

# Persistent trigeminal artery detected on computed tomography angiography

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## Research Article

**Keywords:** Carotid-vertebrobasilar anastomosis, persistent trigeminal artery, computed tomography angiography, blood vessels

**Posted Date:** April 11th, 2022

**DOI:** <https://doi.org/10.21203/rs.3.rs-1526010/v1>

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# Abstract

## Purpose

This study aimed to investigate the prevalence of persistent trigeminal arteries (PTAs) using computed tomography (CT) angiography, emphasize its major characteristics, and compare the findings with those reported in the relevant literature.

## Methods

Patients who underwent cerebral CT angiography in our radiology clinic for any preliminary diagnosis between December 2013 and December 2020 were included in this retrospective study. The patients were reviewed in terms of their age, sex, and the presence of PTAs. The localization of the PTA, vascular connection, PTA type (according to Saltzman and Salas classification), and vascular pathology at the level of anastomoses were examined in the patients with PTAs.

## Results

A total of 1150 patients, (632 [55%] males and 518 [45%] females) were included in this study. A total of seven (0.6%) patients had PTAs. PTAs were located on the right and left sides in 3 (43%) and 4 (57%) patients, respectively. A total of 3 (43%), 2 (28%), and 2 (28%) cases were classified as types I, II, and III PTA based on the Saltzman classification, respectively. Moreover, 4 (57%) and 3 (43%) cases were lateral and medial types based on the Salas classification, respectively.

## Conclusion

In conclusion, understanding the diagnosis and classification of PTAs is crucial for the diagnosis of possible vascular pathologies by neuroradiologists and physicians performing neurovascular interventional procedures or operations. If these vascular pathologies remain undetected, they may cause fatal bleeding or embolism during surgeries and endovascular procedures.

## Introduction

Four transient anastomoses primarily appear between the carotid and vertebrobasilar systems in the course of intracranial vascular development during the intrauterine period. These anastomoses include the trigeminal, otic, hypoglossal, and proatlantal intersegmental arteries. The anastomoses disappear within a week following the development of posterior arterial circulation and vertebral arteries, whereas in rare cases, the anastomoses remain patent and can be seen postpartum and even in adults [1–3].

The persistent trigeminal artery (PTA) is the most prevalent persistent carotid–vertebrobasilar anastomosis, and it is usually unilateral [4, 5]. During the intrauterine period, the trigeminal artery supplies the basilar artery before the development of the posterior communicating and vertebral arteries. The PTA originates from the junction between the petrous and cavernous internal carotid artery (ICA), extends posterolaterally throughout the trigeminal nerve (41%), or crosses over or through the dorsum sellae (59%). The vertebral, posterior communicating and caudal basilar arteries are often hypoplastic in PTA cases [1, 4].

## Classification

There are different classifications for PTAs based on the course of the artery, termination pattern, and comorbid vascular pathologies. Saltzman first described two types of PTAs in 1959. Saltzman type I is characterized by the PTA supplying the distal vertebrobasilar arteries. The posterior communicating, basilar, and distal vertebral arteries may be absent, absent or

hypoplastic, and hypoplastic, respectively. Saltzman type II is characterized by the PTA supplying the superior cerebellar arteries, while the posterior cerebral arteries are supplied by the posterior communicating artery. A combination of types I and II has been defined as Saltzman type III over a period of time [6, 7]. On the other hand, Salas et al. classified the PTA in terms of its relationship with the abducens nerve as the medial (sphenoidal) and lateral (petrosal) types [8].

The present study aimed to investigate the prevalence of PTAs using computed tomography (CT) angiography, emphasize the major characteristics and clinical importance of PTAs, and compare the findings with those reported in the relevant literature.

## Material And Methods

All patients who underwent cerebral CT angiography in our radiology clinic for any preliminary diagnosis between December 2013 and December 2020 were included in this retrospective study. The patients were reviewed in terms of their age, sex, and the presence of PTAs. The localization of the PTA, vascular connection, PTA type (according to Saltzman and Salas classification), and vascular pathology at the level of anastomoses were examined in patients with PTAs. Furthermore, the magnetic resonance imaging (MRI) results of all the patients with PTAs were available and used for analyzing the MRI findings of the brain parenchyma.

Cases in which all the segments of vascular structures could not be followed owing to surgical operations, interventional procedures, mass, hemorrhage, and edema, among others; contrast agents could not be used optimally; and images had artifacts, were excluded from the study as per the exclusion criteria. Furthermore, cases previously diagnosed with PTAs and followed-up were excluded from the study, as the present study investigated the prevalence of PTAs.

All the examinations were performed using a 64-slice CT device (Philips Brilliance 64 Channel, Philips Healthcare, Eindhoven, the Netherlands). The imaging parameters were as follows: 120 kVp 300 mAs radiation, 0.8-mm section thickness, 0.5 pitch, and 220-mm imaging field. During imaging, a total of 100-ml contrast material was administered through the upper extremity (antecubital vein) via a 20-gage cannula using an automatic injector at a rate of 5 ml/sec.

All the images were uploaded to the Radiological Imaging and Archiving System (picture archiving and communication system) and evaluated using multiplanar images, maximum intensity projection, and three-dimensional volume rendering images. All the images were examined by two radiologists with at least 5 years of experience in the field of vascular imaging. Images whose findings were disagreed upon were evaluated collectively to reach a consensus. The presence of a patent vascular structure extending from the ICA to the basilar artery was considered as the diagnostic criterion for PTAs. PTAs were classified based on the frequently used Saltzman et al. [6] and Salas et al. [8] classification.

This study was approved by the local ethics committee (Non-Invasive Clinical Research Ethics Committee, XX University Faculty of Medicine; Date: 10.25.2021 Number: 440)

IBM Statistical Package for Social Sciences for Windows 22.0 software was used for the statistical analyses of the study findings. Descriptive data were expressed in absolute (n) and relative (%) frequencies for categorical data, whereas mean  $\pm$  standard deviation was used to express continuous data. Pearson's chi-squared test was used to compare categorical variables between groups. For continuous variables, conformity of the data to normal distribution was tested using the Kolmogorov–Smirnov test. Fisher's exact test was used for pairwise comparisons. A p value of  $< 0.05$  was considered statistically significant.

## Results

A total of 1150 patients, including 632 (55%) males and 518 (45%) females, were included in the study. The patients' age ranged from 18 to 85 years, with a mean age of  $46.3 \pm 19.1$  years. A total of 7 (0.6%) patients had PTAs. The age of

patients with PTAs ranged from 23 to 83 years, and the mean age was 55.8 years. The prevalence of PTAs was higher in females (0.96%; 5/518) compared to males (0.32%; 2/632), albeit not statistically significant (Fisher's exact test,  $p = 0.254$ ).

PTAs were located on the right and left sides in 3 (43%) and 4 (57%) patients, respectively (Fig. 1, 2, and 3). A total of 3 (43%), 2 (28%), and 2 (28%) cases were classified as types I, II, and III PTA based on the Saltzman classification, respectively. Moreover, 4 (57%) and 3 (43%) cases were lateral and medial type based on the Salas classification, respectively (Table 1).

Table 1  
Characteristics of persistent trigeminal arteries in our study

Patient no/ Sex/ Age	Localization	Subtype based on Saltzman classification	Subtype based on to Salas classification	Comorbid vascular pathology	Basilar artery hypoplasia	Cerebrovascular disease	Internal carotid artery segment
1/83/F	Left	type II	Medial	-	-	chronic ischemic change	C4
2/23/F	Left	type III	Lateral	-	+	venous angioma	C4
3/44/M	Left	type I	Medial	Fusiform aneurysmic dilatation	+	chronic infarct of the right bulb	C4
4/70/F	Left	type I	Lateral	Diffuse wall calcification	-	chronic ischemic change	C4
5/50/F	Right	type III	Medial	-	+	-	C4
6/82/M	Right	type I	Lateral	-	-	chronic ischemic change	C4
7/39/F	Right	type II	Lateral	-	-	-	C3

One of the cases with a left-sided PTA had significant wall calcification at the level of the anastomoses, and one had mild fusiform aneurysmal dilatation (Fig. 2). In addition, basilar artery hypoplasia was observed in three cases (43%; Table 1).

The brain MRIs of the patients showed a chronic infarct in the right half of the medulla oblongata (Fig. 4), developmental venous anomaly, and chronic ischemic alterations in one, one, and three patients, respectively (Table 1)

PTAs originated from the posterior ICA cavernous segment (C4) and petrosal segment (C3) in 6 (85%) and 1 cases (15%), respectively.

## Discussion

In the present study, the prevalence of PTAs on CT angiography was 0.6% and mostly left-sided (57%). Most PTA cases are often asymptomatic and PTAs are found incidentally on angiographic imaging performed for other reasons.

As per literature, depending on the procedures employed (such as CT angiography, MRI angiography, and DSA) PTAs have an estimated prevalence of approximately 0.1–1%. [9]. The prevalence of PTAs were reported as 0.54, 0.33, 0.51, and 0.63 by Chen et al. [10], Weon et al. [11], Uchino et al. [12], and Bai et al. [13], respectively in studies conducted using MR

angiography. Kalmykov et al. [14] found the incidence rate as 0.58 in a study conducted using CT angiography. The reported incidence rates ranged from 0.2 to 0.37 in studies performed assessments using conventional, CT, as well as MR angiographies [9, 15]. In the present study, only CT angiography images were investigated, and the prevalence of PTAs was found to be consistent with the results reported by the majority of the relevant studies. Some studies reported that the prevalence of a right-sided PTA was higher than that of a left-sided PTA [9,15-16], whereas others suggested the opposite [10]. In the present study, a left-sided PTA was more prevalent than a right-sided PTA, and there was no bilateral PTA case.

In the literature, PTAs have been more frequently observed in females than in males. However, no statistically significant difference was found in terms of sex [9, 18]. Although the majority of the patients (70%) with PTAs in our study were female, there was no significant correlation between the prevalence of PTAs and sex, consistent with the literature.

PTAs are associated with a variety of pathologies, including vascular nerve compression syndromes, such as trigeminal neuralgia and ophthalmoplegia, caused by oculomotor nerve involvement or abducens palsy. PTAs were also suggested to be associated with hypopituitarism owing to a spontaneous or traumatic intracavernous fistula and brain aneurysms [9]. PTA rupture and bleeding during surgical or interventional procedures is often fatal. Accordingly, the extension, localization, and classification of PTAs and accompanying vascular pathologies significantly influence potential surgical or interventional procedures. In addition, the relationship of PTAs with the abducens nerve should be clarified as PTA may present with different clinical manifestations [8]. In a study that examined 4,650 patients who underwent brain MR angiography and classified patients with PTAs based on Saltzman classification, the prevalence of each type was as follows: type I, 24%; type II, 16%; and type III, 60% [10]. In the present study, type I was the most prevalent type and types II and III were found at a similar rate. Similar to other studies in the literature, lateral/petrosal-type predominance was found in terms of the relationship of the PTAs with the abducens nerve [9, 10, 12, 14, 15].

The prevalence of intracranial vascular anomalies increases in the presence of PTAs [13]. Proximal basilar artery hypoplasia is the most prevalent vascular anomaly and occurs in 65–75% of PTA cases. Accordingly, it is an auxiliary marker in addition to the radiological detection of PTA [11–15]. Although the most prevalent comorbid vascular pathology in the present study was basilar artery hypoplasia, it was found at a lower prevalence (42%) compared to that reported in the literature.

Certain studies have reported that the prevalence of aneurysms increases to 14% in the presence of PTA owing to the hemodynamic forces arising from the presence of persistent artery and congenital disorders of the medial layers of the cerebral vessels. Most aneurysms occur at the level of the vascular junction and originate at the circle of Willis. Aneurysms of the PTA are exceptionally rare [7, 11, 14, 17]. In the present study, there was no significant aneurysm originating at the circle of Willis. A fusiform aneurysm was found at the PTA junction in 1 case (14%); this prevalence is higher than that reported in the literature. This might have been attributable to the relatively small number of PTA cases in the present study.

In addition, diffuse wall calcification at the PTA level was observed in 1 case. PTA case with this feature has not been found in the literature.

It has been reported that the presence of PTA may also be associated with ischemic stroke [18–20]. In patients with PTA and vertebrobasilar hypoplasia, the vascular supply to the posterior fossa may tend to decrease. Relevant literature suggests that there may be a relationship of transient ischemic attack and vertigo, which is considered as the first symptom of transient ischemic attack, with PTA [21–26]. In the present study, one patient had a chronic ischemic infarct in the right half of the bulb. This patient had left-sided Saltzman type I and Salas medial type PTA along with basilar artery hypoplasia.

PTAs can originate from different segments of the ICA. Arra'ez-Aybar et al. reported that most of the PTAs originated from the posterior wall of the cavernous segment of the ICA (C4) and a small number of PTAs originated from the petrous segment [9]. The C4 segment is often reported as the origin of PTAs [9, 17–21]. Most of the PTA cases in the present study

(85%) originated from the posterior wall of the cavernous segment (C4) of the ICA, and few (15%) originated from the petrous part. These findings are consistent with studies in the literature.

Our study had some limitations. It was designed as a retrospective study and reflected the results of a single-center study with a comparatively small number of patients. Further prospective and multicenter studies are warranted.

## Conclusion

In conclusion, understanding the diagnosis and classification of PTAs is crucial for the diagnosis of possible vascular pathologies by neuroradiologists and physicians performing neurovascular interventional procedures or operations. If these vascular pathologies remain undetected, they may cause fatal bleeding or embolism during surgeries and endovascular procedures. Understanding the characteristics of PTAs on brain CT angiography and highlighting these findings is extremely important as this can prevent possible complications.

## Statements And Declarations

**Acknowledgments:** Our research's data was presented as an oral presentation at the 42nd National Radiology Congress (TURKRAD-2021, Antalya, 26-31 October 2021)

**Competing Interests:** The authors have no competing interests to declare that are relevant to the content of this article.

**Author contributions:** MA Deniz: Project development, Data Collection, Manuscript writing, M Turmak: Data collection, Project development S Hattapoğlu: Data collection, Manuscript writing, M Tekinhatun: Statistical analysis

**Funding:** The authors did not receive support from any organization for the submitted work.

**Ethics approval:** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the local ethics committee (Non-Invasive Clinical Research Ethics Committee, XX University Faculty of Medicine; Date: 10.25.2021 Number: 440)

**Consent to participate:** Informed consent was obtained from all individual participants included in the study.

**Consent to publish:** Patients signed informed consent regarding publishing their data and photographs.

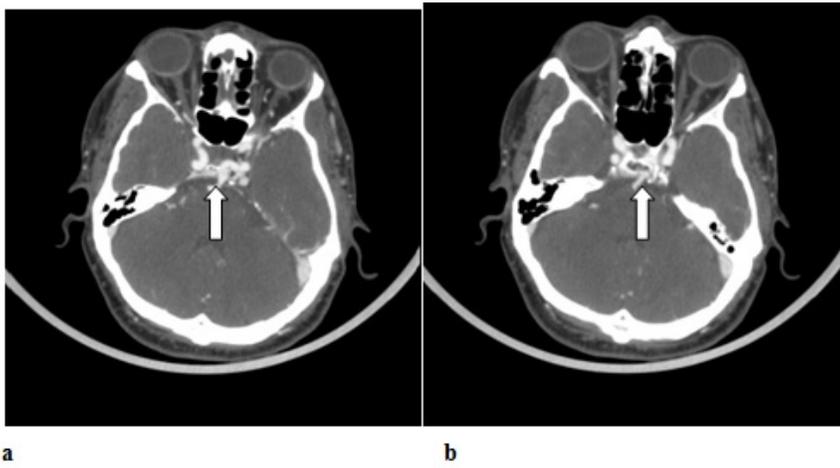
**Meeting Presentation:** This study was presented as an oral presentation at the 42nd National Radiology Congress (TURKRAD 2021).

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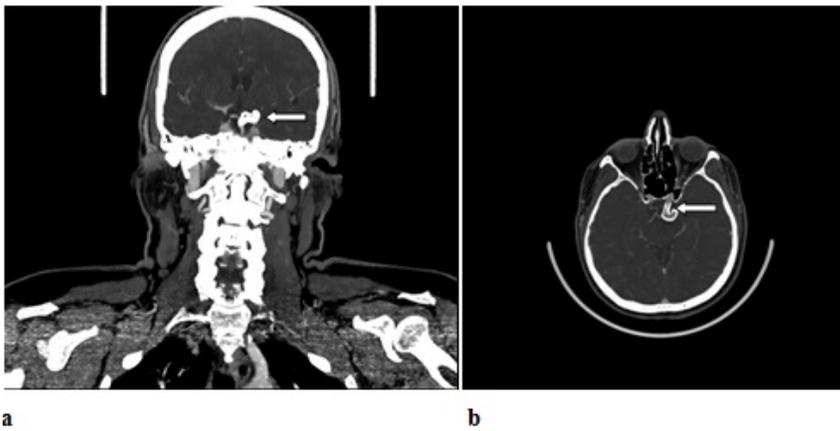
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## Figures



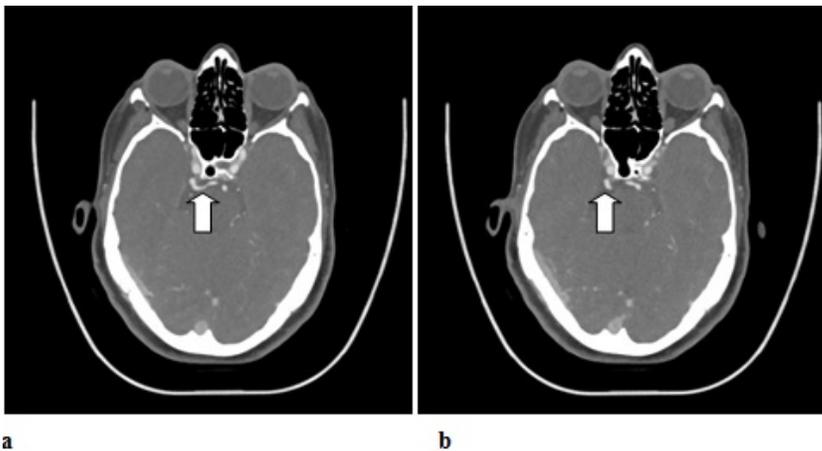
**Figure 1**

A 44-year-old male patient with a persistent trigeminal artery (PTA) extending from the basilar artery to the left internal carotid artery (ICA) on computed tomography angiography



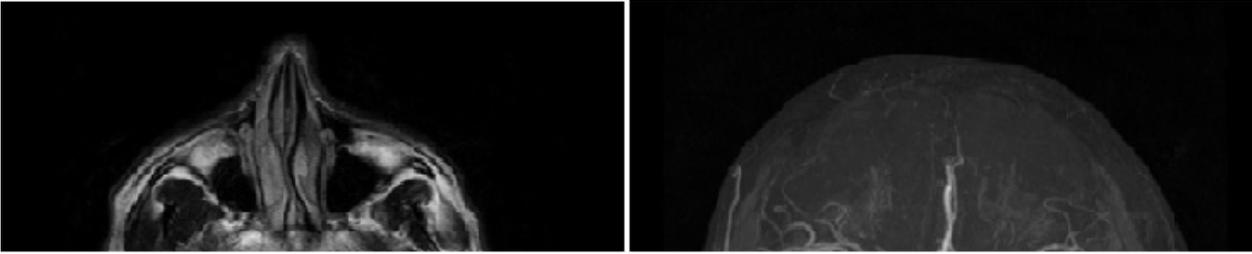
**Figure 2**

A 70-year-old female patient with a PTA with wall calcification extending from the basilar artery to the left ICA on computed tomography angiography



**Figure 3**

A 50-year-old female patient with a PTA extending from the right ICA to the basilar artery on computed tomography angiography



**Figure 4**

A 44-year-old male patient with an infarct in the right half of the bulb and a PTA extending from the basilar artery to the left ICA on magnetic resonance angiography