

**Anatomical Variations****RARE TRIPLE ANATOMICAL VARIATION OF THE CEREBRAL ARTERIAL CIRCLE****Joaquín García Pisón, Matías Negrotto, Alejandra Garretano, Andrés Pouy, Carolina Fernández, Eduardo Olivera***Departamento de Anatomía, Facultad de Medicina, Universidad de la República, Montevideo, Uruguay***RESUMEN**

Se reporta la rara asociación de un aneurisma de arteria trigeminal persistente lateral derecha (Tipo II de Saltzman), aplasia del segmento pre-comunicante de ambas arterias cerebrales posteriores y la presencia de arterias cerebrales posteriores fetales en forma bilateral, en una mujer de 64 años que consultó de diplopía y parálisis del nervio abducens derecho, probablemente debida a compresión del nervio en el espacio latero-celular. Se realizó con éxito la embolización endovascular con coils, sin complicaciones inmediatas. Los hallazgos de CT, RM y angiografía son presentados. Aunque cada una de estas variaciones son infrecuentes en forma individual, la combinación de las mismas no ha sido reportada en la literatura hasta nuestro conocimiento, siendo de enorme importancia en el manejo diagnóstico y terapéutico de pacientes con stroke de mecanismo embólico, así como para la planificación de procedimientos endovasculares diagnósticos y terapéuticos.

**Palabras clave:** Círculo arterial cerebral; arteria cerebral posterior; arteria trigeminal persistente; nervio abducens.

**ABSTRACT**

We report the rare association of an aneurysm of a lateral right persistent trigeminal artery (Saltzman type II), bilateral aplasia of the pre-communicating segment of both posterior cerebral arteries and bilateral fetal posterior cerebral arteries, in a 64 years old woman who suffered from progressive diplopia and right abducens nerve palsy, most likely due to nerve compression in the latero-cellar space. Successful endovascular coils embolization of the aneurysm was performed, with no immediate complications. CT, MR and angiographic findings are presented. Although infrequent as single variations, the association of these

three arterial variations has not been reported in literature to our knowledge, having special importance in the diagnostic workup and therapeutic procedures in a patient with an embolic stroke, as well as in the planification of intracranial endovascular diagnostic and therapeutic procedures.

**Key words:** cerebral arterial circle; posterior cerebral artery; persistent trigeminal artery; abducens nerve.

**INTRODUCTION**

In 1664 Thomas Willis described for the first time the anastomotic arterial circle in the inferior surface of the brain: the cerebral arterial circle (CAC). It represents the main intracranial anastomotic system, connecting both right and left hemispheric circulation as well as anterior or carotid and posterior or vertebro-basilar systems. It has a major protective role over the arterial supply of the brain, allowing revascularization of one or more of the circle's vessels through the remaining patent arteries.

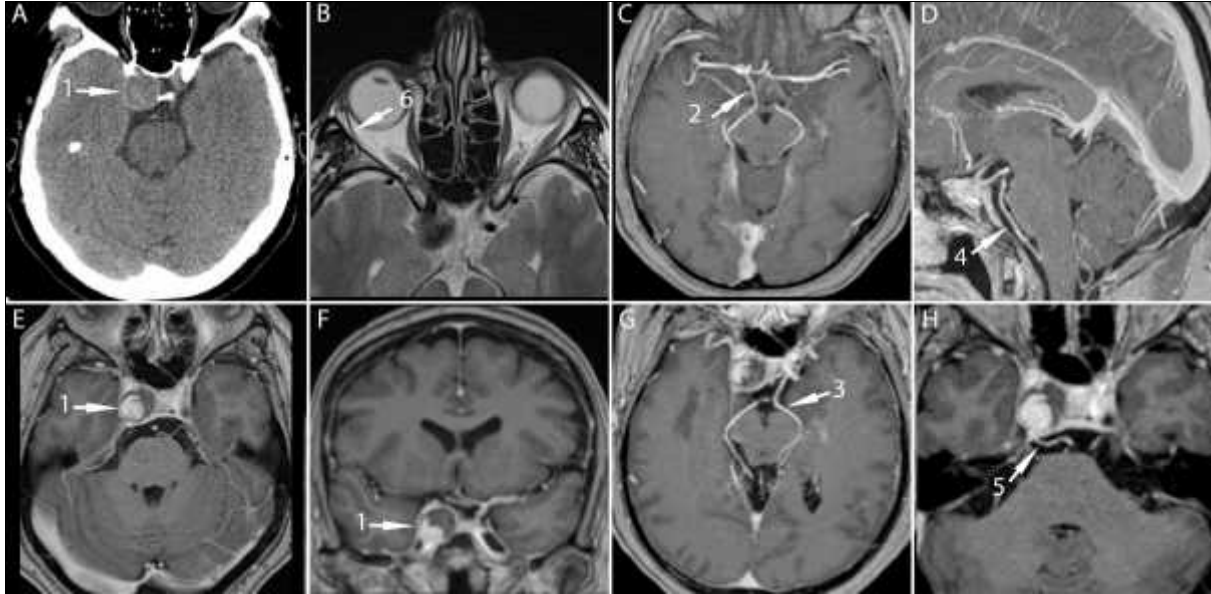
During fetal life, the development of four transient vascular channels connecting the fetal ICA with the longitudinal neural arterial plexus (which will later form the BA) takes place, ensuring blood flow to the cerebellum and brainstem during early fetal life (Meckel et al, 2013): the otic, hypoglossal, proatlantal and trigeminal arteries.

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Once the vertebral arteries (VA) and the posterior communicating arteries (PcomA) have fully developed, these four arteries obliterate, the

trigeminal artery being the last one to regress. It persists in 0.1 to 1% of the general population (Azab et al, 2012; Meckel et al, 2013).



**Figure 1** – Brain CT and MRI. A (axial non-enhanced CT) and E-F (axial and coronal contrast-enhanced T1 MRI sequence): partially thrombosed PTA aneurysm (1) with mild mass effect. B (axial T2 MRI sequence): atrophic right lateral rectus (6) and medial deviation of the eye. C and G (axial T1 MRI sequence, MIP reconstruction): right (2) and left (3) fetal posterior cerebral arteries. D (Sagittal T1 MRI sequence, MIP reconstruction): patent BA with regular diameter (4). H (Axial T1 MRI MIP reconstruction): right lateral PTA coursing through the pre-pontine cistern (5).

## CASE REPORT

A 64-years-old woman was admitted to the hospital after three months of progressive diplopia. Complete right abducens nerve palsy was found at physical exam.

Non-enhanced brain CT demonstrated a right latero-cellular round formation, of discrete borders, with thin peripheral calcifications and mild mass effect (figure 1). Magnetic resonance was advised to complete diagnosis.

Following brain MR with and without gadolinium (figure 1) showed a right PTA measuring 12mm in length, with a diameter ranging between 1.1 and 1.3mm. It coursed lateral to the right abducens nerve.

The right lateral-cellular rounded formation observed in CT corresponded to a partially thrombosed aneurysm adjacent to the carotid origin of the PTA, measuring 23mm x 16mm in diameter. It had a patent light of 13mm x 10mm (figure 1).

The basilar artery had a typical origin and trajectory. Its diameter ranged from 2mm to 1.8mm, in its proximal and distal parts, respectively, with no hypoplastic segments. Its

terminal branches were the right and left superior cerebellar arteries. Pre-communicating segment of PCA was absent and fetal configuration of the PCA was identified bilaterally (figure 1). The rest of the CAC had a normal configuration and no other vascular anomalies were identified.

Asymmetry in the size of both lateral rectus of the eyes was noted, the right one being atrophic (figure 1).

Brain arteriography was performed with diagnostic and therapeutic objectives. The existence of a PTA aneurysm was confirmed and successful embolization with coils was performed. Absent P1 in both PCA's and bilateral fetal PCA's were also confirmed (figure 2).

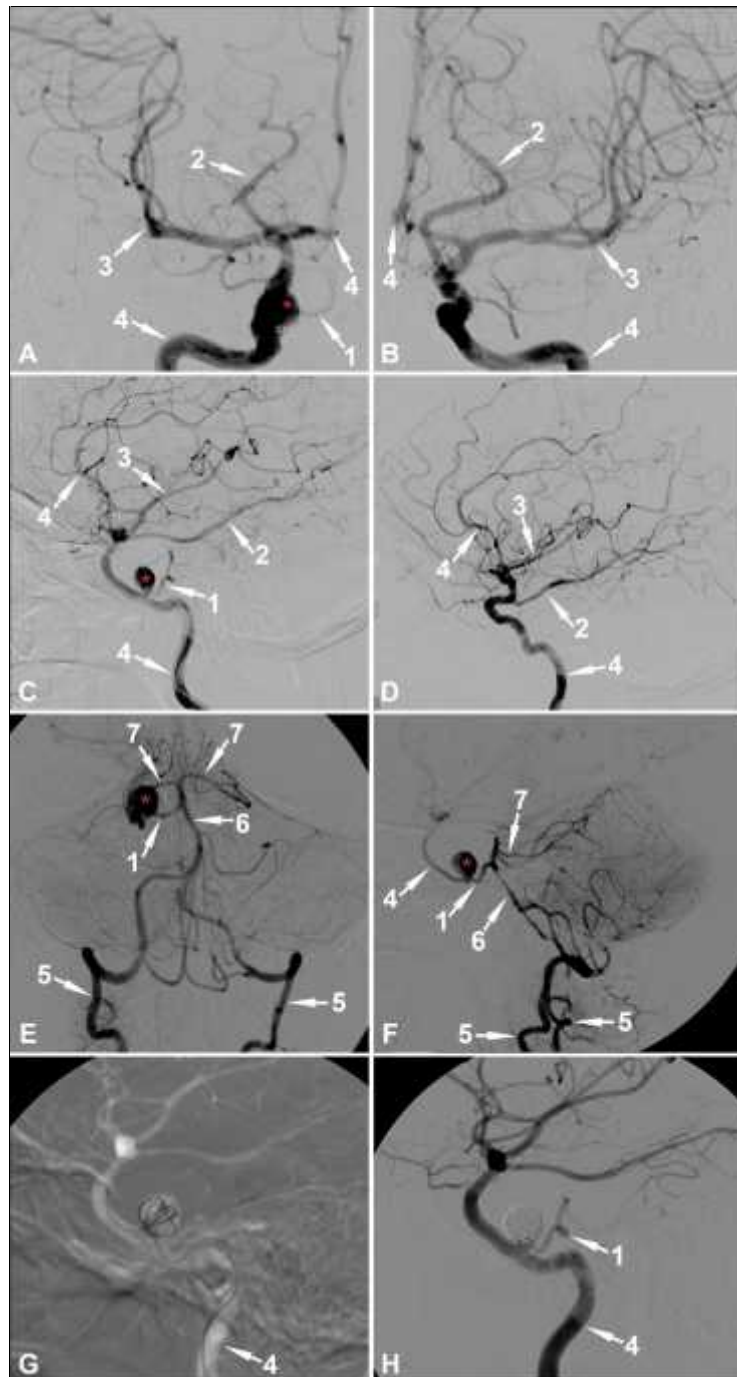
Angiographic control after embolization demonstrated a complete occlusion of the aneurysm and patent PTA and ICA, with normal opacification of the CAC's arteries (figure 2).

## DISCUSSION

Cerebral arterial circle variations have been widely reported in literature, being classified as

aplasia, hypoplasia, fenestration or an aberrant origin of any of its arteries. Variations with respect to its classic configuration, as described by Thomas Willis, are found in 27-95.4% of the cases (El Khamlichi et al, 1984; Da

Silva et al, 2011; Iqbal, 2013; Klimek-Piotrowska, 2015). The posterior aspect is by far the most inconstant part of the CAC, presenting variations in 72% of the cases (Boleaga et al, 2004).



**Figure 2** - Brain digital subtraction angiography. A and C: right ICA injection - anterior (A) and lateral (C) views. B and D: left ICA injection - anterior (B) and lateral (D) views. E and F: left vertebral injection - anterior (E) and lateral (F) views. G and H: right ICA injection (lateral view) during (G) and after (H) embolization. 1: right persistent trigeminal artery; 2: posterior cerebral artery; 3: middle cerebral artery; 4: internal carotid artery; 5: vertebral arteries; 6: basilar arteries; 7: superior cerebellar arteries; red asterisk: PTA aneurysm.

**Persistent trigeminal artery.**

This artery originates from the cavernous segment of the ICA (IVth segment), courses posteriorly through the peripontine cisterns to finally join the BA somewhere between the origin of the superior cerebellar arteries (SCA) and the anterior inferior cerebellar arteries (AICA) (Dimmick and Faulder, 2009). Through its course, it may give branches to supply the pons, the trigeminal ganglion, the pituitary gland and the cerebellum. Therefore, its preservation during surgery or endovascular procedures is mandatory (Azab et al, 2012).

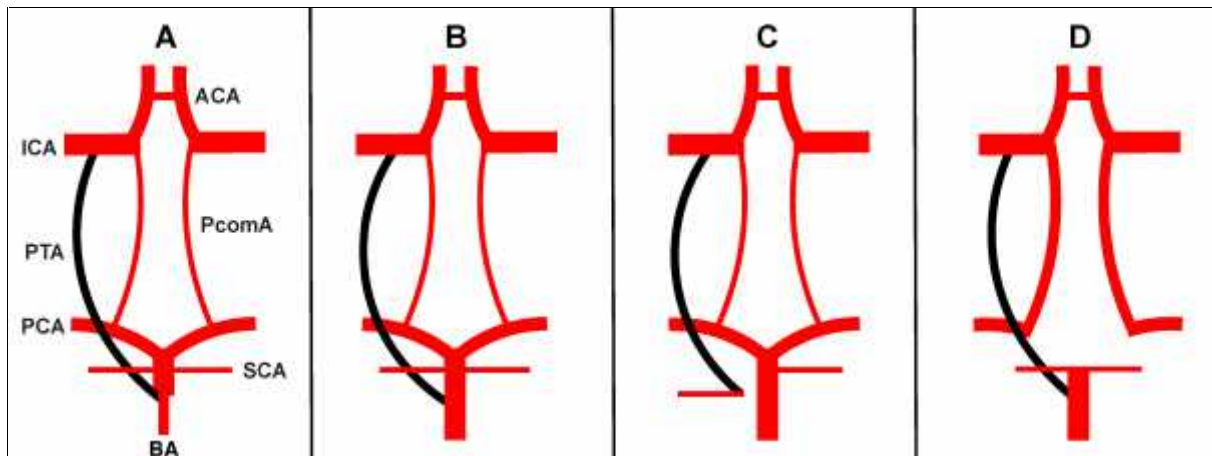
The first classification of PTA anatomy was performed by Saltzman in 1959, after a series of 8 angiographic cases (figure 3):

1. Saltzman type 1 (fetal type): the BA proximal to the PTA is usually hypoplastic and the

PcomA may be absent. The PTA is the main vascular supply to the brainstem, cerebellum and PCAs.

2. Saltzman type 2 (adult-type): the PTA joins the BA below the SCA origin and the PCA is filled mostly through the PcomA. The BA completely fills from one or both VAs and therefore, PTA is not a mandatory channel for posterior fossa vascularization. This was the configuration found in the patient presented.

Saltzman type 3 was later described, where the PTA directly joins one of the cerebellar arteries, most commonly the AICA or SCA (figure 3). Consequently, the cerebellar artery involved seems to originate directly from the cavernous ICA, being its blood flow completely dependent on the PTA patency.



**Figure 3** – Persistent trigeminal Saltzman classification—A, B and C: Saltzman type 1, 2 and 3. D: cerebral arterial circle of the patient presented. ACA: anterior cerebral artery; ICA: internal carotid artery; PcomA: posterior communicating artery; PCA: posterior cerebral artery; SCA: superior cerebellar artery; BA: basilar artery; PTA: persistent trigeminal artery.

Although Saltzman classification may not reflect the embryologic aspects of PTA, which even led some authors to claim it has no meaning (O'uchi and O'uchi, 2010), it is often used for surgical or endovascular planning.

In 1998 Salas et al (1998) addressed the anatomical relations of the PTA after one cadaveric dissection and review of the literature, and proposed a new classification with two groups regarding the relation of PTA and abducens nerve, with distinct clinical implications:

- A lateral or petrosal group, in which PTA arises from the posterolateral aspect of the cavernous ICA and crosses under the abducens nerve, which may be displaced, and pierces the dura medial to the sensory root of the Vth cranial nerve. This variation has been

associated with clinical symptoms such as trigeminal neuralgia and diplopia (Salas et al, 1998).

- A medial or sphenoid group, in which the artery arises from the posteromedial aspect of the cavernous ICA coursing medial to the abducens nerve, close or into the sella turcica, and pierces the dura of the dorsum sellae. Besides being exposed to iatrogenia during sellar surgery, this variation is associated with transient ischemic attack of the posterior fossa, with symptoms such as dizziness, vertigo, gait disturbance and ataxia (Salas et al, 1998).

Vascular anomalies, such as PTA aneurysms or trigeminal cavernous fistulas, are present in up to 25% of cases of patients with PTA (de Bondt,

2007; Meckel et al, 2013). Although early reports stated there was an association between PTA and other intracranial aneurysms, a large MR angiographic study over 16415 patients concluded there was no difference in intracranial aneurysms incidence among patients with and without PTA (O'uchi and O'uchi, 2010).

Aneurysms of the PTA occur in 3-15% of the patients (Cloft et al, 1999; Ladner et al, 2013) and have been described both in its carotid and basilar ends, the first being more frequent possibly due to hemodynamic turbulence at the carotid origin of the PTA. Being aware of its anatomical relations is key to understand the two most common symptoms that may be present in patients with a PTA's aneurism: trigeminal neuralgia due to trigeminal ganglion compression or abducens palsy due to sixth cranial nerve compression, as was the case of the patient presented. It is assumed that symptoms are caused by pulsatile motion of the aneurysm rather than mass effect and compression, which makes endovascular embolization a perfect therapeutic option, allowing for interruption of blood flow into the aneurysm immediately, being far less aggressive than surgical clipping.

The association of a right PTA and P1 bilateral aplasia in the presented case determined that PTA stands as the only significant anastomotic channel between the anterior and posterior arterial circulations. Hence, flow compensation between anterior and posterior circulation in case of occlusion of one of the CAC branches would be limited, potentially predisposing to ischemia. Moreover, in case of hypoplastic or occluded VA, the only endovascular access route to the BA and its branches would have been through ICA-PTA. Likewise, BA-PTA becomes an invaluable endovascular route to the anterior circulation in case of ICA occlusion (Meckel et al, 2013).

During brain angiography, PTA was filled both after carotid and vertebral injection, allowing for bidirectional blood flow. This finding has two major implications:

First, a thrombus originated in the ICA could flow through PTA and impact in one of the BA branches, determining brainstem or cerebellar ischemia. Similarly, a thrombus originated in the vertebro-basilar system could migrate to the anterior circulation through PTA and occlude one of the ICA branches, resulting in hemispheric or retinal ischemia. Shall the presence of PTA remain unknown in a patient suffering from a stroke, the origin of the thrombus could be misinterpreted, and initial workup studies would be misleading, potentially conducting to iatrogenic procedures (Azab et al, 2012).

Second, since bidirectional flow is present, the

presence of a PTA must be assessed before performing a Wada test (injection of anesthetics in the ICA to predict language deficit before carotid artery surgery) to avoid perfusion of barbiturates into the posterior circulation (Meckel et al, 2013).

#### *Bilateral aplasia of P1 and bilateral fetal PCA:*

Early in fetal life, PCA originates from the ICA, being the complete arterial blood supply to the posterior hemispheres dependent on the latter artery. After the longitudinal neural arteries fuse and form the BA, two vascular stems arise from its cephalic end and join the ipsilateral PCA, forming P1 segment. Once the VA completely develop, PCA vascular supply switches to the vertebro-basilar system, and the segment of PCA between the ICA and P1, the PcomA, partially regresses, which determines an adult CAC configuration.

Fetal PCA is present when PcomA fails to regress and remains of equal or larger diameter than P1, in which case posterior hemispheres vascular supply mostly depends on the ICA. This is the most frequently found variation of the CAC, with a reported incidence of 15-46% and 8-19.6%, uni and bilaterally, respectively (Shaban et al, 2013; Kova et al, 2014; Gunnal et al, 2015).

In the case presented, given the association of bilateral fetal PCA and bilateral P1 aplasia, both PCA were supplied exclusively by the ICA. This would not allow for revascularization of an occluded PCA through the posterior branches of the CAC, should a proximal occlusion occur, most likely leading to occipital lobe ischemia. On the other hand, such arterial configuration would protect hemispheric circulation from embolic ischemia in case of BA occlusion or thromboembolism (Gunnal et al, 2015).

Although P1 hypoplasia associated to a fetal CAC is not that infrequent (2.3-6%), its complete absence is extremely rare (0-0.5%) (Dimmick and Faulder, 2009; Gunnal et al, 2014; Kova et al, 2014). Despite bilateral P1 aplasia was identified during brain MR and angiography in our patient, anatomical confirmation was not possible for obvious reasons. Whether P1 never developed or simply was not detected by imaging studies (i.e.: extremely low flow) will remain unknown, although a bilateral occlusion limited to P1 seems unlikely given the territory supplied by this segment of the PCA (thalamus, choroidal plexus of the third and lateral ventricles and mesencephalon) and the lack of corresponding symptoms.

Although the importance of each individual anatomical variation in the case presented has been widely addressed in literature, the association of these three vascular variants of the CAC

has unique clinical, diagnostic and therapeutic implications, principally regarding ischemic brain disease and endovascular diagnostic and therapeutic procedures. Physicians, surgeons, radiologists and endovascular practitioners must be aware this CAC configuration and its significance to achieve the correct diagnosis, perform the right therapeutic procedure and avoid iatrogenia.

#### Conflict of interests

None.

#### Funding

None.

#### Ethical approval

Does not correspond.

#### Informed consent

Informed consent was obtained from the patient.

#### Authors contributions

JGP: images review and processing, writing of the manuscript. MN: images review and processing. AG, AP and CF: literature review and writing of the manuscript. EO: writing of the manuscript and reviewing the final text.

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