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PRIMARY ENDOSCOPIC MANAGEMENT OF THE FRONTAL SINUS

Frederick A. Kuhn, MD, and Amin R. Javer, MD

Historically, frontal sinus disease was treated surgically using the external approach and obliterative procedures.[7, 14, 37] It was later believed that preservation of the frontal sinus and maintenance of the patency of the nasofrontal recess and internal frontal ostium resulted in a better overall outcome. This resulted in the development of external procedures designed to remove disease from the frontal sinus and re-establish the frontal sinus pathways.[32] Lynch[23] described a procedure to remove part of the sinus floor, the entire sino-orbital wall, and as much of the sinus mucosa as possible. He advocated placement of a rubber tube into the newly created nasofrontal connection to maintain its patency. Because of a significant failure rate (approximately 30%) several modifications to the original procedure were introduced, including the use of stents of various materials ranging from gold to silastic sheeting.[1, 11, 30] This later evolved into the use of mucosal free grafts[29] and split-thickness skin grafts[31] with limited success.

Mucoperiosteal flaps as described by Sewall and later modified by McNaught and Boyden resulted in better outcomes.[2] Several modifications and outcomes of these procedures have been reported since the original description. Dedo et al[9] recently described their 25-year experience with the external frontoethmoidectomy and Sewall-Boyden reconstruction. They reported a 97% patency rate of the nasofrontal pathway. Overall, these modifications have resulted in failure rates that range between 15% and 20% in the long-term.[35]

From the Georgia Rhinology and Sinus Center, Savannah, Georgia (FAK); and the University of British Columbia, Vancouver, British Columbia, Canada (ARJ)

Over the last decade, functional endoscopic sinus surgery (FESS) has been accepted as the procedure of choice for the surgical management of chronic sinusitis.[10, 13, 15, 27, 38] Because of the complex anatomy of the frontal recess, endoscopic intranasal approaches to this region continue to be an area of controversy.[3, 8, 18] Several investigators have devoted much energy to renewing interest in the Lothrop procedure.[3, 8] Maintenance of mucous membrane in the frontal sinus drainage pathway is the key to a successful functional outcome. We do not advocate the use of powered instrumentation in the frontal recess except for the occasional use of a curved debriding blade to remove curetted debris from the frontal recess region.[17] FESS advocates removal only of tissue necessary to relieve obstruction, thereby restoring natural sinus drainage and ventilation. The ideal methodology in dealing with the frontal drainage pathway is to carry out a careful and delicate dissection from below using the appropriate instrumentation and causing the minimum amount of damage to the mucosa of the internal frontal ostium. Using the correct technique and with increasing experience, the success rates of the endoscopic intranasal frontal sinusotomy have surpassed those of the external approach in centers specializing in sinus diseases.[17, 38] It has less morbidity than nonendoscopic sinus procedures, can be done on an outpatient basis, has a shorter convalescent period, and leaves no external scarring on facial skin.[6, 13, 27, 38] Preservation of normal frontal sinus anatomy has the advantage that future radiologic or endoscopic evaluation is not distorted.[18]

The frontal sinus is the most challenging of the four paranasal sinuses to treat endoscopically. Its anterosuperior location and complex relatively narrow frontal recess anatomy makes visualization difficult and predisposes it to stenosis. Significantly, serious complications are possible because of the frontal recess' proximity to the anterior ethmoid artery, orbit, and anterior cranial fossa. With a complete knowledge of the anatomy and potential pitfalls, however, and a thorough preoperative evaluation, the FESS surgeon can successfully restore normal frontal sinus physiology.[4]

INDICATIONS

Indications for endoscopic frontal sinusotomy are derived from assessment of the patient's history, diagnostic endoscopy, and the CT scan. Endoscopic intranasal frontal sinusotomy can be used successfully in most primary cases of chronic frontal sinusitis, and in revision frontal sinus surgery. It can also be used in place of trephine to treat acute frontal sinusitis; however, bleeding may be a problem because of the inflammation. Other applications are frontal sinus mucoceles[19] and frontal recess inverting papillomas.[25, 43]

Frontal sinus allergic fungal sinusitis, mucoceles with erosion of the posterior table or superior orbital wall, inverting papilloma of the frontal sinus, and extensively pneumatized frontal sinuses are contraindications to obliteration. These conditions are best managed with an intranasal

endoscopic approach or a combined osteoplastic flap without obliteration and intranasal approach where the frontal recess and internal frontal ostium can be followed postoperatively in the office.[20, 24, 39]

Endoscopic frontal sinusotomy by itself is contraindicated for (1) frontal sinus tumor, (2) inverting papilloma of the frontal sinus, (3) broadly based osteomas, (4) frontal recess stenosis, and (5) laterally based mucoceles.

PREOPERATIVE EVALUATION

A thorough evaluation including a complete history and review of previous surgical records is important. An outcomes measure (i.e., RSOM-31 or SNOT-20)[21] including postnasal drainage, intermittent fever, frontal pressure, and headache is helpful for documentation and follow-up. The nature of the headache should be reviewed in detail to rule out a nonsinus cause. Contingent medical disorders, such as allergies, asthma, congenital illnesses, or immune deficiencies, are important to document.

Endoscopic description of abnormalities, such as polyps, purulence, concha bullosa, persistent uncinate process, frontal recess scarring, presence or absence of partially resected turbinates,[12] and the absence of landmarks, should be documented. Computer-assisted photography is an excellent means of documentation. Direct examination of the frontal recess may be possible using the 30- or 70-degree telescopes. Any purulence or allergic mucin should be cultured endoscopically for bacteria and fungi to select treatment accurately (Fig. 1).

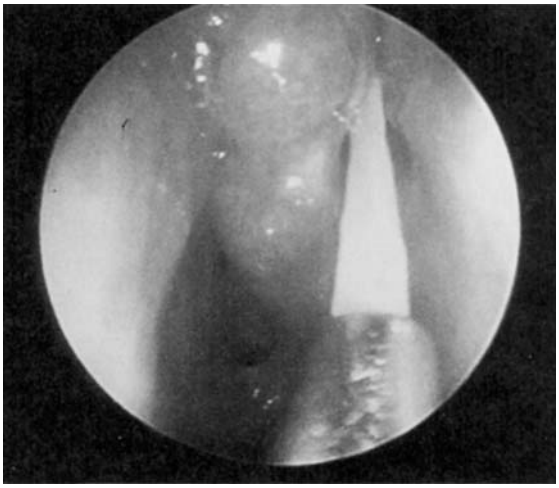

Figure 1. Seventy degree endoscopic view showing a culture being taken from the frontal sinus with a 90° angled suction tip.

All patients with chronic frontal sinusitis should be given a substantial trial of medical therapy. A 3- to 6-week trial of culture-directed antibiotics used with combinations of decongestants, mucolytics, topical or oral steroids, or antihistamines may be indicated. Immunotherapy should be considered for patients with an allergic component to their sinusitis. Failure of extensive, individualized medical therapy to alleviate symptoms within 6 to 8 weeks warrants a CT scan to rule out an anatomic obstruction. If frontal sinus or recess disease is identified radiographically or endoscopically, then the patient is counseled about the potential risks and benefits of FESS.[4]

The standard coronal CT scan of the sinuses provides us with a great deal of information; however, it is inadequate to understand three-dimensional frontal recess anatomy. Sagittal reconstruction provides the most information for evaluating the anteroposterior dimension. Thin axial sections (1 mm) and helical scans have been shown to give safe corneal radiation levels, excellent sagittal and coronal reconstruction, and clearly show frontal sinus anatomy and the various cells that obstruct the frontal sinus.[40] The benefit of the thin axial sections extends to the use of frameless stereotactic surgical navigation devices.

INSTRUMENTATION

As noted previously, the frontal recess' anterosuperior location requires very specialized instruments specifically for this surgery. Frontal recess suction and nonsuction, 45- and 90-degree curettes, forceps, and seekers have been developed over the past decade and continue to evolve to solve this problem (Fig. 2). The 90-degree hook on the frontal sinus ostium seeker helps palpate, identify, and remove bony debris from the frontal ostium and the frontal recess. Additional necessary instruments include giraffe forceps: the forceps must be available in side-to-side and front-to-back biting orientation. The curettes are extremely useful for dissecting soft tissue and bony cell walls out of the frontal recess to a position where they may be grasped and removed. An instrument that has proved extremely valuable in this region is the frontal sinus mushroom punch and the through cutting Heuweisser (Karl Storz), which aids in the removal of horizontal shelves created by bone or scar obstructing the frontal recess. Although most FESS carried out for the other paranasal sinuses uses the 0-degree endoscope, the frontal recess requires visualization with the 30-degree and the 70-degree telescope. No. 8 and No. 9 French malleable suctions (Karl Storz) angled at 45, 90, and 110 degrees are necessary to aspirate in this area. The angled instruments are generally intended for use below the telescope, reaching around its anterior end (Fig. 3). Consequently, the 45-degree instruments work well with the 30-degree scope and 90-degree angled instruments complement the 70-degree endoscope. Powered instrumentation, as mentioned previously, should not play a significant role in endoscopic frontal sinus surgery in most cases.

Revision endoscopic frontal sinus surgery is even more challenging in the presence of significant frontal recess scar tissue and lateralized middle

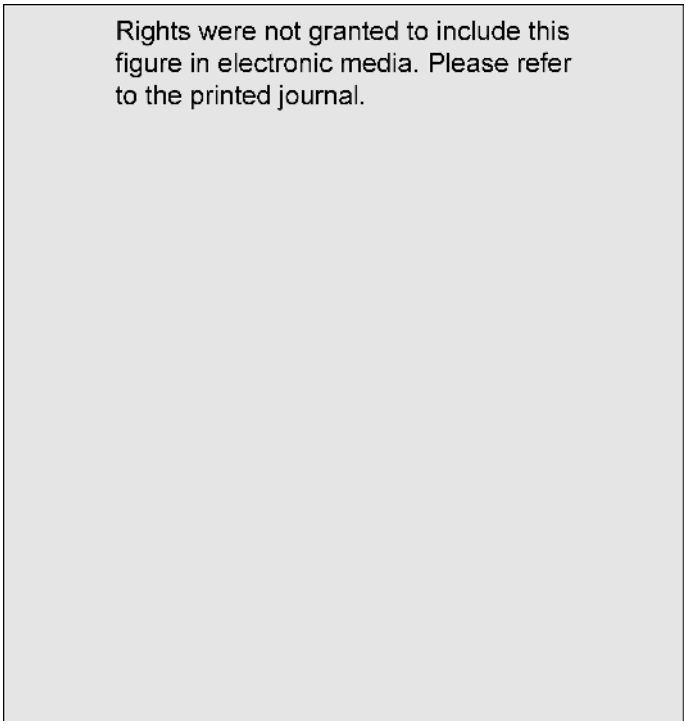

Figure 2. *A*, Latest addition of Kuhn frontal sinus seekers by Karl Storz, Germany. *B*, Suction Kuhn frontal sinus curettes (MedTREK, Mystic, CT).

or uniturbinates.[12] A "uniturbinate" refers to a single, more posteriorly based turbinate formed as a result of scarring between a partially resected middle turbinate and the superior turbinate. A loss of normal landmarks to the frontal recess and skull base ensues. Surgery in this situation can be greatly enhanced with the use of an intraoperative image guidance system that can allow for precise dissection in the region of the frontal recess (Fig. 4). The recent development of specifically angled tips to reach the frontal recess and internal frontal ostium has made image-guided surgery even more useful in this region (Fig. 5).[12, 28]

OPERATIVE TECHNIQUE

Anatomy

Any discussion of frontal sinus surgery must begin with an anatomic review of the cells, which may potentially obstruct the frontal recess. These include agger nasi cells, supraorbital ethmoid cells, frontal cells type I to

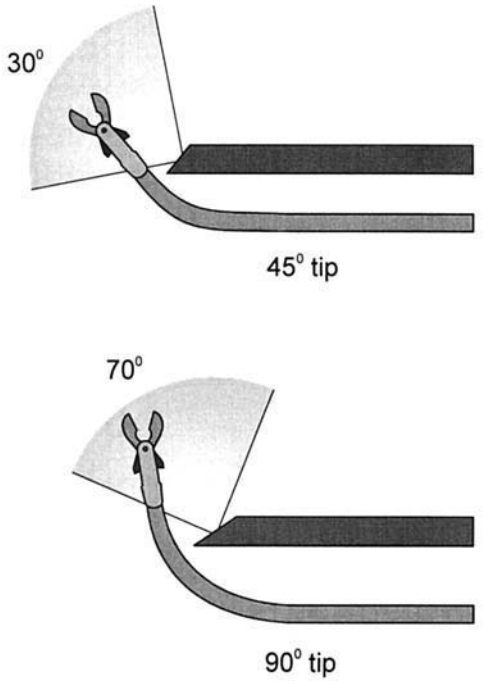

Figure 3. The correct use of 45° and 90° instruments with 30° and 70° telescopes.

IV, frontal bulla cells, suprabullar cells, and interfrontal sinus septal cells. The first three of these cells are the more common anterior ethmoid cells, which pneumatize the frontal recess and either cause frontal sinus obstruction or confuse the operating surgeon as to whether the frontal sinus has been opened. Further details and discussion of these cells can be found elsewhere.[5, 15, 18, 26, 34] A successful surgical outcome requires thorough clinical and radiologic frontal recess evaluation. This includes thin axial section CT with sagittal reconstruction to determine the cell types that may be involved in its obstruction. If disease in the frontal recess does not resolve after prolonged medical treatment, the obstruction must be removed before drainage from the frontal sinus can be effected.

Operative Technique

It is imperative that the frontal recess mucus membrane be preserved using a delicate surgical technique. Removal of the mucus membrane leads to osteoneogenesis, scarring, and frontal sinus stenosis.[15] In a previously unoperated patient the procedure is carried out in the following manner.

Step 1. The uncinate process is removed and the natural maxillary ostium is identified using the technique previously described by Owen and Kuhn.[33] The maxillary sinus outflow tract is left undisturbed.

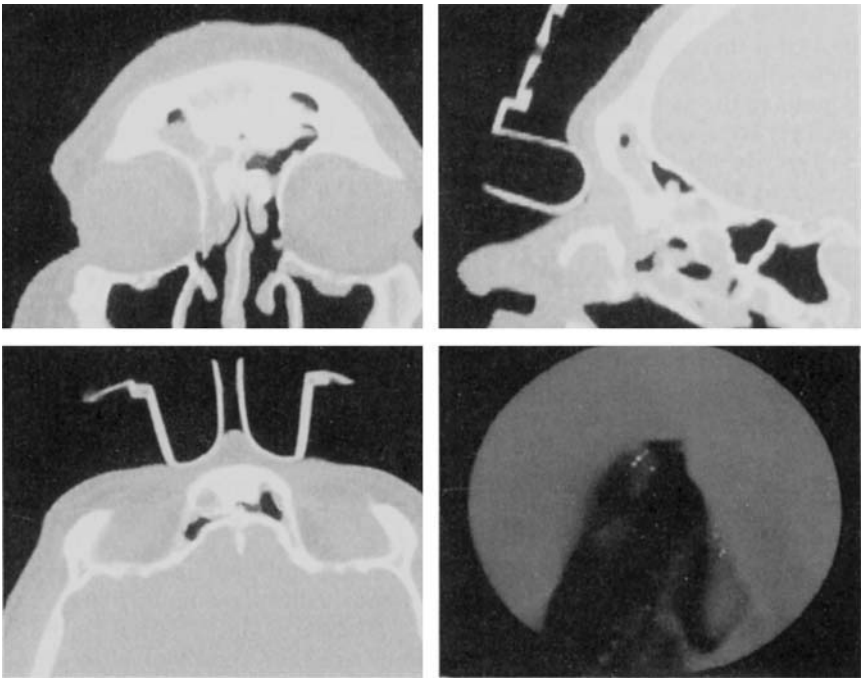

Figure 4. Intraoperative view of the InstaTrak system (Visualization Technologies, Inc., Boston, MA) used in a case with uniturbinates and loss of landmarks.

Figure 5. Curved suction tips available for the InstaTrak image-guided system (Visualization Technologies, Boston, MA).

Step 2. The ethmoid bulla and posterior ethmoid cells are then removed if there is evidence of disease extending into this region. If a complete ethmoidectomy is being done, one should go through the basal lamella to the face of the sphenoid. The face of the sphenoid is followed superiorly to the skull base. The skull base is then followed anteriorly from posteriorly removing all lamella with through-cutting instruments. The posterior and anterior ethmoids should be cleaned out first. As the anterior ethmoid artery is approached, the skull base begins sloping sharply upward. This is the posterior entrance to the frontal recess (Fig. 6). The surgeon's movements should be from posterior to anterior, with very limited side-to-side action, protecting the orbit and anterior cranial fossa. Great care is taken to avoid injuring the lamina papyracea laterally and the lateral lamella of the cribriform plate medially. The weakest point of the entire anterior skull base is at the roof of the ethmoid where it is penetrated by the anterior ethmoid artery.[41] This corresponds to the lateral lamella of the cribriform plate. The bone may only be 0.1 to 0.2 mm thick at this point. This area is even more susceptible to injury in a Keros type III anatomic variation where the olfactory groove is deep creating a taller lateral lamella of the cribriform plate (Fig. 7).[15]

Step 3. The angled frontal recess curettes can then be slipped up the posterior frontal recess wall behind any bony cellular elements that occupy the frontal recess (Fig. 8*A*). The curette and cell walls can then be pulled down and forward. The bony fragments are then removed with giraffe forceps (Fig. 8*B*). This step is repeated carefully until the internal frontal ostium is visualized and its obstruction removed.

Figure 6. Seventy degree endoscopic view of the frontal recess and sloping skull base showing the anterior ethmoid artery (postoperative healed endoscopic result).

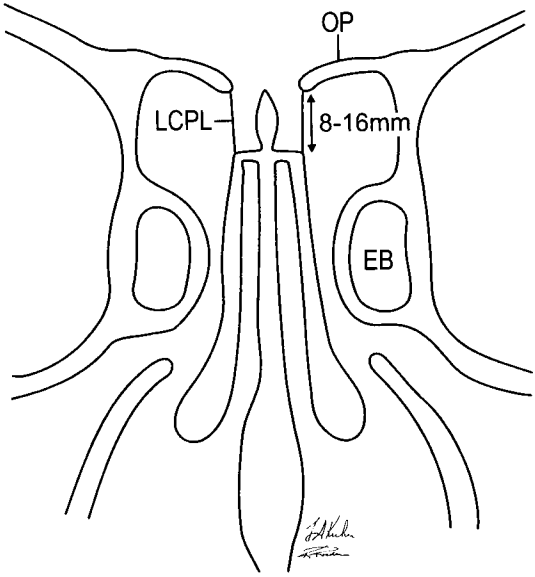

Figure 7. A Keros type III configuration with a deep olfactory groove. LCPL = lateral cribriform plate lamellae; OP = orbital plate; EB = ethmoid bulla.

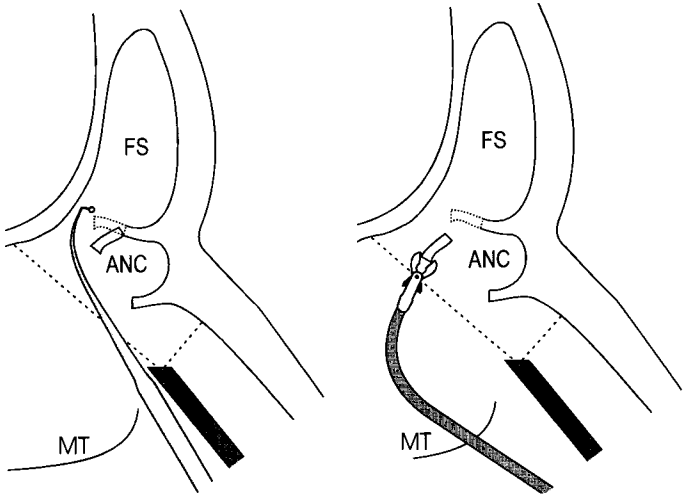

Figure 8. Frontal endoscopic sinusotomy technique using a 70° endoscope and 90° instrumentation to remove bone and mucosal membrane obstruction. FS = frontal sinus; ANC = agger nasi cell; MT = middle turbinate.

Special Situations

Step 4A. If the patient has an agger nasi cell, the posterior wall and dome of the agger nasi cell must be removed. The superior aspect of the dome can sometimes be removed most easily with a frontal sinus mushroom punch after breaking down the posterior and medial walls with the 90-degree curettes.

Step 4B. If the patient has a supraorbital ethmoid cell, the common wall between the frontal sinus and the supraorbital ethmoid cell should be removed as high into the frontal recess as possible (Fig. 9). If these walls are not adequately removed, they may become chronically edematous because of mucociliary mucous clearance disruption, resulting in frontal sinus obstruction. Disruption of mucociliary flow patterns in partially removed cells leads to mucus recirculation and edema, which may close off the drainage pathways.[33]

Step 4C. Interfrontal sinus septal cells can be challenging to deal with. One of the major problems is the difficulty translating the CT appearance (Fig. 10) into the endoscopic view. Interfrontal sinus septal cells generally empty into the frontal recess medial and anterior to the internal frontal ostium (Fig. 11). It may be difficult distinguishing between these two ostia.

Step 4D. If the patient has had the anterior aspect of the middle turbinate resected with lateralization of the remnant stump obstructing the frontal recess then a frontal sinus rescue procedure can be carried out. This involves removal of the anterior middle turbinate stump together with the mucus membrane on its medial aspect. The mucus membrane

Figure 9. Seventy degree endoscopic postoperative view showing the partition between a supraorbital ethmoid cell and the frontal ostium.

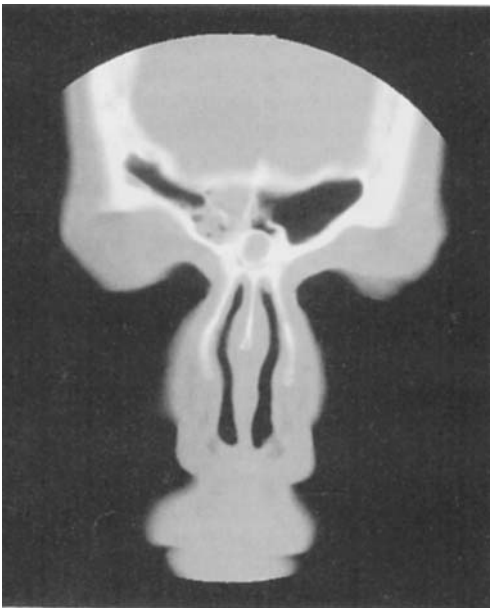

Figure 10. Coronal CT showing an opacified intersinus septal cell.

on its lateral aspect is carefully preserved and draped medially over the denuded area where the previous stump had been resected. This results in a large mucosalized opening into the previously obstructed frontal sinus. This procedure is explained in significant detail elsewhere in this issue.

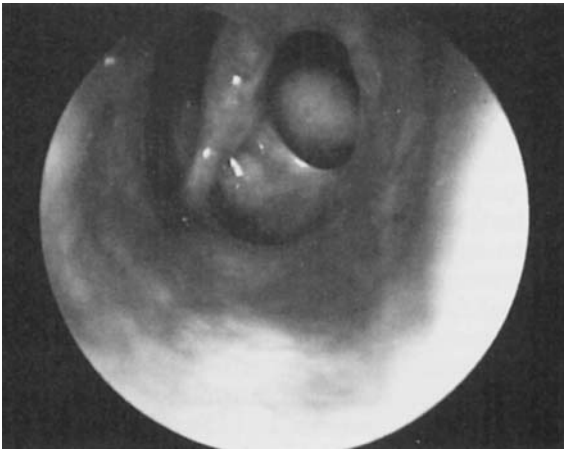

Figure 11. Seventy degree endoscopic view of drainage pathway of a left intersinus septal cell (medial opening) and internal frontal ostium (lateral opening).

If only anterior ethmoidectomy is necessary, the basal lamella may be followed upward to the skull base and frontal recess, as described by Loury,[22] or in the case of isolated frontal sinus disease the ethmoid bulla may be left intact as described by Sethi (unpublished data, 1998). The only pitfall with this technique is not removing the bulla lamella completely and leaving a supraorbital ethmoid cell undetected behind it. It is much better to follow the middle turbinate basal lamella to the skull base instead and then work forward.

ADDITIONAL TECHNIQUES

In some cases the intranasal endoscopic technique by itself is insufficient. As noted previously, revision cases may be complicated by dense bone and frontal recess scarring. Frontal cells or superiorly pneumatized agger nasi cells may be unreachable endoscopically. In such special situations, an external frontal sinus trephination can be made to work on the frontal recess simultaneously from above and below.[4]

Step 1. As completely as possible, an endoscopic intranasal frontal sinusotomy is first carried out as described previously.

Step 2. A 2-cm incision is then made in the medial aspect of the eyebrow, angling the incision through the skin to match the angulation of the hair shafts. Once through the skin, blunt dissection is used down to the periosteum.

Step 3. Staying supra periosteal, the tissue is slid superiorly and medially well above the supraorbital ridge. An incision is then made in the periosteum and, using a 4-mm cutting burr, a hole is made into the anterior frontal sinus table.

Step 4. A 30- or 70-degree endoscope can then be inserted through the burr hole to inspect the frontal sinus and cultures can be taken directly from the sinus.

Step 5. An angled scope is then positioned at the outer entrance of the burr-hole and curettes or other instruments can be inserted into the sinus to break down bony partitions or scar tissue so that it can be removed with giraffe forceps (Fig. 12).

When wider exposure is necessary, as after failed fat obliteration of the frontal sinus, an osteoplastic flap may be necessary rather than a trephine to unobliterate the frontal sinus. In many instances, these "above and below" approaches may provide the only opportunity to restore normal sinus ventilation and drainage.[4]

If the dissected frontal recess is too narrow, stenting may be carried out to maintain patency. Soft rather than rigid stents have been found to yield the best results.[30] Thin Silastic rolled into a stent provides soft support of the surgically manipulated frontal recess (Fig. 13). A size 8 or 10F pediatric biliary T-tube can also be cut to create a T-shaped stent that fits loosely into the internal frontal ostium. Recently, there has been some concern regarding the formation of a biofilm on the stents that can result

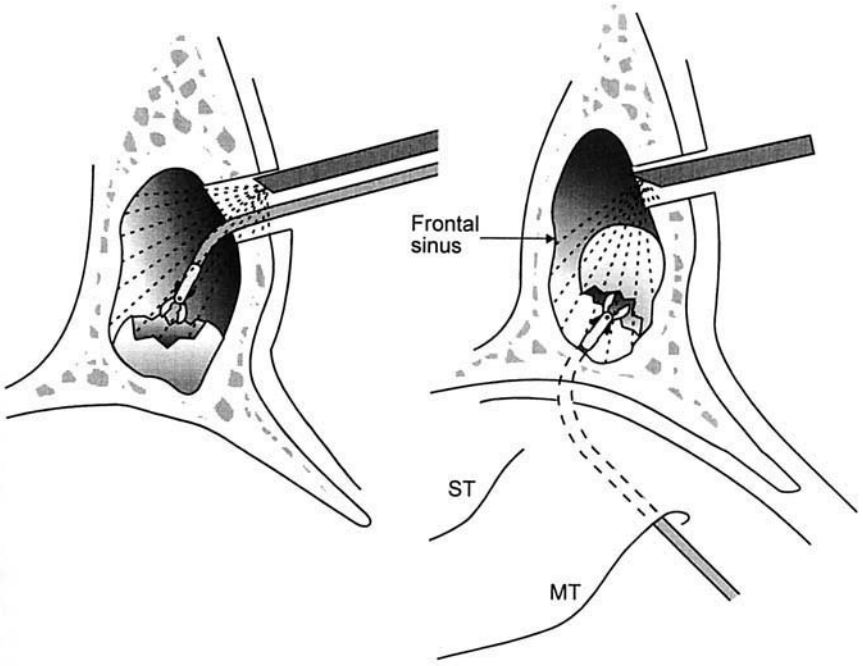

Figure 12. The above and below approach using an anterior table trephine. ST = superior turbinate; MT = middle turbinate.

in multiple antibiotic-resistant bacteria.[36] The development of medically coated stents is in progress at our center to counter this problem.

Postoperative Care

Proper immediate and long-term postoperative care begins in the operating room and has a pivotal role in achieving a good functional result.[19] Good postoperative care requires proper office instrumentation, a schedule of postoperative visits, intranasal endoscopic debridement, patient counseling, and postoperative medical management.

The most important factors in achieving good functional results are scar prevention and avoiding middle meatal collapse. Mucus membrane preservation and postoperative fibrin clot debridement are extremely important aspects of scar prevention. Because fibrin clot can progress to granulation tissue and then scar, it is important to perform postoperative endoscopic debridement in the office. This removes as much clot as possible before it becomes organized. The clinician should not cause bleeding in the aggressive pursuit of fibrin clot removal, however, because this starts the process over again. Removal of mucous membrane in a difficult area like the frontal recess, especially if the bone is curetted, rasped, or

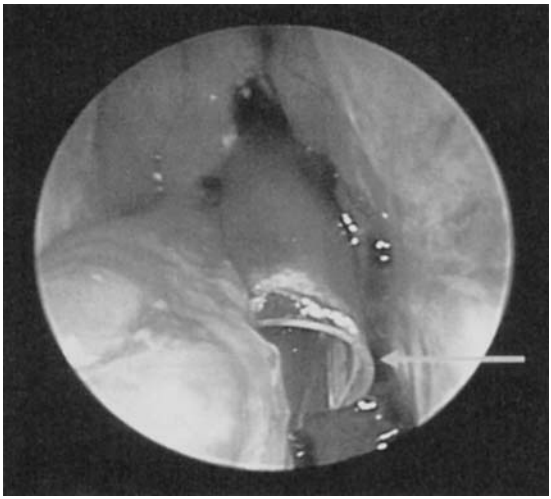

Figure 13. Endoscopic view of a silastic stent in the left frontal recess and extending into the left middle meatus.

drilled, stimulates osteoneogenesis with potential bony closure of ostia and recesses.

Middle meatal collapse can result in disaster. It not only can prevent inspection of the frontal recess but may end up obstructing the frontal and other sinus cavities. If there is any doubt of middle turbinate stability at the end of the procedure, it is wise to Bolgerize it.[19] To reduce fibrin clot accumulation in the middle meatus, a middle meatal spacer is placed intraoperatively and removed on the fourth postoperative day.[19]

To accomplish adequate postoperative debridement in the frontal recess, one must have the proper equipment. Office instrumentation should include 30- and 70-degree endoscopes, malleable suctions curved to 45 and 90 degrees, 45- and 90-degree frontal sinus curettes, and a frontal ostium seeker. Forty-five- and 90-degree frontal recess giraffe forceps opening front-to-back and side-to-side are also required if proper postoperative office debridement in the frontal recess region is desired. The 45-degree instruments are used in conjunction with the 30-degree telescope, and the 90-degree instruments are used in conjunction with the 70-degree endoscopes (see Fig. 3).

On the first postoperative day the nose may be cleaned back to the middle meatus to remove some of the crusting, and the patient is told to begin saline irrigations. The need for postoperative antibiotics and steroids is assessed, depending on findings at surgery. On day 4, the patient returns for middle meatal spacer removal and endoscopic cleaning, with the clinician paying particular attention to the ethmoid roof and frontal recess. The patient is then reinstructed in the use of saline irrigations and encouraged to perform them more vigorously. The third visit is 1 week later. Nasal endo-

scopic debridement is again performed, removing fibrin clot and polyps with debridement of any devitalized bone. The need for postoperative antibiotics and steroids is reassessed at each visit. The fourth postoperative visit is 2 weeks later if the frontal recess looks good at the third visit. Nasal endoscopy is performed, evaluating the need for additional cleaning and the progress of healing. Revision procedures may be performed as necessary in the office: breaking down synechiae, removing polyps, and placing spacers if the middle turbinate starts to lateralize. If the patient is doing well at this visit (21 to 25 days postoperatively), the next visit is scheduled approximately 3 weeks later.

Antibiotics and steroids are used when needed, but are not part of the routine. If the patient does not have an infection at the time of surgery, antibiotics are generally not prescribed. Endoscopically guided cultures are obtained by aspirating the sinus contents into a Leukens trap with a curved suction or a Xomed Sinus Secretion Collector (Xomed, Jacksonville, FL) as a matter of routine when purulence is noted (see Fig. 1). Hypertonic saline irrigation is an important part of the healing process. We prefer noniodized, pickling, or sea salt as opposed to table salt to minimize the amount of irritants contacting the nasal mucous membrane during the healing process. We do not favor the use of powered dental irrigation devices for fear that the device may become colonized with bacteria, such as *Pseudomonas*. Instead, disposable 60-mL irrigating syringes are used that can be washed and dried or thrown away and replaced as necessary.

HIGHLIGHTS

1. The preservation of peripheral mucus membrane in the frontal recess and internal ostium is crucial for success of this procedure.
2. One must always be aware of the presence of supraorbital ethmoid cells that may masquerade as part of the frontal sinus if the CT scan is not critically evaluated.
3. In most instances the intranasal endoscopic approach can be accomplished successfully without the need for an external procedure.
4. In revision cases with extensive scarring or extremely superiorly pneumatized frontal or agger nasi cells, one may need to resort to an external trephine, thereby allowing an "above and below" approach.
5. The dissection should always be carried out in a posterior to anterior direction, and meticulous technique should be used to remove all free bone particles and debris from the frontal recess to prevent future scarring and osteitis.
6. Postoperative endoscopic care is integral to the success of endoscopic frontal sinusotomy. The availability of proper office equipment to perform postoperative care is critical. In fact, if it is not available, the procedure should not be done.

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Address reprint requests to

Frederick A. Kuhn, MD
Georgia Nasal and Sinus Institute
4750 Waters, Suite 112
Savannah, GA 31404