using a high-flow sucker, the main surgeon with a much clearer surgical field and using some forceps, i.e. Blakesley, will gently place the crushed muscle directly on the bleeding site and maintain pressure on the patch for 5–10 min. Neurosurgical patties may be applied onto the muscle patch, while the Blakesley forceps can be slowly lessened. Once the bleeding subsides, the patties may be removed and replaced with a few squares of Surgicel (Ethicon Inc., Somerville, NJ, USA), which is placed over the patch [52]. A pedicle septal flap may also be used. The flap is rotated to cover the muscle patch. This is then glued into place and covered with Gelfoam and a pack, i.e. Merocel or ribbon gauze, which is placed over the flap to allow a continuous pressure to be applied to the flap and muscle patch. The pack is then removed under general anaesthesia 5–7 days later [52].

Interventional Radiologist/Endovascular

An angiogram is then performed to reconfirm the location and to ensure that the bleeding is secured. In a situation where the bleeding is not controlled, endovascular intervention is required, and the vessel can be either stented or coiled. The angiogram should be repeated at 6 weeks and 3 months to ensure that no pseudoaneurysm has formed [35].

10.6.1.3 Injury to Surrounding Structures

The mucosa of the nasal airway is very vascular. The vascularity is very important to humidify the respiratory air coming in and out. Injury to the nasal mucosa is usually due to the instruments introduced through the narrow space. Besides bleeding to the mucosa, the structure could be injured. The injuries can be divided according to the location. Below are the injuries according to the location and measures to prevent the injuries (Table 10.4).

10.6.2 Intraorbital Complications

Intraorbital complications in ESS are rare. The complications may occur due to the proximity of the paranasal sinuses to the orbit and its contents. The majority of orbital complications are minor ranging from 0.5% to 5%, mostly during maxillary antrostomy or ethmoidectomy [60, 61]. Only less than 0.3% causes permanent disabilities. Examples of factors that may contribute to the complications are disease extension, changes from previous endoscopic surgery, and coexisting medical comorbid and certain medications such as anticoagulant treatment.

Siedek et al. classified ophthalmic complications into [62]

1. **Grade I**: Minor, e.g. injury to the lamina papyracea
2. **Grade II**: Major, e.g. injury to the lacrimal duct
3. **Grade III**: Serious, e.g. retroorbital haemorrhage, injury to the optic nerve or any reduction of vision or blindness, and injury of orbital muscle

10.6.2.1 Breach of the Lamina Papyracea and Orbital Fat Injury (Grade I)

The lamina papyracea is usually breached through the medial orbital wall during ESS, i.e. during ethmoidectomy, maxillary antrostomy, or uncinectomy (anterograde more likely than retrograde uncinectomy) [63]. The recognition of this area and a cautious approach are pivotal in avoiding any permanent sequelae [38, 61, 64]. Therefore, it is routine to ask the assistants to palpate the globe while operating in the area, to see any movement [40]. Once you see orbital fat (confirm by floating test in water-filled gallipot), manipulation of the fat should be avoided to prevent further injury. Furthermore, powered instruments should be avoided as well as rigorous suctioning. Regular assessment of the eye during and post-surgery should be done to ensure no intraorbital haematoma. A nasal packing should be avoided in such cases; rather, a silicon sheet can be placed temporarily on the area of the

Table 10.4 Procedure, types of injuries, and preventive measures

Procedure	Location and injury	Prevention
Uncinectomy	1. Middle turbinate (MT) (a) Laceration (b) Fracture the attachment of the MT 2. Lacrimal duct injuries	1. Use appropriate instrument. Avoid multiple instruments. Gentle medialization of MT at the inferior and anterior edge of the MT, thus avoiding the risk of fracturing the MT at its superior attachment 2. In the anterograde uncinectomy, identify the maxillary line and locate the attachment of the uncinate to the lacrimal bone before dissecting it using a sharp sickle blade. In retrograde uncinectomy, only 1–2 bites using the back bitter or Kerrison punch to avoid injury to the lacrimal bone housing the lacrimal sac and duct
Medial maxillary antrostomy	1. Middle turbinate (MT) (a) Laceration (b) Mucosa	1. Use appropriate instrument. Avoid multiple instruments at the same time. Good visualization. Avoid stripping the mucosa. Remove the intended mucosa with sharp cutting instruments
Anterior ethmoidectomy	1. Middle turbinate (MT) (a) Laceration (b) Medialized MT, i.e. flappy MT 2. Lamina papyracea 3. Anterior and posterior ethmoidal arteries 4. Skull base	1. Use appropriate instrument. Avoid multiple instruments at the same time. Good visualization. Gentle medialization of MT at the inferior and anterior edges of the MT, thus avoiding the risk of fracturing the MT at its superior attachment 2. Identify the lateral boundaries of the anterior ethmoidal sinus air cells, which is the lamina papyracea. For the beginners, avoid using the powered instruments; rather use a sharp bone-cutting forceps to remove the ethmoidal sinus bones from the lamina papyracea 3. The anatomical location is paramount in order to avoid injuries to these structures. Once the area is located, use upturned bone-cutting forces to remove the remaining bony partition 4. Always remember that the skull base has a sloping descent posteriorly from the roof of the ethmoidal air cells to the sphenoidal sinus roof. The fixed landmark that can be used is the roof of the maxillary where an imaginary line is drawn horizontally to the septum. Ethmoidal air cells below this line can be safely removed until the roof of the sphenoid is identified
Posterior ethmoidectomy	1. Middle turbinate (MT) (a) Laceration (b) Medialized MT, i.e. flappy MT 2. Lamina papyracea 3. Posterior ethmoidal artery	Similar to the precautions during anterior ethmoidectomy, the possibility of complications is the same
Sphenoidectomy	1. Superior turbinate 2. Lateral wall and its adjacent structures in the sphenoid lateral and posterior walls 3. Skull base	1. In locating the sphenoid ostium, the superior turbinate might be injured. ST is used to locate the sphenoid ostium, which is medial to its posterior end 2. Indented on the lateral wall of the sphenoid are important structures such as optic nerve and ICA. Anatomical knowledge is paramount to avoid injuries to these structures. Study the CT scan before surgery
Frontal sinusotomy	1. Axilla of the MT 2. Superior attachment of uncinate and the anterior part of the MT 3. Frontal recess 4. AEA 5. Olfactory fibres	1. The landmark to identify the frontal recess is the axilla of the MT. in these procedures, sometimes it is inevitable that the axilla is injured; therefore, one of the fixed landmarks in ESS will be missing for future reference. Therefore, careful with probing and only dissect whenever necessary, i.e. Draf IIb 2. Overzealous and aggressive manipulation of the region can also cause injuries to the superior attachment of the anterior part of the MT and uncinate process. 10% of the attachment is to the skull base, and these will have a higher risk of CSF leak. Study the CT scan and avoid twisting and rotating the attachments when removing it 3. At the frontal recess, avoid circumferential stripping of the mucosa so as to avoid stenosis at the recess 4. Be aware of the AEA proximity, which is usually located just posterior to the frontal recess 5. In Draf III or modified Lothrop, the posterior limit is the first olfactory fibres. These fibres may be injured

defect if needed. Usually, no repair of the defect is necessary [35].

10.6.2.2 Orbital Emphysema (Grade I)

Orbital emphysema, i.e. periorbital and subcutaneous emphysema post ESS, is rare. Postoperative orbital emphysema may occur following excessive nose blowing or sneezing [65]. The most common site of emphysema would be the upper eyelid. The management is usually conservative, and it will subside within a week, but, although very rare, it may require urgent intervention because of the risk of increased intraocular pressure, impaired blood supply to the globe, and even blindness [61, 66].

10.6.2.3 Intraorbital Haematoma (Grade I)

The incidence of intraorbital haematoma is rare at around 0.1% [63, 67]. The normal intraocular pressure is 12–22 mmHg, and the average orbital volume is 26 cc. A 4.0 cc increase in volume will result in 6 mm proptosis [51]. Retrobulbar haematoma with accompanying loss of vision has 50% risk of permanent blindness [52]. Intraorbital haematoma occurs from injury to the anterior or posterior ethmoid arteries, which retract laterally, therefore causing an acute increase in the intraorbital pressure resulting in retinal ischemia; however, injury to orbital or ophthalmic veins results in a slower process of accumulation of blood. The window of opportunity to intervene is about 90 min, where the retina can tolerate the ischemia before irreversible damage happens (Table 10.5) [68]. The treatment approach is determined by the severity and is outlined in Fig. 10.19.

Table 10.5 Signs and symptoms of intraorbital haemorrhage [69]

1. Tense globe
2. Increased intraocular pressure
3. Progressive proptosis with chemosis
4. Conjunctival vessel congestion and subconjunctival haemorrhage
5. Pupillary dilation
6. Loss of pupillary reflex
7. Eye pain
8. Limitation of eye mobility
9. Visual field loss and loss of vision

Note

- Lateral canthotomy and cantholysis will reduce intraorbital pressure (IOP) by approximately 14 mmHg and 30 mmHg, respectively. These procedures are indicated when [51]
  1. The intraocular pressure is more than 40 mmHg
  2. There is loss of pupillary reflex
  3. There is cherry red macula
- Endoscopic medial orbital wall decompression will reduce IOP by approximately 10 mmHg. The bleeding can also be controlled through endoscopic or external artery ligation

10.6.2.4 Injury to the Lacrimal Duct (Grade II)

Injury to the nasolacrimal duct can occur during uncinectomy or enlarging the maxillary ostium, i.e. when the back-biting forceps is used too far anteriorly. Symptoms include epiphora and dacryocystitis.

10.6.2.5 Extraocular Muscle Injury (Grade III)

The medial rectus muscle is the most susceptible muscle to injury during endoscopic sinus surgery due to its proximity to the lamina papyracea. The injury may occur during posterior ethmoidectomy. Injury to the medial rectus muscle will cause diplopia and exotropia [72]. Huang et al. reported that the incidence of extraocular muscle injury is rare accounting for about 0.00014% [38]. Other eye muscles are less often injured, i.e. inferior rectus muscle (maxillary sinus surgery) [73]. The use of microdebriders in ESS is the main culprit for injury to the extraocular muscle [63]. Besides muscle transection, several other types of injury have been described, including muscle entrapment, contusion or haematoma, and oculomotor nerve branch injury [38]. Symptoms may vary across exotropia, ocular adduction deficits, and abduction deficit, which only occur during muscle entrapment [69]. Management will have to offer a prompt referral to the ophthalmology team, and the surgical option is strabismus surgery. A primary surgical reanastomosis, interposition grafting, or use of adjustable sutures may be attempted depending on the amount of tissue loss. The surgical option is not always successful in restoring the full range

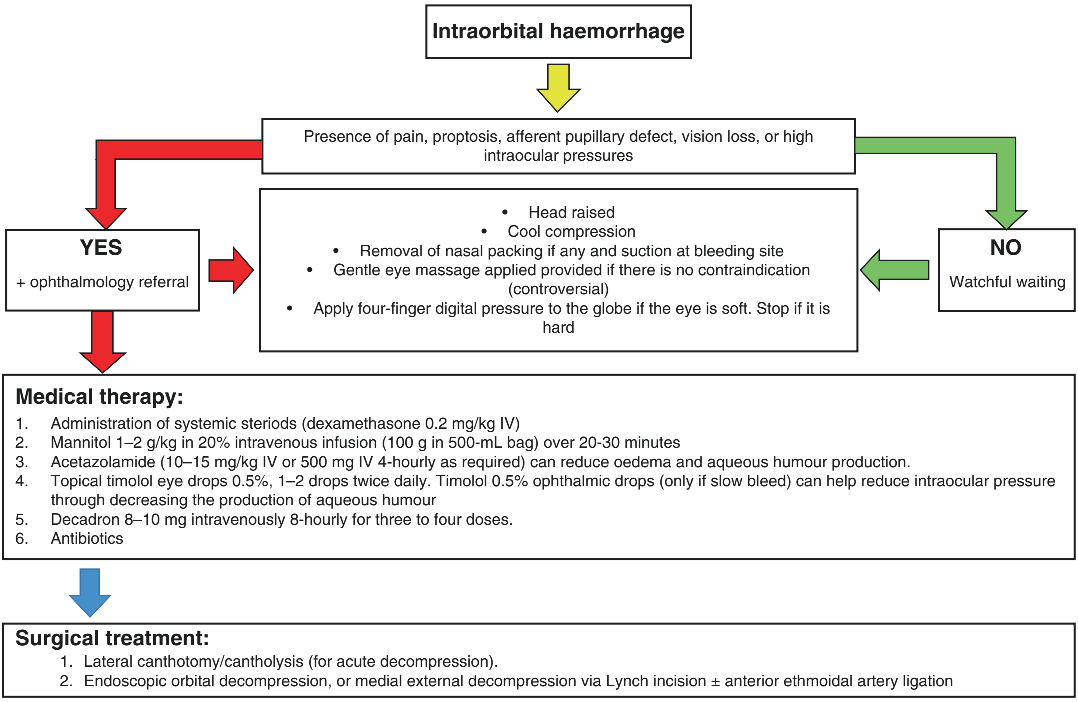

Fig. 10.19 Outline of the management of intraorbital haemorrhage [35, 69]

of motion of the globe and should be performed within 2–3 weeks from injury, i.e. after the resolution of the oedema. Hong et al. advocated the administration of systemic corticosteroid and the use of Botox injection in the ipsilateral lateral rectus muscle as a useful adjunct in the first few weeks after repair to reduce tension across the anastomosis site [74].

10.6.2.6 Optic Nerve Injury (Grade III)

The injury to the optic nerve is very rare and may occur in sphenoid surgery since its location usually can be identified as an indentation in the superolateral sphenoid sinus wall. About 5% of the optic nerve can be dehiscence [35]. The presence of Onodi cells, which are present in about 8–14% of the general population, may also increase the risk of optic nerve injury [75]. Ali et al. found a prevalence of 42.8% of Onodi cells, which is higher than the prevalence found in a recently reported study [76, 77]. The high percentage of Onodi cells may be contributed by the usage of the cone beam computed tomography (CBCT) scan, which is more precise in the recognition of bony structures of the paranasal sinus [76]. Optic nerve injury might cause a partial loss of vision or blindness. The initial step when an injury to the optic nerve is suspected is to normalize the blood pressure, refer to the ophthalmology team, and immediately start a high-dose systemic corticosteroid (dexamethasone 0.5–1 mg/kg body weight IV). By using the CT scan to evaluate the location and extent of this injury, optic nerve decompression may be considered [35].

10.6.3 Intracranial Complications

Intracranial complication due to ESS is a dreadful complication but fortunately is a very rare complication, which is about 0.47–0.54% [78]. Common among the complications is cerebral spinal fluid (CSF) leak. Other complications include direct intracranial injury evidenced by pneumocephalus—the presence of gas (air) in the cranial cavity and obviously damage to cerebral vasculature or to the brain itself. For intracranial complication, the immediate sign includes intracranial haemorrhage, but the majority of signs and symptoms occur post-operatively, i.e. persistent headache, neurologic deficit, intracranial infection, and meningoencephalocele [69]. All intracranial complications must be referred to and managed with the neurosurgery team.

10.6.3.1 CSF Leak

Once a persistent watery rhinorrhoea, which is usually unilateral post-endoscopic sinus surgery, is seen and documented, CSF leak should be ruled out. The incidence of iatrogenic endoscopic sinus surgery injury to the skull base resulting in CSF leak is 0.5% [34]. The most liable regions to injury which are the weakest (0.05–1 mm thin) areas of the skull base are:

1. At the junction of the anterior ethmoid artery and the middle turbinate along the anterior ethmoid roof
2. At the lateral lamella of the olfactory fossa which is susceptible for injury [79]

The best management of CSF leak due to ESS is immediate repair, which has a 90% good outcome according to Banks et al. (2009) [80]. Intraoperative localization can be facilitated by intrathecal instillation of fluorescein, which will colour the CSF fluorescent green. Studies have suggested that a low dose of intraoperative or post-operative intrathecal fluorescein administration is a safe and sensitive method for localization of CSF leakage sites. The protocol in our centre is to withdraw 10 mL of CSF from the lumbar puncture and add 0.1 mL of filtered 10% fluorescein, creating a 0.1% final concentration that is slowly infused intrathecally 30–60 min before the procedure [69]. Nevertheless, appropriate informed consent must be obtained before using fluorescein due to the fact that studies have showed that intrathecal administration of fluorescein has been associated with some severe side effects including seizures, flash pulmonary oedema, headache, and distal lower extremity numbness [80, 81].

A CSF leak may be detected after surgery if the patient complains of a clear, watery, salty-tasting nasal discharge. Known tests that can be performed at the bedside include: positive glucose in the fluid, halo sign, handkerchief sign and reservoir sign, i.e. an exacerbation of CSF rhinorhea when bending over or using the Valsalva monuver. However, the gold standard test would be the biochemical confirmation via a β2-transferrin assay [69]. The integrity of the skull base, location of the bony defect, and any sign of other intracranial injury and complication, i.e. pneumocephalus, should be assessed via a CT scan. The area of importance as described above, which is the area most common to sustained injury, should be examined thoroughly as well as the assessment of the skull base should be done via the Keros classification (Fig. 10.4). Some surgeons also describe the asymmetry of the skull base as Keros type IV, which occurs in approximately 10% of the population [40]. Management of CSF leak has a 90% greater outcome if it is identified during surgery and managed at the same setting [80, 82]. If the leak was detected after surgery, prophylactic antibiotics can be started. The patient has a more than 90% success if the repair was done via transnasal endoscopic approach [82, 83]. Techniques of repair are shown in Fig. 10.20.

Generally, the patient will have nasal packing to secure the flaps for at least 3–7 days. The patient is also advised for bed rest with the head-end elevation (40–70°) when sleeping, prescribed antibiotics as a prophylaxis, and asked to avoid strenuous activity and sneezing with an open mouth. Laxatives may be prescribed for patients with constipation. Large defect repair and revision cases with increased intracranial pressure almost always require lumbar drains.

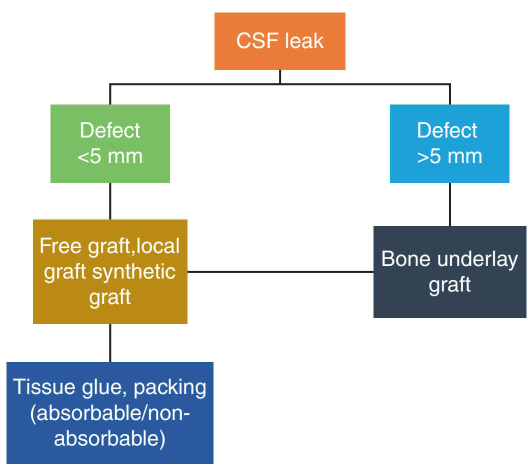

Fig. 10.20 Flow chart of CSF leak repair depending on the size of the defect [84]

10.6.4 Post-operative Complication

10.6.4.1 Epistaxis

Epistaxis can occur due to inadequate haemostasis or about a week post operation when the crust starts to peel or dislodge. It may also occur during the first visit after surgery when the surgeons are inspecting the nasal cavity and removing the dry crust. If the bleeding occurs at home, the basic compression can be applied with the patient in the Trotter's position while applying cold pack over the forehead or soaking the head with cold water or towel. The bleeding should subside within 10–15 min. If the bleeding persists, then it should be managed at the nearest clinic with proper nasal packing. Ideally, an examination with nasoendoscopy should be done to locate the bleeding site. A simple but effective method to prevent post-op epistaxis is not to pack the nose if, at the end of the ESS, excessive bleeding is absent.

10.6.4.2 Nasal Synechia

Synechia is a very common complication in ESS occurring in about 10% of cases, but more than half of the cases do not impair the nasal function [32]. The synechia usually occurs between the injured mucosa between the lateral wall and the septum and also in between the medial side of the middle turbinate and the lateral wall (Fig. 10.21). It can also occur due to infections post ESS. Henriquez et al. found that more synechia occurs in revision cases, and although both groups improve, the degree of QoL improvement appears to be less in those who form post-operative synechia after surgery compared to those who do not [85].

Basic measures that can prevent and reduce the risk of synechia include the following:

1. Nasal packing to be removed within 48 h (for the non-absorbable packing).
2. Silastic sheet: A temporary soft, thin silicone sheet placed between raw mucosa and held in place by suture of nasal packing. Preferably, the sheet is lubricated with topical antibiotics cream, i.e. chloramphenicol 1% ointment.

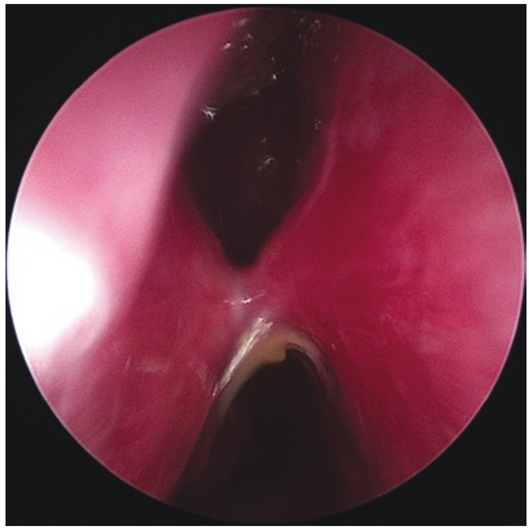

Fig. 10.21 Synechia between the middle turbinate and septum

3. Nasal irrigation with saline 24–48 h post operation. A gentle douching is advised for the first few douching.
4. Removing crusting 5–7 days post operation. Mechanically cleaning the nasal cavity of crust will reduce the risk of infection that may lead to synechia.
5. Prophylactic antibiotics.
6. Nasal decongestant and nasal steroid sprays.

In cases of a floppy middle turbinate occurring when the vertical part of the middle turbinate is detached from the second part of the middle turbinate (basal lamella), the medial surface of the middle turbinate is scored as well as the septal area opposite to it induced adhesion medializing the middle turbinate. Lateralized floppy middle turbinate will sometimes obstruct the drainage area of the ostiomeatal complex (OMC). It is also known as Bolgerization or middle turbinate medialization. Other methods of middle turbinate medialization include application of fibrin glue to the medial surface of the middle turbinate and suturing the middle turbinate to the nasal septum.

10.6.4.3 Other Complications

These are the complications that may occur post ESS (Table 10.6).

Table 10.6 Other complications of ESS

No.	Complications	Description and management
1.	Infection	1. Post-op ESS infection may present as sinusitis, which is usually due to the injury to the nasal mucosa, therefore exposing it to bacterial infection especially within 24–48 h of surgery (Fig. 10.22). At this critical time, the mucociliary clearance of nasal secretions is affected, thus making it prone to infection. Management: Prophylactic antibiotics in ESS cases as well as early nasal irrigation and nasal toileting to remove crust. 2. Atrophic rhinitis occurring post ESS especially in revision cases where there is a significant amount of mucosa removed, including the turbinates, i.e. inferior and middle turbinates. Iatrogenic atrophic rhinitis is categorized as secondary atrophic rhinitis and the symptoms including merciful ozaena and paradoxical nasal obstruction where the foul smell is not detected by the patient and the nasal blockage complaint although the nasal cavity is roomy, respectively. The reported incidence of atrophic rhinitis is less than 1% [40]. Management: Mucosal sparing procedures and avoid removing the turbinates as well as prophylactic antibiotics, nasal irrigation, and nasal toileting. 3. Meningitis has been reported to occur between 1% and 3% as reported by Ranson et al., post rhino-neurosurgical procedures and CSF leak should be ruled out [70]. The practice of giving prophylactic antibiotics has not reduced the risk of meningitis in skull base surgery. Whether it is congenital or post-traumatic, direct extension via osteomyelitis of the sinus walls or bony defects is uncommon [71].
2.	Smell disturbances	Hyposmia occurs post ESS due to inflammation and nasal congestions. Occurring about 24–48 h post-op, patient should be warned about this and nasal irrigation with nasal decongestion will help to reduce the symptoms. Some patients will experience anosmia. The smell disturbances should progressively improve within 2–6 weeks.

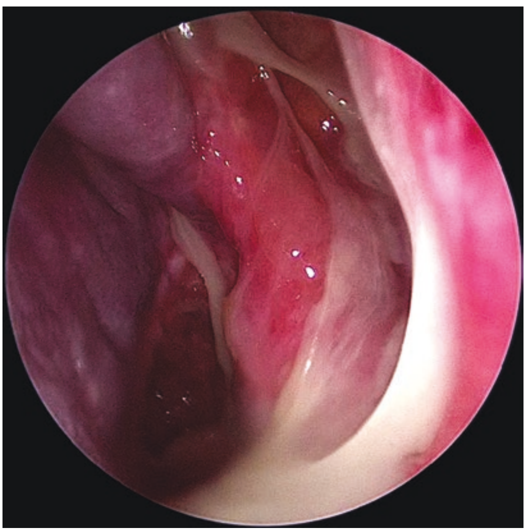

Fig. 10.22 Sinusitis post endoscopic sinus surgery

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