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MR Evaluation of Frontal Sinus Osteoplastic Flaps with Autogenous Fat Grafts

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PURPOSE: To investigate the MR findings in patients who have had osteoplastic frontal sinus flaps placed for inflammatory sinonasal disease. **METHODS:** The MR images of 13 patients who had improvement of symptoms after osteoplastic frontal sinus flap placement with fat autograft were prospectively evaluated for the presence of high intensity on T2-weighted scans, contrast enhancement, and replacement of frontal sinus fat by lower-signal soft tissue. All studies were performed on a 1.5-T unit using a 5-in round surface coil placed over the nasion. Sagittal T1-weighted, axial and coronal fast spin-echo T2-weighted, and precontrast and postcontrast axial and coronal T1-weighted images were obtained through the operative bed. The T2-weighted and postgadolinium sequences were done with a fat-suppression technique. **RESULTS:** Hyperintensity within the frontal sinuses on T2-weighted images and enhancement (peripherally and/or centrally where fat was replaced with soft tissue) were found to some degree in all patients. The degree of replacement of frontal sinus fat with soft tissue ranged from 4% to 85% (mean, 43%). Five patients with persistent symptoms had no distinguishing MR features when compared with asymptomatic patients. **CONCLUSIONS:** Although increased T2-weighted intensity, fat replacement, and enhancement are findings compatible with inflammation, these changes may be seen in patients who are asymptomatic after placement of osteoplastic frontal sinus flaps; they may represent the normal granulation process. MR findings after flap placement are nonspecific and have limited utility in distinguishing symptomatic patients with recurrent inflammatory disease from asymptomatic patients whose imaging findings are related to postoperative scar tissue.

Index terms: Paranasal sinuses, magnetic resonance; Paranasal sinuses, surgery; Magnetic resonance, postoperative

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Patients who have had osteoplastic frontal sinus flaps placed for management of chronic sinus inflammatory disease or trauma may have pain in the frontal sinus and/or orbital regions after the surgery. Possible explanations for the pain are: (a) frontal neuralgia related to surgical transection of supraorbital and supratrochlear sensory nerves (more commonly seen with brow incisions); (b) recurrent sinusitis; or (c) mucocele formation. Distinguishing between

these sources of pain clinically, in the absence of other constitutional symptoms of infection (fever, purulent drainage), is difficult, and imaging studies frequently are performed to exclude sinusitis. Computed tomography has been the mainstay of postoperative imaging, but fibrosis in the surgical bed and sinusitis may have identical density and enhancement characteristics (1). Magnetic resonance (MR) imaging, because of its refined soft-tissue discrimination, seems well suited for the evaluation of patients after osteoplastic frontal sinus flap placement, particularly when a fat autograft is used. The initial experience with conventional spin-echo imaging and fat-suppressed, contrast-enhanced MR imaging in symptomatic patients yielded a stereotypical pattern: a peripheral rim of high-intensity tissue amid fat-suppressed autograft centrally on T2-weighted images, which was isointense to muscle on pre-

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TABLE 1: MR findings after frontal sinus osteoplastic flap placement with autogenous fat graft

Case	Fat Resorption, %	Enhancement†	High Intensity on T2-weighted Images†	Mucocele	Disease in Other Paranasal Sinuses
1*	75	Mild peripheral > central	Moderate central > peripheral	No	Mild
2*	35	Moderate central	Moderate peripheral, mild central	No	Mild
3*	37	Mild peripheral (superior), central (inferior)	Moderate peripheral > central	No	Mild
4*	85	Moderate peripheral	Moderate central	Yes (superior)	Marked
5*	4	Mild peripheral	Mild peripheral	No	Moderate
6*	60	Mild peripheral (superior), central (inferior)	Mild central	No	Moderate
7*	58	Mild peripheral and central	Moderate peripheral and central	No	Marked
8*	60	Moderate central	Moderate central	No	Absent
9	75	Moderate central	Moderate central > peripheral	No	Mild
10	12	Mild peripheral	Mild peripheral	No	Absent
11	6	Mild central (inferior)	Mild peripheral (inferior)	Yes (inferior)	Marked
12	22	Mild peripheral	Moderate peripheral, mild central	No	Marked
13	35	Mild peripheral	Moderate central	Yes (superior)	Moderate

*Asymptomatic patients.

†Central refers to regions in which soft tissue has replaced adipose tissue; peripheral refers to tissue along the inner osseous margins of the frontal sinuses surrounding the autogenous fat graft.

contrast T1-weighted images and enhanced dramatically (2). However, in two patients who had no frontal sinus symptoms and were being evaluated for other reasons, the same constellation of imaging findings was noted. This led us to investigate the postoperative appearance in asymptomatic patients after placement of osteoplastic flaps with fat obliteration. By having a baseline of asymptomatic patients, one may better evaluate the images of symptomatic patients.

Methods

Permission was obtained from our institutional review board to investigate prospectively with enhanced MR patients who had undergone osteoplastic frontal sinus flap placement. All patients enrolled in the study were required to sign a standardized consent form. Thirteen patients (8 women, 5 men), representing the experience of three sinonasal surgeons, were recruited by the otorhinologists who performed the surgery and/or the neuroradiologists. Patients were either asymptomatic or had experienced partial resolution of symptoms referable to the frontal sinuses after osteoplastic flap placement. Office sinonasal endoscopic evaluation on the same day after the MR study in 7 patients, within 2 weeks of the MR in 3 patients, and between 1 and 2 months after MR in the remaining 3

patients, confirmed the absence of active frontal recess inflammation.

Ten of the 13 patients had MR studies between 9 and 14 months after frontal sinus obliteration. The remaining 3 patients had MR evaluations at 32 months, 9 years, and 12 years after surgery, respectively. All studies were performed on a 1.5-T Signa unit (General Electric, Milwaukee, Wis) using a 5-in round surface coil placed over the nasion. Sagittal (600/11/1 [repetition time/echo time/excitations]), axial and coronal (600/11/2), axial and coronal fast spin-echo (2500/90/2), and postgadolinium (0.1 mmol/kg) axial and coronal (600/11/2) images were obtained through the surgical bed. Other imaging parameters included a section thickness of 3 mm, with 1-mm intersection gaps and a matrix size of 256 × 192. The fast spin-echo T2-weighted and postgadolinium sequences were done with a frequency-selective fat-suppression technique. The quality of fat saturation on T2-weighted and contrast-enhanced images was graded by two neuroradiologists independently and was deemed excellent in all but 2 patients (in 1 of these cases fat suppression was not applied, and in the other fat saturation was only partially achieved). Enhanced imaging was done immediately after the intravenous administration of gadopentetate dimeglumine (Magnevist Berlex, Wayne, NJ) in axial and coronal planes.

Images were analyzed independently by two neuroradiologists. First, the frontal sinuses/surgical bed was evaluated to determine the degree of fat resorption (replace-

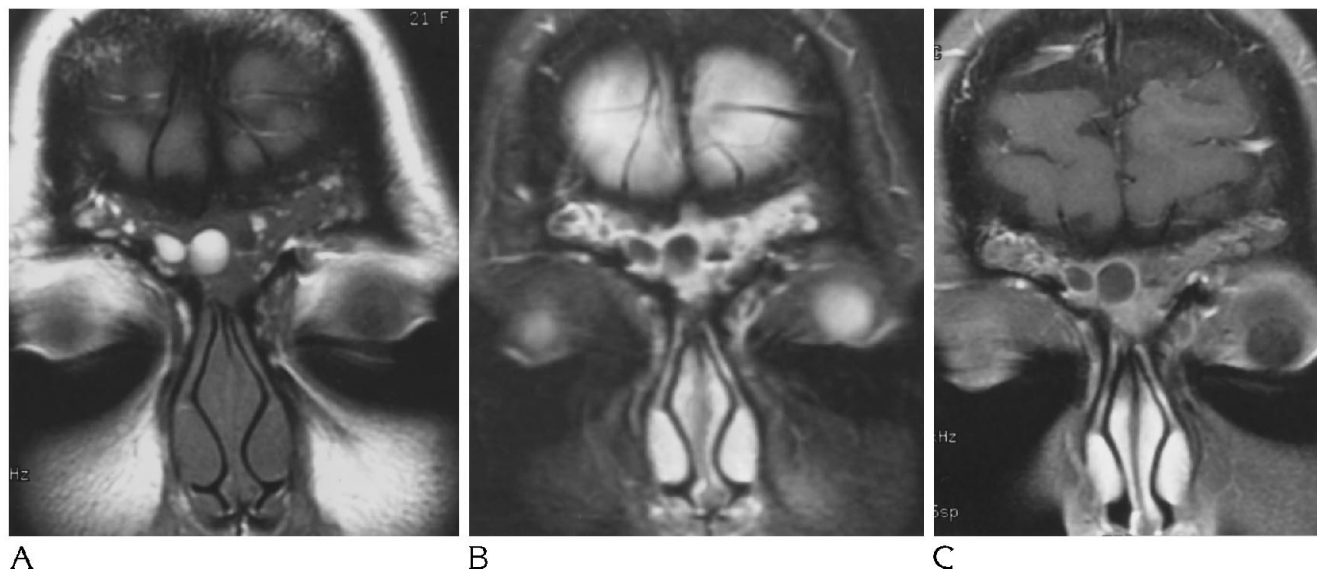


Fig 1. Coronal MR images 14 months after placement of an osteoplastic frontal sinus flap for treatment of chronic sinusitis. Since the surgery, this patient has had marked improvement of symptoms, with only occasional left frontal/orbital headaches.

A, T1-weighted image demonstrates only a small residuum of high-intensity fat (evaluation of serial images showed approximately 75% of the fat to be replaced with soft tissue).

B, T2-weighted image with fat saturation shows the central soft tissue replacing the fat to be hyperintense.

C, Fat-suppressed T1-weighted image with contrast shows moderate central enhancement of the soft tissue.

ment of adipose tissue with lower-signal soft tissue). The percentage of fat replacement based on a fraction of the cross-sectional area was estimated by each neuroradiologist, and the mean of these two values was recorded. Variability in the estimation of fat replacement between the two readers for each case ranged from 0% to 10%. Next, in regions where the fat autograft was replaced with soft tissue (which was isointense to muscle on the T1-weighted images), fat-suppressed T2-weighted images were evaluated for corresponding high-signal intensity, and postcontrast images were evaluated for associated enhancement. In addition, peripheral (rim) or central high-intensity tissue on T2-weighted images as well as enhancement along the inner osseous margins of the frontal sinuses surrounding the autograft were noted. Hyperintensity on T2-weighted images and enhancement were graded as absent, mild, moderate, or marked. When the results of film analysis by the two neuroradiologists were compared, there was no discrepancy in the pattern of hyperintensity or enhancement. If there was a difference in interpretation of changes as mild or moderate, the films were reviewed and a consensus obtained. Finally, mucocoeles in the frontal sinus surgical bed and inflammatory disease (absent, mild, moderate, or marked) in the other paranasal sinuses were evaluated.

Results

Of the 13 patients who reported improvement in their symptoms after the osteoplastic flap

procedure, 8 were asymptomatic and 5 had significant improvement of their symptoms, although they had persistent complaints. In these latter 5 patients, residual symptoms included brow pain, orbital pain, frontal headaches, and/or frontal sinus fullness. None of these patients had purulent nasal drainage or fevers at the time of MR imaging. Endoscopic evaluations revealed no evidence of active inflammation.

MR demonstrated replacement of adipose tissue with lower-signal soft tissue in all patients, though the degree of fat replacement ranged widely from 4% to 85%, with a mean of 43% (Table 1). There was no apparent difference in the degree of fat replacement among the 3 patients imaged between 2.75 and 12 years after surgery and the 10 patients imaged between 9 and 14 months after placement of osteoplastic flaps. The mean degree of fat replacement was 30% (range, 6% to 75%) and 51% (range, 4% to 85%) for the 5 patients with residual symptoms and the 8 asymptomatic patients, respectively. Hyperintensity within the frontal sinuses on T2-weighted images and enhancement (peripherally amid the autograft and/or centrally where fat autograft was replaced with soft tissue) also

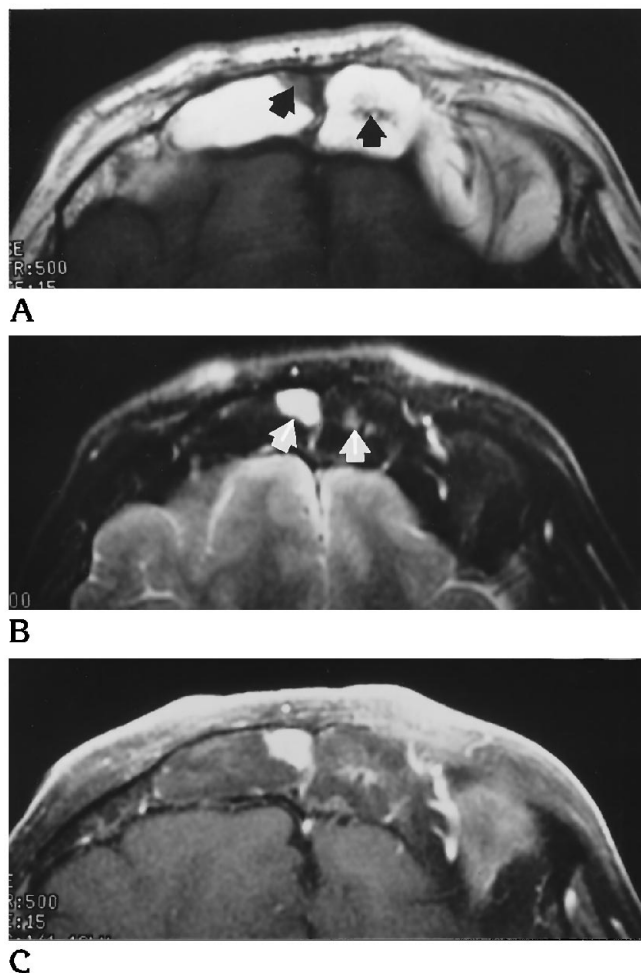


Fig 2. Axial MR images 13 months after osteoplastic frontal sinus flap. This patient remains asymptomatic.

A, T1-weighted image shows the fat autograft in the frontal sinus surgical bed. With the exception of a small amount of soft tissue (arrows) centrally within the left frontal sinus and anteromedially on the right, the fat is relatively preserved.

B, T2-weighted image with fat saturation shows the soft tissue to be hyperintense (arrows).

C, The soft tissue enhances on this T1-weighted fat-suppressed image.

were found to some degree in all patients (Table 1). The most common imaging pattern was that of peripheral rim (9 cases) and central (10 cases) T2-weighted hyperintensity with associated peripheral ($n = 6$) or central ($n = 7$) enhancement, respectively (Figs 1 and 2). In the cases in which no T2-weighted hyperintensity was noted (peripheral, $n = 4$; central, $n = 3$), peripheral or central enhancement was nonetheless demonstrated in 3 and 1 cases, respectively. A mucocoele (characterized on MR as an expansile mass with only rim enhancement) in the surgical bed was identified in 3 patients.

MR evaluation of the remaining paranasal sinuses demonstrated minimal or no disease in six patients and moderate to marked chronic inflammatory changes in seven cases.

Sinonasal endoscopy demonstrated surgical sealing (occlusion) of the nasofrontal duct in 23 of 26 instances (evaluation of the right and left ducts in 13 patients; Table 2). Small unilateral passageways were identified in 3 patients (the contralateral nasofrontal ducts were sealed). In 1 of these cases, the passageway was communicating with the frontal sinus. Even in retrospect, this was not appreciated on MR. In the other 2 patients, the passageways were felt to represent tiny, blind-ending tracts. In addition, endoscopy confirmed the absence of acute sinusitis in the remaining paranasal sinuses; however, chronic inflammatory extrafrontal changes were identified in 7 patients whose corresponding MR exams showed moderate or marked disease (Table 1).

Discussion

Frontal sinusitis is a common complication of upper respiratory tract infections. Although many patients with acute frontal sinusitis respond to conventional medical treatment, there are some series in which as many as 50% of patients ultimately require surgical intervention (3). Osteoplastic frontal sinus flaps with sinus obliteration are most often placed in patients for management of symptoms related to chronic inflammatory disease; however, this procedure also may be used in patients after trauma or, less frequently, to treat frontal sinus osteomas and mucocoeles (4, 5). Successful surgery requires meticulous technique in which (a) the frontal sinus mucosal lining is completely removed and (b) the frontal sinus is obliterated and isolated from the nasal cavity by plugging the nasofrontal duct (4, 6–8). Successful sinus obliteration is not easy; investigators have experimented with several materials including fat, bone, hydroxyapatite, Proplast, methyl methacrylate, and other materials to achieve this end (6, 8–10). When an autogenous fat graft (usually obtained subcutaneously from the abdominal wall) is used to obliterate a sinus, there are competing forces at play. On the one hand, there may be fibrovascular ingrowth and osteogenesis from the nasofrontal duct wall, which favorably creates a fibroosseous plug in this passageway. On the other hand, there may be

TABLE 2: Clinical data after frontal sinus osteoplastic flap placement

Patient	Symptoms	Duration between Surgery and MR	Endoscopic Exam of Nasofrontal Ducts
1	None	12 mo	L and R sealed off
2	None	9 mo	L and R sealed off
3	None	12 mo	L sealed; R tiny tract
4	None	12 y	L open; R sealed off
5	None	12 mo	L and R sealed off
6	None	32 mo	L sealed; R tiny tract
7	None	12 mo	L and R sealed off
8	None	14 mo	L and R sealed off
9	Residual left frontal and orbital headache*	14 mo	L and R sealed off
10	Recurrent pain and swelling forehead	12 mo	L and R sealed off
11	Mild recurrent brow pain*	13 mo	L and R sealed off
12	Left frontal pain and pressure*	14 mo	L and R sealed off
13	Frontal headache*	9 y	L and R sealed off

*Symptoms significantly improved since surgery.

retraction of the fat by scar leading to a patent nasofrontal channel.

Failure of frontal sinus osteoplastic flaps with fat autograft may be related to either replacement of the adipose tissue with fibrous tissue and/or incomplete removal or regeneration of the mucosal lining (8, 11). The health of the fat within the sinus is dependent on its close apposition to the intact osseous sinus walls. The vascularity of bone aids in the viability of the fat via neovascularity, preventing its retraction and thus inhibiting the ingrowth of mucosa through the nasofrontal duct. When portions of the bone are resected or are missing from trauma, retraction and replacement of the fat graft frequently occur. New bone growth in successful fat obliterations occurs in only 5% of cases (10).

It has been shown that mucosa left behind or regenerating frontal sinus mucosa have a particular propensity to form cysts and/or small mucocoeles, which then may become secondarily infected (7, 12, 13). Retraction and replacement of fat from the nasofrontal duct allow ingrowth of epithelium from the nasal cavity into the frontal sinus, which also may encyst, leading to inflammatory disease and subsequent mucocoele formation. The overall long-term success rate for frontal osteoplastic proce-

dures with fat obliteration ranges from 75% to 93% (3, 13).

Complications inherent to the procedure include recurrent sinusitis, infection of the fat autograft, cellulitis, osteomyelitis of the osteoplastic flap, and mucocoeles (1). Cellulitis usually presents with skin thickening and erythema, and osteomyelitis in addition may present with bulging of the osteoplastic flap. However, detection of recurrent sinus inflammatory disease may be difficult, because postoperative neuralgia may simulate recurrent sinusitis at an early stage before muco(pyo)cele formation has begun (1). It is imperative to detect these complications promptly after osteoplastic obliteration, because the attendant risks to the intracranial and orbital structures are huge. Such risks include meningitis, epidural abscess, subdural empyema, cerebritis, thrombophlebitis, orbital cellulitis, and perivascular and perineural spread of infection. Although MR is excellent for assessing orbital and intracranial complications related to sinus inflammatory disease, it would be advantageous to be able to detect recurrent sinusitis early so as to significantly reduce the likelihood of these secondary complications. Unfortunately, the analysis of CT and MR images for recurrent sinus inflammatory disease after osteoplastic flaps is difficult.

One previous publication has addressed the dilemma of radiographic evaluation of failed frontal sinus osteoplastic flaps (1). This manuscript was published in a clinical journal, and analysis of the signal intensity of the sinus con-

TABLE 3: Proposed pathologic substrates corresponding to MR findings

Central	
↑ T2-weighted SI, no enhancement	→ Secretions
↑ T2-weighted SI, enhancement	→ Granulation tissue or inflammation
↓ T2-weighted SI, no enhancement	→ Fat, scar, or fibrosis
↓ T2-weighted SI, enhancement	→ Granulation or scar tissue
Peripheral (rim)	
↑ T2-weighted SI, no enhancement	→ Mucosa or fluid
↑ T2-weighted SI, enhancement	→ Mucosa or granulation tissue
↓ T2-weighted SI, no enhancement	→ Fibrosis
↓ T2-weighted SI, enhancement	→ Granulation tissue, neovascularity

Note.—Central T2-weighted signal findings were isointense to muscle on corresponding T1-weighted images; peripheral T2-weighted findings were isointense or hypointense on corresponding T1-weighted images; ↑ indicates increased; ↓, decreased; and SI, signal intensity.

tents was ambiguous (1). In addition, postcontrast images were not evaluated. The authors' conclusions that high intensity on T2-weighted images reflects inflammation of the autograft fat, whereas low intensity is attributable to fibrovascular ingrowth, do not reflect the experience of others elsewhere in the head and neck (14). Furthermore, the findings in this study do not agree with their conclusions.

In the present study, hyperintensity within the frontal sinuses on T2-weighted images and enhancement (peripherally and/or centrally where fat was replaced with soft tissue) were found to some degree in all patients. The degree of replacement of frontal sinus fat with soft tissue ranged from 4% to 85% (mean, 43%). The five patients with persistent symptoms had no MR features to distinguish them from the eight asymptomatic patients.

It is the prevailing sentiment that postoperative granulation tissue and scar material are dynamic tissues that may have wide-ranging and variable intensity and enhancement characteristics. For example, central hyperintensity on T2-weighted images associated with enhancement on corresponding postcontrast T1-weighted images could represent granulation tissue or inflammation, whereas central hypointensity on T2-weighted images associated with enhancement may similarly represent scar tissue (Table 3). In our study, hyperintensity and enhancement within the frontal sinuses (peripherally, centrally, or both) were found to some degree in all patients who reported resolution or improvement of their symptoms. On endoscopic evaluation, none of these patients had evidence of acute inflammatory disease.

The area where MR examination after flap placement may prove to be most useful is in the early detection of mucocoele formation in relatively asymptomatic patients, as was the case in three of our patients. The development of mucocoeles implies the presence of regenerating sinus mucosa with cyst formation. These cysts or mucocoeles may become secondarily infected or may enlarge and lead to symptoms. Hence, mucocoele detection on MR may identify those patients at highest risk for recurrent frontal sinus inflammatory disease at a time when endoscopy is unremarkable.

In conclusion, we speculate that MR findings after osteoplastic frontal sinus flap surgery represent a spectrum of tissues including not only chronic inflammatory changes and retained secretions, but also scar material, including granulation tissue and fibrosis. MR findings after osteoplastic frontal sinus flap placement are nonspecific and have limited utility in distinguishing symptomatic patients with recurrent inflammatory disease from asymptomatic patients whose imaging findings are related to postoperative scar tissue.

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