# Incidence of Vascular Anomalies and Variants Associated with Unilateral Venous Pulsatile Tinnitus in 242 Patients Based on Dual-phase Contrast-enhanced Computed Tomography

**Cheng Dong[1], Peng-Fei Zhao[2], Ji-Gang Yang[3], Zhao-Hui Liu[2], Zhen-Chang Wang[1]**

[1]Department of Radiology, Capital Medical University, Beijing Friendship Hospital, Beijing 100000, China
[2]Department of Radiology, Capital Medical University, Beijing Tongren Hospital, Beijing 100000, China
[3]Department of Nuclear Medicine, Capital Medical University, Beijing Friendship Hospital, Beijing 100000, China

## Abstract

**Background:** A comprehensive assessment of various vascular anomalies and variants associated with venous pulsatile tinnitus (PT) by radiography is essential for therapeutic planning and improving the clinical outcome. This study evaluated the incidence of various vascular anomalies and variants on the PT side and determined whether these lesions occurred as multiple or single entities.
**Methods:** The dual-phase contrast-enhanced computed tomography images of 242 patients with unilateral venous PT were retrospectively reviewed. The vascular anomalies and variants on the symptomatic and asymptomatic sides were analyzed, and the incidences of anomalies or variants on each side were compared. The number of anomalies and variants on the symptomatic side in each patient was calculated.
**Results:** (1) A total 170 patients (170/242) had more than one anomaly or variant on the symptomatic side, and 58 patients (58/242) had a single lesion on tomography. (2) There was a statistically significant difference in the incidence of dehiscent sigmoid plate ($P = 0.000$), lateral sinus stenosis ($P = 0.014$), high jugular bulb ($P = 0.000$), sigmoid sinus diverticulum ($P = 0.000$), jugular bulb diverticulum ($P = 0.000$), dehiscent jugular bulb ($P = 0.000$), and a large emissary vein ($P = 0.006$) between the symptomatic and asymptomatic sides. (3) Dehiscent sigmoid plate (86.4%) was the most frequent lesion on the symptomatic side, followed by lateral sinus stenosis (55.8%), high jugular bulb (47.1%), sigmoid sinus diverticulum (34.3%), jugular bulb diverticulum (13.6%), dehiscent jugular bulb (13.6%), large emissary vein (4.1%), sinus thrombosis (1.2%), and petrosquamosal sinus (0.8%).
**Conclusions:** Various vascular anomalies and variants occur more frequently on the venous PT side. Preliminary findings suggest that venous PT patients may have multiple vascular anomalies or variants on the symptomatic side.

**Key words:** Computed Tomography; Etiology; Tinnitus; Tomography

## Introduction

Vascular pulsatile tinnitus (PT) is a perceived sound synchronous with the heartbeat without any external stimulus and is attributed to arterial and venous causes.[1-3] Venous PT is more common than arterial PT and is caused by numerous vascular anomalies and variants; surgical and endovascular interventions have proven successful for some lesions.[1,4-9] It is important to distinguish these anomalies or variants on imaging to determine the appropriate treatment strategy. Thus far, previous studies on the incidence of these anomalies and variants of venous PT have notable limitations; they used small sample sizes and did not include several recently described venous PT anomalies, such as a dehiscent sigmoid plate and petrosquamosal sinus.[3-5,8,10-16] In addition, a more effective technique (dual-phase contrast-enhanced computed tomography [DP-CECT]) capable of detailing the vessels and temporal bones simultaneously has been gaining popularity for PT diagnosis, but it has not been investigated previously.[3,17,18] Therefore, additional research evaluating the incidence of vascular anomalies and variants in venous PT is needed.

Previous studies have found that PT does not resolve completely or recur in select PT patients postoperatively.[4,19] It is speculated that treatment of only one anomaly may not work when more than one PT anomaly exists on a single

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**Address for correspondence:** Prof. Zhen-Chang Wang, Department of Radiology, Capital Medical University, Beijing Friendship Hospital, Beijing 100000, China
E-Mail: cjr.wzhch@vip.163.com

side. However, there are no studies indicating whether these venous PT anomalies and variants are multiple or single, which could significantly impact the prognosis of venous PT patients.

Therefore, we sought to identify the incidence of vascular anomalies and variants of venous PT by retrospectively reviewing the DP-CECT images of 242 unilateral venous PT patients and determine whether these anomalies and variants occur as multiple or single lesions on the symptomatic side of each patient.

## Methods

### Patients

A total 242 venous PT patients (27 men, 215 women; mean age 40.9 years; age range 11–69 years) were enrolled in the current study between February 2010 and March 2013. The criteria for inclusion were as follows: (1) PT in one ear; (2) the PT sound was persistent and synchronous with the heart beat; and (3) PT resolved after compression of the internal jugular vein ipsilateral to the tinnitus and when turning the head to the PT side.[13,20,21] In addition, patients with arterial abnormalities, tumors involving the temporal bones, otosclerosis, and poor-quality images were excluded. Of the 242 patients, 156 patients had right-sided venous PT, and 86 patients had left-sided venous PT. The mean duration of venous PT was 36.9 months (range: 7 days to 36 years). Hearing loss was diagnosed on the PT side in 34 patients by audiologic examination. A total 83 patients had dizziness, and 26 had headache.

Informed consent was obtained from all patients. Ethical approval was provided by the Institutional Review Board of our Institution.

### Imaging method

All patients underwent DP-CECT scanning using a 64-slice multidetector CT (Brilliance 64; Philips, Best, The Netherlands) with the following parameters: 360 mA; 100 kVp; rotation time 0.75 s; detector collimation 64 mm × 0.625 mm; pitch 0.89:1; field-of-view 22 cm × 22 cm; and matrix 512 × 512. The scanning range was from the vertex to the sixth cervical vertebrae. An iodinated nonionic contrast agent (iopamidol [370 mg iodine/mL]; Bracco, Shanghai, China) was administered intravenously at 5 mL/s using an electric power injector. The contrast agent was dosed at 1.5 mL/kg according to the patient weight. The arterial phase scan was trigged by the Bolus-Tracking program (Trigger Bolus Software; Philips, Best, The Netherlands) after administering the contrast agent and performed in a cephalocaudal direction. The ascending aorta served as the trigger point, and the trigger area was 200 $mm^2$. The trigger threshold was set at 120 Hu. The arterial phase scan time ranged 8–12 s. Venous phase scanning was performed in the opposite direction after a fixed 8 s delay. Standard algorithms were used to reconstruct all arterial phase images, and standard and bone algorithms were used in all venous phase images. Multi-planar reconstruction images were generated on a workstation with a 1 mm slice thickness and no slice gap. The axial images were reconstructed by setting the position baseline parallel to the bilateral lateral semicircular canals; the coronal images were generated by setting the position baseline perpendicular to the bilateral lateral semicircular canals. Narrower settings (width 700 Hu; level 200 Hu) were used to evaluate the arterial and venous systems, and bone window settings (width 4000 Hu; level 700 Hu) were used to evaluate the sigmoid plates and temporal bones.

### Image interpretation

All CT images were individually evaluated by three radiologists with 5, 6, and 11 years of experience. All findings were determined by consensus. The vascular anomalies and variants on symptomatic and asymptomatic sides were analyzed and evaluated retrospectively. These evaluated vascular anomalies and variants were diagnosed on the following previously described criteria [Figure 1]: (1) High jugular bulb, the jugular bulb extended above the inferior border of the round window;[1] (2) dehiscent jugular bulb or dehiscent sigmoid plate, the incomplete thin bone around the jugular bulb or the sigmoid sinus;[4,10] (3) jugular bulb diverticulum, prominent protrusion or an irregular out-pouching of jugular bulb that was clearly distinguished from a smooth ellipsoidal form;[22] (4) sigmoid sinus diverticulum, a diverticulum entered into the mastoid bone;[9] (5) lateral sinus stenosis, the L/S ratio (L = the largest area of the vein; S = the smallest area of the vein) was >4.75;[11] (6) large emissary vein, diameter of the emissary veins was >3.5 mm;[12] (7) petrosquamosal sinus, embryologic emissary vein running along the petrosquamosal Fissure;[15] and (8) sinus thrombosis, signs of thrombosis were noted, including the empty δ-sign or an irregular filling defect.[23] These anomalies and variants were analyzed in each patient and summed.

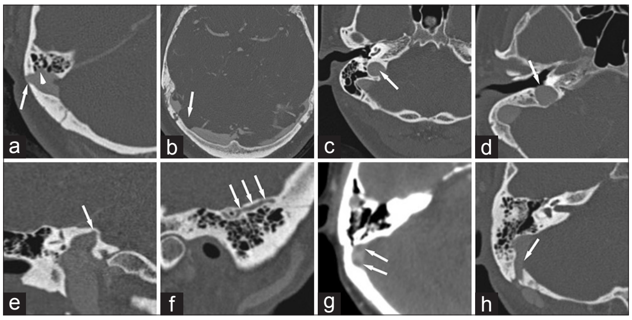


**Figure 1:** Various vascular anomalies and variants of venous pulsatile tinnitus detected on venous phase computed tomography (CT) images in this study. Axial CT image; (a) Sigmoid sinus diverticulum (arrow) accompanying with a dehiscent sigmoid plate (arrowhead). Axial CT image; (b) A stenosis in right transverse sinus (arrow). Axial CT image; (c) A high jugular bulb (arrow) and axial CT image; (d) A right jugular bulb dehiscence (arrow). Coronal CT image; (e) A jugular bulb diverticulum (arrow). Sagittal CT image; (f) A petrosquamosal sinus running into the temporal bone (arrow). Axial CT image; (g) A filling defect (thrombosis) in the superior curve of right sigmoid sinus (arrow). Axial CT image; (h) A large emissary vein (arrow).

The venous sinus systems were classified into three types based on standards proposed by Krishnan *et al*.[4,17] Co-dominant venous systems were identified when the diameters of the bilateral mid-transverse sinus differed by ≤ 3 mm. Right or left dominant venous systems were identified according to the side with the largest diameter.

### Statistical analysis

All statistical tests were performed using statistical software (SPSS, version 17.0; SPSS, Chicago, IL, USA). A $P < 0.05$ was considered statistically significant. The vascular anomalies and variants on symptomatic sides and asymptomatic sides were counted and summed. The incidences of the anomalies and variants were compared on each side using the Chi-square test or the Fisher exact test. In addition, number of findings on the symptomatic side in each patient was calculated to analyze the anomaly and variant diversification of venous PT. Spearman rank correlation test was used to evaluate the correlation between the side of PT and the side of dominant venous system.

## Results

The number of lesions detected on the symptomatic side in each patient is summarized in Table 1. A total 228 (228/242) patients had at least one vascular anomaly or variant on the symptomatic side on CT. Of these 228 patients, 170 patients (170/242) had more than one anomaly or variant on the symptomatic side, and 58 patients (58/242) had only one anomaly or variant. The mean number of lesions on the symptomatic side was 2.19 ± 1.21.

**Table 1: The summed number of vascular anomalies and variants on the symptomatic side in 242 venous PT patients**

| Number of anomalies or variants* | Number of patients | Ratio (%) |
|---|---|---|
| No anomaly and variant | 14 | 5.8 |
| One anomalies or variants | 58 | 24.0 |
| Two anomalies or variants | 83 | 34.3 |
| Three anomalies or variants | 55 | 22.7 |
| Four anomalies or variants | 22 | 9.1 |
| Five anomalies or variants | 8 | 3.3 |
| Six anomalies or variants | 2 | 0.8 |
| Total | 242 | 100 |

*Refer to the number of anomalies or variants detected on the symptomatic side of one PT patient. PT: Pulsatile tinnitus.

The specific diagnoses are summarized in Table 2. There was statistically significant difference in the incidence of dehiscent sigmoid plate ($P$ = 0.000), lateral sinus stenosis ($P$ = 0.014), high jugular bulb ($P$ = 0.000), sigmoid sinus diverticulum ($P$ = 0.000), jugular bulb diverticulum ($P$ = 0.000), dehiscent jugular bulb ($P$ = 0.000), and large emissary vein ($P$ = 0.006) between the symptomatic and asymptomatic sides [Table 2]. Of these lesions, a dehiscent sigmoid plate, accounting for 86.4% of all venous PT patients, was the most frequent anomaly on the symptomatic side in this study. No significant difference was found in the incidences of sinus thrombosis ($P$ = 0.249) and petrosquamosal sinus ($P$ = 1.000) between the symptomatic and asymptomatic sides.

**Table 2: The summarized vascular anomalies and variants detected on venous phase CT images of unilateral venous PT patients**

| Vascular anomalies and variants | The number of patients | | $\chi^2$ | $P$ |
|---|---|---|---|---|
| | Symptomatic side (ratio) (%) | Asymptomatic side | | |
| Dehiscent sigmoid plate | 209 (86.4) | 32 | 258.92 | 0.000 |
| Lateral sinus stenosis | 135 (55.8) | 108 | 6.03 | 0.014 |
| High jugular bulb | 114 (47.1) | 39 | 53.76 | 0.000 |
| Sigmoid sinus diverticulum | 84 (34.3) | 5 | 85.92 | 0.000 |
| Jugular bulb diverticulum | 33 (13.6) | 5 | 22.39 | 0.000 |
| Dehiscent jugular bulb | 33 (13.6) | 4 | 24.61 | 0.000 |
| Large emissary vein | 10 (4.1) | 1 | 7.54 | 0.006 |
| Sinus thrombosis | 3 (1.2) | 0 | * | 0.249 |
| Petrosquamosal sinus | 2 (0.8) | 2 | 0.00 | 1.000 |

*Fisher exact test. PT: Pulsatile tinnitus; CT: Computed tomography.

Of the 242 venous PT patients, right dominant venous systems were identified in 129 patients while 41 patients had left-sided systems. There were 155 patients with PT on the dominant side of the venous systems and 15 patients with PT on the opposite side. Co-dominant systems were diagnosed in 72 patients (36 with left-sided PT; 36 with right-sided PT). The association between the side of PT and the dominant side of the venous system showed a moderate correlation according to the Spearman rank correlation test ($\chi^2$ = 103.78, $P$ = 0.000, $r$ = 0.55).

## Discussion

We aimed to determine whether venous PT patients showed multiple vascular anomalies or variants on the PT side, which has rarely been assessed previously.[4,12,15,18,24] To that end, we detected with more than one vascular anomaly or variant on the symptomatic side in 170 patients (70.2%) using CT, while only 58 patients (24.0%, 58/242) were diagnosed with a single lesion. Signorelli *et al*.[13] described a case of PT associated with both sigmoid sinus stenosis and ipsilateral jugular bulb diverticulum; the tinnitus resolved after successful treatment of both conditions, which illustrates that the vascular PT lesion may not be singular. Similarly, our results suggested that the sound of venous PT may be triggered by multiple lesions within the veins. This may explain why some venous PT patients experience no relief or report recurrence after a single surgery.[4,19] This is a novel finding for venous PT and implies that a single intervention of only one anomaly may not resolve PT completely. Therefore, it is crucial that radiologists identify every potential anomaly and variant on the symptomatic side on preoperative CT and sufficiently describe these lesions to clinicians.

In contrast to the anomalies described previously,[5,25,26] such as a venous sinus stenosis and a high jugular bulb, a dehiscent sigmoid plate was the most frequent anomaly on the symptomatic side in the current study, diagnosed in 86.4% of all venous PT patients. This discordance reflects certain anomalies and variants measured in this study that were not analyzed in previous studies. Furthermore, PT patients in previous studies were evaluated using different imaging methods, some of which are unable to detect a dehiscent sigmoid plate effectively, such as digital subtraction angiography, magnetic resonance imaging, and magnetic resonance angiography. In addition, the samples of venous PT patients in some studies were inadequate, which can compromise the validity of the results. In a study based on 15 PT patients with a dehiscent sigmoid plate, 12 patients recovered completely postoperatively.[4] The same result was reported by Santa Maria.[16] These studies confirm that a dehiscent sigmoid plate is a definite cause of venous PT, and reparative surgery could improve symptoms to some extent. Therefore, it is essential to determine whether a dehiscent sigmoid plate exists.

Based on the results of the present study, the symptomatic side was significantly more likely to have a vascular anomaly or variant than the asymptomatic side. Recent studies reported that the venous hum of venous PT is caused by turbulent and nonlaminar blood flow, which is then transmitted to the cochlea.[2,27] The vascular anomalies and variants detected in this study are all factors potentially capable of changing normal perfusion (such as a dehiscent sigmoid plate, lateral sinus stenosis, sigmoid sinus diverticulum or jugular bulb diverticulum, large emissary vein, petrosquamosal sinus, and sinus thrombosis) or sound transmission (such as a dehiscent sigmoid plate and dehiscent jugular bulb).[3,4,11,12,15,28] Our results support the notion that venous PT is closely related to these vascular anomalies and variants.

In the current study, the incidence of a high jugular bulb was significantly higher on the symptomatic side than on the asymptomatic side ($\chi^2 = 53.76$; $P = 0.000$). However, there is an ongoing debate on the role played by the high jugular bulb in causing venous PT because this lesion is also common in asymptomatic patients. We speculate that a high jugular bulb can change perfusion from laminar to nonlaminar. However, PT also requires conditions that transmit the sound to the cochlea, like the dehiscent jugular bulb. Thus, a high jugular bulb should be considered a contributing factor to venous PT rather than a definitive cause.

In other studies, the majority of patients with venous PT were female.[6,8,14] Similarly, in our study, venous PT was found more frequently in female subjects (215, 88.8%). This characteristic is likely associated with benign intracranial hypertension, which is common in women and can present with PT as the only symptom.[8,29,30]

Previous studies have reported a higher PT prevalence on the right-side, which could be associated with the right-sided dominance of the cerebral venous system.[8,28,31] Our data were similar, and we diagnosed right-sided venous PT in 64.5% (156/242) of patients. Furthermore, the side of PT and the side of the dominant venous system showed moderate correlation ($P = 0.000$, $r = 0.55$). As Friedmann *et al*. demonstrated in their study, cardiac venous pulsation from the dominant vein can strike the jugular sinus and cause expansion of the jugular bulb.[31] In addition, an increased diameter in the right-sided dominant vein increases the likelihood of turbulent flow than on the left-side.[31]

Dual-phase contrast-enhanced CT includes an arterial and venous phase, and can demonstrate the status of vessels and temporal bones simultaneously in a single study. Krishnan *et al*.[17] prospectively evaluated 16 PT patients and concluded that the DP-CECT technique can effectively detect arterial, venous, and inner ear causes of PT. In our study, the DP-CECT image demonstrated the details of each anatomic structure and ensured the accuracy of diagnosis.

This study had some limitations, including intrinsic bias secondary to a retrospective review and selection bias due to patients being recruited from a single tertiary care center. A multi-center trial using a standardized imaging protocol would be ideal to evaluate venous PT patients. Second, in certain anomalies or variants, it was impossible to prove an association between venous PT and a therapeutic response in some cases. However, all of these lesions have been reported or confirmed as contributing factors or causes of venous PT in previous studies. Additional study performing a comparison of venous variation incidence to normal control subjects in a large patient population is needed. In addition, the weight of different vascular anomalies or variants in each patient was not analyzed in this study. Further investigation is needed evaluating their role in generating PT symptoms.

## Conclusions

Various vascular anomalies and variants can be detected more frequently on the PT side using DP-CECT of venous PT patients. In addition, preliminary findings suggest that venous PT patients may have multiple vascular lesions on the symptomatic side, which implies venous PT could be a consequence of multiple factors within the veins.

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