CT characteristics of dehiscent sigmoid plates presenting as pulsatile tinnitus: a study of 23 patients

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Abstract

Background: Although some features of dehiscent sigmoid plates as a cause of pulsatile tinnitus (PT) have been reported, detailed imaging findings have not been evaluated.

Purpose: To retrospectively evaluate the computed tomography (CT) features of dehiscent sigmoid plates associated with PT.

Material and Methods: The CT images of 23 PT patients were assessed to evaluate the features of the dehiscent sigmoid plates, lateral sinuses, and temporal bone pneumatization.

Results: A total of 31 defects were found on the PT side. Twenty-five defects involved the superior curve or the descending segment, four involved above both sites, and only two involved the inferior curve. Twenty-six defects involved the anterior border or the anterolateral border, and only five involved the lateral border of the sigmoid sinus. The dehiscent sigmoid plate was on the dominant side in all 18 patients with a unilateral dominant lateral sinus, and on the right side in two patients and on the left side in three patients with co-dominant lateral sinuses. Fourteen patients had hyperpneumatization and nine had good pneumatization of temporal bone. Fifteen of the 17 patients with resolution of PT after surgery had a single defect. Four of the six patients with persistence of PT after surgery had more than one defect.

Conclusion: Sigmoid plate dehiscence often involves the anterior or anterolateral border of the superior curve or the descending segment of the sigmoid sinus on the side of the dominant lateral sinus, which often coexists with extensive pneumatization of the temporal bone.

Keywords
Pulsatile tinnitus, temporal bone, sigmoid plate, computed tomography

Introduction

Pulsatile tinnitus (PT) associated with sigmoid sinus pathology has been described in many reports. The reported underlying pathological conditions include a diverticulum (also referred to as an aneurysm) (1,2), thrombosis (3), stenosis (4), and a unilateral dominant sigmoid sinus (5). A dehiscent sigmoid plate resulting in PT is a rare condition that has been described in only three reports. Xue et al. (6) reported three patients who underwent surgical reconstruction of a dehiscent sigmoid plate, with subsequent resolution of their PT. Santa Maria (7) reported a patient with a dehiscent sigmoid plate that presented as PT, which was successfully treated by resurfacing the site of dehiscence with soft tissue. Eisenman (8) reported 15 patients with PT associated with a sigmoid sinus diverticulum and/or dehiscent sigmoid plate, of which 14 were successfully treated by extraluminal transmastoid surgery. Although these reports described dehiscent sigmoid plates in patients with PT, there are still many outstanding questions regarding the pathophysiology underlying dehiscence of sigmoid plates, and the

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detailed imaging characteristics of this condition have not been systematically evaluated.

The aim of this paper was to retrospectively review the computed tomography (CT) images of 23 patients with PT resulting from a dehiscent sigmoid plate.

**Material and Methods**

**Patient population**

The Institutional Review Board of Capital Medical University, Beijing Tongren Hospital approved this retrospective study and waived the need for further patient consent.

This study included 23 patients (20 women, 3 men; mean age, 37.8 years; age range, 20–56 years) treated for unilateral persistent PT resulting from a dehiscent sigmoid plate between May 2008 and January 2013. Ten patients had left-sided PT and 13 had right-sided PT. The mean duration of PT was 3.5 years (range, 4 months to 19 years). The patients all underwent surgical correction using the method reported by Otto et al. (9).

**CT imaging**

All patients underwent preoperative dual-phase contrast-enhanced CT from the vertex to the level of C6 using a 64-slice multi-detector scanner (Brilliance 64, Philips Medical Systems, Best, The Netherlands) with analysis using Bolus-Tracking software (Trigger Bolus; region of interest, 200 mm²; trigger point, the ascending aorta; trigger threshold, 120 HU). Iodinated non-ionic contrast material (iopamidol, 370 mg iodine per mL; 1.5 ml/kg; Bracco, Shanghai, PR China) was administered intravenously followed by 20 mL of normal saline as a flush, using an automated injector at a rate of 5 mL/s. The scanning parameters were as follows: 120 kV and 300 mAs/slice; table feed, 54.1 mm/s; matrix, 512 x 512; field of view, 22 x 22 cm to 24 x 24 cm; rotation time, 0.75 s; and collimation, 64 x 0.625 mm. The arterial phase was scanned in a cephalocaudal direction and the venous phase was scanned in the opposite direction after 8 s.

All the arterial phase images (reconstructed using standard algorithms) and venous phase images (reconstructed using standard and bone algorithms) were imported into a workstation and postprocessed using multiplanar reconstruction (MPR). The MPR slice thickness was 1 mm, with no slice gap. The arterial and venous phase MPR images reconstructed with standard algorithms were used to evaluate the arterial and venous systems with narrower settings (width, 4000 HU; level, 700 HU). The venous phase MPR images reconstructed with bone algorithms were used to assess the integrity of the sigmoid plate and the temporal bone using bone window settings (width, 4000 HU; level, 700 HU).

**Image interpretation**

Two experienced head and neck radiologists (8 and 12 years of experience, respectively) reviewed all the CT images, and the findings were recorded by consensus. Sigmoid plate dehiscence was defined as a focal defect in the cortical bone overlying a normal sigmoid sinus. When there was a difference of more than 3 mm between the diameters of the right and left midtransverse sinuses, the side of the larger transverse sinus was regarded as dominant, as proposed by Krishnan et al. (5). If the difference was 3 mm or less, the transverse and sigmoid venous sinuses were regarded as codominant. The degree of pneumatization of the temporal bone was categorized as hyper-pneumatization, good pneumatization, moderate pneumatization, or hypopneumatization, as proposed by Han et al. (10).

**Results**

**CT findings**

A total of 31 sigmoid plate defects were detected on the side of PT in the 23 patients. Seventeen patients had a single defect (Fig. 1a, b), five patients had two defects (Fig. 2a, b), and one patient had four defects. Ten defects involved the superior curve (Fig. 2a), 15 involved the descending segment (Fig. 1a, b), two involved the inferior curve (Fig. 2b), and four involved the superior curve and the descending segment of the sigmoid sinus. Fourteen defects involved the anterior border (Fig. 2a, b), 12 involved the anterolateral border (Fig. 1a, b), and five involved the lateral border of the sigmoid sinus.

Eighteen patients had a unilateral dominant lateral sinus (11 right-sided and 7 left-sided) and five patients had co-dominant lateral sinuses. All the dehiscent sigmoid plates were on the side of the dominant lateral sinus (Fig. 1c). In the five patients with codominant lateral sinuses, the dehiscent sigmoid plate was on the right side in two patients and on the left side in three patients (Fig. 2c).

There was air in the temporal bone on the side of PT in all patients. Fourteen patients had hyper-pneumatization and nine had good pneumatization of the temporal bone (Figs. 1d, 2d).

**Therapeutic outcomes**

After transmastoid reconstruction of the sigmoid plate, the PT resolved completely in 17 patients and decreased significantly in the remaining six patients. Fifteen of the 17 patients with complete resolution of PT after surgery...
had a single sigmoid plate defect (Fig. 1a, b), and the other two patients had two defects. Among the six patients with reduction of PT after surgery, two had a single defect, three had two defects (Fig. 2a, b), and one had four defects.

**Discussion**

The numerous vascular causes of PT can be divided into arterial and venous causes. In this study, the PT resolved or improved after surgery in all cases, confirming that a dehiscent sigmoid plate is a treatable cause of PT. Topal et al. (11) and Tüz et al. (12) hypothesized that cortical bone completely surrounding an internal carotid artery can act as an insulator. Similarly, an intact sigmoid plate can act as an insulator and impede the transmission of sound from the sigmoid sinus to the air cells of the temporal bone. When the integrity of the sigmoid plate is compromised, this insulating characteristic may also be

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**Fig. 1.** A 33-year-old man with complete resolution of right-sided PT after surgery. Axial (a) and oblique sagittal (b) CT images showing a single defect at the anterolateral border of the descending segment of the right sigmoid sinus (arrow). (c) Axial CT image showing a dominant right lateral sinus (arrowheads). (d) Axial CT image showing good pneumatization of the right temporal bone (asterisk).
compromised, resulting in transmission of sound from the sigmoid sinus to the air cells in the temporal bone (13).

Sigmoid plate dehiscence is not a congenital condition, because PT presents in adulthood. All the sigmoid plate defects involved the anterior or anterolateral wall of the sigmoid sinus, suggesting that they may have been caused by the high pressure and shear rate that occur in the outer wall of a curved blood vessel (14,15). The forceful impact of the blood flow may cause gradual thinning of the sigmoid plate that eventually results in a bone defect.

The air cells in the temporal bone are located on the path of sound transmission, and may be an important contributor to PT resulting from a dehiscent sigmoid plate. The small air cells in a hypo-pneumatized temporal bone may constitute an acoustic barrier to sound transmission (11,12). In contrast, the large air cells in an extensively pneumatized temporal bone may prolong or amplify sounds, or reduce the ability to block sound transmission. Patients with co-dominant lateral sinuses had similar prevalences of right and left sigmoid plate defects, but in the 18 patients with a unilateral dominant lateral sinus, all the sigmoid plate defects were on the

Fig. 2. A 23-year-old woman with significant reduction of left-sided PT after surgery. Axial CT images showing defects at the anterior border of the superior curve (a) and the descending segment (b) of the left sigmoid sinus (arrow). (c) Axial CT image showing codominant lateral sinuses (arrowheads). (d) Axial CT image showing good pneumatization of the left temporal bone (asterisk).
dominant side. These results suggest that there may be increased turbulence of blood flow in the dominant lateral sinus (16), which may play an important role in the development of sigmoid plate dehiscence and PT.

In our study population, the PT resolved completely in patients with a single small or moderate defect (88.2% of patients with a single defect) or with two defects that were close together (40% of patients with two defects). However, in patients with a single large defect (11.8% of patients with a single defect) or with two or more defects that were not close together (66.7% of patients with more than one defect), the PT improved but did not disappear. These results suggest that large or multiple defects of the sigmoid plate are difficult to reconstruct completely, and that a venous bruit can still be transmitted to the cochlear system via residual dehiscence of the sigmoid plate, resulting in PT.

Some strategies have been developed to improve diagnosis of the cause of PT (5). The primary choice of radiological examination for patients with PT at our institution is dual-phase contrast-enhanced CT, including arterial and venous images with a narrow window, and venous CT images with a bone window. These images provide a thorough evaluation of the arterial and venous structures as well as the temporal bone, and are an effective screening tool for dural arteriovenous fistulas (17,18).

We acknowledge some limitations to our study. Because of the retrospective design, we only assessed the structural characteristics of sigmoid plate dehiscence associated with PT. Flow abnormality in the sigmoid sinus is an essential factor in PT that is not well understood, and was not evaluated in this study. A long-term follow-up study is needed to further evaluate this condition.

In conclusion, sigmoid plate dehiscence resulting in PT frequently involves the anterior or anterolateral wall of the superior curve and/or the descending segment of the sigmoid sinus. The dehiscence is often located on the side of the dominant lateral sinus, and often coexists with extensive pneumatization of the temporal bone.

Conflict of interest
None declared.

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References
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