Persistent Trigeminal Artery

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ABSTRACT

OBJECTIVE: Persistent primitive carotid-basilar artery anastomoses are uncommon, and are usually seen on an angiogram or discovered at autopsy. The most frequent type of anastomosis is the persistent trigeminal artery.

METHODS: A single case of a medial variation of the persistent trigeminal artery, as seen in a well-preserved human adult anatomic specimen injected with red latex, is presented, and the anatomy of this uncommon anastomosis is discussed.

RESULTS: This specimen is unique in its clear preservation of the artery, which arises from the medial portion of the right intracavernous carotid artery and gives rise to two branches, the inferior hypophyseal artery and the dorsal meningeal artery to the clivus.

CONCLUSION: A new variation of the persistent trigeminal artery is described, which is important to support the possibility that more than one variety of carotid-basilar anastomosis exists in this region.

INTRODUCTION

In the 3- to 5-mm human embryo, prominent arterial anastomosis, in the form of the trigeminal, otic, hypoglossal, and proatlantal arteries, joins the dorsal aorta (the future internal carotid artery in its cranial portion) to the bilateral longitudinal neural arteries (the future basilar artery) (1, 4, 8, 10, 19, 21, 22, 25, 26, 29). The trigeminal artery is the largest of these arteries, and it persists for the longest embryonic period, usually being obliterated by the 11.5- to 14-mm embryonic stage (1, 4, 8, 19, 22, 25, 26, 29). It is named for its usual ventromedial course to the trigeminal ganglion to provide most of the blood supply to the developing hindbrain before development of the posterior communicating and vertebral arteries, after which the trigeminal artery regresses (4, 8, 22, 25, 26, 29). The trigeminal artery is the most common of the primitive carotid-basilar anastomoses that persist into adulthood, with an incidence of 0.1 to 1.0% (5, 8, 20, 22, 24, 25, 29, 30). A number of cases of persistent trigeminal artery (PTA) and its variants found at autopsy, on cerebral angiograms (2, 3, 5, 9, 13, 14, 17, 19, 25, 27, 29–32, 34), and, more recently, on magnetic resonance imaging scans and magnetic resonance angiograms (3, 7, 28) show the anatomy of this primitive anastomosis (14, 22, 25, 29, 33) and its relationship to various vascular diseases (1, 4, 6, 8, 11, 16, 20, 23, 24). Different methods of treatment, i.e., surgical and/or endovascular (1, 4, 11, 16, 18, 23, 24), and considerations when the PTA is associated with vascular diseases of the sellar region (22) or as a cause of facial pain (12, 24) have also been reported.

The specimen presented in this study is unique in its clear preservation of the artery and its branches, and it shows features that have not been previously reported (25, 29, 33). We review similar anatomic cases (14, 25, 29) and discuss the clinicotherapeutic relevance of the PTA as interventional neuroradiology becomes more common in the management of intracranial vascular pathological conditions.

METHODS

The PTA in this adult anatomic specimen was found incidentally while removing the clivus to elucidate the anatomic structures of the posterior skull base. The arteries had been injected with red latex before the dissection. The artery and its branches were dissected under magnification.

ANATOMIC DESCRIPTION

In this specimen, the right-sided PTA arose from the superomedial portion of the distal horizontal segment of the intracavernous carotid artery. The PTA coursed medially and immediately posteroinferiorly, passing between the posterior bend of the carotid artery laterally and the pituitary gland medially. In its course, it gave off two branches: the inferior hypophyseal artery medially and the dorsal meningeal artery to the clivus inferolaterally. The capsular artery of McConnell arose from the inferomedial portion of the intracavernous carotid artery, and crossed below the PTA in its course to the pituitary capsule (Fig. 1, A–D). The tentorial artery arose directly from the intracavernous carotid artery in its posterior bend, but was lost during the dissection. There was a slight medial bend with narrowing in the trigeminal artery as it passed the junction of the posterior clinoid process and the pituitary gland to exit the posterior wall of the cavernous sinus (Fig. 1C, arrows). There was an indentation in the posterior clinoid process at the point at which the artery passed. Still subdurally, but within its own dural sleeve, the artery passed farther posteroinferiorly over the basilar venous plexus and the clivus, with the abducens nerve lateral to it (Fig. 1, B and D). It then curved medially at the junction of the upper and middle third of the pons, and passed through a dural opening to become intradural, joining the basilar artery approximately midway between the origins of the anteroinferior and superior cerebellar arteries (Fig. 1D, arrows). The basilar and vertebral arteries below the junction with the PTA were hypoplastic (Fig. 1). The diameter of the PTA equaled that of the basilar artery above their anastomosis.

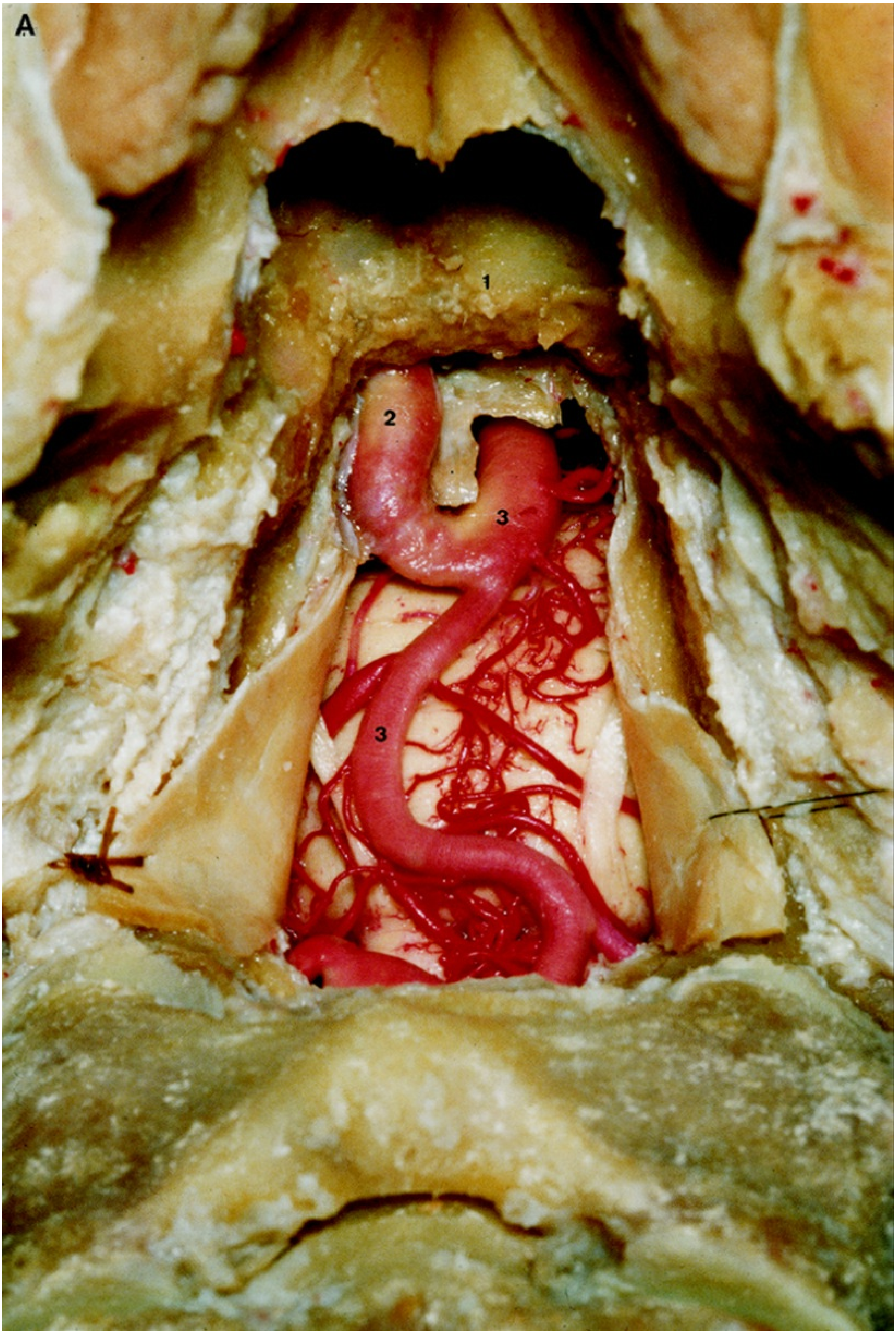

Figure 1 (A). Photographs showing the stepwise dissection of the inferior aspect of the base of the skull. A, the clivus has been removed to the

level of the sellar floor and the dura mater has been opened to show the PTA as it exits the posterior wall of the cavernous sinus. (Image courtesy of AL Rhoton, Jr.)

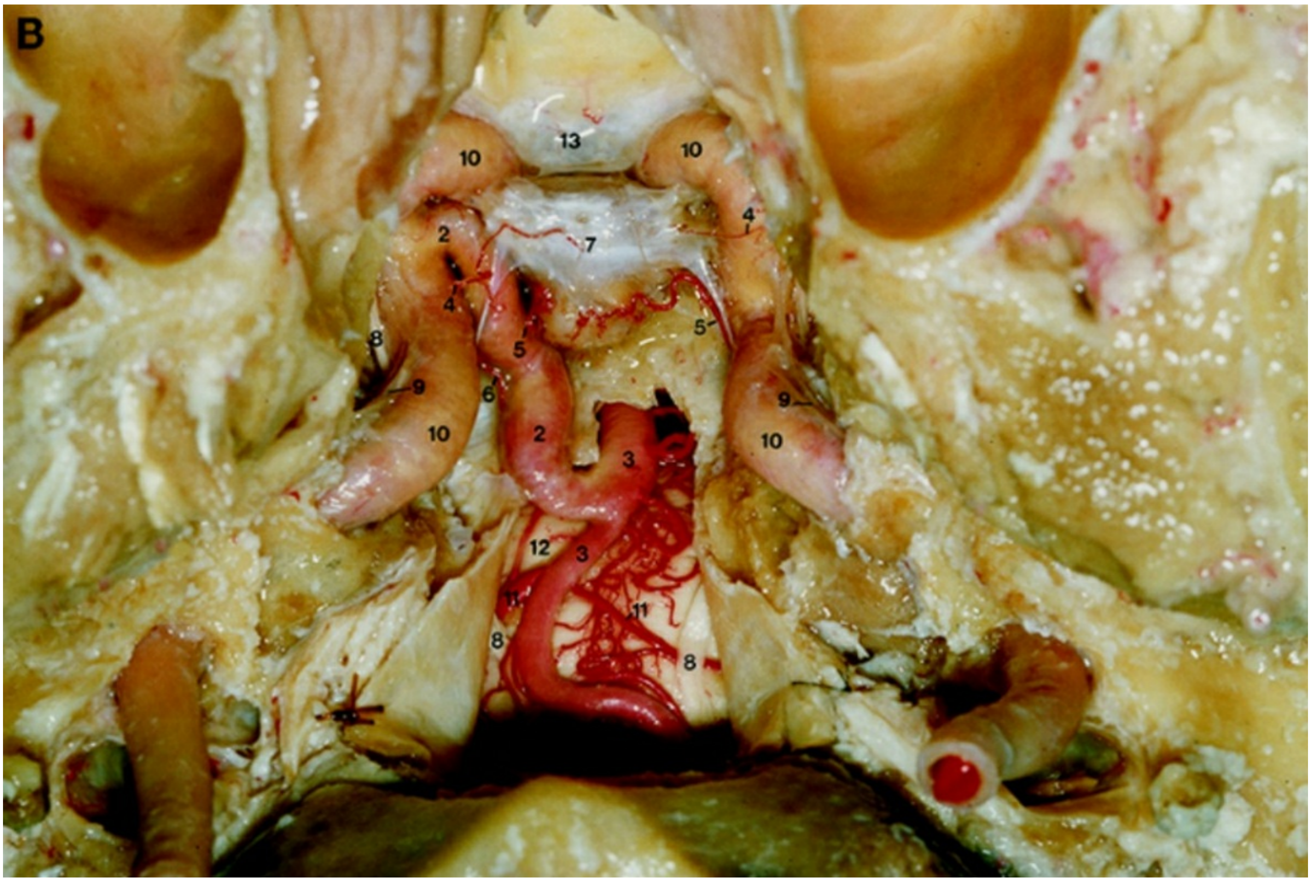

Figure 1 (B). B, The dissection was extended anteriorly to expose the planum sphenoidale and the pituitary gland and laterally to fully expose the course of the PTA and of the intracavernous carotid artery. The PTA arises from the superomedial portion of the distal horizontal segment of the carotid artery. (Image courtesy of AL Rhoton, Jr.)

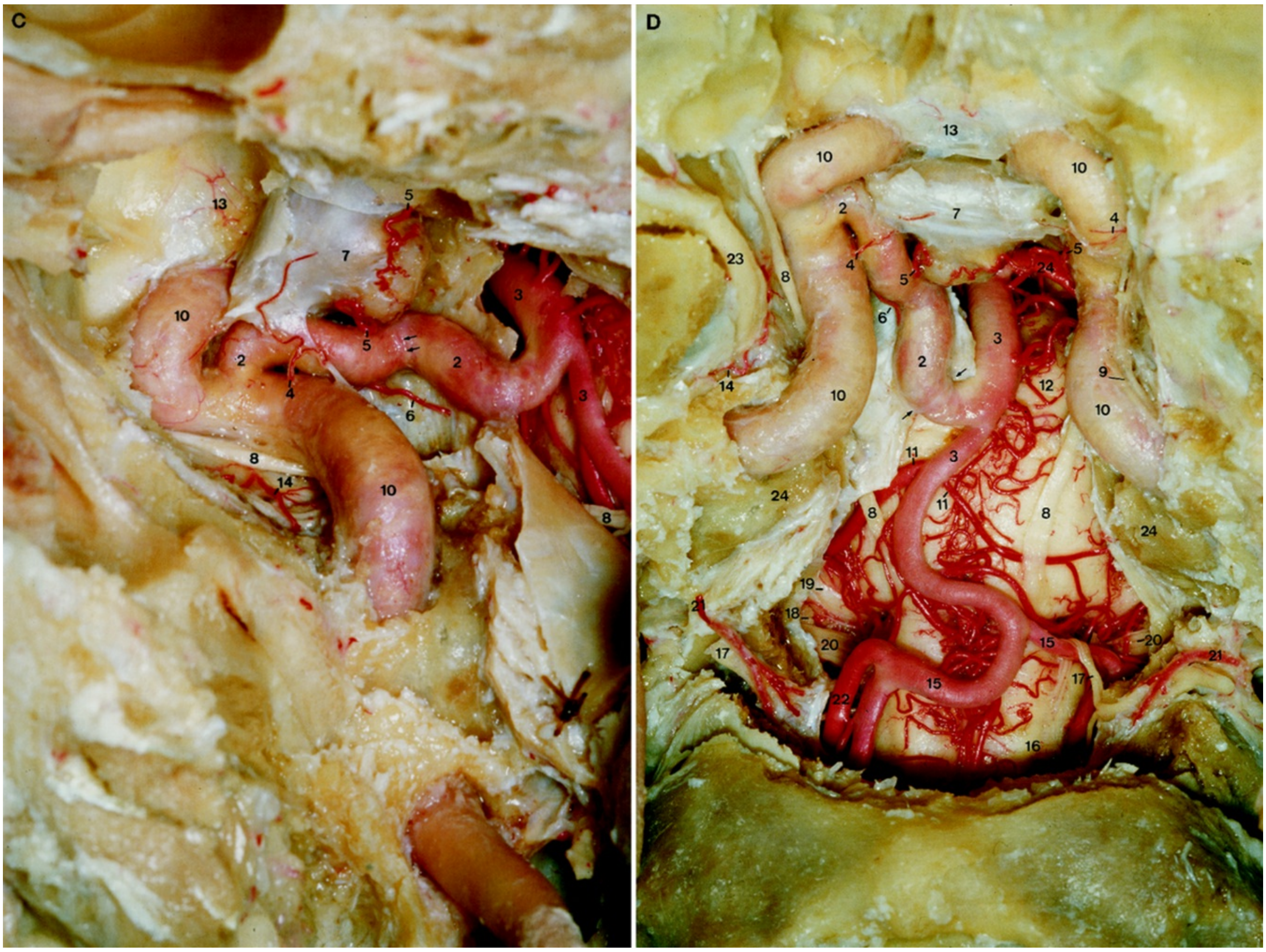

Figure 1 (C–D). C, the branches of the intracavernous carotid artery and their relationship with the PTA can be appreciated. Note the narrowing of the PTA (arrows) as it passes lateral to the pituitary gland at the level of the posterior clinoid process. D, the dissection has been carried farther laterally to expose the second division of the trigeminal nerve and posteriorly to expose the basilar artery and its branches as well as the lower cranial nerves. Note the exit point of the PTA from the cavernous sinus (arrows) and the hypoplastic basilar artery proximal to its anastomosis with the PTA. 1, sellar floor; 2, PTA; 3, basilar artery; 4, capsular artery of McConnell arising from the inferomedial portion of the carotid artery, and crossing below the PTA in its course to the pituitary capsule; 5, inferior hypophyseal artery arising from the medial surface of the PTA on the right;6, dorsal meningeal artery to the clivus arising from the inferolateral surface of the PTA; 7, pituitary gland; 8, abducens nerve; 9, sympathetic nerve fibers; 10, intracavernous carotid artery; 11, anteroinferior cerebellar artery; 12, pons; 13, planum sphenoidale; 14, artery of the inferior cavernous sinus (also known as the inferolateral trunk);15, vertebral artery; 16, medulla; 17, hypoglossal nerve; 18,

choroid plexus;19, flocculus; 20, glossopharyngeal and vagus nerves; 21, meningeal branch ascending the pharyngeal artery; 22, posteroinferior cerebellar artery; 23, maxillary branch of the trigeminal nerve;24, left superior cerebellar artery. (Images courtesy of AL Rhoton, Jr.)

The artery to the inferior cavernous sinus was present on the right side. It branched off from the lateral aspect of the horizontal segment of the intracavernous carotid artery above the abducens nerve, as usual. On the opposite side, McConnell's arteries arose from the inferior part of the horizontal segment of the intracavernous carotid artery and anterior to the inferior hypophyseal artery, which arose from the medial portion of the horizontal segment of the intracavernous artery (Fig. 1A).

Other interesting features of this specimen included a fenestrated oculomotor nerve on the left side around the posterior cerebral artery as it emerged from the midbrain in the interpeduncular fossa, a fetal posterior communicating artery on the right side, and a duplicated right superior cerebellar artery (Fig. 2 , A and B). A hypoplastic left-sided anteroinferior cerebellar artery was also observed (Fig. 1).

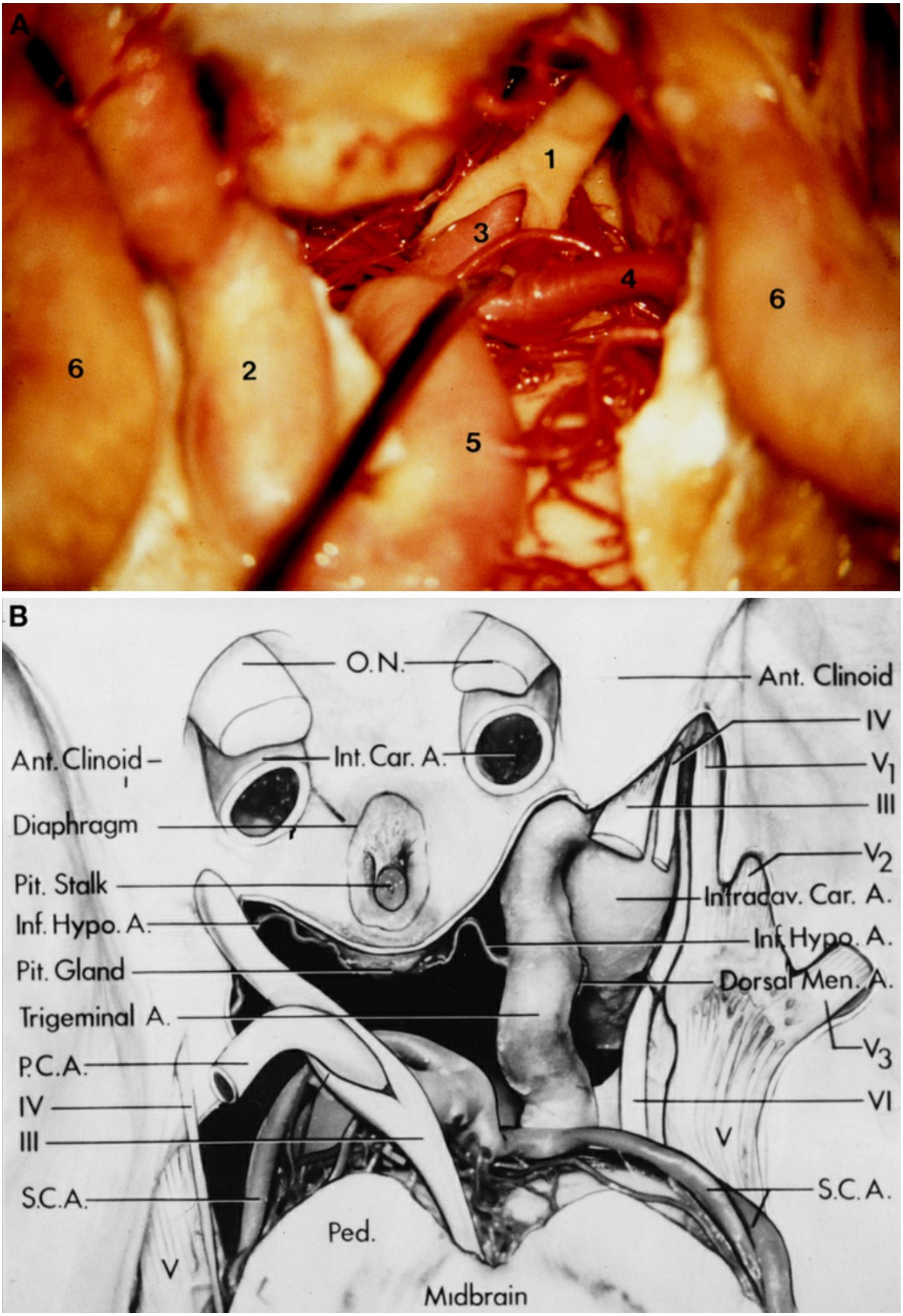

Figure 2 (A–B). A, photograph (inferior view) showing the fenestrated left-sided oculomotor nerve encircling the left posterior cerebral artery.

1, oculomotor nerve;2, PTA;3, posterior cerebral artery;4, left superior cerebellar artery; 5, basilar artery; 6, intracavernous carotid artery. B, illustration (superior view) showing the sellar and parasellar region. The dura mater has been removed from the superior, lateral, and posterior walls of the cavernous sinus, exposing the intracavernous carotid artery (Intracav. Car. A.) and the PTA (Trigeminal A.). The left-sided oculomotor nerve (III) is fenestrated around the left posterior cerebral artery (P.C.A.) just after it has emerged from the midbrain. A duplicated superior cerebellar artery (S.C.A.) is seen in the right side. There is also no direct relationship between the PTA and the abducens nerve (VI). O.N., oculomotor nerve; Ant. clinoid, anterior clinoid process; Int. Car. A., internal carotid artery; Pit. Stalk, pituitary stalk; Inf. Hypo A., inferior hypophyseal artery; Pit. Gland, pituitary gland; Dorsal Men. A., dorsal meningeal artery; Ped., peduncle;V1, first ophthalmic branch of the trigeminal nerve;V2, maxillary branch of the trigeminal nerve;V3, mandibular branch of the trigeminal nerve; IV, IVth cranial nerve; V, Vth cranial nerve. (Images courtesy of AL Rhoton, Jr.)

DISCUSSION

In relation to the dorsum sellae, approximately 50 to 59% of all cases of PTA penetrate the sella turcica, course along their own groove, perforate the dura near the clivus, and then join the basilar artery. Thinning of the sellar floor and abnormalities of the dorsum sellae are frequent. In the other 41 to 50% of cases, the PTA runs lateral to the sella turcica (22, 25).

Branches from a PTA in an adult anatomic specimen have been previously reported only three times (14, 25, 29). Ohshiro et al. (25) described a meningohypophyseal trunk (MHT) that, similar to the artery of the inferior cavernous sinus, arose from the origin of the PTA in the inferolateral aspect of the intracavernous carotid artery. In this case, the PTA gave rise to branches to the trigeminal nerve root and pons. Salas et al. (29) described a PTA that gave rise to four pontine perforating arteries. In both of these cases, the PTA arose from the inferolateral aspect of the intracavernous carotid artery. Khodadad (17) also reported 3 cases of fetal PTA, which gave perforating branches to the pons.

The uniqueness of this specimen lies in its clear preservation of the PTA and its relationship with the intracavernous artery and the abducens nerve. The presence of branches from the PTA, namely the inferior hypophyseal artery and the dorsal meningeal artery, are noteworthy. In this case, the PTA had no relationship to and was not responsible for the blood supply to the trigeminal nerve root or ganglion.

The subdural course of the PTA over the clivus within its own dural sleeve or canal, before becoming intradural and anastomosing with the basilar artery, has not been previously reported, nor has the PTA origin from the superomedial portion of the distal horizontal segment of the intracavernous carotid artery. The most common sites of origin for a PTA are the posterior bend or lateral wall of the intracavernous carotid artery (25, 27, 29) In our case and the case presented by Schmid (30), the PTA arose from the medial wall.

Basilar artery hypoplasia proximal to its anastomosis with the PTA is frequently associated with this type of vascular anomaly, and, as suggested by Boyko et al. (3), it is a congenital variation caused by a poor-flow-related stimulus for further development. Parkinson and Shields (27) raise the question of whether there is more than one variety of congenital connection between the carotid and basilar arteries in this region: one that passes below the abducens nerve, and one that passes above it. They question whether both could be called a true PTA. Our case may support such a possibility.

Salas et al. (29) reported an interesting classification of PTA variations: a lateral petrosal variation and a medial sphenoid variation. It appears that the lateral variation gives rise to perforating branches to the pons, as was seen in a similar pattern reported by Ohshiro et al. (25). They were the only other authors to mention the possibility of an ischemic lesion in the brainstem, with the occlusion of the PTA secondary to obstruction of these branches.

Why a primitive vessel persists into adulthood, or why a vessel cannot be resorbed once it reaches a critical size, is not completely clear. It is thought that no rigid genetic programming exists in the development of the cerebral blood vessels, and that the momentary needs in the dynamic process of the developing brain continually reshape the vessels by formation, regression, and anastomosis. As suggested by Lasjaunias and Berenstein (21), the hemodynamic constraint imposed near a developing territory orientates that territory toward a particular vessel to maintain a hemodynamic balance. This results in the persistence of that vessel and, thus, an anatomic variant. To further explain variations in the branches of the intracavernous carotid artery, these authors divided the internal carotid artery into autonomous embryonic segments, each lying between two consecutive embryonic vessels. If there is agenesis of a particular segment of the carotid artery, the embryonic vessel becomes the point of entry of vascular rerouting. The course of the artery then determines its branches of supply.

We think that two interesting “pieces” can be added to the “PTA puzzle,” based on the analysis of the three previous studies of MHT branches and perforating branches to the pons that arise from the PTA (14, 25, 29) and the present case. The medial variation presented by Salas et al. (29) and the superior variation presented by Parkinson and Shields (27) may represent a different carotid-basilar anastomosis from the PTA, and the MHT may be the remnant of this vessel. The second and most interesting piece of the puzzle, which has therapeutic implications, is that the lateral or inferior variation is the true PTA; if we recall the embryology and the study presented by Khodadad (17), the PTA provides the blood supply to the hindbrain and to the trigeminal ganglion. The two studies that demonstrated preserved branches illustrate this fact (25, 29): both were lateral or inferior PTA variations.

Distinguishing these intracavernous carotid-basilar anastomotic variations is important for future therapeutic and prognostic applications. Currently, magnetic resonance imaging and magnetic resonance angiography are used to diagnose intrasellar and other related vascular diseases (1, 3, 7, 28). They can also be useful for neurosurgical procedures in the region, i.e., balloon microcompression or radiofrequency lesions for trigeminal neuralgia.

Several studies of surgical, endovascular, and combined treatments exist in the literature of pathological conditions associated with a PTA (1, 4, 16, 23, 24). The factors considered for these treatment procedures ignore possible perforating branches from the PTA and their preservation. The other interesting fact is that, in cases found on angiography, there was always a superior or medial PTA variation. Ahmad et al. (1) reported a case of a PTA aneurysm treated with a prophylactic extracranial-intracranial bypass, internal carotid artery ligation, and PTA clipping. They discussed two different types of PTA in relation to the treatment used to justify an eventual sacrifice of the PTA: an adult type with posterior circulation independent of the PTA, and the fetal type with posterior circulation dependent on the PTA. There was no mention of the perforating branches, only consideration of the hemodynamic factors. Therefore, different variations in the vascular anatomy must be individualized on the basis of the events that occurred during embryonic development, and, unless clear patterns emerge from accumulated cases, these anomalies will continue to be a source of interesting debate.

Like Ohshiro et al. (25), we think that when considering therapy that involves this kind of persistent embryological anastomosis, which can be in 25% of cases (1), one must consider the preservation of the PTA; however, we add the factor of the type of PTA variation, which may be important. The medial PTA variation that can give rise to MHT branches has the advantage of cross anastomosis with the opposite side in this region, but the lateral PTA variation in its intradural portion can give rise to perforated branches to the pons and trigeminal ganglion; in this particular variation, the possibility of brainstem ischemia exists. Therefore, we think that the therapeutic decision to sacrifice the PTA in a specific pathological condition must take into account the particular PTA variation, and not only hemodynamic factors (15).

CONCLUSION

The origin and course of the artery in this specimen raises more embryological questions than answers. Whether this artery, despite its medial origin from the intracavernous carotid artery, is the precursor of the MHT, as dictated by its branches of supply, or whether it is a remnant of another primitive vessel is not known. Based on the analysis of this case and similar, previously reported cases, we think that more "pieces" have now been added to the "PTA puzzle," i.e., the definition and variations of the PTA. The therapeutic implications of these variations not only should be considered from a hemodynamic point of view, but also should take into account the embryological role of this vessel, which gives irrigation to the hindbrain, trigeminal root, and ganglion. Sometimes, and for unknown reasons, this primitive carotid-basilar anastomosis persists, and we think that there is not only an anatomic persistence of the vessel, but also a persistence of some of its embryological function.

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The Neurosurgical Atlas is honored to maintain the legacy of Albert L. Rhoton, Jr, MD.

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