Persistent primitive trigeminal artery associated with a cavernous carotid aneurysm. Case report and literature review.

Jeremy Jia Hong Lam[1], Mohammad Taufik Bin Mohamed Shah[2,3], Siok Li Chung[2], Chi Long Ho[2,3,4*]

1. Department of Diagnostic Radiology, Singapore General Hospital, Singapore

2. Department of Radiology, Sengkang General Hospital, Singapore

3. Duke-NUS (National University of Singapore) Graduate Medical School, Singapore

4. Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore

* **Correspondence:** Chi Long Ho, Sengkang General Hospital, Department of Radiology, 110 Sengkang East Way, Singapore 544886, Singapore
(*ho.chi.long@singhealth.com.sg*)

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ABSTRACT

The persistent primitive trigeminal artery is the most common persistent carotid-vertebrobasilar anastomosis. Patients are usually asymptomatic and the persistent primitive trigeminal artery is commonly found incidentally on imaging. Rarely, they may present with symptoms of neurovascular conflict or cranial nerve compression syndromes as the artery may be intimately related to the cranial nerves. The basilar artery is often hypoplastic in this condition and blood supply to the posterior circulation is predominantly via the persistent primitive trigeminal artery. Recognizing the persistent primitive trigeminal artery is imperative as disease of the artery may result in ischemia of the posterior circulation. To date, there is no clear association between this artery and cerebral aneurysms. We present a rare case of a patient with a persistent primitive trigeminal artery and a concomitant cavernous carotid aneurysm together with a literature review.

CASE REPORT

CASE REPORT

A 71 year-old woman of Chinese origin presented with symptoms of transient bilateral upper visual field defects. The physical examination was unremarkable. Her symptoms were initially attributed to amaurosis fugax or a transient ischemic attack.

Magnetic resonance imaging (MRI) of the brain showed no evidence of acute infarct. Time-of-flight magnetic resonance angiography (TOF-MRA) showed the presence of a large wide-necked saccular aneurysm arising from the cavernous segment of the right internal carotid artery (ICA) (Figure 1 and 2). It measured approximately 1.3 x 1.2 x 0.9 cm, causing expansion of the right cavernous sinus with mass effect on the adjacent pituitary gland. Computed tomography angiogram of the circle of Willis (CTA COW) showed the presence of a right persistent primitive trigeminal artery (PPTA) arising just proximal to the superomedially directed right cavernous ICA aneurysm (Figure 3). There were persistent fetal origins of the bilateral posterior cerebral arteries (PCAs) whilst the bilateral vertebral arteries terminated as the posterior inferior cerebellar arteries (PICA). The basilar artery proximal to the carotid-vertebrobasilar anastomosis was hypoplastic and hence the bilateral superior

cerebellar arteries were supplied by the PPTA (Figure 1). This corresponded to a Saltzman type II PPTA.

As part of the pre-treatment evaluation, a catheter angiogram was performed (Figures 4 and 5). The case was also subsequently discussed at the multi-disciplinary meeting. There were potential risks for endovascular treatment with coil embolization due to the considerable size of the aneurysm. Endovascular stenting was considered with placement of a suitable sized flow-diversion stent across the aneurysm although there were potential risks for inadvertent occlusion of the PPTA at its origin due to its close proximity to the cavernous ICA aneurysm.

The potential treatment options of surgical clipping and endovascular treatment were discussed with the patient. The decision was eventually made for conservative management and close monitoring. The patient remained asymptomatic for more than 2 years of follow-up in the outpatient clinic.

DISCUSSION

Etiology & Demographics:

There are four persistent fetal anastomoses between the carotid and vertebrobasilar circulations [1]. These primitive anastomoses represent non-obliterated remnants of the pre-segmental dorsal arteries which comprise the persistent primitive trigeminal (PPTA), persistent hypoglossal (PHA), persistent otic (acoustic) artery (POA) and proatlantal intersegmental arteries (PIA) [1]. The four primitive carotid-vertebrobasilar anastomoses occasionally persist into the adult period and may be detected incidentally.

In the early embryonic stage, the blood supply to the hindbrain is mainly via the four carotid-vertebrobasilar anastomoses. The primitive carotid-vertebrobasilar anastomoses then regress within a week as the posterior communicating and vertebrobasilar arteries begin to develop (Figure 6). Rarely, there is failure of regression and the trigeminal artery is not obliterated in the embryonic stage and persists into adulthood. The PPTA is the most common of the four carotid-vertebrobasilar anastomoses with a prevalence of 0.1-0.6%, and represents up to 85% of the persistent embryological anastomoses [1, 2, 3, 4].

Clinical & Imaging Findings:

The PPTA originates from the ICA distal to its exit from the carotid canal and forms an anastomosis with the basilar artery. The basilar artery caudal to the anastomosis is usually diminutive [2].

The PPTA may be classified into the lateral or medial subtype, both of which are equally common. In the lateral subtype, the PPTA follows a posterolateral course associated with the trigeminal nerve roots and neural structures. In the medial subtype, the PPTA courses posteromedially from its origin with an intra-sellar or trans-hypophyseal course. In such cases, the PPTA is in close proximity to the pituitary gland with mass effect on its stalk which may result in hypopituitarism [5, 6]. Rarely, patients with PPTA may also present with neurovascular conflict or cranial nerve compression syndromes such as trigeminal neuralgia, oculomotor, trochlear or abducens nerve palsies as the PPTA may be intimately related to the aforementioned cranial nerves [6].

As the PPTA is commonly associated with hypoplasia of the basilar artery, the main blood supply to the posterior circulation is predominantly by the ICA via the PPTA. As such, thromboembolic phenomena, dissection or atherosclerotic disease of the ICA may result in ischemia of the posterior circulation and/or brainstem [6].

The PPTA may also be classified according to the Saltzman classification system which is based on the configuration of the ipsilateral posterior cerebral artery (PCA) (Figure 7). In Saltzman type 1, the PPTA supplies the entire vertebrobasilar system cranial to the anastomosis. The posterior communicating artery is either absent or poorly opacified. In Saltzman type 2, the PPTA joins the basilar artery caudal to the origins of the superior cerebellar arteries, and blood supply to the posterior circulation is predominantly via the posterior communicating arteries rather than via the PPTA as in Saltzman type 1 [2, 3, 7, 8].

As in our case, the radiological diagnosis of PPTA is made on MRA, CTA and conventional cerebral angiography. On all three imaging modalities, the PPTA is shown as an anomalous vessel arising from the posterior aspect of the ICA, coursing posteriorly towards the basilar artery. The configuration of the horizontal and vertical portions of the ICA as well as the proximal PPTA resembles the Greek symbol Tau (Figures 1D, 3D and 5D), giving rise to the Tau sign [9]. Our patient had a lateral subtype PPTA which coursed posterolaterally and was closely related to the right trigeminal nerve roots at the pre-pontine cistern. Furthermore, it was classified as Saltzman type 2 as the PPTA joined the basilar artery caudal to the origins of the superior cerebellar arteries. In this case, the blood supply to the posterior circulation was mainly via the bilateral fetal PCAs rather than via the PPTA.

The association between PPTA and concomitant intracranial aneurysms remains unclear, with some authors describing a prevalence of associated aneurysms ranging from 14 to 32% [6]. More recently, other authors found that the co-existence of cerebral aneurysms with PPTA were similar to that of the general population without PPTA [1, 10].

Incidentally, there is a higher frequency (12-16%) of children with PHACE syndrome with PPTA [11]. The acronym PHACE and PHACES (P = posterior fossa; H = hemangioma; a = arterial; C = cardiac; E = eye; S = sternal cleft) indicates malformative abnormalities occurring with infantile hemangiomas of the face. The association of PPTA together with cardiovascular and structural brain anomalies is thought to be part of an embryonic error in vasculogenesis [7, 11].

Treatment & Prognosis:

Typically, patients are asymptomatic and no treatment is required. The PPTA itself may be a potential site for aneurysm

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formation as it usually occurs at a vascular bifurcation. There is no indication for cerebral aneurysm screening when a PPTA is incidentally found on imaging as there is no greater predisposition for cerebral aneurysm formation in PPTA cases than in other vascular conditions. Aneurysms related to the PPTA may cause mass effect on the cavernous sinus with associated cranial nerve palsies predominantly involving the oculomotor or abducens nerves. Complications following surgical treatment of PPTA related cerebral aneurysms such as aneurysm rupture or dissection with subsequent cranial nerve palsies may occur due to manipulations in the region of the cavernous sinus or Meckel's cave. Hence, endovascular treatment such as balloon-assisted or stent-assisted techniques may be considered. If a PPTA aneurysm ruptures, patients may present with acute subarachnoid haemorrhage with possible involvement of the trigeminal nerve or trigeminal-cavernous fistula. The treatment of trigeminal-cavernous fistula involves occlusion of the fistula with preservation of the parent artery. This may be performed by various endovascular techniques by using a trans-arterial balloon or coil embolization. It is important to understand the vascular anatomy in patients with PPTA as in patients with Saltzman type 1 PPTA, the PPTA must not be sacrificed because it may result in infarction of the posterior circulation. In Saltzman type 2, the blood supply to the posterior circulation is predominantly via the posterior communicating arteries, hence the PPTA may not be necessarily preserved. While endovascular techniques remain the primary treatment of choice, neurosurgical treatment such as bypass surgery, surgical packing or carotid artery ligation may be considered when embolization fails [7].

Differential Diagnoses:

a. Persistent hypoglossal artery (PHA)

The PHA is the second most common primitive carotid-vertebrobasilar anastomosis with a prevalence of 0.02%–0.10% [2]. The PHA usually originates from the cervical ICA distal to the carotid bifurcation between C1 and C3, and it enters the hypoglossal canal before anastomosing with the basilar artery [1, 2]. Patients are typically asymptomatic although there were reports of associated hypoglossal nerve paralysis and glossopharyngeal neuralgia [2]. As the PHA is the major supplier of the posterior circulation in these patients, any disease or occlusion of the artery may result in ischemia of the posterior circulation or brainstem [5]. Rarely, the PHA is associated with intracranial aneurysms. The ascending pharyngeal artery (APA), a branch of the external carotid artery, is apparently a remnant of the PHA. Hence, one must be aware of the potential anastomosis between the APA and the vertebrobasilar system as well as the ICA when planning an embolization procedure [5].

b. Persistent otic artery (POA)

The POA is extremely rare with only a handful of previous reports in the literature. It arises from the petrous ICA, courses through the internal auditory canal and anastomoses with the proximal basilar artery.

c. Persistent proatlantal intersegmental artery (PIA)

The persistent proatlantal intersegmental artery (PIA) is extremely rare and approximately 40 cases have been reported [2, 3]. The PIA arises either from the ICA, external carotid artery or common carotid artery bifurcation. It joins the vertebral artery at the sub-occipital region through the foramen magnum. Clinically, the PIA becomes most apparent in steno-occlusive disease of the vertebral or carotid arteries. One must be aware of the existence of the PIA because of the potential risk of thromboembolism when planning an embolization procedure. [5]

TEACHING POINT

The persistent primitive trigeminal artery (PPTA) is the most common of the persistent carotid-vertebrobasilar anastomoses. While most cases are incidental, rarely, patients may present with symptoms of neurovascular conflict, cranial nerve compression, PHACE syndrome, cerebral aneurysm or posterior circulation stroke, hence, it is imperative to promptly recognize the imaging features of PPTA.

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FIGURES

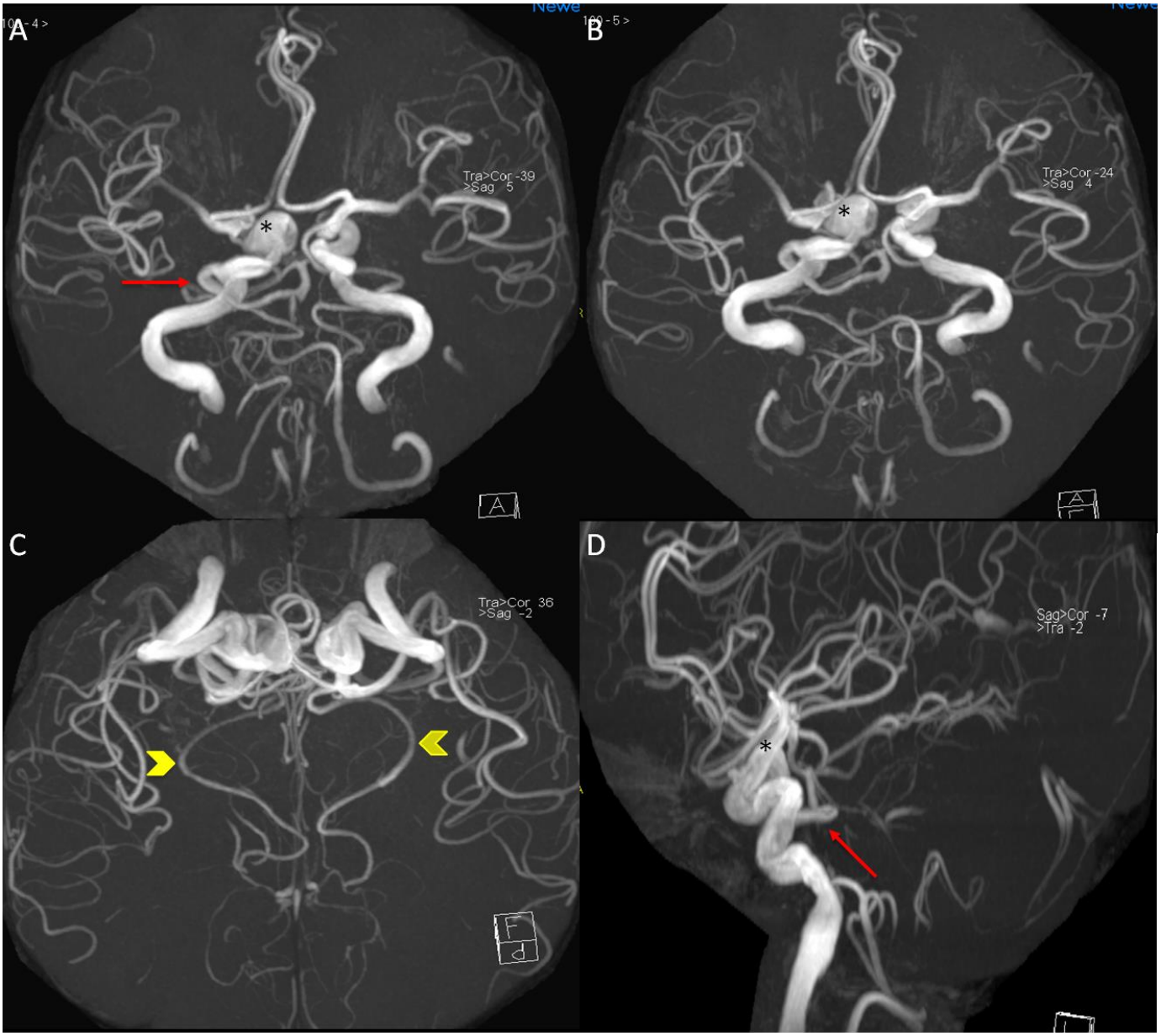

Figure 1: A 71 year-old woman with a cavernous carotid aneurysm and persistent primitive trigeminal artery.
FINDINGS: Time-of-flight magnetic resonance angiography (TOF-MRA) maximum intensity projection (MIP) images in the axial (A, B and C) and sagittal (D) planes demonstrates a wide-necked saccular aneurysm measuring 1.3 x 1.2 x 0.9 cm involving the cavernous segment of the right internal carotid artery (ICA) (*). An ipsilateral PPTA (red arrow) arises from the ICA proximal to the saccular aneurysm. The PPTA subsequently follows a posterolateral course and communicates with the distal portion of the basilar artery whilst the proximal basilar artery is hypoplastic. The posterior circulation is mainly supplied via the bilateral fetal posterior cerebral arteries (yellow arrow heads). The sagittal image (D) demonstrates the configuration of the flow signal in the horizontal and vertical portions of the ICA as well as the proximal PPTA (red arrow), resembling the Greek symbol Tau.
TECHNIQUE: TOF-MRA with MIP of the 71 year-old woman in the axial and sagittal planes. Siemens MAGNETOM Skyra. Magnetic strength = 3 Tesla. TR = 23 ms. TE = 7 ms. Slice width = 0.6 cm. No intravenous contrast was administered.

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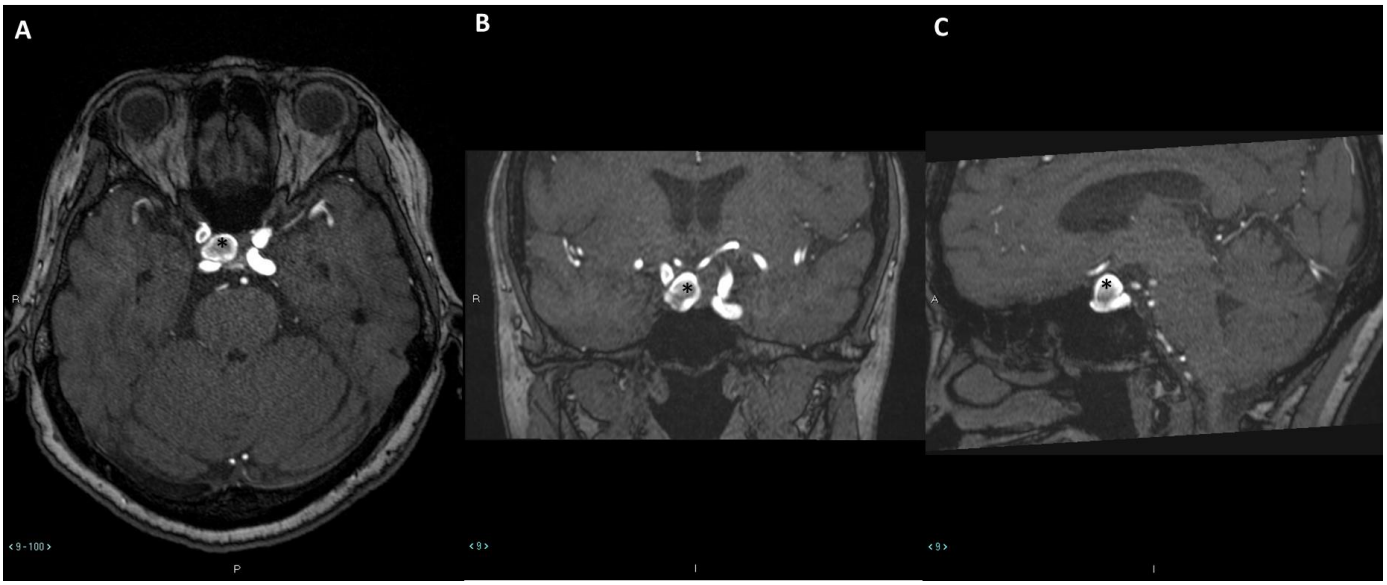

Figure 2: A 71 year-old woman with a cavernous carotid aneurysm and persistent primitive trigeminal artery.
FINDINGS: TOF-MRA in the axial (A), coronal (B) and sagittal (C) planes demonstrated a 1.3 x 1.2 x 0.9 cm wide-necked saccular aneurysm (*) arising from the cavernous segment of the right ICA causing expansion of the right cavernous sinus with mass effect on the adjacent pituitary gland.
TECHNIQUE: TOF-MRA of the 71 year-old woman in the axial, coronal and sagittal planes. Siemens MAGNETOM Skyra. Magnetic strength = 3 Tesla. TR = 23 ms. TE = 7 ms. Slice width = 0.6 cm. No intravenous contrast was administered.

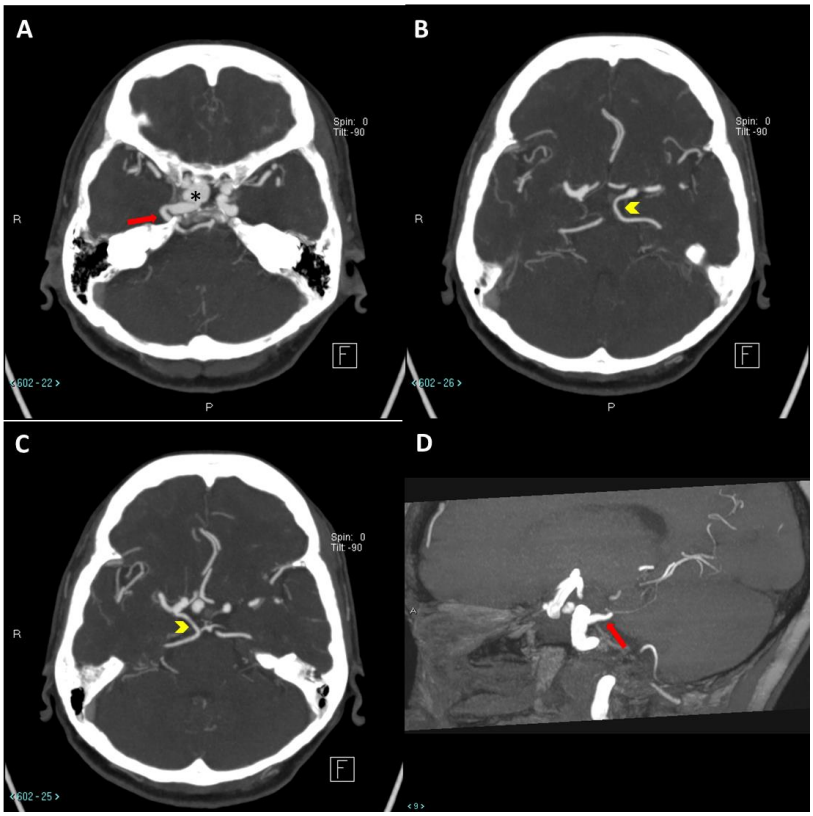

Figure 3: A 71 year-old woman with a cavernous carotid aneurysm and persistent primitive trigeminal artery.
FINDINGS: Contrast-enhanced CT angiogram of the circle of Willis in the axial (A, B and C) and sagittal (D) planes with maximum intensity projection (MIP) showing a wide-neck saccular aneurysm (*) arising from the cavernous segment of the right ICA with an ipsilateral PPTA (red arrow) arising from the posterior aspect of the ICA just proximal to the aneurysm. The PPTA courses posterolaterally towards the posterior fossa and communicates with the basilar artery. It may be closely related to the trigeminal nerve root or other neural structures at the prepontine cistern. Persistent fetal origins of the bilateral posterior cerebral arteries are noted (yellow arrow heads).
TECHNIQUE: Siemens SOMATOM Definition Flash. Axial contrast-enhanced CT circle of Willis of the 71 year-old woman in the arterial phase with MIP. Slice thickness 3 mm. Tube voltage 120 kV. Tube current 186 mAs. A total of 50 mls of Iopamiro 370 was administered intravenously.

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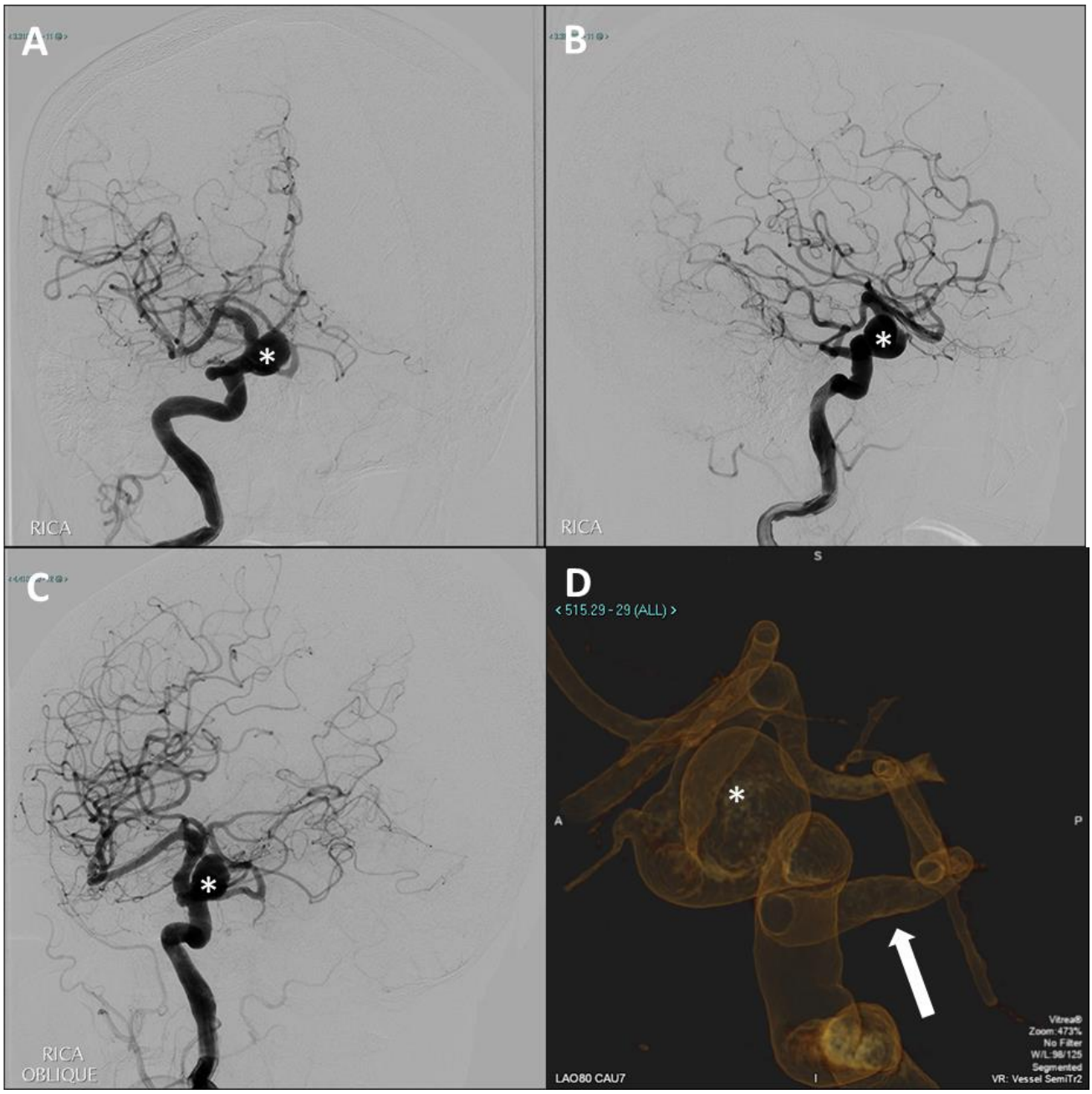

Figure 4: A 71 year-old woman with a cavernous carotid aneurysm and persistent primitive trigeminal artery.
FINDINGS: Conventional angiography demonstrating the right ICA aneurysm (*) on the frontal (A), lateral (B) and oblique (C) projections. Post-processing on the VITREA software (D) demonstrated the persistent primitive trigeminal artery (white arrow) arising just proximal to the aneurysm. The horizontal and vertical portions of the ICA and proximal PPTA resemble the Greek symbol Tau, giving rise to the Tau sign.
TECHNIQUE: Conventional angiography of the 71 year-old woman. Catheter angiogram was performed via a right common femoral arterial puncture followed by selective right ICA injection. A total of 115 mls of Omnipaque 350 was administered.

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Figure 5: A 71 year-old woman with a cavernous carotid aneurysm and persistent trigeminal artery.
FINDINGS: 3D conventional cerebral angiogram demonstrating the saccular cavernous carotid aneurysm on the frontal view (A). The posterior (B) and inferior (C) views show the PPTA (red arrow) arising from the posterior aspect of ICA, proximal to the saccular aneurysm. The PPTA courses posterolaterally and joins the distal third of the basilar artery (white block arrow). The proximal and middle thirds of the basilar artery is hypoplastic.
TECHNIQUE: 3D conventional cerebral catheter angiography of the 71 year-old woman was performed via a right common femoral arterial puncture followed by selective right ICA injection. A total of 115 mls of Omnipaque 350 was administered.

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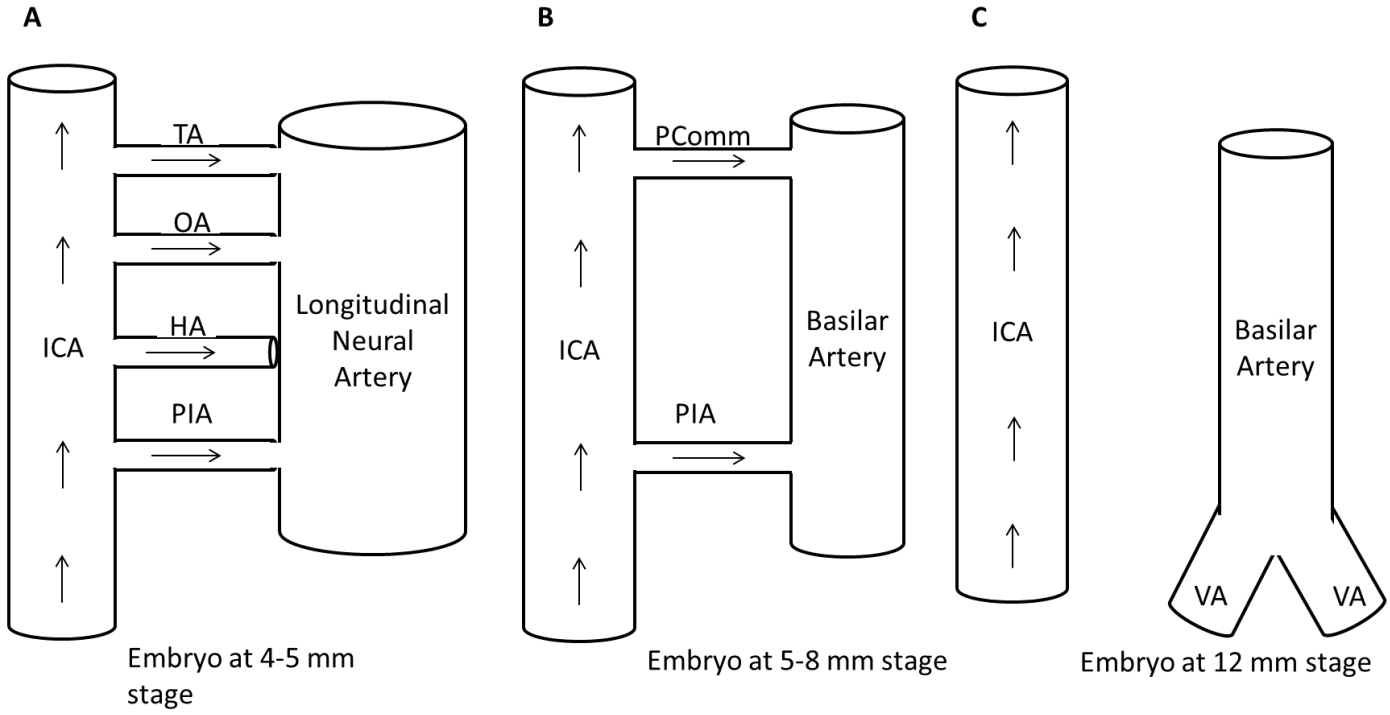

Figure 6: Schematic diagram showing the primitive carotid-vertebrobasilar anastomoses. In the early stages of development, the posterior circulation is supplied almost entirely by blood supply from the anterior circulation via the carotid-vertebrobasilar anastomoses (A). As the posterior communicating and verebrobasilar arteries develop, there is progressive regression of the primitive carotid-vertebrobasilar anastomoses. HA = hypoglossal artery, ICA = internal carotid artery, OA = otic artery, PIA = proatlantal intersegmental artery and TA = trigeminal artery.

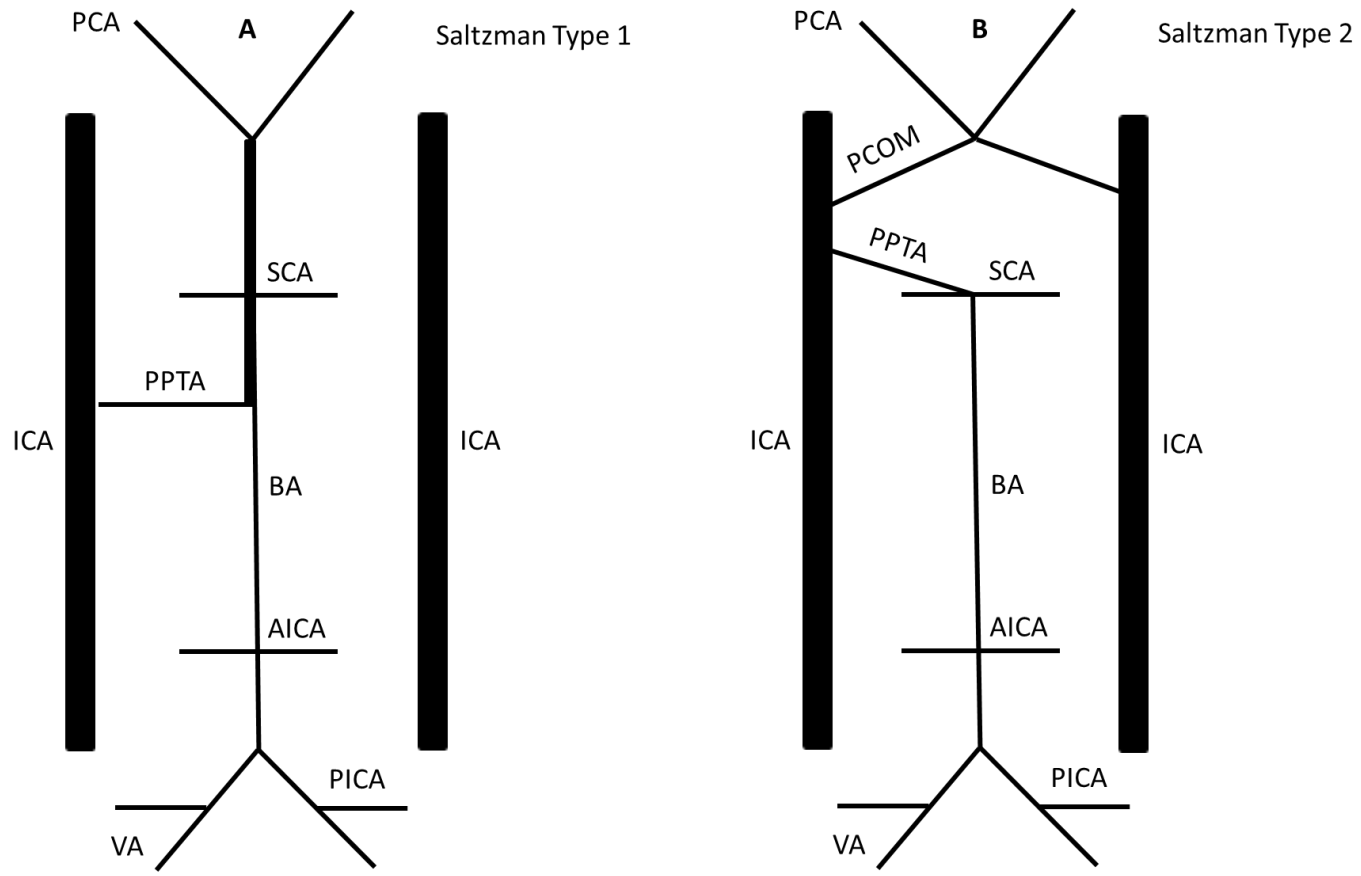

Figure 7: Schematic diagram showing the Saltzman type 1 (A) and Saltzman type 2 (B) persistent primitive trigeminal artery (PPTA). In Saltzman type 1, the PPTA supplies the entire vertebrobasilar system cranial to the anastomosis and the basilar artery is often hypoplastic. The posterior communicating artery is either absent or poorly opacified. In Saltzman type 2, the posterior communicating arteries are present and provide blood supply to the posterior cerebral arteries. AICA = anterior inferior cerebellar artery, BA = basilar artery, ICA = internal carotid artery, PCA = posterior cerebral artery, PCOM = posterior communicating artery, PICA = posterior inferior cerebellar artery, PPTA = persistent primitive trigeminal artery, SCA = superior cerebellar artery, VA = vertebral artery.

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Embryology/ Etiology	• In the early embryonic stage, the blood supply to the hindbrain is via the four carotid-vertebrobasilar anastomoses: namely, the trigeminal, hypoglossal, proatlantal intersegmental and otic arteries. • The primitive carotid-vertebrobasilar anastomoses then regress within a week as the posterior communicating and vertebrobasilar arteries begin to develop. • Rarely, there is failure of regression and the trigeminal artery is not obliterated in the embryonic stage and persists into adulthood.
Incidence	• 0.1-0.6%
Gender ratio	• Male=Female
Age predilection	• N/A
Risk factors	• N/A
Treatment	• Typically, patients are asymptomatic, and no treatment is required except in co-existence with an intracranial aneurysm.
Prognosis	• N/A
Associations	• Commonly associated with basilar artery hypoplasia and majority of the posterior circulation is supplied by the ICA via the PPTA. • The incidence of cerebral aneurysms in patients with PPTA is similar to that of the general population. • There is a higher frequency of PPTA with PHACE syndrome, possibly due to an underlying embryonic error in vasculogenesis. • The medial subtype of PPTA may cause mass effect on the pituitary stalk, with resultant hypopituitarism. • The PPTA may also run in close proximity to the trigeminal, occulomotor or abducens nerve and patients may present with neurovascular conflict or cranial nerve compression syndromes.
Findings on imaging notably CTA, MRA and catheter angiogram	• The PPTA is shown as an anomalous vessel arising from the posterolateral or posteromedial aspect of the intra-cavernous ICA which then follows a posterior course towards the basilar artery. • The PPTA may also arise from the petrous ICA before entering the cavernous sinus although this is less common. • The medial subtype of the PPTA courses posteromedially from its origin with an intra-sellar or trans-hypophyseal course. • The lateral subtype of the PPTA follows a posterolateral course with the trigeminal nerve. • On the sagittal projection of CTA and MRA, the configuration of the horizontal and vertical portions of the ICA and proximal PPTA resemble the Greek symbol Tau as well as a trident, giving rise to the Tau and trident sign, respectively.

Table 1: Summary table of persistent primitive trigeminal artery (PPTA).

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Types	Findings on CTA, MRA or catheter angiogram	Incidence, presentation and associations
Persistent primitive trigeminal artery (PPTA)	• The PPTA is shown as an anomalous vessel arising from the posterolateral or posteromedial aspect of the intra-cavernous ICA which then follows a posterior course towards the basilar artery. • The PPTA may also arise from the petrous ICA before entering the cavernous sinus although this is less common. • The medial subtype of the PPTA courses posteromedially from its origin with an intra-sellar or trans-hypophyseal course. • The lateral subtype of the PPTA follows a posterolateral course with the trigeminal nerve. • On the sagittal projection of CTA and MRA, the configuration of the horizontal and vertical portions of the ICA and proximal PPTA resemble the Greek symbol Tau as well as a trident, giving rise to the Tau and trident sign, respectively.	*Incidence:* 0.1-0.6% *Presentation:* Typically, patients are asymptomatic except in co-existence with an intracranial aneurysm. *Associations:* • Commonly associated with basilar artery hypoplasia and majority of the posterior circulation is supplied by the ICA via the PPTA. • The incidence of cerebral aneurysms in patients with PPTA is similar to that of the general population. • There is a higher frequency of PPTA with PHACE syndrome, possibly due to an underlying embryonic error in vasculogenesis. • The medial subtype of PPTA may cause mass effect on the pituitary stalk, with resultant hypopituitarism. • The PPTA may also run in close proximity to the trigeminal, occulomotor or abducens nerve and patients may present with neurovascular conflict or cranial nerve compression syndromes.
Persistent hypoglossal artery (PHA)	• Originates from the cervical ICA, courses through an enlarged hypoglossal canal and anastomoses with the basilar artery.	• *Incidence:* 0.02%–0.10%. The second most common of the embryonic carotid-vertebrobasilar anastomoses after the PPTA • *Presentation:* Typically, asymptomatic. Possible dysfunction of hypoglossal nerve and glossopharyngeal neuralgia. *Associations:* • The PHA becomes the major supplier of the posterior circulation and any disease or occlusion of the PHA may result in ischemia of the posterior circulation or brainstem. • Rarely, PHA is associated with intracranial aneurysms. • The ascending pharyngeal artery (APA) may represent a remnant of PHA, hence, one must be aware of the potential anastomosis between APA and the vertebrobasilar system as well as the ICA when planning an embolization procedure.
Persistent otic artery (POA)	• Arises from the petrous ICA, courses through the internal auditory canal and anastomoses with the proximal basilar artery.	• *Incidence:* Only a handful of previous reports in the literature • *Presentation:* Usually asymptomatic
Persistent proatlantal intersegmental artery (PIA)	• Arises from the internal carotid artery at the C2-4 levels, external carotid artery or common carotid artery bifurcation. • It then joins the vertebral artery at the sub-occipital region through the foramen magnum.	• *Incidence:* Extremely rare; incidence is unknown. About 40 reports in literature • *Presentation:* Usually asymptomatic *Associations:* • This embryonic anastomosis becomes most apparent in steno-occlusive disease of the carotid or vertebral arteries. • One must be aware of the existence of PIA because of the potential risk of thromboembolism when planning an embolization procedure.

Table 2: Differential diagnoses table for persistent primitive trigeminal artery (PPTA).

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ABBREVIATIONS

AICA = anterior inferior cerebellar artery
BA = basilar artery
CTA COW = Computed tomography angiogram of the Circle of Willis
ICA = Internal carotid artery
MIP = Maximum intensity projection
MRI = Magnetic resonance imaging
PCA = Posterior cerebral artery
PCOM = posterior communicating artery
PHA = Persistent hypoglossal artery
PHACE(S) = Posterior fossa, hemangioma, arterial, cardiac, eye(, sternal cleft)
PIA = Proatlantal intersegmental artery
PICA = Posterior inferior cerebellar artery
POA = Persistent otic artery
PPTA = Persistent primitive trigeminal artery
SCA = Superior cerebellar artery
TOF-MRA = Time-of-flight magnetic resonance angiography
PICA = posterior inferior cerebellar artery
VA = vertebral artery

KEYWORDS

Computed tomography angiogram; cavernous carotid aneurysm; magnetic resonance angiography; magnetic resonance imaging; persistent primitive trigeminal artery; vertebrobasilar anastomosis

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