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What is This?
Management of Lateral Frontal Sinus Pathology in the Endoscopic Era

Bryant T. Conger Jr, MD¹, Elisa Illing, MD¹, Benjamin Bush, MD¹, and Bradford A. Woodworth, MD¹

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

Abstract

Objectives. Considerable advances in endoscopic technique and experience have allowed an increasing number of patients with complex frontal sinus disease to be treated with endoscopic surgery. The objective of the current study was to evaluate management strategies and outcomes regarding treatment of lateral frontal sinus disease.

Study Design. Prospective case series.

Setting. Academic tertiary medical center.

Subjects and Methods. Prospectively collected data concerning frontal sinus pathology located lateral to the plane of the lamina papyracea (lateral disease) were reviewed. Data were collected regarding demographics, etiology, surgical technique, revision rate, anatomic considerations, and clinical follow-up. Only patients with at least 24 weeks of clinical follow-up and pathology who required removal and dissection in this region were included in the study.

Results. Over 5 years, 156 patients (mean age, 47.9 years; range, 14-84 years) with 183 lateral frontal sinus pathologies and an average clinical follow up of 76 weeks (range, 24-237 weeks) were evaluated. Endoscopic or open surgery was attempted in 84 patients (54%) prior to intervention at our institution. Primary pathologies included inflammatory/obstructive diseases (n = 119), skull base defects (n = 33), and tumors (n = 31). Initial interventions included endoscopic (Draf IIA, n = 76; Draf IIB, n = 52; Draf III, n = 23), extended (IIA + trephine, n = 1; III + trephine, n = 2; III + osteoplastic flap, n = 2), and open (osteoplastic flap, n = 3; Reidel, n = 1; cranialization, n = 1) procedures. Seven patients (4%) required a subsequent revision procedure.

Conclusion. The vast majority of lateral frontal sinus pathology was managed using endoscopic techniques with excellent outcomes and a low revision rate in the current study.

Keywords

sinusitis, sinus surgery, skull base, extended frontal sinusotomy, endoscopic sinus surgery, endoscopic skull base surgery, CSF rhinorrhea, chronic rhinosinusitis, frontal sinus, sinusotomy

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The treatment of frontal sinus pathology remains one of the most difficult areas to address in sinus surgery. Over the past 2 decades, significant advances in endoscopic technique, coupled with the development of novel endoscopic instruments to specifically address the frontal sinuses, have allowed sinus surgeons to treat an increasing number of complex cases that previously would not have been amenable to endoscopic surgery. These advances notwithstanding, the endoscopic treatment of benign and malignant frontal sinus pathology lateral to the lamina papyracea remains challenging.¹

While a large portion of the literature on the treatment of frontal sinus pathology has been devoted to inflammatory disease and the creation and expansion of the drainage pathway and frontal recess, lateral frontal sinus disease may present with a wide variety of pathologies, including inflammatory and obstructive diseases, skull base defects with associated encephaloceles and cerebrospinal fluid (CSF) leaks, benign and malignant neoplasms, and trauma. Furthermore, expanded techniques have allowed for revision “rescue” procedures to be completed without the use of open procedures. Despite this shifting paradigm, lateral frontal sinus disease remains in the realm of open or trephine-assisted surgery.

The current study sought to investigate the management strategies and surgical outcomes of patients treated for lateral frontal sinus disease over the past 5 years at our institution.

Methods

Subjects and Outcome Measures

Prospective evaluation and data collection of study subjects was approved by the University of Alabama at Birmingham ¹Department of Surgery/Division of Otolaryngology, University of Alabama at Birmingham, Birmingham, Alabama, USA

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Institutional Review Board. Patients undergoing treatment for lateral frontal sinus pathology were enrolled in the study (2008-2012). The mere presence of lateral pathology was not the only inclusion criterion for the study. Qualification was made intraoperatively with triplanar computed tomography (CT)—guided surgical navigation where dissection with frontal sinus instruments was required past the plane of the lamina papyracea over the orbit. For example, chronic frontal sinusitis or mucocele formation was included only when the source of obstruction (eg, type IV cell) was located above the orbit lateral to the aforementioned plane. Demographics, indication for surgery, pathology, type of surgical treatment, need for revision, special anatomic considerations, postoperative follow-up times, and complications were collected. The primary outcome measure was need for revision due to persistent or recurrent disease, determined by history and physical examination, office endoscopy with a 70-degree endoscope, and/or postoperative CT.

Surgical Technique

Triplanar CT assessment of frontal recess anatomy and CT-guided image guidance were used in all cases. The techniques for Draf IIa and IIb were consistent with those previously reported. The technique for Draf III was performed as previously reported with modifications as described below. In 2012, our group described a novel technique using mucosal grafts to cover the exposed anterior bone in Draf III procedures. This resulted in greatly decreased osteoneogenesis and no clinically significant frontal ostium stenosis. All of the Draf III patients in the current study underwent this modification.

The techniques for osteoplastic flaps, frontal trephination, cranialization, and Reidel procedures were consistent with those previously reported.

For most cases, specialized frontal instruments were used, including long Kuhn-Bolger seekers, Hosemann frontal punch, Cobra frontal sinus punch, a 70-degree endoscope with reverse or “offset” light post (light post above or away from the surgeon when scope is in up position), and a variety of 70-degree diamond burr drills. An “instrument-above-scope” technique was frequently employed to extend the reach of the instruments, where the surgeon keeps the endoscope inferior to the instrument within the sinonasal cavity to allow for greater visualization and superior, lateral reach of the instrument. Cerebrospinal fluid leak and tumor removal were performed as previously described.

Results

From 2008 to 2012, a total of 156 patients (average age 47.9 years [range, 14-84 years]; 97 male) underwent surgical treatment for lateral frontal sinus disease at our institution by a single otolaryngologist (B.A.W.). Due to the bilateral nature of some patients’ pathology, there were a total of 183 lateral frontal sinuses affected and treated. The average clinical follow-up was 76 weeks (range, 24-237 weeks). Primary pathologies were divided into 3 categories (Table 1). Inflammatory or obstructive diseases (n = 119) comprised most cases, including chronic frontal sinusitis (n = 67), allergic fungal sinusitis (n = 19), mucocele (n = 27), osteomyelitis (n = 4), and pneumocele (n = 2). Lateral septations or cells were dissected in all cases. Individuals with osteomyelitis were provided standard postsurgical intervention, including 6 weeks of culture-directed antibiotics. Cerebrospinal fluid leaks/skull base defects were the second primary category and included both traumatic (n = 22) and spontaneous (n = 11) etiologies. Finally, tumors (n = 31), including benign (n = 30) and malignant (n = 1) pathologies, were included in the study. It is important to note that the bulk of Draf III procedures performed for tumors of the anterior cranial base were excluded from analysis because the origin of the pathology was most often medial. Likewise, obstructive/inflammatory etiologies (eg, mucoceles and allergic fungal sinusitis) were included in the study only when present over the orbit (supraorbital) with orbital or skull base erosion present, and dissection of frontal cells or septations in the lateral frontal sinus were required.

Endoscopic or open surgery was attempted in 84 patients (54%) by other physicians prior to presentation at our institution. Initial surgical procedures by the senior author (B.A.W.) included endoscopic, extended endoscopic (endoscopic + open), and open procedures (Table 2). Endoscopic interventions included Draf IIa (n = 76), Draf IIb (n = 52), and Draf III (n = 23). Extended endoscopic procedures included Draf IIa with trephination (n = 1), Draf III with trephination (n = 2), and Draf III with osteoplastic flap (n = 2). Open procedures included osteoplastic flap (n = 3), Reidel (n = 1), and cranialization (n = 1) procedures.

Seven patients (4%) required a subsequent revision procedure after their initial treatment by the senior author (B.A.W.). All of these patients initially had an endoscopic procedure, and 3 required a revision open procedure (cranialization, Reidel, osteoplastic flap) while the other 4 were successfully revised endoscopically. All but one of these patients had previous endoscopic surgery prior to being treated at our institution.

### Table 1. Disease Etiology

<table>
<thead>
<tr>
<th>Pathology</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflammatory/obstructive</td>
<td></td>
</tr>
<tr>
<td>Chronic frontal sinusitis</td>
<td>67</td>
</tr>
<tr>
<td>Allergic fungal sinusitis</td>
<td>19</td>
</tr>
<tr>
<td>Mucocele</td>
<td>27</td>
</tr>
<tr>
<td>Osteomyelitis</td>
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</tr>
<tr>
<td>Pneumocele</td>
<td>2</td>
</tr>
<tr>
<td>CSF leak/skull base defect</td>
<td></td>
</tr>
<tr>
<td>Traumatic</td>
<td>22</td>
</tr>
<tr>
<td>Spontaneous</td>
<td>11</td>
</tr>
<tr>
<td>Tumor</td>
<td></td>
</tr>
<tr>
<td>Benign</td>
<td>30</td>
</tr>
<tr>
<td>Malignant</td>
<td>1</td>
</tr>
</tbody>
</table>

Abbreviation: CSF, cerebrospinal fluid.
Discussion

In the past decade, there has been a shifting paradigm in the treatment of frontal sinus disease. Frontal sinus pathology located lateral to the lamina papyracea has traditionally required extensive endoscopic approaches like the Draf III, extended procedures combining open and endoscopic approaches, or strictly open procedures such as osteoplastic flaps or cranialization. While the frontal sinus is considered the most difficult area to address using endoscopic techniques, the accumulation of experience and the development of frontal-specific instruments have allowed an increasing number of lateral sinus pathologies to be treated using endoscopic methods. Proper dissection of the frontal recess using a mucosal-sparing technique is paramount to achieving excellent success following an endoscopic frontal sinusotomy. Data presented in the current study indicate that advanced instrumentation and techniques can manage the overwhelming majority of lateral frontal sinus pathology.

The majority of lateral disease was addressed using standard Draf IIA and Draf IIB techniques. A 70-degree endoscope with the light post reversed or "offset" to permit maneuverability above and below the scope is indispensable for proper visualization of the frontal sinus during these procedures (Figure 1). In addition, the instrument-above-scope technique allows extended instrumentation of the lateral frontal sinus. For example, a 50-year-old man with chronic frontal sinusitis refractory to aggressive medical therapy was found on CT scan to have 4 completely opacified individual cells within the left frontal sinus—1 intersinus septal cell and 3 isolated compartments of the lateral aspect created by septations (Figure 2). Using a 70-degree endoscope, an anatomic dissection of the frontal recess was performed opening the frontal sinus and draining the intersinus septal cell. To acquire a better angle to the type IV cells, a Draf IIA procedure was converted to a Draf IIB by removing the anterior portion of the middle turbinate and extending the frontal dissection medially to the anterior septum. Using Kuhn-Bolger frontal instruments, a Hosemann frontal punch, and a 70-degree diamond burr, the bottom of each individual cell was opened and marsupialized with "instruments above the scope," sparing the surrounding mucosa. The 70-degree endoscope was critical for the dissection due to the superior and lateral locations of the cells. In the postoperative anesthesia unit, the patient reported dramatic resolution of his severe, debilitating headache despite surgical pain. The patient is symptom free at 18 months with the frontal sinus and all marsupialized cells widely patent (Figure 3).

The procedure revision rate in this study was 4%, with the majority of cases (4/7) for neoplastic disease, where tumor burden had to be completely cleared. This is in contrast to inflammatory or obstructive disease where establishment of a drainage pathway and clearance of gross disease are the goals. In these categories, there were no revisions required, and no case required an open procedure for assistance or treatment.

Of the 7 patients who underwent revision procedures, only 3 required open procedures for revision. One required a Reidel procedure with removal of an infected implant after debridement of osteomyelitic bone, and the other 2 individuals were for tumors (1 failed skull base repair requiring cranialization and 1 severe neoosteogenesis/closure requiring an osteoplastic flap).

Lateral endoscopic frontal sinus techniques continue to be refined, and new techniques are constantly under development. Our practice has previously reported on our experiences with novel endoscopic techniques employed to

Table 2. Surgical Intervention.

<table>
<thead>
<tr>
<th>Technique</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoscopic</td>
<td></td>
</tr>
<tr>
<td>Draf IIA</td>
<td>76</td>
</tr>
<tr>
<td>Draf IIB</td>
<td>52</td>
</tr>
<tr>
<td>Draf III</td>
<td>23</td>
</tr>
<tr>
<td>Extended</td>
<td></td>
</tr>
<tr>
<td>IIA + Trephine</td>
<td>1</td>
</tr>
<tr>
<td>III + Trephine</td>
<td>2</td>
</tr>
<tr>
<td>III + OPF</td>
<td>2</td>
</tr>
<tr>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>OPF</td>
<td>3</td>
</tr>
<tr>
<td>Reidel</td>
<td>1</td>
</tr>
<tr>
<td>Cranialization</td>
<td>1</td>
</tr>
</tbody>
</table>

Abbreviation: OPF, osteoplastic flap.

Figure 1. Instrument-above-scope technique using a reverse (A) and offset (B) endoscope. Note how the light post and cords (black arrow) are positioned so that an instrument (white arrow) can switch from an inferior to superior position.

Figure 2. (A) Two-dimensional coronal computed tomography and (B) 3-dimensional reconstruction of complex lateral frontal sinus pathology. Note the intersinus cell (arrow) is separate from the superior and lateral trapped compartments within the frontal sinus.
manage specific lateral frontal sinus pathologies, including frontal sinus CSF leak repair, endoscopic repair of posterior table fractures, and anterior table mucosal grafting techniques after Draf III and other advanced frontal sinus procedures.\textsuperscript{4,20,24} In the fracture repair study, we found that posterior table frontal sinus fractures up to 30 mm in length can be reduced adequately with transnasal endoscopic techniques (\textbf{Figure 4}). All patients in that study had patent frontal sinuses at their last operation, and there were no complications or CSF leaks. In the mucosal grafting study, septal mucosal grafts were used to cover the exposed bone of the anterior frontal recess after a Draf III drill-out procedure. Grafting provided far better outcomes than reported literature standards regarding revision surgery and frontal sinus closure. It is also possible to repair lateral frontal CSF leaks endoscopically, and in the present series, we required only trephine-assisted repair (mini-trephine to support lateral placement of the graph) in 1 of 24 cases (4%). These are just 3 examples of how refinement of technique has improved access to lateral frontal sinus pathologies.

Revision rates were low across the patient population, supporting the routine use of endoscopic management of frontal sinus pathology, at least as the initial therapy, in the majority of lateral disease. Current limitations for endoscopic techniques include lack of visualization of the far lateral frontal sinus, inability to obtain adequate margins or remove malignant pathology, and when frontal sinus patency would be unlikely postoperatively (\textbf{Figure 5}). Furthermore, it is crucial

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3}
\caption{(A) Intraoperative 70-degree endoscopy reveals no communication of the septated cells upon opening the frontal recess and the intersinus septal cell. (B) The bottom of the medial cell is removed with a Hosemann punch (left). The lateral cell is penetrated and reflected medially (right). The instrument is above the endoscope during dissection. (C) The central cell is now penetrated with complete drainage of all three cells (left). Endoscopic view at 6 months shows persistent patency (right). Arrows denote the marsupialized compartments. IS, area of opened intersinus septal cell.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4}
\caption{A 70-degree nasal endoscopy (A) and axial computed tomography (CT) scan (B) of an anteriorly displaced frontal sinus posterior table fracture (arrow) with CSF leak. Endoscopic view (C) of the posterior table after reduction corresponds well to the 6-week postoperative axial CT (D) after skull base repair.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5}
\caption{Axial computed tomography scan of a patient presenting with frontal osteomyelitis with draining fistula after 4 previous osteoplastic flap procedures (A). A Reidel procedure was performed due to the extent of bone infection and low probability of postoperative frontal patency. The patient was infection free at 6 months but elected not to undergo reconstruction of his forehead (B).}
\end{figure}
that the surgeon have a complete battery of frontal sinus instruments and a 70-degree endoscope at his or her disposal—preferably with an offset or reverse light cord. Adjustable angle endoscopes, higher speed drills, refined hand instruments, and robotics may provide even greater access to complex frontal sinus disease in the future.

Limitations of this study include heterogeneity of the subject population, etiology of frontal pathology, and the lack of a control group. While the purpose of the current study was to report outcomes on management of lateral frontal disease and not directly compare the endoscopic and open approaches, the ultimate choice of techniques will be variable based on surgeon experience. Thus, pursuing an open approach may be the most suitable and reliable method even when pathology could be addressed endoscopically.

Conclusion
Lateral sinus pathologies present complex challenges to the practicing rhinologist. New instruments and techniques have allowed for an increasing number of cases to be successfully treated with endoscopic methods. In the present study, most lateral sinus pathology was appropriately treated using endoscopic procedures with excellent outcomes and a low revision rate.

Author Contributions
Bryant T. Conger Jr, analyzed data, wrote article; Elisa Illing, wrote and revised article; Benjamin Bush, collected data, revised article; Bradford A. Woodworth, designed study, revised article.

Disclosures
Competing interests: Bradford A. Woodworth is a consultant for Gyrus, Olympus, ArthroCare ENT, and Cook Medical.
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