



Surgical treatment of pulsatile tinnitus related to the sigmoid sinus

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ABSTRACT

Objective: Tinnitus—a common clinical symptom—can be categorized into pulsatile tinnitus (PT) and non-PT. Among these, PT is usually associated with sigmoid sinus symptoms, such as sigmoid sinus wall defect or diverticulum, for which various surgical treatments are available. We have discussed the clinical efficacy of surgery for sigmoid sinus-associated PT via the transmastoid approach in this study.

Methods: We conducted a retrospective review of 4 patients who underwent surgery for sigmoid sinus-associated PT via the transmastoid approach at Nanjing Drum Tower Hospital from January to December 2020. Of these, 2 patients had sigmoid sinus wall defect and 2 had sigmoid sinus diverticulum. Postoperative tinnitus grading and surgical efficacy were determined.

Results: After surgery, PT dissolved in 3 patients, while tinnitus significantly decreased in 1 patient. During the follow-up period of 12–18 months, none of the 4 patients showed complications related to increased intracranial pressure or venous sinus thrombosis, and tinnitus symptoms disappeared in 3 patients without recurrence, although 1 patient occasionally developed tinnitus. Postoperative thin-slice CTA of the temporal bone indicated that the sigmoid sinus bone wall defect or diverticulum was completely repaired with a thick soft tissue coverage.

Conclusion: Surgical repair of sigmoid sinus-associated PT via the transmastoid approach deserves clinical promotion as it exhibited better efficiency while being relatively less invasive.

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1. Introduction

Tinnitus is a common clinical symptom that exists in 2 forms;

Abbreviations: PT, pulsatile tinnitus; SSWA, sigmoid sinus wall abnormality; TEQ, tinnitus evaluation questionnaire.

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objective and subjective tinnitus (Cortese et al., 2021). Subjective tinnitus refers to the auditory experience of the patient's perception of sound in the absence of external acoustic stimulus around the ear or in the brain. On the other hand, objective tinnitus refers to tinnitus that involves real physical sound wave vibrations that can be detected by others or recorded by instruments (Sonmez et al., 2007). Pulsatile tinnitus (PT) is objective tinnitus that can be divided into vascular and non-vascular types. Vascular tinnitus includes venous origin, arterial origin, and other etiologies. Venous origin of PT has been described and identified with increasing frequency recently, while sigmoid sinus wall abnormality (SSWA) is an often unrecognized yet potentially treatable venous etiology of PT. This type includes both sigmoid sinus diverticulum and sigmoid sinus dehiscence (Eisenman et al., 2018, Essibayi et al., 2021).

From an epidemiological perspective, PT may have a female and right-sided predominance. One hypothesis supporting this is that the jugular foramen is larger in females and located on the right

side, which possibly leads to a blood flow vortex. Moreover, the majority of the affected women have an elevated body mass index (Harvey et al., 2013). Nevertheless, persistent tinnitus severely affects the quality of life of the patients.

Several therapeutic techniques have been proposed for sigmoid sinus-associated PT, including endovascular intervention and surgery. Endovascular intervention can rectify the vortex by embolizing the coil diverticulum. Surgical techniques include craniectomy reconstruction and sigmoid sinus wall reconstruction.

This study reported the psychological and physical outcomes of 4 sigmoid sinus-associated PT patients from January 2020 to March 2021. Preoperative imaging findings suggested a sigmoid sinus wall defect or sigmoid sinus diverticulum. After repairing the sigmoid sinus via the transmastoid approach, tinnitus disappeared or substantially decreased during 12–18 months of follow-up according to the disease prognosis.

2. Materials and methods

2.1. Patients

We reviewed the records of 4 patients who received surgical treatment for sigmoid sinus-associated PT at Nanjing Drum Tower Hospital from January to December 2020. The following conditions were also met simultaneously: (1) all patients showing persistent PT that sounds like the beating heart or blood vessel pulse. All PT being regular and increasing significantly with exercise. The patients' quality of life is affected by tinnitus, including persistent PT. (2) Preoperative CTA of the temporal bone showing a defect in the sigmoid sinus bone wall or diverticulum based on the evaluation of the location, size, and continuity of bone (Fig. 1). (3) The internal jugular vein compression test is positive, and tinnitus can be reduced or eliminated after compression of the affected internal jugular vein. (4) Imaging examination (MRA/MRV/DSA) excluded other causes of tinnitus, such as secretory otitis media, middle ear

cholesterol granuloma, idiopathic intracranial hypertension, hydrocephalus, arteriovenous fistula, intracranial occupancy, tympanic body tumor, and cardiovascular conditions. (5) Otoscopy indicated that bilateral external acoustic meatus was unobstructed, and the tympanic membrane was intact and marked. Pure tone audiometry in both ears exhibited normal hearing, and the tympanogram exhibited "A" type in both ears. Written consent was obtained from all participants (Table 1).

2.2. Surgical procedure

All 4 patients underwent sigmoid sinus bone wall repair via the transmastoid approach under general anesthesia. A 5-cm-long incision was prepared behind the ear by lifting forward the flap to separate the musculoskeletal flap. The position of the tip of the musculoskeletal flap depended on the location of the diverticulum or the bone wall defect, with the tip of the musculoskeletal flap remaining above the defect of the sigmoid sinus, the tip of the diverticulum or the defect in the middle of the sigmoid sinus remained posterior, and the tip of the musculoskeletal flap below the defect at below the sigmoid sinus to cover the sigmoid sinus defect or diverticulum. The mastoid process was incised with an electric drill while the cortical bone powder was collected for subsequent use. The mastoid process was opened with the posterior wall of the external acoustic meatus left intact, and the sigmoid sinus diverticulum or the bone defect was fully exposed. Immediately, the diverticulum was filled with a yarn mixed with bone wax or the bone wall defect was compressed. The surface was then covered with bone powder and the musculoskeletal flap in turn, and the postauricular incision was closed layer by layer, such that the area was bandaged with pressure (Fig. 2).

2.3. Evaluation of the surgical outcome

Tinnitus evaluation questionnaire (TEQ) was employed to assess

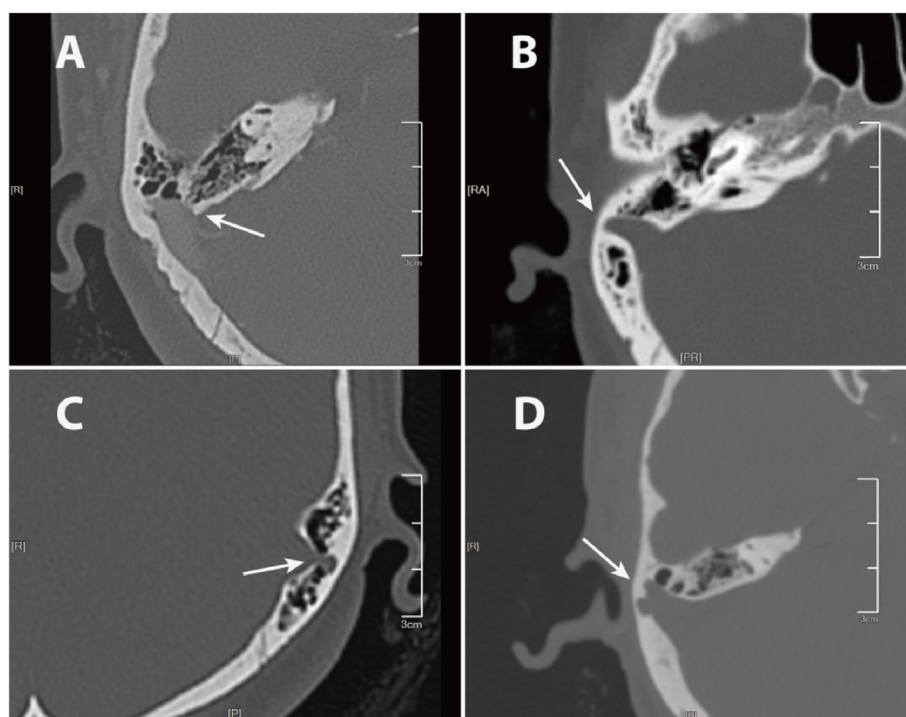


Fig. 1. Pre-operative CTA images of the 4 study patients (arrow). A: Bone wall defect of the right sigmoid sinus (No. 1). B: Bone wall defect of the right sigmoid sinus and protrusion of the sigmoid sinus into the bone cortex (No. 2). C: Left sigmoid diverticulum (No. 3). D: Right sigmoid diverticulum (No. 4).

Table 1
Information of the 4 study patients with PT.

No.	Age	Gender	Side	Size of defect (mm)	Preoperative TEQ	Postoperative TEQ	Surgical efficacy	Follow-up (months)
1	39	female	right	3.62	5	0	healing	18
2	45	female	right	3.45	5	1	reduced	15
3	35	female	left	2.85	4	0	healing	12
4	56	female	right	3.65	5	0	healing	12

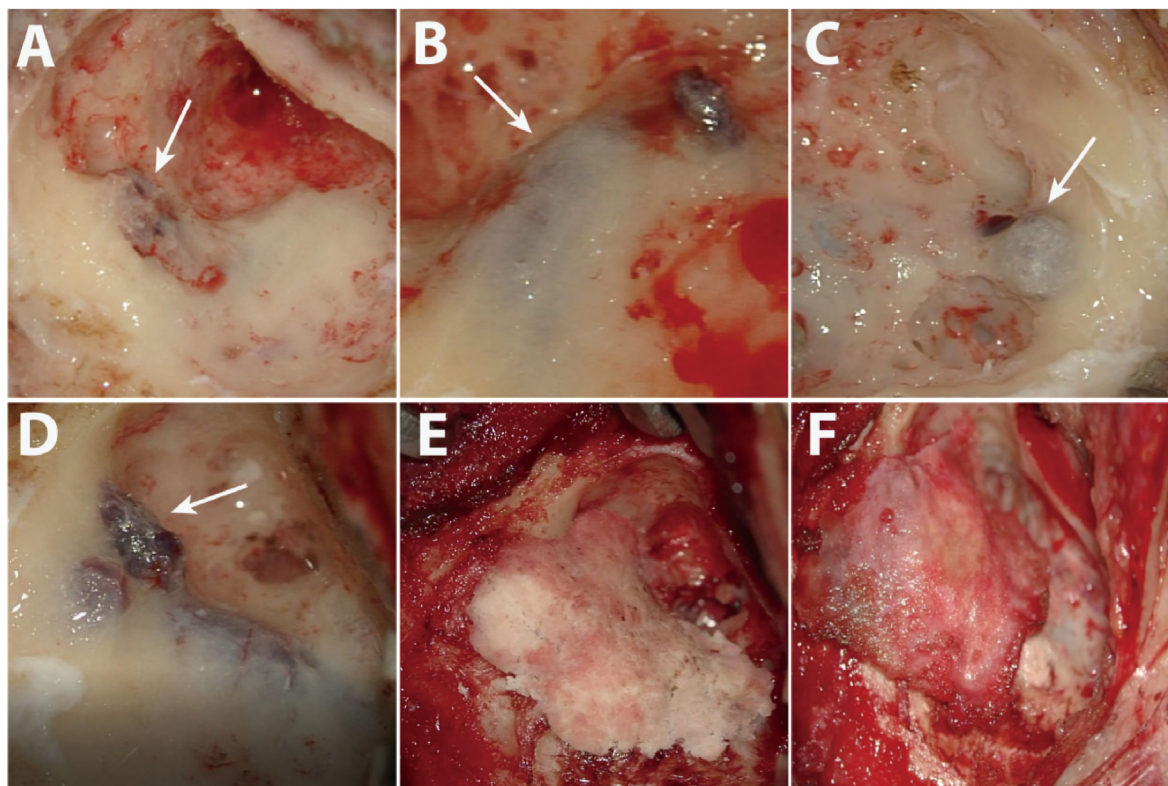


Fig. 2. Intraoperative views in the 4 study patients. A–D: A patient with intraoperatively revealed sigmoid sinus bone wall defect or diverticulum (arrow). E: Patient A's sigmoid sinus defect covered with bone powder. F: Patient A's sigmoid sinus defect covered with a musculocutaneous flap.

the effectiveness of PT at the time of follow-up and the surgical complications were recorded over 12–18 months of follow-up. TEQ ranged from slight, tinnitus only perceived tinnitus in quiet environments (1) to catastrophic (5). Based on the patient's subjective feelings, the change in the tinnitus and surgical efficacy were evaluated to examine whether it showed healing (tinnitus disappeared), reduced (the degree of tinnitus was reduced by > 2 levels (including 2 levels), and ineffective healing (no change in tinnitus severity) (Liu et al., 2012).

3. Results

After surgery, PT disappeared in 3 patients and was significantly reduced in 1 patient. None of them exhibited symptoms or complications related to vertigo, nausea, cerebrospinal fluid leakage, venous sinus thrombosis, and increased intracranial pressure.

The follow-up of 12–18 months indicated no recurrence of PT in 3 patients after the symptoms had disappeared, and occasional tinnitus was recorded in 1 patient with a satisfactory treatment outcome. Re-examination of the temporal bone thin-slice CTA displayed the complete repair of the sigmoid sinus wall defect, with a visibly thicker soft tissue coverage on the surface, with no obvious defect or diverticulum communicating with the mastoid airspace (Fig. 3).

4. Discussion

When abnormalities occur in the structure of the blood vessels or muscles of the head and neck, the blood flow in the vessels changes and may lead to abnormal sound production that the patient perceives as PT through the inner ear (Wang et al., 2017). The mechanism of the PT occurrence remains uncertain, although some studies have demonstrated that two conditions need to be met to induce venous PT: the presence of a vortex in the venous blood, which converts potential energy into sound, and the capability to transmit sound to the middle ear (Yeo et al., 2018). A complete sigmoid may insulate vibrations from the adjacent flow through the sigmoid sinus; however, with dehiscence, the flow sounds may be transmitted into the mastoid and cochlea, leading to PT (Kumar et al., 2021). The transverse sinus-sigmoid sinus transition zone on the side of the dominant venous sinus displayed thick arachnoid granules, which can easily result in lumen adhesions during inflammation, and the blood flowing through the transverse sinus stenosis undergoes hemodynamic changes and murmurs (Ettyreddy et al., 2021). A past study indicated that increased turbulent flow in the transverse-sigmoid-internal jugular vein system is one of the causes of PT (Han et al., 2017). In case of congenital weakness or trauma in the sigmoid sinus wall, it gradually expands

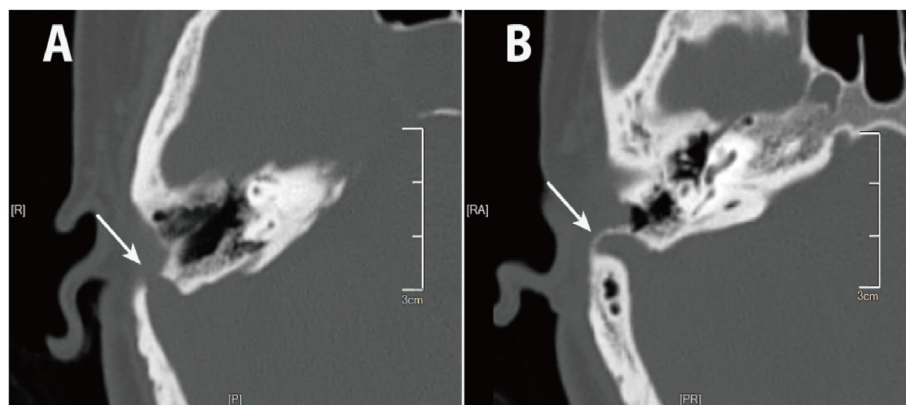


Fig. 3. Postoperative review of the CTA images of the study patients (arrow). A: Patient A was re-examined on CTA in the 8th month after surgery, and the surface of the original bony defect of the sigmoid sinus was covered by a soft tissue with no communication with the mastoid airspace. B: Patient B was re-examined in the 15th month after surgery and CTA showed no bony defects in the sigmoid sinus with the surface covered by soft tissues.

under the impact of blood flow and then compresses the adjacent temporal bone, resulting in the formation of the diverticulum (Cortese et al., 2021). Therefore, past studies have confirmed the necessity of careful assessment of the morphology of the sigmoid sinus via temporal bone CTA. Owing to the broader sigmoid sinus and higher blood flow in the right than the left in most people (Koesling et al., 2005), PT is more likely to occur on the right side, which is consistent with the reported data (Eisenman et al., 2018).

The surgical treatment of PT associated with sigmoid sinus was initially performed via intravascular intervention, and a study by Houdart et al. (2000) reported that, based on postoperative angiography, tinnitus was completely dissolved in patients whose sigmoid sinus diverticulum disappeared after coil embolization. Subsequently, several scholars also addressed the sigmoid diverticulum with a balloon or coil to relieve the tinnitus symptoms of the patients (Lenck et al., 2012, Park and Kwon, 2010). Although these methods can resolve tinnitus symptoms, they involve the risk of balloon or coil displacement and the need for long-term anticoagulation therapy to prevent thrombosis. The obstruction of the sigmoid sinus site can be dangerous as it eliminates the alternative pathways through the petrosal sinus, resulting in the disruption of venous access, which can lead to serious concerns. The surgeon must be fully aware of these risk factors. In one study (Otto et al., 2007), the researchers first filled the diverticular cavity of the sigmoid sinus in 3 patients with fascial, muscular, and bone wax in 2007, which reduced the cavity and successfully made it disappear. Another study (Eisenman, 2011) applied bipolar electrocoagulation and autologous bone plates to reconstruct the localized distension of the sigmoid sinus; consequently, the tinnitus completely disappeared in all 14 affected ears after the surgery. Yet another study (Eisenman et al., 2018) conducted sigmoid sinus wall repair and reconstruction through fascial repair in 40 patients with sigmoid sinus wall defects, of whom, 36 exhibited a significant reduction in tinnitus. In this study, a hemostatic material mixed with bone wax was used to fill the diverticulum or compress the bone wall defect in all 4 patients, with the surface being sequentially covered with autologous bone powder and musculoskeletal flap, which not only eliminated the abnormal blood flow induced by the diverticulum but also effectively prevented the sound conduction to the mastoid air chamber. These results imply that PT disappeared in 3 patients after surgery and that there was no recurrence in the follow-up for more than a year. In addition, 1 patient's tinnitus was significantly alleviated after surgery, exhibiting occasional tinnitus, with the treatment effect being satisfactory. These results are basically consistent with those reported by domestic and foreign scholars

(Newberry et al., 2021).

In this paper, a significant therapeutic effect was achieved in all 4 patients, albeit CTA re-examination of the temporal bone displayed the left visible partial loss of the sigmoid sinus bone, which was considered as follows: (1) although the sigmoid sinus wall was still partially missing, the defective part was reinforced by autologous bone powder and the musculoskeletal flap to reconstruct the smooth sigmoid sinus wall in order to inhibit the vortex of blood and eliminate tinnitus at its source. (2) The missing sigmoid sinus bone was covered with bone powder and musculoskeletal flap, which significantly elevated the efficiency of sound insulation as well as blocked the sound transmission. (3) Owing to the filling of bone powder and musculoskeletal flap, the reduced volume of the mastoid cavity could eliminate the resonance effect elicited by the original mastoid cavity and further attenuate the propagation of abnormal sounds in the middle ear (Lee et al., 2020).

This operation of sigmoid sinus wall repair via the transmastoid approach offers advantages over endovascular interventions in terms of fewer implant displacements and no requirement for postoperative anticoagulation. However, a study by Wee et al. (2012) indicated the demand for preventing complications caused by increased intracranial pressure during sigmoid sinus repair. In this study, no complications of increased intracranial pressure were recorded in any of the 4 patients after surgery, which can possibly be ascribed to the sigmoid diverticulum being closed with bone wax, bone powder, and cartilage tissue without using any filling material in the sigmoid sinus cavity during the operation. Therefore, the role of the sigmoid sinus in the reflux of intracranial venous blood was unaffected, and the entry of the hemostatic materials was prevented from filling the sigmoid sinus during severe bleeding to causing sigmoid sinus thrombosis. Our research has some limitations. For instance, after 12–18 months of follow-up, no recurrence of PT symptoms was noted in 3 patients after the disappearance, while 1 patient showed occasional tinnitus. In this case, the follow-up period was short. In a 3-year-long follow-up by Cindy (2018), a case of PT recurrence was detected, which was generally ascribed to occur after emotional excitement, severe diseases, or other trigger factors; nevertheless, the exact mechanism behind it remains unclear. Therefore, it is still necessary to extend the postoperative follow-up of patients to obtain more stable and reliable data.

Some of the currently unexplained problems have also been recorded in clinics, such as imaging findings of sigmoid sinus diverticulum pathologic variation or sigmoid sinus bone wall defect in healthy individuals whose chief complaint is not tinnitus. Thus, it

remains to be further investigated whether sigmoid sinus diverticulum or local bone defect is an absolute contributing factor in the development of PT. Moreover, there is a lack of relevant research on the extent of sigmoid sinus diverticulum or bone wall loss or the severity of PT symptoms and the degree of correlation among them.

5. Conclusion

Through our current results, we have updated the understanding of PT and provided information helpful in modifying its treatment approach with the development of medical technology. For PT caused by a sigmoid sinus wall defect or diverticulum, the reconstruction of the sigmoid sinus wall via the transmastoid approach is thus a safe and effective approach worthy of clinical promotion.

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Informed consent

Informed consent was obtained from all individual participants included in the study.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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