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Reduction of cerebrospinal fluid rhinorrhea after vestibular schwannoma surgery by reconstruction of the drilled porus acusticus with hydroxyapatite bone cement

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Object. Cerebrospinal fluid (CSF) rhinorrhea remains a significant cause of morbidity after resection of vestibular schwannomas (VSs), with rates of rhinorrhea after this procedure reported to range between 0 and 27%. The authors investigated whether reconstruction of the drilled posterior wall of the porus acusticus with hydroxyapatite cement (HAC) would decrease the incidence of postoperative CSF rhinorrhea.

Methods. A prospective observational study of 130 consecutive patients who underwent surgery for reconstruction of the posterior wall of the drilled porus acusticus with HAC was conducted between October 2002 and September 2005. All patients underwent a retrosigmoid transmeatal approach for VS resection and were followed up to document cases of CSF rhinorrhea, incisional CSF leak, meningitis, or rhinorrhea-associated meningitis. A cohort of 150 patients with VSs who were treated with the same surgical approach but without HAC reconstruction served as a control group.

Results. The authors found that HAC reconstruction of the porus acusticus wall significantly reduced the rate of postoperative CSF rhinorrhea in their patients. In the patients treated with HAC, rhinorrhea developed in only three patients (2.3%) compared with 18 patients (12%) in the control group. This was a statistically significant finding ($p = 0.002$, odds ratio = 5.8).

Conclusions. The use of HAC in the reconstruction of the drilled posterior wall of the porus acusticus, occluding exposed air cells, greatly reduces the risk of CSF rhinorrhea. *(DOI: 10.3171/JNS-07/08/0347)*

KEY WORDS • cerebrospinal fluid rhinorrhea • hydroxyapatite bone cement • vestibular schwannoma

CEREBROSPINAL fluid rhinorrhea remains one of the most common complications of VS surgery despite great advances in the microsurgical technique first described by Harvey Cushing[5] over 80 years ago. Authors of other studies have reported the incidence of CSF rhinorrhea after surgery for VS as ranging between 0 and 27%.[2–4,6–9,16,17,19–22] Postneurosurgical CSF leaks are particularly challenging because brain edema and attendant increased intracranial pressure cause further CSF drainage, often through surgical bone defects that are too large to seal spontaneously. The presence of an established CSF fistula also increases the risk of meningitis, with an incidence reported as high as 16%.[10,12] This significant rate of morbidity has encouraged the development of various methods for reducing CSF rhinorrhea.

Valtonen and colleagues[22] reported a reduction in CSF rhinorrhea with the use of endoscopy-assisted visualization and occlusion of the petrous air cells with bone wax. Leonetti et al.[15] described a dural flap technique used to contain fat in the drilled porus acusticus with lower purported rates of CSF rhinorrhea. Other methods have included treating the exposed petrous air cells with bone wax, bone dust, bone cement, fat, muscle, fascia, dural flaps, oxidized cellulose, and/or fibrin glue.

The development and US Food and Drug Administration approval of HAC for temporal bone reconstruction and other craniofacial work has spurred interest in its application in the reduction of CSF leaks. Arriaga and Chen[1] retrospectively evaluated 108 cases of VS surgery performed via the translabyrinthine approach and compared those patients treated with abdominal fat graft closure with those treated with HAC-augmented closure. The authors identified a trend toward the reduction of CSF rhinorrhea when HAC was used, but this finding did not reach statistical significance.

In the present study, we evaluate the use of HAC (Norian Craniofacial Repair System, Synthes) in reducing the rate of postoperative CSF rhinorrhea. Hydroxyapatite cement in a semi-liquid state can be used to reconstruct the drilled posterior wall of the porus acusticus, thus occluding petrous air cells from cisternal CSF. We prospectively observed and collected follow-up data in patients who underwent

Abbreviations used in this paper: CSF = cerebrospinal fluid; CT = computed tomography; HAC = hydroxyapatite cement; LOS = length of stay; SD = standard deviation; VS = vestibular schwannoma.

a retrosigmoid, transmeatal approach for resection of a VS with HAC reconstruction of the porus acusticus. These results were compared with those from a cohort of patients who underwent VS resection without HAC reconstruction.

Clinical Material and Methods

Patient Population

The total study population consisted of 280 patients who underwent a retrosigmoid transmeatal approach for VS resection between September 1998 and September 2005 at The Johns Hopkins Hospital. One of five neurosurgeons performed the neurosurgical portion of the case, and one of five neurootologists performed the drilling of the porus acusticus. One neurosurgeon contributed 42% of the cases in this series. The study population was further divided into a prospective group (130 patients) who underwent HAC reconstruction of the drilled porus acusticus (the HAC group), and a control group of both retrospectively and prospectively collected patients who did not undergo such reconstruction (150 patients).

Operative Technique

All patients underwent a retrosigmoid craniectomy to gain access to the cerebellopontine angle. Via the transmeatal approach the posterior wall of the porus acusticus was drilled to gain access to the intracanalicular portion of the tumor. The dura mater was skeletonized along the long axis of the internal auditory canal using progressively smaller cutting burs and then diamond burs. The dura of the porus was exposed over at least 180° with emphasis placed on decorticating the roof of the porus to facilitate facial nerve identification and dissection. Exposed air cells adjacent to the craniectomy site were occluded with bone wax or HAC in the HAC group, and with bone wax in the control group. The drilled posterior wall of the porus acusticus was reconstructed with HAC in the HAC group, and with traditional methods in the control group. The traditional methods used included the use of bone wax, fat, muscle, fibrin glue, or a combination thereof placed in the drilled porus acusticus. Lumbar drains were not used in a routine fashion postoperatively in either group.

Hydroxyapatite Cement Group

The HAC group consisted of 130 consecutive, prospectively followed patients who underwent operations between October 2002 and September 2005. In all cases the drilled posterior wall of the porus acusticus was reconstructed with calcium HAC (Norian Craniofacial Repair System), regardless of whether air cells were visualized (Fig. 1). Exposed air cells of the mastoid at the craniectomy site were treated in a similar fashion or occluded with bone wax.

Control Group

The control group consisted of 120 consecutive patients reviewed retrospectively, who underwent operations between September 1998 and September 2002, and 30 consecutive patients who were prospectively observed between October 2002 and June 2004, for a total of 150 patients in the control group. During this period, traditional methods of preventing CSF leaks through exposed air cells at the drilled porus acusticus were employed in every case. The patients in the prospectively chosen control group underwent operations during the time in which two of the operating neurosurgeons continued to use traditional methods for occluding exposed air cells at the porus acusticus. Since June 2004, all of the operating neurosurgeons have used HAC for occluding exposed air cells at the porus. The 30 patients in the prospective control group cohort were treated over a time period that overlapped with the HAC group. Exposed air cells in the mastoid at the craniectomy site were typically occluded with bone wax in the prospective control cohort.

Diagnosis of CSF Fistulas

Cerebrospinal fluid rhinorrhea was defined as clear fluid egress from the nose or throat that necessitated one or more of the following interventions: 1) more than one lumbar puncture; 2) continuous lumbar CSF drainage; and/or 3) operative repair of a suspected fistula site in the petrous or mastoid air cells. Transient CSF rhinorrhea that did not require any of these interventions was not included in this study. Incisional CSF leaks were defined as a clear fluid egress from the incision and were recorded.

Statistical Analysis

The incidence of CSF rhinorrhea, incisional CSF leaks, meningitis, interventions required for CSF leak repair, postoperative House–Brackmann grade (at the time of discharge), number of patients in whom this was the first operation, tumor size, incidence of hydrocephalus, the previous history of radiation therapy, and LOS were identified in both groups. Two-by-two contingency tables were created to compare the incidence of CSF rhinorrhea, incisional CSF leaks, total CSF leaks, meningitis, rhinorrhea-associated meningitis, operation number, perioperative hydrocephalus, and history of previous radiation therapy between the two groups. The Fisher exact test was used to calculate the probability value, confidence interval, and odds ratio for comparisons of the binomial variables. The Student t-test was used to evaluate for any significant difference in the continuous variables. A probability value less than 0.05 was considered statistically significant.

Results

Patient and Clinical Characteristics

The mean age ($\pm$ SD) of patients was 49 $\pm$ 11 years and 50 $\pm$ 13 years in the HAC and the control groups, respectively, and the mean tumor size was 2.1 $\pm$ 1.2 cm in the HAC group and 2.3 $\pm$ 1.2 cm in the control group. The median follow-up duration was 3.8 months in the HAC group, and 15 months in the control group. Table 1 shows the patient and clinical characteristics of the study population.

Clinical Outcome

Patients who underwent reconstruction of the porus acusticus with HAC experienced significantly lower rates of CSF rhinorrhea (Table 2). In the HAC group, rhinorrhea developed in only three patients (2.3%) compared with 18 patients (12%) in the control group. This difference reached statistical significance with a probability value of 0.002, and an odds ratio of 5.8 for the risk of developing CSF

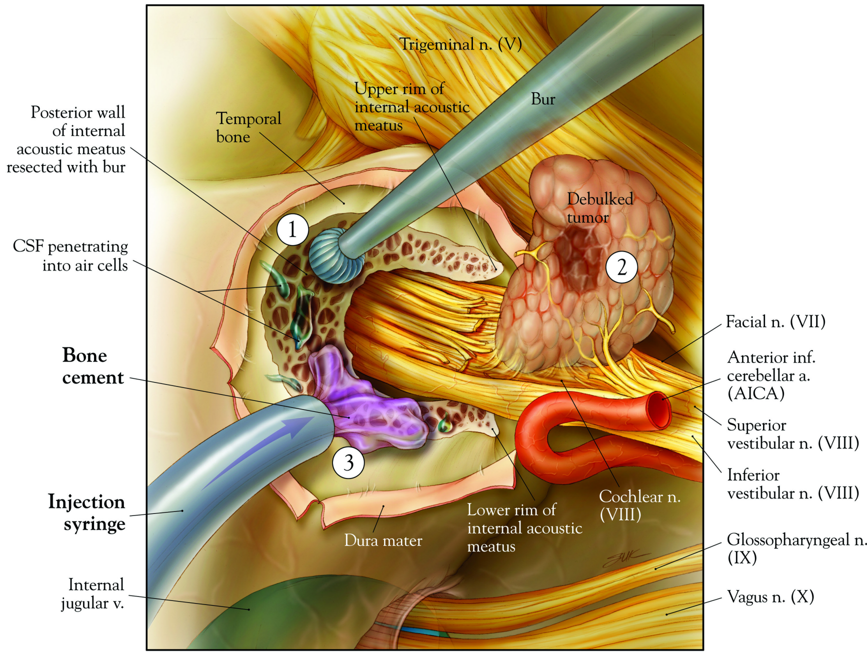

FIG. 1. Artist's illustration demonstrating the application of HAC to reconstruct the drilled posterior wall of the porus acusticus after tumor resection. Number 1 represents drilling the porus with exposure of air cells; 2 represents the final tumor removal; and 3 represents the application site of the HAC. a. = artery; inf. = inferior; n. = nerve; v. = vein.

rhinorrhea without the use of HAC in reconstructing the porus. Comparison of both subgroups of the control group (the retrospective and prospective cohorts) demonstrated no statistically significant difference in the rate of CSF rhinorrhea ($p = 0.74$).

In addition, patients in the HAC group also had significantly lower overall rates of CSF leakage. In the HAC group, 13 patients (10%) had CSF leakage (rhinorrhea or incisional) compared with 28 patients (18.7%) in the control group who developed CSF leakage postoperatively. The difference in the overall rate of CSF leakage was significant based solely on the rate of rhinorrhea ($p = 0.041$). There was no statistical significance in the incisional leak rate between the two groups.

The time to identification of CSF rhinorrhea was less than 2 weeks in both groups except for one patient in the control group in whom the CSF rhinorrhea was identified 6 months postoperatively. In the HAC group, rhinorrhea was repaired surgically in two patients. Intraoperatively it was noted that one of these patients seemed to have leaked CSF from porus air cells, while in the other patient CSF appeared to leak from the mastoid air cells adjacent to the craniectomy site. In the third patient with CSF rhinorrhea in the HAC group, the rhinorrhea stopped after 48 hours of continuous lumbar drainage, and no surgical intervention was required. These measures were successful in all three cases. Repair of CSF rhinorrhea in the control group was performed via surgical intervention in 10 patients (56%), continuous lumbar drainage in four patients (22%), and multiple lumbar punctures in four patients (22%). These measures were successful in 16 (89%) of 18 patients. One patient in whom lumbar drainage was used required a subsequent operation, and one patient who initially underwent surgical repair required a second operation for CSF rhinorrhea.

Patients who underwent HAC reconstruction of the porus acusticus had rates of CSF rhinorrhea-associated meningitis that approached statistical significance. In the HAC group, one patient (0.08%) developed rhinorrhea-associated meningitis compared with seven patients (4.7%) in the control group. This difference approached statistical significance ($p = 0.072$).

The overall meningitis rate was 3.8% (five of 130 patients) in the HAC group and 7.3% (11 of 150 patients) in the control group, but this finding did not reach statistical significance ($p = 0.3$). The rate of incisional CSF leaks in the HAC group was 7.7% (10 of 130 patients), and 6.7% (10 of 150 patients) in the control group ($p = 0.74$). The postoperative difference in mean House–Brackmann grades did not reach statistical significance either ($p = 0.83$), with a grade of 2.6 in the HAC group and 2.5 in the control group. The total average LOS for patients in the HAC group and control group was 5.6 and 6.8 days, respectively; this finding approached statistical significance ($p = 0.059$).

The results of HAC reconstruction of the porus acusticus

TABLE 1

*Clinical characteristics of the HAC group (130 patients) compared with the control group (150 patients)**

Characteristic	HAC Group	Control Group	p Value
mean age (yrs)	49 ± 11	50 ± 13	NS
mean tumor size (cm)	2.1 ± 1.2	2.3 ± 1.2	NS
1st operation (%)	122 (94)	143 (95)	NS
had previous radiation (%)	2 (1.5)	6 (4)	NS
had periop hydrocephalus (%)	1 (0.7)	2 (1.3)	NS

* Mean values are presented ± SDs. Abbreviations: NS = not significant; periop = perioperative.

TABLE 2

*Comparison of the outcomes after reconstruction of the drilled porus in the HAC group and control group**

Clinical Outcome	HAC Group	Control Group	Odds Ratio (95% CI)	p Value
CSF rhinorrhea (%)	3 (2.3)	18 (12)	5.8 (1.6–20)	0.002
incisional CSF leak (%)	10 (7.7)	10 (6.7)	0.85 (0.35–2.1)	0.740
total CSF leak (%)	13 (10)	28 (18.7)	2.1 (1.1–4.2)	0.041
meningitis (%)	5 (3.8)	11 (7.3)	1.9 (0.66–5.9)	0.3
rhinorrhea-associated meningitis (%)	1 (0.8)	7 (4.7)	6.3 (0.76–52)	0.072
mean LOS (days)	5.6 ± 3.3	6.8 ± 6.6	NA	0.059
mean postop HB grade	2.6 ± 1.8	2.5 ± 1.8	NA	0.83

* Mean values are presented ± SDs. Abbreviations: CI = confidence interval; HB = House–Brackmann; NA = not applicable.

as viewed on CT scanning can be seen in Fig. 2. In the HAC group, 25 patients who underwent magnetic resonance imaging between 3 and 12 months postoperatively were subjectively reviewed. There was no contrast enhancement related to the HAC reconstruction, nor were there any signs of complications. Furthermore, there were no documented complications associated with the application of HAC to reconstruct the porus.

Discussion

Our results demonstrate a significant reduction in the incidence of CSF rhinorrhea when HAC is used to reconstruct the drilled posterior wall of the porus acusticus. Authors of other studies have demonstrated a wide range in the incidence of CSF rhinorrhea after surgery for VS, between 0 and 27%. Some authors have reported a reduction in CSF rhinorrhea achieved with other methods, but the variability is broad. One factor affecting the variability in the incidence of rhinorrhea is the extent of drilling at the posterior wall of the porus.[7]

The semiliquid state of HAC allows the surgeon to fill in air cells at the site of the drilled porus in a predictable fashion, regardless of the extent of drilling. This creates the advantage of a reproducible reduction in CSF rhinorrhea that can be seen even among different surgeons. Hydroxyapatite cement sets quickly (5–7 minutes for fast set, 10 minutes for injectable), and afterward is resistant to CSF pulsations. At normal body temperature, the setting cement maintains physiological pH and isothermy. Curing of the cement continues over approximately 24 hours. The cost of HAC is about $1200 for the typical application of 5 ml. This minimal cost should be defrayed by the reduction in costs associated with CSF rhinorrhea, namely increased LOS, hospital readmissions, and further interventions.

The anatomical complexity of the pneumatized temporal bone introduces the potential for CSF rhinorrhea regardless of the surgical approach used. Bone removal is required to adequately access tumors and facilitate tumor dissection with nerve preservation. In drilling posterior to the porus, the surgeon may enter subarcuate air cells; in drilling cephalad to the porus, air cells of the petrous apex are often exposed. Adequate bone removal may create defects that allow CSF spaces to communicate with the petrous apex and subarcuate air cell tracts, in addition to the air cells commonly found in the retrosigmoid bone adjacent to the craniectomy site. Lang and Kerr[13] demonstrated a pneumatized posterior wall of the porus acusticus in 22% of temporal bones studied histologically, while Jen et al.[11] demonstrated pneumatization in 33% as seen on CT imaging. Although there are probably several instances in which there were no exposed air cells at the drilled posterior wall, applying HAC overcomes the possibility of missing air cells located more laterally in the canal or small air cells that can be difficult to visualize or reach using bone wax or fat. Cerebrospinal fluid leaks via the retrosigmoid air cells adjacent to the craniectomy site are also a concern. However, the air cells in this location are more easily visualized and occluded, and thus less likely to contribute to CSF rhinorrhea than the petrous air cells.

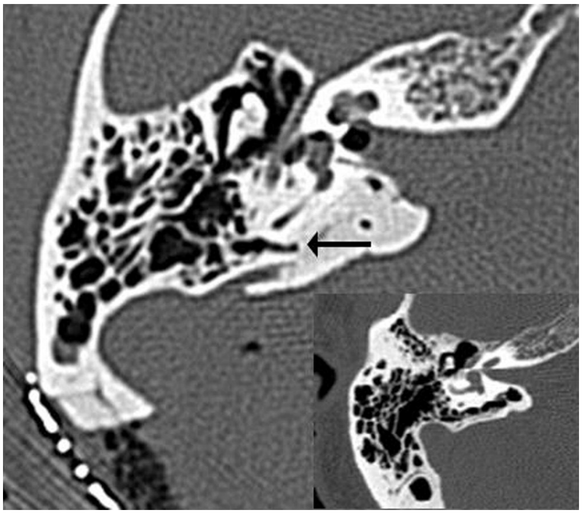

Fig. 2. Temporal bone CT scan showing the HAC cement reconstruction of the posterior wall of the porus with occlusion of an exposed air cell *(arrow)*. *Inset:* The posterior wall of a different porus acusticus with well-pneumatized bone highlighting the susceptibility to CSF fistula formation if not occluded after drilling.

Several important factors contribute to the development of a CSF fistula at the petrous air cells. First, visualization often makes the identification of exposed air cells cumbersome if not impossible when using standard techniques. Valtonen and colleagues[22] have attempted to overcome this limitation with the use of endoscopy-assisted visualization. Second, occlusion of exposed air cells in the canal can be technically difficult when using traditional methods. For example, bone wax may not reach the laterally placed air cell, fat or muscle may not conform to the defect, and fibrin-based tissue adhesives may not adhere adequately. Third, fat, muscle, and other materials placed in the drilled porus may become dislodged by CSF pulsations. Leonetti and colleagues[14,15] have described a petrous dural closure method to help reduce the effect of CSF pulsations on dislodging implanted materials, underscoring the need for supplementing bone defects with vascularized tissue to improve the likelihood of sealing cisternal CSF spaces.[18] Other possible causes of CSF leaks are often related to general technique (such as wound closure) or patient condition (such as pronounced cerebellar swelling, postoperative emesis, or diabetes mellitus, among others). These causes should be addressed with meticulous surgical technique, neuroanesthesia, and postoperative care.

In their metaanalysis of CSF leaks, Selesnick et al.[21]

showed an average postoperative rhinorrhea rate of 6.1%. However, if one excludes the studies with fewer than 100 patients, the average rhinorrhea rate is 17.2%. The rate of CSF rhinorrhea in the control group in our study (12%) approximates the average from the larger series in the literature.[21] The incidence of postoperative CSF rhinorrhea in the control group was stable across time. The control group was therefore determined to be a stable, average patient population.

A comparison of the HAC group to the control group showed a highly significant reduction in CSF rhinorrhea from 12 to 2.3%. Patients in this study incurred a nearly six-fold reduction in the risk of clinically significant CSF rhinorrhea when HAC was used. This reduction appears to reflect one of the strongest preventative measures published in light of our relatively large patient population and the prospective methods of observation in the HAC group.

All of the limitations inherent to retrospective studies apply to the control comparisons (excluding the small portion of prospective controls) in this study. The prospectively observed HAC group may lessen some of the potential for error. Overall, the results of this study should be interpreted with the limits of retrospective studies in mind. The number of surgeons who participated may also increase the chances for uncontrolled variability. The data from the largest contributing neurosurgeon (42%) was statistically significant, while the results from the other surgeons individually did not reach statistical significance. The other surgeons remained in the analysis to increase the power and reduce the risk of a Type I statistical error. The overall low incidence of the outcomes analyzed may limit statistical significance. For example, the incidence of rhinorrhea-associated meningitis approached statistical significance in this study ($p = 0.072$). Statistical significance may be achieved with increasing numbers of patients.

Conclusions

Cerebrospinal fluid rhinorrhea remains the most common postoperative complication after VS resection, second to facial nerve paresis; the use of HAC to reconstruct the drilled posterior wall of the porus acusticus significantly reduces this complication. As alternative methods of treatment for VSs become increasingly popular, we must continue to take steps toward perfecting our microsurgical technique. Effective reconstruction of the drilled posterior wall of the porus acusticus with HAC is one such step.

Disclaimer

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