

Middle Cranial Fossa (MCF) Approach without the use of Lumbar Drain for the Management of Spontaneous Cerebral Spinal Fluid (CSF) Leaks

Running head: MCF CSF Leaks

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Financial disclosures: none

Authors disclose no conflict of interest

This is the author's manuscript of the article published in final edited form as:

Nelson, R. F., Roche, J. P., Gantz, B. J., & Hansen, M. R. (2016). Middle Cranial Fossa (MCF) Approach Without the Use of Lumbar Drain for the Management of Spontaneous Cerebral Spinal Fluid (CSF) Leaks. *Otology & Neurotology*, 37(10), 1625–1629. <https://doi.org/10.1097/MAO.0000000000001208>

1 **Objective:** To determine the efficacy and morbidity of repairing spontaneous cerebrospinal
2 fluid (CSF) leaks with the middle cranial fossa (MCF) approach without the use of a lumbar
3 drain (LD), as perioperative use of LD remains controversial.

4
5 **Study Design:** Retrospective review from 2003-2015

6
7 **Setting:** University of Iowa Hospitals and Clinics and Indiana University Health Center

8
9 **Patients:** Those with a confirmed lateral skull base spontaneous CSF leaks and/or
10 encephaloceles.

11
12 **Intervention:** MCF approach for repair of spontaneous CSF leak and/or encephalocele without
13 the use of lumbar drain. Assessment of patient age, sex, body mass index (BMI), and medical co-
14 morbidities

15 **Main Outcome Measure:** Spontaneous CSF leak patient characteristics (age, sex, BMI,
16 obstructive sleep apnea) were collected. Length of stay (LOS), hospital costs, post-operative
17 complications, CSF leak rate, and need for LD were calculated.

18
19 **Results:** 65 operative MCF repairs were performed for spontaneous CSF leaks on 60 patients (5
20 had bilateral CSF leaks). CSF diversion with LD was used in 15 of 60 patients, mostly prior to
21 2010. After 2010, only 3 of 44 patients (6.7%) had post-operative otorrhea requiring LD. The
22 use of LD resulted in significantly longer LOS (3.6 ± 1.6 vs. 8.7 ± 2.9 days) and hospital costs
23 (\$29,621). There were no postoperative complications in 77% (50 of 65) of cases. Three cases
24 required return to the operating room for complications including frontal subdural hematoma (1),
25 subdural CSF collection (1) and tension pneumocephalus (1). No patients experienced long-term
26 neurologic sequelae or long-term CSF leak recurrence with an average length of follow up of
27 19.5 months (range 3-137 months). The average patient BMI was 37.5 ± 8.6 kg/m². The
28 average age was 57.5 ± 11.4 years and 68% were female. Obstructive sleep apnea was present in
29 43.3% (26 of 60) of patients.

30

31 **Conclusions:** The morbidity of the MCF craniotomy for repair of spontaneous CSF leaks is low
32 and the long-term efficacy of repair is high. Universal use of peri-operative lumbar drain is not
33 indicated and significantly increases length of stay and hospital costs. Obesity and obstructive
34 sleep apnea are highly associated with spontaneous CSF leaks.

35

36

37 **INTRODUCTION**

38

39 Spontaneous cerebrospinal fluid (CSF) leaks of the lateral skull base occur through defects of the
40 dura and the lateral skull base (also known as the tegmen) overlying the pneumatized middle ear
41 and mastoid. In addition, brain tissue can herniate through the bony defect resulting in an
42 encephalocele. CSF leaks are termed spontaneous when there is no preceding trauma, surgery, or
43 inciting cause.

44

45 The pathologic mechanism of spontaneous CSF leaks is still not well understood. There is a
46 strong association between obesity and spontaneous CSF leaks (1-3). As the obesity epidemic
47 increased between 1980 and 2010, the number of spontaneous CSF leak repairs has nearly
48 doubled in the past decade (4). Though not seen in all obese patients, those with spontaneous
49 CSF leaks have thinning of the skull base in addition to the skull calverium (3). This finding
50 implicates an additional ‘obesity-associated’ intracranial process leading to skull thinning (3).

51 This process could be due to elevated intracranial pressure. Chronically elevated intracranial
52 pressure (ICP) over many years may lead to erosion of the skull, including the skull base.

53 Spontaneous CSF leaks are associated with idiopathic intracranial hypertension (IIH), also
54 known as benign intracranial hypertension or pseudotumor cerebri (5). Interestingly,
55 measurements of CSF pressures during lumbar puncture in patients undergoing repair of
56 spontaneous CSF leak show that only 10-36% of patients have elevated ICP (6,7). Alternatively,
57 it is possible that there are transient spikes in ICP that may not be detected on routine lumbar
58 puncture. It is known that obstructive sleep apnea (OSA) is highly associated with obesity (8,9)
59 and OSA patients have transient large spikes in ICP during apnea spells (10,11). We have
60 hypothesized that obesity-associated OSA leads to elevated ICP, which leads to skull base
61 thinning and spontaneous CSF leaks (3).

62

63 Spontaneous CSF leaks have a very low rate of spontaneous closure. Surgical approaches to
64 repair temporal bone spontaneous CSF leaks include middle cranial fossa (MCF) craniotomy
65 (12-17), transmastoid (TM) (2,7,18-20) or a combined (MCF/TM) (1,21,22) approach. The
66 transmastoid approach is appealing as it avoids the risks of a craniotomy. However, the
67 recurrence rate of CSF leaks after transmastoid approach ranges from 6-20% (7,20). In addition,

68 the MCF approach allows for a more comprehensive evaluation of the entire tegmen, since up to
69 50% of patients have multiple tegmen defects (15). The reported perioperative risks of MCF
70 approach are low, but can include hematomas, stroke and seizures.

71

72 In addition, the use of CSF diversion through the use of a lumbar drain (LD) during the repair of
73 spontaneous CSF leaks is controversial. The use of LDs during endoscopic repair of anterior
74 skull base CSF leaks has been studied and found to not reduce the rates of recurrent CSF leaks
75 (23,24). There is currently no consensus on if and when to use a LD for spontaneous CSF leak
76 repairs from the temporal bone. In addition, LD utilization has been associated with increased
77 complication rate of up to 12.3%, including pneumocephalus, persistent headaches, meningitis,
78 uncal herniation and lumbar radiculopathy (25).

79

80 Here we report a large cohort of patients who have undergone MCF repair for spontaneous CSF
81 leaks. We review our perioperative complications of the MCF approach to repair spontaneous
82 CSF leaks. Also, we determine the effectiveness of the MCF repair without the use of lumbar
83 drains and the long-term stability of the repair.

84

85

86

87

88 **MATERIALS AND METHODS**

89 Retrospective evaluation and data collection of patients were approved by the institutional
90 review boards at the University of Iowa (#201307714) and Indiana University Health
91 (#49109189). Patients were treated by 3 neurotologists (BJG, MRH, RFN) with spontaneous
92 CSF leaks from 2003 to 2015. CSF leaks were considered spontaneous when there was
93 persistent clear otorrhea associated with tegmen defect(s) noted on high resolution CT IAC
94 imaging and no previous history of skull base surgery, trauma or skull base fracture.

95
96 The following patient characteristics were documented from the medical record: (1) body mass
97 index (BMI) calculated as kilograms per square meter (kg/m^2), (2) age, (3) sex, (4) obstructive
98 sleep apnea. Long term follow up was calculated from the date of operation to the last recorded
99 clinic visit in the medical record. Complications were recorded by review of clinic notes in the
100 medical record. For adults aged 20 years and older, obesity was defined as a BMI of 30.0 or
101 higher (26). Obstructive sleep apnea was confirmed if the patient had (in the chart or per patient
102 report) a positive polysomnogram (apnea-hypopnea index > 5) or was using continuous positive
103 airway pressure (CPAP) or bilevel positive airway pressure (BiPAP). Patients without the
104 clinical diagnosis of OSA were not independently tested. However, starting in 2014, all patients
105 at Indiana University Health with spontaneous CSF leaks were prospectively tested for OSA
106 with polysomnogram. Differences in means were tested with a 2-tailed T test with significance
107 set to $\alpha \leq 0.05$.

108
109 All patients were treated with an MCF approach. Briefly, a pterional incision was performed
110 with harvesting of a large temporalis fascia graft. The temporalis muscle was incised to leave a
111 cuff of muscle and fascia attached to the calvarium and the muscle was reflected anteriorly. A
112 4.5 x 4.5 craniotomy was performed over the middle ear and mastoid. Intraoperative mannitol
113 (0.5 gram per kilogram) was administered and the patient was hyperventilated to end-tidal CO_2
114 < 30 . The temporal lobe dura was elevated and the dura and skull base defects were identified.
115 The entire floor of the middle fossa was explored including anterior petrous apex.
116 Encephaloceles were amputated and removed with bipolar electrocautry when present.
117 Reconstruction consisted of a multilayer closure with a fascia soft tissue seal on the skull base,
118 split calvarial bone grafts over bone defects and collagen matrix abutting the native dural defects.

119 Some cases were repaired with intradural placement of collagen matrix. The craniotomy was
120 replaced and the muscle and galeal layers were sutured in a water-tight fashion. The patient was
121 extubated after the case and ambulation commenced on post-operative day 1.

122
123 Lumber drains were placed if there was persistent otorrhea or CSF rhinorrhea on post-operative
124 days 2 or 3. Many patients had an ipsilateral pressure equalizing tube typically placed by an
125 outside otolaryngologist prior to the diagnosis. CSF was drained at 10 ml/hour for 5 days when
126 LD was used. In our cohort of patients, we did not routinely use diuretics or acetazolamide to
127 manage CSF pressure in the post-operative period.

128
129 Procedural and hospital costs were estimated based upon previous charges for spontaneous CSF
130 leak patients with lumbar drains using 2016 data. These estimated charges can vary based upon
131 patient comorbidities and hospital location. These amounts are specified as billed charges and do
132 not reflect actual amount reimbursed or paid as these later amounts are variable depending upon
133 insurance coverage. The charges for lumbar drain placed at bedside (CPT 62272) are for the
134 device and facility charges and does not include surgeon fees. The daily hospital charges include
135 progressive care unit facility charges.

136

137 **RESULTS**

138 We examined medical records of 60 patients (65 cases) from 2 academic medical centers who
139 underwent MCF repair of spontaneous CSF leaks of the temporal bone from 2007 to 2015. Five
140 (5) patients had bilateral temporal bone CSF leaks. Figure 1 is representative CT image of patient
141 with a dehiscent tegmen mastoidium and fluid filling the mastoid (**Figure 1A**). Many patients
142 have multiple areas of tegmen dehiscence (**Figure 1B**).

143
144 The average age was 57.5 ± 11.4 years and 68.3% of the patients were female (**Table 1**). Most
145 patients (83.3%) were overweight ($BMI >25 \text{ kg/m}^2$) and the average BMI was $37.5 \pm 8.7 \text{ kg/m}^2$
146 (**Table 1**). The rate of obstructive sleep apnea was 43.3% (**Table 1**). Many patients were not
147 prospectively tested for OSA. Starting in 2014, all patients at Indiana University Health with
148 spontaneous CSF leaks underwent polysomnogram and all patients (6 of 6) had OSA.

149
150 There were no perioperative complications in 77% (50 of 65) of the cases. The most common
151 complication was persistent otorrhea noted on post-operative days 2 or 3 (**Table 2**). In all such
152 cases, a LD drain was placed for 5 days and the otorrhea resolved. There were 2 cases of mental
153 status change with temporal lobe edema that resolved with steroid treatment. Three cases
154 required return to the operating room. One patient developed a subdural hematoma that required
155 a burr hole evacuation. Another patient developed a frontal subdural CSF fluid collection after
156 hospital discharge that required burr hole evacuation. Lastly, one patient developed tension
157 pneumocephalus that required return to the operating room for evacuation. Intraoperatively it
158 was noted that the split calvarial bone grafts had not formed a tight seal on the middle fossa floor
159 resulting in a 'ball valve' effect leading to trapping air intracranially. The temporalis fascia was
160 placed over the skull base to form a soft tissue seal, prior to replacement of the bone grafts. All 3
161 patients recovered fully. Isolated cases of delayed facial paralysis, atrial fibrillation, meningitis
162 and seizure were treated medically and patients demonstrated full recovery. There were no cases
163 of ipsilateral CSF leak at last follow up (**Table 2**).

164
165 Early in the study, prior to 2010, 21 patients underwent MCF CSF leak repair. Approximately
166 half of the patients had lumbar drains placed intra-operatively during MCF repair and the other
167 half did not have a lumbar drain. There were no post-operative CSF leaks in either group

168 suggesting that lumbar drain placement may not be necessary for a successful repair. Thus,
169 starting in 2010, we performed 44 MCF repairs of spontaneous CSF leaks with the intention of
170 not using a perioperative LD. After 2010, only 3 of 44 patients (6.7%) has post-operative
171 otorrhea requiring LD. The average length of stay for patients without LD was significantly
172 shorter than those who had a LD placed preoperatively (3.6 ± 1.6 vs. 8.7 ± 2.9 days; $P < 0.01$;
173 **Table 3**). In addition, the use of lumbar drains increases cost. We estimated the cost (in 2016
174 dollars) to be \$13,316 for placement of the LD and \$3,261 per day for hospital room and nursing
175 care. Thus, for 5 additional hospital days and LD, the added cost is approximately \$29,621
176 (**Table 3**).

177

178

179 **DISCUSSION**

180 Here we show that the MCF approach to repair temporal bone spontaneous CSF leaks is highly
181 effective and is safe. The use of a LD is not required for successful repair in most cases.
182 Preemptive use of LDs increases length of stay and cost.

183
184 Consistent with other previous reports (1,2,4), we find a strong association between spontaneous
185 CSF leaks and obesity. The obesity epidemic developed in the United States starting in the 1990s
186 (27). The percentage of American that are obese (BMI ≥ 30) has risen from 12% in 1991 to
187 19.8% in 2000 to 29% in 2010 (28). The mechanism of how obesity could lead to skull thinning
188 remains unknown. Previously, we showed that patients with spontaneous CSF leaks were obese
189 and had thinning of the calvarium in addition to the skull base, while a control group of obese
190 patients without spontaneous CSF leaks did not have thinning of the calvarium. Because obesity
191 is highly associated with spontaneous CSF leaks, these data suggest that there is another obesity-
192 associated factor which contributes to skull thinning and spontaneous CSF leaks. This obesity-
193 associated factor likely leads to elevated intracranial pressure either chronically or on an
194 intermittent basis.

195
196 Spontaneous CSF leaks are associated with IIH (5), and some patients (~36%) have elevated ICP
197 during lumbar puncture (6). This shows that not all patients with spontaneous CSF leaks have
198 elevated baseline ICP, and other factors may contribute to transient elevations in ICP. Patients
199 with spontaneous CSF leaks have a high rate of OSA and patients with OSA have been found to
200 have elevations in ICP and arterial blood pressure during apnea events (10). It is postulated that
201 apneas lead to hypercarbia, which in turn leads to cerebral vasodilation and elevated ICP. Our
202 data show that patients with spontaneous CSF leaks have a much higher prevalence of OSA
203 (~43%) than the national average. In addition, these patients presented with the diagnosis of
204 OSA and many had not had a polysomnogram. Thus, this rate may underestimate the true rate of
205 OSA in patients with spontaneous CSF leaks. Since 2014, we have tested all patients with
206 spontaneous CSF leaks for sleep apnea with a polysomnogram.

207
208 Superior semicircular canal dehiscence (SSCD) has been associated with tegmen erosion (29,30)
209 and the surgeon should be alerted to the possibility of SSCD as the dura is elevated from the

210 middle fossa floor. In this study, we did not specifically evaluate or repair SSCD unless the
211 patient had vestibular symptoms consistent with SSCD (i.e. Tullio's phenomena). However,
212 during the repair we resurface the SSC as we resurface the skull base with soft tissue and bone
213 grafts.

214
215 Several previous reports have used LDs during MCF repair of temporal bone spontaneous CSF
216 leaks (15,17,21,22) with postoperative CSF leaks rates of 4-9%. Since 2010 we have not used
217 LD during our MCF CSF leak repairs and our post-operative leak rate in 44 patients was 6.7%.
218 In addition, we estimated that the added cost of a LD and 5 days in the hospital to be close to
219 \$60,000. Given that it is not necessary in the vast majority of cases, we advocate against the
220 preemptive use of LDs for spontaneous CSF leaks. A review study using LD for anterior skull
221 base CSF leaks also failed to show significant benefit in CSF leak repair (24).

222
223 The vast majority of patients who underwent MCF CSF leak repair had no postoperative
224 complications. The most common complication was a postoperative CSF leak that was managed
225 effectively with a LD. We placed the LD relatively early in the postoperative period (day 2-3) if
226 there was persistent otorrhea. While it is possible that some of these cases may have gone on to
227 resolve without the need for a LD if they had been observed longer, we favored early
228 intervention in these cases. There were no long term sequela from using the MCF approach.

229
230 There are inherent limitations to this study. By design the study is retrospective and non-
231 randomized. In addition, increased surgeon experience over time could account for a decreased
232 post-operative CSF leak rate. Finally, the generalizability of the results to all centers irrespective
233 of surgical experience with MCF approach may not be possible.

234
235 Thus, we find the morbidity of the MCF craniotomy for repair of spontaneous CSF leaks is low
236 and the long-term efficacy of repair is high. The universal preoperative placement of LD does
237 not appear to be indicated. We advocate for LD only in the infrequent case of post-operative
238 otorrhea. Use of LD significantly increases length of stay and hospital costs. Finally, we also
239 advocate for all patients with spontaneous CSF leaks to be tested for OSA.

240

241 **FIGURE LEDGENDS**

242

243 **Figure 1:** **A.** Representative coronal temporal bone CT scan image demonstrating a right tegmen
244 mastoideum defect with fluid in the mastoid. **B.** Intraoperative view of a left middle fossa floor
245 showing multiple tegmen defects (arrows). AE = arcuate eminence, L = Lateral, M = Medial, A
246 = Anterior, P = Posterior.

247

248 **Table 1:** Patient characteristic; BMI = Body Mass Index; kg = kilograms; m = meter

249

250 **Table 2:** Post-operative Complications (65 cases). * = required return to the operating room

251

252 **Table 3:** Lumbar Drain Use and Estimated Cost

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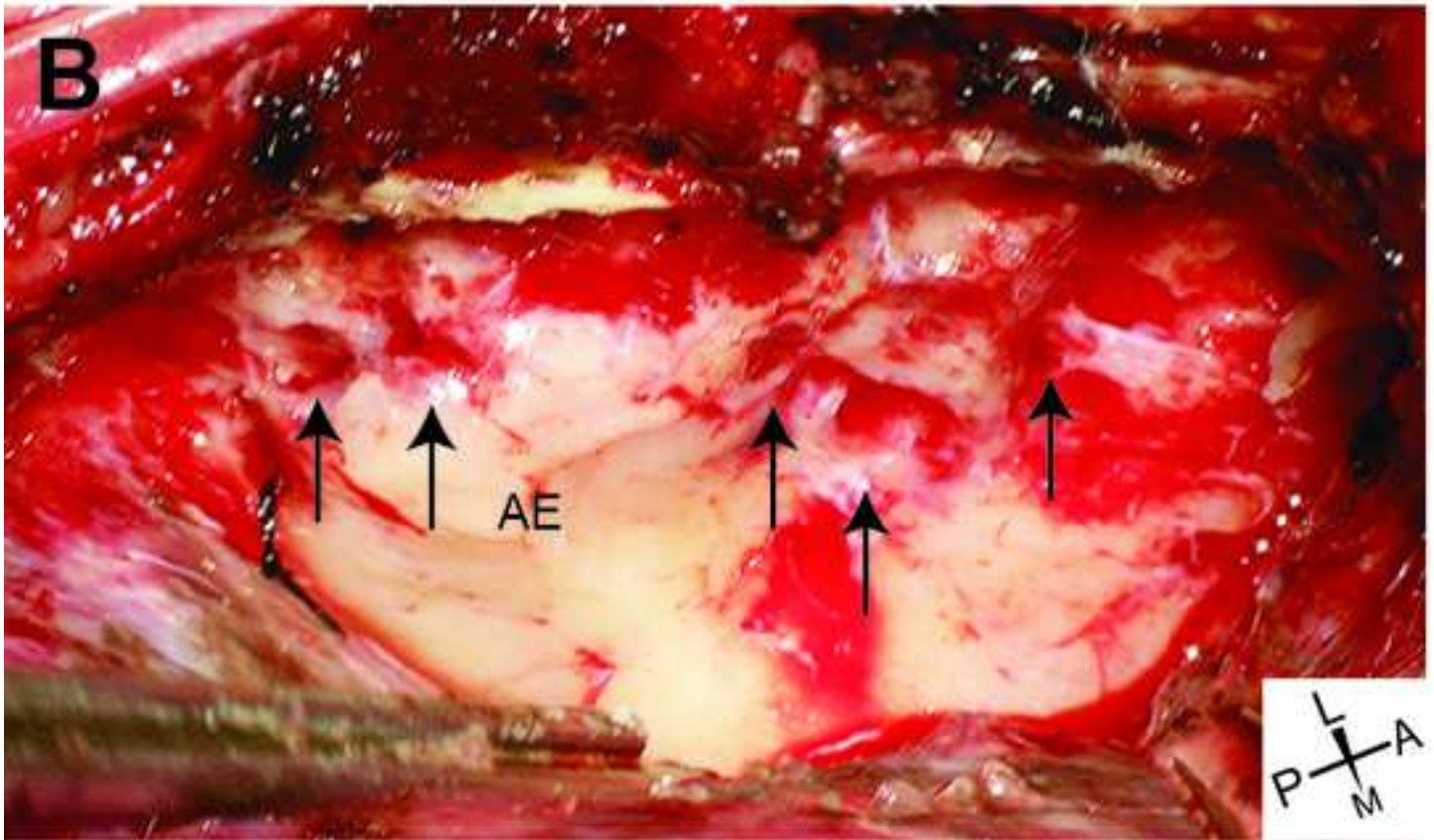
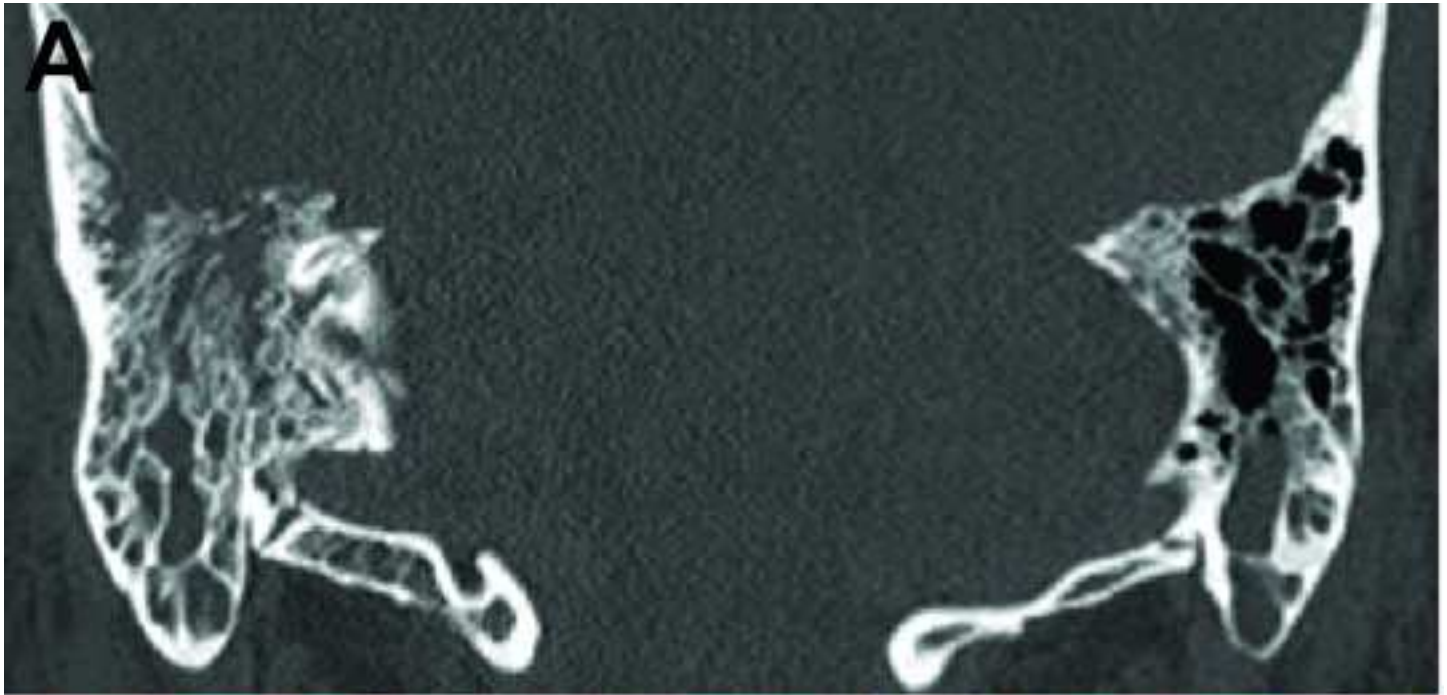


Table1

Gender	Number (%)
Male	19 (31.7%)
Female	41 (68.3%)
	Total = 60
Age (Years)	Number (%)
21-30	1 (1.7%)
31-40	6 (10.0%)
41-50	6 (10.0%)
51-60	18 (30.0%)
61-70	23 (38.3%)
71-80	5 (8.3%)
81-90	1 (1.7%)
Average = 57.5 ± 11.4	
BMI (kg/m²)	Number (%)
≤24.99	2 (3.3%)
25.00-29.99	8 (13.3%)
30.00-34.99	15 (25.0%)
35.00-39.99	13 (21.7%)
40.00-44.99	13 (21.7%)
45.00-49.99	5 (8.3%)
50.00-54.99	2 (3.3%)
55.00-59.99	0 (0%)
60.00-64.99	2 (3.3%)
65.00-69.99	1 (1.7%)
Average = 37.5 ± 8.7	
Comorbidities	Number (%)
Obstructive Sleep Apnea	26 (43.3%)

Table2

Complication (<30 days post-op)	Number (%)
Persistent otorrhea requiring LD	5 (7.7%)
Confusion with Temporal Lobe Edema	2 (3.1%)
Frontal Subdural Hematoma*	1 (1.5%)
Subdural CSF Collection*	1 (1.5%)
Tension Pneumocephalus*	1 (1.5%)
Delayed Facial Paralysis	1 (1.5%)
Meningitis	1 (1.5%)
Seizure	1 (1.5%)
Atrial Fibrillation	1 (1.5%)
Complication (>30 days post-op)	Number (%)
Wound drainage	1 (1.5%)
Complex partial seizure	1 (1.5%)
Word finding difficulty	1 (1.5%)
Ipsilateral CSF leak	0 (0%)

Table3

Perioperative Lumbar Drain (# cases)	Length of stay (days)
No (50)	3.6 +/- 1.6
Yes (15)	8.7 +/- 2.9
Type of Charge	Cost (estimated)
Lumbar drain	\$ 13,316
Hospital Room + Nursing	\$ 3,261 (per day)
5 day total charge	\$ 29,621