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ORIGINAL RESEARCH

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Tailored re-roofing technique for pulsatile tinnitus caused by sigmoid sinus dehiscence or diverticulum

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Abstract

Background: Sigmoid sinus diverticulum/dehiscence (SSD) is one of the treatable causes of venous pulsatile tinnitus. It can be diagnosed using temporal bone computed tomography (CT) or magnetic resonance angiography/venography (MRA). In cases where patients find their symptoms intolerable, surgical treatment is typically preferred. Here, we have presented a novel surgical technique involving sigmoid sinus re-roofing and have analyzed its feasibility.

Methods: Between January 2020 and July 2023, approximately 150 patients with pulsatile tinnitus were evaluated at two different tertiary hospitals. Of these, 12 patients were diagnosed with SSD, and seven underwent surgical treatment. Five patients were treated with tailored reroofing (TRR) of the sigmoid sinus and two with transmastoid resurfacing (MRS) of the sigmoid sinus. We compared the Korean tinnitus handicap inventory (K-THI) score, pure tone audiogram (PTA) threshold, and CT findings before and a month after surgeries for these two techniques. The operation time was also analyzed.

Results: In TRR cases, the K-THI score reduced from 55.0 ± 31.4 preoperatively to 4.0 ± 3.0 postoperatively, and the SSD was well-repositioned and covered by a bone chip postoperatively. In MRS cases, the K-THI score reduced from 41.0 ± 9.9 preoperatively to 15.0 ± 21.2 postoperatively, and the SSD was well-covered with bone cement postoperatively. The average surgical time of five TRR and two MRS cases were 77.5 ± 32.5 and 174.0 ± 75.0 min, respectively. No complications were noted.

Conclusions: Despite the insufficient number of cases, we noted that TRR requires a reasonable amount of time, involves a smaller incision, and may provide favorable outcomes compared to conventional MRS in cases of pulsatile tinnitus associated with SSD.

Level of evidence: IV.

KEYWORDS
diverticulum, sigmoid sinus, tinnitus

1 | INTRODUCTION

Sigmoid sinus dehiscence/diverticulum (SSD) was first reported in 1995 as "a laterally placed sigmoid sinus"[1] and was previously described as an "aneurysm of the sigmoid sinus."[2,3] It is one of the treatable causes of venous pulsatile tinnitus but rarely reported in the literature.[4] The phenomenon may result from abnormal mechanical somatosound production (due to abnormal turbulence or location of vascular flow) or enhanced perception (due to increased transmission of the somatosound or reduced conduction of normal sound).[5]

It is diagnosed using temporal bone computed tomography (CT) or magnetic resonance angiography/venography (MRA). In the case of intolerable symptoms, treatment recommendations include endovascular intervention, surgery, or medication for intracranial hypertension. However, surgical treatment is typically preferred due to concerns related to the migration of coiling/stent and the need for long-term maintenance of anti-coagulants.

Herein, we presented a new surgical method for SSD treatment, named as the tailored re-roofing (TRR) of the sigmoid sinus re-roofing, and analyzed its advantages compared with the conventional transmastoid re-surfacing (MRS) of the sigmoid sinus.

2 | METHODS

2.1 | Study design

From January 2020 to July 2023, approximately 150 patients presenting with pulsatile tinnitus were evaluated at two different tertiary hospitals. Brain MRA and temporal bone CT were performed in most patients, and a combined diagnosis was made by a senior radiologist and a senior otorhinolaryngologist.

Of the patients, 12 were diagnosed with SSD, of whom seven underwent surgical treatment. Five patients underwent TRR of the sigmoid sinus and two underwent MRS of the sigmoid sinus. Overall, there were two surgeons involved; one performed five TRRs, while the other performed two MRSs.

We analyzed and compared the patients' clinical features using the Korean-Tinnitus Handicap Inventory (K-THI),[6,7] pure tone audiogram (PTA) analysis, and temporal bone CT.

K-THI is a representative questionnaire for patients who have subjective or objective tinnitus in Korea. It comprises 25 questions, and patients can respond to each question with the following options: yes (4 points), often (2 points), or no(0 points). Additionally, it incorporates tinnitus evaluation scales, ranging from 0 to 10 points, covering the loudness of tinnitus (loudness), influence on daily life (awareness), and actual discomfort level (annoyance).

We defined SSD according to the criteria outlined by previous reports,[8,9] and identified SSD through the following signs: (1) irregularity of the normal semicircular contour of the bony sinus wall, (2) focal thinning of the calvarial cortex overlying the adjacent sinus wall, and (3) absence of the normal thin layer of cortical bone overlying the sinus.

Additionally, we set the following surgical indications: (1) pulsatile tinnitus over a moderate degree (18–36 or a higher K-THI score) and (2) apparent SSD observed in CT following Eisenman's[7] criteria, which were simultaneously confirmed by a senior otorhinolaryngologist or and a senior radiologist.

A reduction of more than 20% in the THI score or 7 points is defined as an improvement in tinnitus.[10] We compared the THI score, PTA threshold, and CT findings before and 1 month after surgeries. Moreover, the operation time was analyzed. This study was approved by the Institutional Review Board of Severance Hospital (4-2023-0699) and was exempt from requiring informed consent.

2.2 | Surgical procedures

The MRS technique involves a 6–7-cm C-shape retroauricular incision. Moreover, conventional mastoidectomy is essential to gain wide access to the sigmoid sinus. Following a simple mastoidectomy, the mastoid cortex is extensively exposed, and skeletonization of the lesion is performed to reveal the diverticulum/dehiscence.[11,12]

Conversely, the TRR technique requires a smaller skin incision (<3 cm) and minimal cortical bone drilling to collect a bone chip and directly expose the SSD area. On identification of the SSD, careful drilling is imperative to avoid vessel injury. Once the SSD is fully exposed, the adjacent bones are safely trimmed. Subsequently, vessel shrinkage is performed to repose the vessel bipolar electrocauterization device. Bone chip is then placed to reposition and cover the vessel. Tisseel® (Baxter International, Illinois, USA) and TachosilR® (Baxter International, Illinois, USA) were applied to reinforce the repositioned bone chip. Finally, the wound is closed (Figure 1 and Video S1).

3 | RESULTS

Table 1 presents the detailed results. All seven patients who initially reported pulsatile tinnitus experienced complete disappearance of symptoms right after the operation, except one patient who had recurrence. In TRR cases, the K-THI score decreased from 55.0 ± 31.4 preoperatively to 4.0 ± 3.0 postoperatively, and SSD was effectively repositioned and covered by a bone chip postoperatively. Conversely, in MRS cases, the K-THI score reduced from 41.0 ± 9.9 preoperatively to 15.0 ± 21.2 postoperatively, and the SSD was well-covered by bone cement postoperatively (Figure 2). All patients demonstrated improvement in their tinnitus with both techniques, however the patients in the TSSR group demonstrated a greater improvement that is clinically significant.

The ipsilateral PTA threshold (6-frequency average) of TRR was 6.5 ± 2.0 dB preoperatively and increased to 8.0 ± 3.0 dB postoperatively. Meanwhile, the preoperative PTA threshold for MRS cases was 8.5 ± 3.5 dB and increased to 12.5 ± 2.1 dB postoperatively.

The average surgical time of the five TRR cases and two MRS cases was 77.5 ± 32.5 and 174.0 ± 75.0, respectively. The median

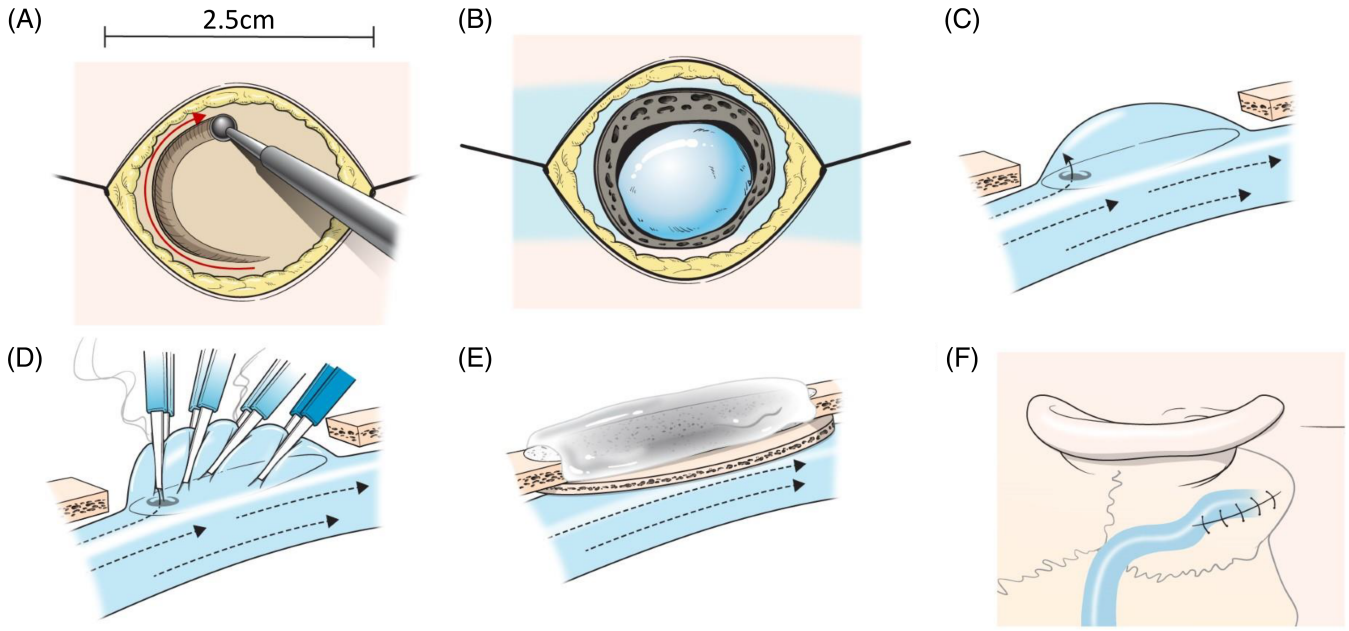

FIGURE 1 Tailored sigmoid sinus reroofing technique. (A) A 25–30-mm tailored retroauricular incision is made around the diverticulum area. Skin, subcutaneous tissue, and periosteum dissections are performed until the diverticulum area is exposed. (B) The bone over the diverticulum is identified and harvested by meticulously drilling to prevent vessel injury. (C) After complete exposure of dehiscence/diverticulum, covered bone is removed safely. (D) Subsequently, complete coagulation is performed to reduce the vessel volume using bipolar electrocauterization. (E) The defect is covered by Tachosil (Baxter International, Illinois, USA), bone chip, and Tisseel (Baxter International, Illinois, USA). (F) Finally, the subcutaneous tissue and skin are sutured using Vicryl 4-0 and Nylon 4-0 threads or bond, respectively.

follow-up period was 13.5 ± 9.3 months, and no complications, including intraoperative massive bleeding, postoperative thrombosis, infection, or wound dehiscence, were observed.

4 | DISCUSSION

For patients with intractable pulsatile tinnitus caused by SSD, surgical intervention remains the most effective treatment option. Advances in imaging have facilitated precise target identification, while innovative bleeding control materials have enabled the use of minimally invasive techniques, involving tailored incision and bone drilling. Our results indicate that the tailored technique reduces surgical time by minimizing drilling and incision, with a shorter duration for suturing. Although bone cement can cover larger defects than bone chips, reroofing, involving vessel repositioning and bone chip reattachment, avoids heat injury and secures complete sealing. Moreover, bone chip offers advantages such as reduced foreign body effects due to autograft material, minimal thermogenic impact, and reduce collapse due to their light weight and small coverage area.

Several studies reported that the conventional transmastoid approach has disadvantages such as prolonged surgical and recovery time, attributed to a sizable incision and excessive drilling.[13] Additionally, these studies demonstrated a relatively high risk of sigmoid sinus injury, venous thrombosis, and aesthetic problems.[14] Eisenman[8] reported that two out of 14 patients experienced major complications: one presented with visual loss and intracranial hypertension, while the other presented with progressive headache and ipsilateral sinus thrombosis. Song[15] underscored the importance of considering potential issues such as sinus violation during dissection, formation of dural sinus to mastoid air cell fistula, or delayed dural arteriovenous fistula formation when employing the conventional surgical approach. Contrarily, Park[16] employed a novel water occlusion test to minimize the extent of the surgical procedure, depending on the causes of the tinnitus.

In this study, TRR and MRS surgeries were performed by two different surgeons on a small number of cases, and the analysis was conducted retrospectively. Therefore, a more extensive prospective study could overcome this limitation.

We believe that the TRR technique may offer reduced risk of complications and improved cosmetic outcomes, although further validation studies are warranted. Moreover, a long-term follow-up is necessary to monitor symptoms or other complications such as recurrence.

5 | CONCLUSION

The TRR technique offers advantages over the MRS technique in terms of surgical time, incision, symptom improvement, and lower risk of complications. Therefore, it can be a potentially superior alternative in treating SSD.

TABLE 1 Patients description and surgical results.

Patient no	Sex	Age	Location	Surgical technique	Operation time (min)	Preoperative tests					Postoperative tests					F/U period (month)
						K-THI	VAS loudness	VAS awareness	VAS annoyance	PTA (dB)	K-THI	VAS loudness	VAS awareness	VAS annoyance	PTA (dB)	
1	F	35	Left	TRR[a]	45	30	8	7	6	11	8	3	2	2	9	5
2	F	28	Right		63	68	7	7	9	11	0	1	0	0	9	4
3	F	29	Right		80	38	7	6	6	7	2	1	1	0	8	4
4	F	24	Right		110	40	10	10	10	5	0	0	0	0	4	4
5	M	19	Right		70	80	9	8	10	6	0	0	0	0	6	2
6	F	30	Right	MRS[b]	227	34	5	6	4	11	0	0	0	0	6	25
7	F	34	Left		121	48	8	8	10	14	30	8	7	6	11	17

Note: THI score: normal (0–16), mild handicap (18–36), moderate handicap (38–56), severe handicap (58–10).

Abbreviations: K-THI, Korean-Tinnitus Handicap Inventory; VAS, Visual Analogue Scale; PTA, pure tone audiogram.

[a]Tailored sigmoid sinus reroofing technique.

[b]Transmastoid sigmoid sinus resurfacing technique.

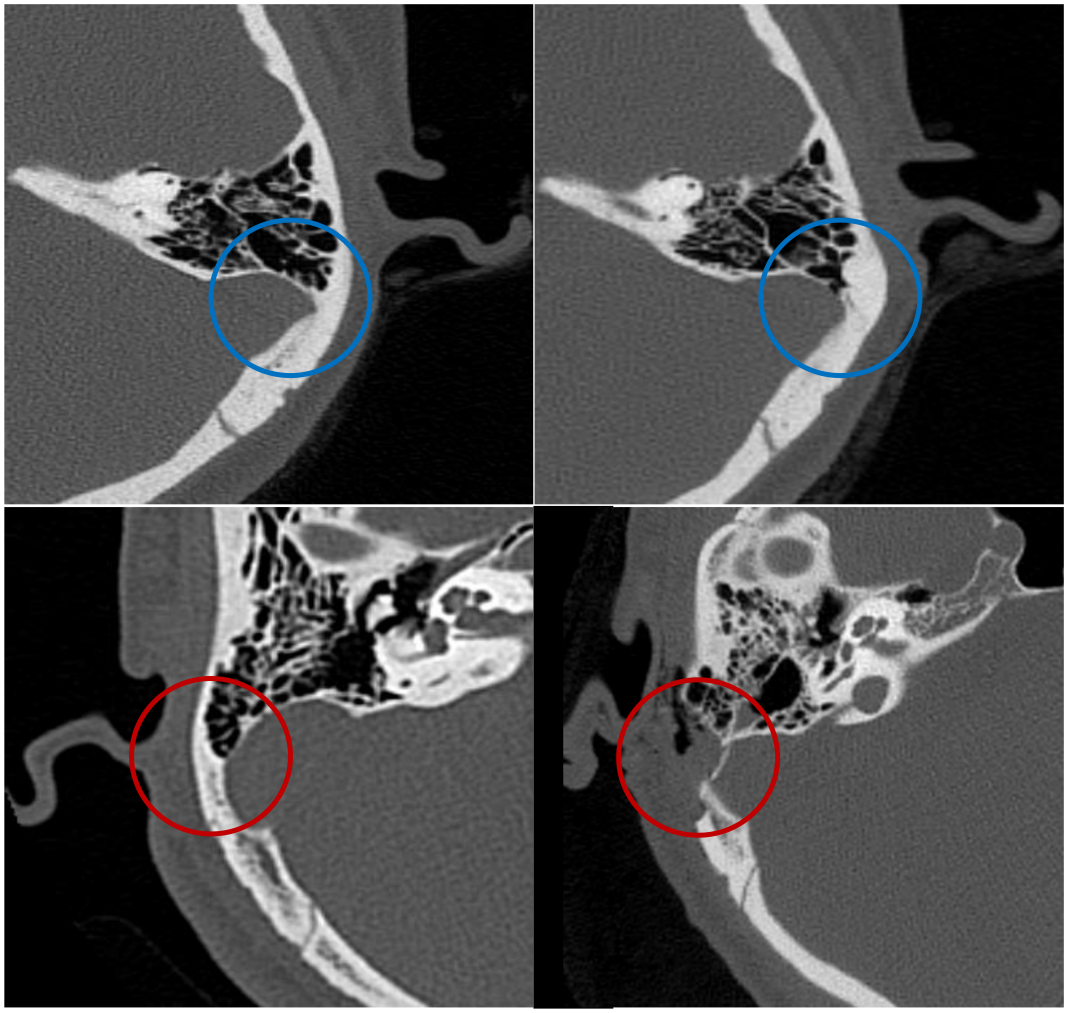

FIGURE 2 Preoperative and postoperative CT scans of both surgeries. (A) Preoperative images; sigmoid sinus dehiscence/diverticulum is noted on the left side. (B) Dehiscence/diverticulum is repositioned and reroofing is performed using bone cement. (C) Preoperative images; sigmoid sinus dehiscence/diverticulum is noted on the right side. (D) Dehiscence/diverticulum is resurfaced using bone chip.

AUTHOR CONTRIBUTIONS

In Seok Moon, **Minbum Kim** designed the study. **Jeong Gum Lee**, **Gina Na**, **Young Kyun Hur**, **Youn Jin Cho** gathered cases and analyzed the data. **Jeong Gum Lee**, **In Seok Moon** drafted the manuscript. **Ji Min Yoon**, **Jeong Gum Lee**, and **Kwak SM** made Video S1. All authors reviewed and approved the manuscript.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest to declare.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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