Evaluation of Hydroxyapatite Cement for Frontal Sinus Obliteration After Mucocele Resection

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Objectives: To retrospectively evaluate our experience with frontal sinus obliteration using hydroxyapatite cement (BoneSource; Stryker Biotech Europe, Montreux, Switzerland) and compare it with fat obliteration over the approximate same period. Frontal sinus obliteration with hydroxyapatite cement represents a new technique for obliteration of the frontal sinus after mucocele resection.

Methods: Exploration of the frontal sinus was performed using bicoronal, osteoplastic flaps, with mucosal removal and duct obliteration with tissue glue and muscle or fascia. Flaps were elevated over the periorbita, and Silastic sheeting was used to protect the BoneSource material from exposure as it dried. The frontal table was replaced when appropriate.

Results: Sixteen patients underwent frontal sinus obliteration with fat (fat obliteration group), and 38 patients underwent obliteration with BoneSource (BoneSource group). Fat obliteration failed in 2 patients, who underwent subsequent BoneSource obliteration, and none of the patients in the BoneSource group has required removal of material because of recurrent complications. Frontobasal trauma (26 patients [68%] in the BoneSource group and 9 patients [56%] in the fat obliteration group) was the most common history of mucocele formation in both groups. Major complications in the BoneSource group included 1 patient with skin fistula, which was managed conservatively, and 1 patient with recurrent ethmoiditis, which was managed surgically. Both complications were not directly attributed to the use of BoneSource. Contour deficit of the frontal bone occurred in 1 patient in the fat obliteration group and in none in the BoneSource group. Two patients in the fat obliteration group had donor site complications (hematoma and infection). Thirteen patients in the BoneSource group had at least 1 prior attempt at mucocele drainage, and no statistical relation existed between recurrent surgery and preservation of the anterior table.

Conclusion: Hydroxyapatite is a safe, effective material to obliterate frontal sinuses infected with mucoceles, with minimal morbidity and excellent postoperative contour.

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ment within 4 to 6 hours. It has been shown that, over time, the hydroxyapatite cement becomes replaced by bone without volume loss. The material has been stable in its use for frontal sinus obliteration. In the present study, we retrospectively review our experience with using hydroxyapatite cement for frontal sinus obliteration after mucocele excision. We also report our final series of patients who underwent frontal sinus obliteration with fat and our use of hydroxyapatite cement for reconstructive sinus obliteration in patients without previous mucocele surgery.

**METHODS**

**PATIENTS**

A retrospective review of all mucocele-related frontal sinus obliterations from 1994 to May 2005 was completed. All patients were treated at a single specialty clinic, with the same team of surgeons providing surgical services for the period reviewed. All patients had been diagnosed as having frontal sinus mucocele. Patients were categorized as either having undergone obliteration with fat, starting in 1994 (fat obliteration group), or with hydroxyapatite cement (BoneSource; Stryker Biotech Europe, Montreux, Switzerland) (BoneSource group), which first became available to our clinic in December 1997. One patient underwent frontal sinus obliteration with lyophilized cartilage, and 4 patients had prior sinus obliterations as part of their treatment for other frontal or skull base trauma, without the presence of frontal sinus mucocele. There were 38 patients in the BoneSource group and 16 patients in the fat obliteration group. Each patient’s medical chart was reviewed preoperatively and postoperatively. Given the nature of the referral patterns to our clinic, some patients referred from other countries were sent back to their countries for follow-up, with only complications or problems being reported back to our clinic.

**SURGICAL APPROACH FOR OBLITERATION**

All patients with evidence of active mucocele infection were given 1 week of antibiotics prior to surgical intervention. A standard coronal approach was used for all sinuses, with subperiosteal dissection up to the orbital rims. The supraorbital nerves were resected from their canals using a Kerrison forceps, and the flaps were brought to the nasal bone inferiorly, with necessary release of the periorbita down to the orbital roof (Figure 1A). The outline of the frontal sinus was identified with light from an endoscope and then traced. A high-speed oscillating saw was then used to remove the anterior table and remnants. Careful attention was paid to the removal of all mucosa with forceps and high-speed cutting and diamond drills. The frontonasal ducts were then visualized, and pericranium or temporalis muscle and fascia were harvested for closing the duct. In most cases, fibrin glue was applied to this muscle to ensure proper sealing of the duct. At this point in the fat obliteration cases, fat was harvested from the abdomen and used to pack the sinus. The frontal table was then replaced as best as possible. In the single case of obliteration with lyophilized cartilage, the cartilage was obtained from Neutromedics, Cham, Switzerland.
For the BoneSource obliteration procedure, the frontal table was discarded in some cases when it was noted to be insufficient. In some cases, this bone was atrophic with noted deficits. Once the frontal sinus mucosa was removed and the duct blocked, the sinus was packed with gauze to help keep the cavity dry. Silastic sheeting was cut and placed against the periorbita to prevent adhesion of the BoneSource material against the eye, leading to theoretical fibrosis (Figure 1B). These sheets also allowed for proper contouring of the orbital roof to provide an even surface for BoneSource material to dry against. Once protected, the nasofrontal ducts were checked to ensure nonmigration inferiorly over the BoneSource. These drains were removed on postoperative days 1 through 3. The patients received 1 week of postoperative antibiotics, with selective use if cultures obtained from the mucocele were positive for evidence of active bacterial infection.

Preoperative and postoperative photographs were obtained. When appropriate, postoperative computed tomographic scans were obtained. More of such postoperative scanning was performed early in the series. Patients were then followed up either in our center or with appropriate specialists in their respective countries. Statistical analysis was performed to determine odds ratios and P values (χ² test; P < .05 was considered significant) using SAS statistical software (SAS Institute Inc, Cary, NC).

RESULTS

Figure 2 and Figure 3 show a frontal sinus mucocele, and Figure 4 shows a frontal sinus demonstrating integration about 1 year after obliteration surgery.

FRONTAL SINUS OBLITERATION WITH FAT

The fat obliteration group included 14 men and 2 women, with a mean age of 47.5 years. The final fat obliteration procedure occurred in 2002. All patients in this group presented with mucoceles. Of the 16 patients, 12 (75%) were followed up in our clinic for a mean of 22.3 months after surgery. Nine patients (56%) had a history of frontal sinus trauma (Table 1). The mean time from the trauma to surgery for the mucocele was 10.6 years (range, 1-20 years). Of these 9 trauma patients, only 1 patient had 2 prior attempts at mucocele drainage with recurrence, while the others were undergoing their first mucocele surgery. The other histories included chronic sinusitis (4 patients), posttumor sinonasal tumor removal (2 patients), and unknown etiology (1 patient). Of the 4 patients with chronic infection as the cause for the mucocele, 2 had drainage attempts at mucocele drainage with recurrence, while the others were undergoing their first mucocele surgery. The other histories included chronic sinusitis (4 patients), posttumor sinonasal tumor removal (2 patients), and unknown etiology (1 patient). Of the 4 patients with chronic infection as the cause for the mucocele, 2 had drainage attempts prior to the fat obliteration. The 2 patients with posttumor sinonasal tumor removal and the 1 patient with mucocele of unknown etiology had no prior mucocele drainage surgical procedures.

In regard to complications in the fat obliteration group (Table 2), the most common was short-term swelling and pain (5 patients). Two patients had supraorbital hypoesthesia. Two patients had abdominal harvesting complications (1 hematoma and 1 infection), which were resolved with appropriate treatment. One patient had a frontal bone contouring defect. The flap hematoma in the one patient self-resolved with conservative treatment. Of the 16 patients, 2 (13%) developed recurrent mucoceles and 6 years after fat obliteration.
These patients then underwent reexploration and obliteration with BoneSource. The single patient who underwent frontal sinus obliteration with lyophilized cartilage also had a history of frontal sinus trauma. This patient had no recurrences or complications as of 8 years after obliteration.

FRONTAL SINUS OBLITERATION WITH BONESOURCE

The BoneSource group included 27 men and 11 women, with a mean age of 44.7 years (range, 19-74 years). The final obliteration reviewed occurred in May 2005. Long-term clinical follow-up or radiographic follow-up with computed tomography was completed at our clinic for 18 patients, with a mean follow-up of 18 months after surgery. Of the 38 patients, 26 (68%) had a history of frontal or skull base trauma, 8 (21%) had histories of chronic sinus infections, 3 (8%) had undergone prior skull base tumor surgery, and 1 had undergone prior orbital decompression surgery. Of the 26 trauma patients, we could identify the exact trauma dates in 23 patients. The mean time from the date of trauma to the BoneSource obliteration was 13.4 years (range, 3-40 years). Of the 38 patients, 13 (34%) had 1 prior procedure attempting to manage the mucocele. In the trauma group, 7 patients had 1 prior surgery attempting to externally (6 patients) or endoscopically (1 patient) drain the mucocele. One patient had 3 prior operations to control a cerebrospinal fluid leak in the late 1970s after severe frontal and skull base trauma. Among the patients with chronic sinus infection in the BoneSource group, 1 had undergone a single prior attempted drainage procedure, 1 had undergone 5 prerelief drainage procedures, and 1 had undergone prior fat obliteration that was performed at our clinic. The other patient in whom the fat obliteration had failed involved a patient with tumor, who underwent a prior juvenile nasopharyngeal angiofibroma skull base resection. Of the other 2 patients with tumor, 1 had undergone a single prior procedure and the other had 8 prior attempts at drainage before the BoneSource obliteration. The orbital decompression patient had also undergone 1 prior drainage attempt. Finally, 1 patient had undergone a previous transfrontal craniotomy and external sphenoid ethmoidectomy for a brain abscess.

Looking at the minor complications in the BoneSource group (Table 2), 3 patients had hematomas, which resolved with conservative, nonsurgical management. A

| Table 1. Histories of the Patients Prior to the Obliteration Procedure* |
|---------------------------------|----------------|----------------|
| History | Fat Obliteration | BoneSource† |
| Trauma | 9 | 26 | 0 |
| Infection | 4 | 8 | 1 |
| Tumor | 2 | 3 | 0 |
| Other | 1 (Unknown cause) | 1 (Orbital decompression) | 0 |

*Data are given as number of patients.
†A hydroxyapatite cement (Stryker Biotech Europe, Montreux, Switzerland).

| Table 2. Complications Encountered for Both Obliteration Procedures* |
|---------------------------------|----------------|----------------|
| Complication | Fat Obliteration | BoneSource |
| Frontal swelling or pain | 5 | 1 |
| Frontal hypoesthesia | 2 | 3 |
| Flap hematoma | 1 | 4 |
| Donor site hematoma | 1 | 0 |
| Donor site infection | 1 | 0 |
| Failed obliteration | 2 | 0 |
| Contouring deficit | 1 | 0 |
| Recurrent mucocele | 2 | 0 |
| Eye edema | 0 | 2 |
| Skin fistula | 0 | 1 |
| Ethmoid abscess | 0 | 1 |

*Data are given as number of patients.
There has been much discussion about the ideal material for frontal sinus obliteration for mucocele infections. Hydroxyapatite cement represents one new material that osteointegrates into the bone and provides a stable contour to the frontal bone. Unlike autologous materials that require the frontal sinus table to remain intact, this material is ideal when there are deficits from severe trauma or infectious bone erosion. While the key to success in this operation is clearly the effective removal of mucosa and obliteration of the frontonasal duct, the ability to properly close the anterior table is difficult in many revision cases after trauma repair, skull base tumor surgery, or failed recurrent infectious drainage. In this case series, we reviewed our 11 years of experience with frontal sinus obliteration for mucoceles using fat, cartilage, and, since 1997, BoneSource.

Our clinic is a large tertiary care trauma and skull base referral center, with patients coming both from our service area and from other countries in Europe and the Middle East. The large volume of treated skull base trauma contributed to this patient group being the largest primary source of our patients with mucoceles. While we followed 12 patients (75%) in the fat obliteration group and 18 patients (47%) in the BoneSource group for a long term in our clinic, the nature of the referral system from other countries is such that patients are followed up in their respective countries and we receive reports of any complications. We are confident using this system of follow-up, given the pathophysiologic features of frontal sinus mucocele disease, which can take many years to manifest. In this series, the mean time from frontal trauma occurrence to the obliteration procedure was 10.6 years in the fat obliteration group and 13.4 years in the BoneSource group. Following up multinational patients over such a long period is nearly impossible. To date, our longest period of follow-up for a patient in the BoneSource group is 8 years, and we feel comfortable with our system of follow-up for patients who can make regular visits to our center and patients for whom other physicians send us reports of any complications.

The surgical techniques we used for treating frontal sinus mucocele are similar to those published previously for fat obliteration by Weber et al and for hydroxyapatite cement by Petruzelli and Stankiewicz. For the fat obliteration procedure, the only difference in our technique is the use of temporalis muscle and fascia with fibrin glue to seal the duct. For the BoneSource obliteration procedure, there are a few modifications in our technique worth mentioning. In patients with identifiable supraorbital nerves, these nerves are released from their foramina and the flap is elevated over the orbits such that the orbital roof is visible. In this area (Figure 1A), Silastic sheets are cut and temporarily placed against the periorbita to protect it from coming into contact with the BoneSource as it dries. This is done to prevent the theoretical problem of having the hydroxyapatite cement dry against the periorbita and cause unwanted adhesion. These sheets also provide a nice surface to properly contour the BoneSource as it comes to the orbital roof.

In the fat obliteration group, 2 patients developed recurrent mucoceles at 4 and 6 years after surgery, giving us a recurrent infection rate of 13% in this small group. The patient who had recurrence 6 years later had 5 prior drainage procedures at outside facilities to manage his...

### Table 3. Histories of Patients in the Cause for BoneSource Obliteration Group and Whether the Anterior Table Was Preserved

<table>
<thead>
<tr>
<th>History</th>
<th>Anterior Table Preserved</th>
<th>Anterior Not Table Preserved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma</td>
<td>12 (41)</td>
<td>14 (31)</td>
</tr>
<tr>
<td>Infection</td>
<td>4 (11)</td>
<td>4 (11)</td>
</tr>
<tr>
<td>Tumor</td>
<td>0</td>
<td>3 (23)</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>1 (11)</td>
</tr>
</tbody>
</table>

*Data are given as number of patients. BoneSource is a hydroxyapatite cement (Stryker Biotech Europe, Montreux, Switzerland).
†Indicates the number of patients in the listed category who had at least 1 previous surgery attempting to manage the mucocele.
chronic frontal sinusitis. This patient is currently in his fifth year after the BoneSource obliteration without evidence of recurrence. The other recurrence was in a patient with extensive skull base tumor surgery for a large juvenile nasopharyngeal angiofibroma. Our recurrence rate is higher than the 3% reported in the largest series by Hardy and Montgomery, 3 though our numbers in this series from 1994 to the present are relatively small. These failures in patients with multiple prior surgical procedures or extensive transfacial sinus surgery brings to light previous observations that despite duct obliteration, poor fat vascularization may contribute to recurrent mucoceles in select cases. 8 To date, these 2 patients in whom fat obliteration had failed have not had recurrence for 5 years and 1 year since the BoneSource obliteration. It will be interesting to see how such patients with multiple or extensive surgical procedures fare in the long term with BoneSource.

The single patient who underwent the lyophilized cartilage obliteration also had no further complications or recurrences of the mucocele to date. Our experience with this substance for frontal sinus obliteration is too limited to make further noteworthy comments. However, we agree that the theoretical risk of disease transmission, the lack of cost savings, and the availability of other substances like hydroxyapatite cement makes this a less attractive option. The single lyophilized cartilage obliteration in this series was completed in 1997, the same year hydroxyapatite cement became available to our clinic.

The other complications in the fat obliteration group were generally minor, though the presence of donor site issues is noteworthy. The swelling, pain, and hematoma complications were managed conservatively without sequelae. While care is taken to preserve the supraorbital nerves, hypoaesthesia is unavoidable in patients with revision surgery raising multiple coronal flaps. Given the large number of trauma patients in this study who had all had previous coronal flaps, the incidence is relatively low in both this group and the BoneSource group. The final complication worth noting was the frontal bone defect noted in 1 patient. One factor that spurred the use of BoneSource in these patients in 1997 was the issue of poor frontal bone contour in patients with previous trauma. The use of hydroxyapatite cement in craniofacial reconstruction has been noted to be safe and effective. 23 Our experience with using hydroxyapatite cement for such reconstructions has been very successful. In the medical chart reviews, we found 4 cases of extensive frontal bone defects from tumors and a hemangioma that were successfully reconstructed with good cosmetic and functional results. In the BoneSource group, all of the patients had good contour in the short-term postoperative evaluation, with similar results noted in those patients we have seen postoperatively.

The complications in the BoneSource obliteration group included 3 patients who developed small-flap hematomas, which resolved without a need for further drainage, and 1 patient who was taken back for drainage. All patients with coronal flaps had coronal drains placed, and care was taken to position these posteriorly so that they do not rise up to where the BoneSource is present. In our experience, however, we have come to believe that it is unlikely, given the intraoperative waiting for BoneSource solidification, that suction drains would affect this substance postoperatively. Because of our superior orbital release for the placement of the protective Silastic sheets, 2 patients had orbital edema, which resolved without sequelae. In the 2 patients with the larger complications of the fistula and the need for revision ethmoidectomy, we do not believe that the BoneSource contributed to either of these complications. The patient with the nasofrontal and supraorbital soft tissue fistula had a prior brain abscess, underlying bone necrosis, and soft tissue chronic inflammation over these areas prior to the surgery, and both fistulas resolved with wound care and antibiotic therapy. The patient with the ethmoid abscess necessitating 2 drainage procedures had 3 prior skull base procedures for cerebrospinal fluid rhinorrhea after his initial frontal sinus and skull base surgery. Neither ethmoidal drainage procedure involved the frontal sinus or subcutaneous tissues, and the BoneSource obliteration did not seem to be affected by this infection. This patient also had not had any more complications after these ethmoid procedures.

In this case series, special focus was given to patients with diagnosed frontal sinus mucoceles, with several patients in whom fat obliteration had failed or who had previous procedures for attempted drainage. Friedman et al 17 originally questioned whether the existence of frontal sinus mucoperiosteal disease increased the complication rate of hydroxyapatite cement implantation. In a recent analysis by Mathur et al, 24 mucoperiosteal disease did not appear to predict complication outcome using carbonated apatite and hydroxyapatite. The combined infection risk in this article was 13%. The authors also cautioned against the use of these substances in obliterating sineses exposed to sinus or oral secretions. 24 Our experience with BoneSource is contrary to these reports, with only 2 patients having recurrent infections after the procedure, both of whom were conservatively treated without implant removal. Several technique variations may have contributed to this low infection rate in a group considered to be at higher risk by previous authors. The first factor may be the use of the protective Silastic sheets to prevent contact of the hydroxyapatite cement with the orbits. We have found that these sheets also prevent the hydroxyapatite cement paste from going into the ethmoid sinus region, which was open in many of the patients from previous procedures. Unfortunately, the presence of open ethmoid cells was not specifically noted in operative reports, which focused on the frontal sinus obliteration. Possibly, placing fascia or pericranium over the open ethmoid roof might be beneficial to block this hypothesized source of infection. Overall, we believe that keeping the hydroxyapatite cement off the nasal mucosa until it dries is an important procedural step. The second favorable factor might be the meticulous obliteration of the frontonasal duct. While this step is key to any obliteration surgery, the use of tissue glue with the muscle or fascia and then waiting for the glue to dry before placing the BoneSource might be key to ensuring proper duct closure. The third factor may be the importance of not replacing the anterior table bone when it is deemed to be of poor stock. While our data showed no statistically significant indicator of which patients had
their bones preserved, we think it is advantageous to remove infected, poorly vascularized, or cosmetically deficient bone and only have BoneSource in the cavity. The final factor was our reluctance to operate on any mucocele with active infection, preferring 1 week of antibiotic therapy prior to surgery.

While long-term follow-up is still needed, none of the patients in the BoneSource obliteration group has had recurrent mucoceles to date. Despite this success, the issue of cost in using this substance cannot be ignored. Fattahi et al.19 have recently published an article questioning the cost-effectiveness of hydroxyapatite cement in frontal sinus obliteration compared with fat. Outside of the contouring issues in select patients in whom BoneSource obliteration is needed because of anterior table loss, an argument can certainly be made that this substance should be used selectively. In this series, neither the presence of previous mucocoele surgery nor the presence of trauma correlated with preservation of the anterior table. This bone was replaced when it was believed to be more advantageous to do so. In the group as a whole, 16 patients were assessed as having good enough anterior table frontal bone to warrant an attempt to provide cover for the BoneSource. In the rest of the patients, it was believed that the frontal sinus contour would be better without the bone being replaced. If cost is a limiting factor, could the condition of the anterior table be the key element in deciding whether to obliterate with fat or hydroxyapatite? There certainly is literature to suggest that the risk of fat obliteration is higher if the frontal sinus bone is missing.8 Given that only long-term mucocele recurrence data exist for fat obliteration and given the lengthy nature of this disease process and its recurrence, the answer to the question of when to use fat vs BoneSource will come when patients like those in our series are followed up for a longer period. To date, our longest period of follow-up for a patient in the BoneSource obliteration group is 8 years without apparent complications, and both of our patients in whom fat obliteration had failed are doing well with the BoneSource.

CONCLUSIONS

This study demonstrates that hydroxyapatite cement is a viable option for frontal sinus obliteration after mucocoele resection. Fat obliteration is the traditional alternative for frontal sinus obliteration for mucocoeles, although the 2 patients in whom this procedure failed were successfully treated with BoneSource obliteration. The majority of patients in this study developed mucoceles after either previous trauma or tumor surgery, with a handful having had multiple prior surgical procedures or prior attempts at mucocele excision. In this complex group, hydroxyapatite cement represented a good option for obliteration, with no patients necessitating implant removal to date. This substance also allows for the option of not replacing the anterior table when deemed insufficient. The postoperative cosmetic contours of the frontal region were noted to be very good in all our patients.

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REFERENCES