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Original Research Article

Vertebral Artery: Normal Anatomy and Variations on Digital Subtraction Angiography

Dr. Gorky Medhi[1], Dr. Hima Pendharkar[2]

[1]MD, DM (Neuro Imaging & Interventional Radiology), Department of Interventional Radiology, Sikkim Manipal Institute of Medical Sciences, Gangtok. 737102
[2]Additional Professor, Department of Neuroimaging & Interventional Radiology, National Institute of Mental Health & Neurosciences, Hosur road, Bangalore.

Corresponding Author: Dr. Gorky Medhi

ABSTRACT

Digital subtraction angiography (DSA) is an imaging modality that is widely used not only to diagnose / confirm but also to treat various vascular pathologies. Knowledge of normal anatomy and variations of neck vessels is of utmost importance to perform any neurovascular diagnostic or interventional procedure for obvious reasons. Here we discuss about some variations of vertebral artery incidentally detected during routine DSA at our institute along with its significance and embryological basis.

Key words: DSA, Variations, Vertebral artery

INTRODUCTION

DSA is the gold standard for detection and evaluation of various intracranial vascular lesions. The endovascular treatment options that it provides are a testimony to the modern technological developments. Several anatomical variations of vertebral arteries are noted during MRA, CTA or DSA of craniocervical vessels: these are important to detect, understand and to analyse for diagnostic as well as endovascular work up prior to interventional procedures.

The fundamental importance of identifying variant origins of cranio-cerebral vessels is that in a given case when the findings on imaging do not correlate with the vessel territory, possibility of variant origin may be the explanation. Also when a vessel is not visualized in its usual location variant origin should be considered prior to concluding its absence. Hence, it is all the more important to do a very meticulous angiography exploring all vessels & then review the images to look for the variant vessels. Identifying them in routine practice trains one to identify them in pathological conditions. We retrospectively analysed the angiograms done in our Angio suite to look for vertebral artery variants & have described the embryology in brief & significance of each variant in this article.

MATERIALS & METHODS

It was a single institutional retrospective study of patients undergoing DSA in our institution for diagnostic as well as therapeutic neurovascular interventional procedures from July 2014 to June 2015. DSA was performed on Axiom Artisd BA biplane system (Siemens Healthcare Sector, Erlangen, Germany). DSA images of 1053patients were reviewed from our PACS. Variations of vertebral arteries were identified. Available literature was reviewed

for possible embryological explanations of the variant.

RESULTS

Direct origin of left vertebral artery from the arch of aorta was found to be the most common variant followed by fenestration of various segments of vertebral artery. Duplication of origin of the right vertebral artery was found in one patient and anomalous origin of right vertebral artery from right common carotid artery (CCA) was found in another patient. We also found Pro-atlantal intersegmental artery (PAIS) type II in one case during this period.

DISCUSSION

Anatomy:

Normally, there are two vertebral arteries; the right VA arises from the postero-superior aspect of the right SCA and courses superiorly to enter the foramen transversarium of C6 transverse process. [1] The left VA arises from the postero-superior aspect of left subclavian artery near its apex & passes cephalad to enter the foramen transversarium of the left C6 vertebra. [1] Rostrally, the two vertebral arteries unite to form the basilar artery [Fig 1 & Fig 2].

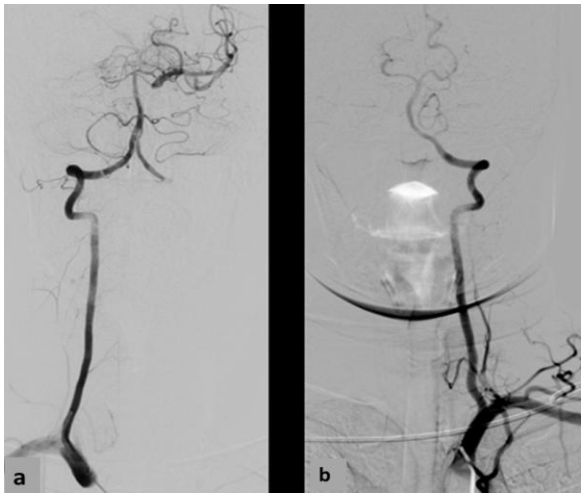

Fig 1a):The course of the normal right vertebral artery arising from right subclavian artery.
Fig 1b): The course of the normal left vertebral artery arising from left subclavian artery.

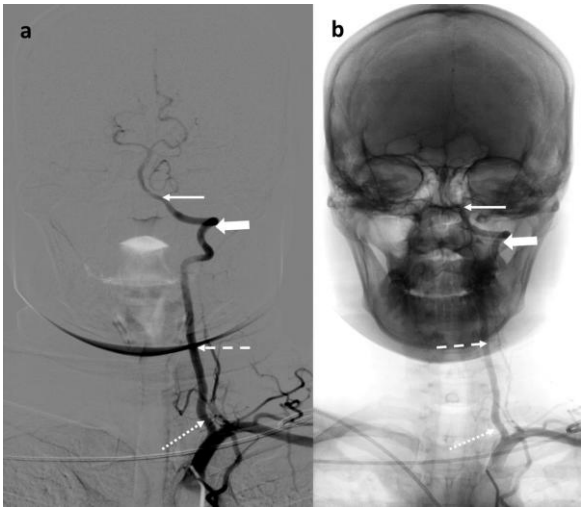

Fig 2:(a) Subtracted and (b) unsubtracted AP view showing left vertebral artery arising from left subclavian artery and its various segments: dotted arrow – V1 (Preforaminal); dashed arrow-V2(foraminal); thick arrow-V3(atlantic, extradural); thin arrow-V4 (intracranial, intradural).

The VA is divided into four segments: [Fig 2].

V1: from origin to entry into foramen of transverse process of cervical vertebra usually 6th.

V2: within the foramen transversaria

V3: from its exit at axis till it penetrates the dura at the skull base

V4: Intradural segment of terminal VA till it joins the contralateral VA to form the basilar artery.

Embryology:

The earliest development of the vertebral artery begins when the embryo is at the 7-mm stage &is usually complete by the 14- to 17-mm stage. [2] At the 7-mm stage, seven cervical intersegmental arteries (CIAs), which originate from each of the paired dorsal aortae, appear. [2] At the 10- to 12-mm stage, longitudinal anastomosis develops between the CIAs. Their connection with the dorsal aorta regresses simultaneously. At the 14- to 17-mm stage, the horizontal parts of the first six CIAs disappear and the remaining seventh CIA becomes part of the subclavian artery. The longitudinal anastomosis persists as the vertebral artery. These developmental processes result in a normal origin of the vertebral artery from the subclavian artery. [2] Variations in the routine embryological

appearances, connections & regressions lead to interesting variations in the VA origin & course.

Anatomical Variants:

1) **Arch origin of left vertebral artery:** The left VA arises directly from the arch of aortain 2.4 – 5.8% cases [3] & then is situated between the left common carotid artery and the left subclavian artery. With an arch origin, the LVA usually enters the transverse foramen of fourth or fifth cervical vertebra rather than the sixth. [4] The RVA may also have an arch origin but is very rare. [5] [Fig 3]

   Embryological basis: Persistence of the sixth intersegmental artery which links the longitudinal channel of LVA with aortic arch leads to the LVA arising from the aortic arch. [2]

   Significance: Variant origin should be considered before misinterpreting non visualisation of VA from its usual location.

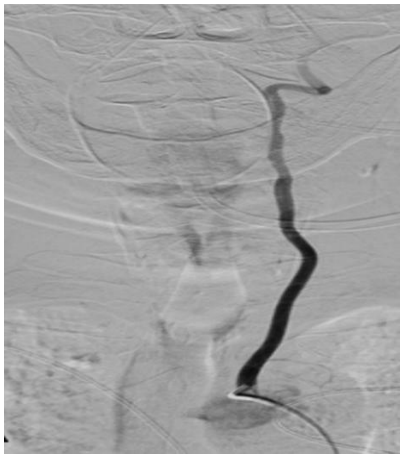

Fig 3: The left VA arising directly from the arch of aorta.

2) **Duplication or dual origin of vertebral artery:** Dual origin of the vertebral artery was first reported in 1844. [6] Incidence of unilateral dual origin is 0.72%. [7] Origin of both the limbs of a vertebral artery from the ipsilateral subclavian artery is more commonly reported on the right side. The term "duplication" should be strictly applied to a vertebral artery that has 2 origins and a variable course and fusion level in the neck. With duplication, both segments are found outside of the spinal canal.

   Embryological basis: Sim et al [8] state that a portion of the primitive dorsal aorta may not regress along with 2 intersegmental arteries that connect to the vertebral artery. It is believed that this arrangement may give rise to vertebral artery duplication or double origin to that vessel.

   How to identify the duplicated vessel: The calibre of the V2 segment is important: a smooth walled vessel with any acute change in the calibre – also smooth - along its course should raise the suspicion of a second limb of V2 segment. [Fig 4] At times contrast may reflux retrogradely to the limb which is not opacified on antegrade injection.

   Significance: Failure to identify duplication may lead to misinterpretation, at times stating a congenitally hypoplastic limb as dissected/ partially occluded. These vessels are also more prone to injury.

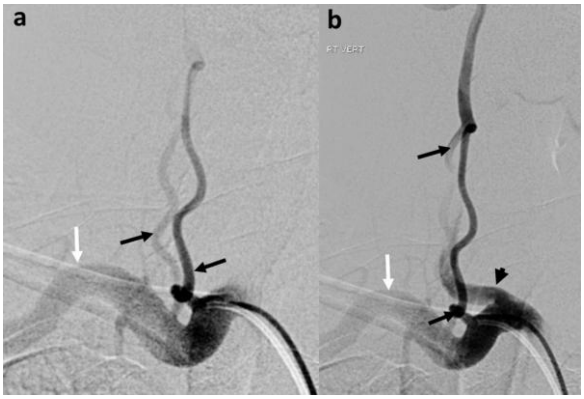

Fig 4(a) & (b) Duplicated origin (solid black arrows) of right vertebral artery extending to V2 segment. Note the difference in caliber of the distal – non duplicated segment & the limbs of duplicated segments, the walls of which are smooth. Right subclavian artery-white arrow, right common carotid artery-arrow head.

3) **Long cervical fenestration of vertebral artery:** Fenestration represents a vessel with a single origin and anywhere along its course the main trunk divides into 2 parallel segments that may lie within or outside of the

vertebral canal, depending on the level of occurrence. [8,9] The incidence of vertebral artery fenestration on autopsy and angiographic studies is 0.23%-1.95%. [10,11] Each channel of a fenestrated artery has its own muscularis layer and is lined by a separate endothelium. Failure of the regression of the second intersegmental artery or the failure of involution of plexiform anastomoses have been proposed as the cause extra cranial fenestration of vertebral artery by various authors. [12,13] Fig 5shows a unique case with respect to the location of such extensive fenestration.

Embryology: According to Lasjaunias, fenestration is the stable expression of an early & transient arterial constraint & not a true anatomical variation. Here, the two lumina correspond to a single path. [14]

Significance: It is important to detect this variation in order to prevent any iatrogenic injury during endovascular interventional procedures because the lumen of each fenestrated segment is much smaller than the entire calibre of the normal segment. It is also imperative to identify this entity so that a fenestrated segment is not mistaken as a focal dissection.

Fig 5: a) Long cervical fenestration. Note the direct origin of the left vertebral artery from the arch. **b):** Selective injection of the vertebral artery demonstrates two separate lumina of the cervical segment of vertebral artery. The vertebral artery divides into two lumina at the level of C7 & then reunites at the level of C4. The calibre of each artery differs but the walls are smooth. Distally the vertebral artery continues as a single vessel. **c)** Unsubtracted image of the fenestrated left vertebral artery shows the extraforaminal course of the vessel.

4) **Intradural duplication of vertebral artery:** A vessel corresponding to an intradural vessel – the lateral spinal artery which accompanies the spinal nerve [fig 6].

Embryology: Duplication recruits two different channels. Here, an additional vessel persists; one of the vessels leaves the vertebral canal to enter the spinal canal. It takes a subarachnoid course, which starts & ends at two different segmental levels. [14]

Significance: The size of the two channels is usually asymmetric – it should not be mistaken for pathology.

5) **Anomalous Origin of the right Vertebral Artery from the Common Carotid Artery:** Anomalousorigin of the vertebral artery from the common carotid artery is rare. [9,14] When it occurs on the right side, it is invariably associated with an ipsilateral aberrant right subclavian artery [9,14,15] [Fig 7]. It may also occur on the left. The embryological explanation for the right & left variants is different. [16]

Embryological Basis of right variant: One of the mechanisms described for VA arising from CCA is the persistence of lower CIA (third to sixth) and an involution of the ipsilateral middle dorsal aorta between the persistent CIA and the seventh CIA. [17] In this type, because of the persistent lower CIA, the vertebral artery comes in contact with the proximal dorsal aorta and fourth aortic arch, which in turn connects to the common carotid artery; and because of the involution of the ipsilateral middle dorsal aorta, the remaining ipsilateral seventh CIA connects to the contralateral dorsal aorta, which results in an ipsilateral aberrant subclavian artery. [16]

Significance: Aberrant origin of VA from CCA is commonly associated with other vascular anomalies. Hence aortic arch injection (using a pigtail catheter) with demonstration of sequence of origin of the great vessels of neck is essential in such cases. This gives a correct mapping of vessels & hence

saves undue efforts in searching the variant vessel.

Fig 6: Intradural duplication of VA: There are two different channels of VA.The medial limb has a subarachnoid course.

Fig 7: a) The right subclavian artery injection: The origin of VA is not visualized at its usual location.
b) Aortic arch injection: Note the sequence of origin of vessels: The right CCA is the first branch to arise from the arch while the right subclavian is the last branch to arise from the arch.
c) Right common carotid artery injection shows right VA arising from the proximal CCA.

6) **Proatlantal artery type II:** Named by Padget, the Proatlantal intersegmental (PAIS) artery is the artery between the occipital somite and the cervical somite that accompanies the first cervical nerve and provides communication between the forming carotid and vertebral circulation. [18] It is thought to contribute to the horizontal or suboccipital segment of the vertebral artery and also to the occipital artery. [19] [Fig 8].

Embryology: The PAIS artery is the major blood supply to the posterior circulation until the definitive vertebral arteries form from the sixth intersegmental arteries at the 12-mm embryonic stage, by which time 2 longitudinal arteries fuse to form the basilar artery. The proatlantal artery usually involutes by the 12- to 14-mm embryonic stage. Rarely, it fails to regress and persists into adult life. [18]

The PAIS artery is of 2 types: Type I corresponds to the first segmental artery and arises from the cervical part of the internal carotid artery. Type II arises from the external carotid artery and corresponds to the second segmental artery. The PAIS - II ascends lateral to the transverse processes of the first cervical vertebra in the neck up to the medial aspect of the mastoid process to join the vertebral artery as seen in the anteroposterior view. In the lateral view, it ascends obliquely posterosuperiorly and passes at the level of the foramen transversarium of the atlas.

Significance: Selective injection of external carotid artery is essential to look for the PAIS artery type II when the VA is not visualized in its usual position.

7) **Vertebro basilar junction fenestration with aneurysm:** Basilar artery fenestration is most commonly located in the proximal basilar trunk close to the vertebro-basilar junction & is reported in 0.6% of angiograms. [11] The incidence of an aneurysm in the presence of a basilar fenestration is reported to be 7%. [12] [Fig 9]

Embryology: The basilar artery is formed by the fusion of two primitive longitudinal neural arteries during the second to fourth stage of embryonic development. The fusion usually occurs during the fifth week of fetal life when the two primitive arteries of the ventral side of the neural tube are approximately 5-6 mm long. In the first steps of this fusion the basilar artery shows multiple irregularities and includes many cell islands. If these cellular islands persist they produce separation of the longitudinal neural arteries; that is, fenestration. [13] The relation of vertebrobasilar junction aneurysms with basilar fenestration is well established and explained by intrinsic defects in the

medial vessel wall of fenestrated arteries.

Significance: Identification of fenestration is important to decide whether the parent bridging artery can be sacrificed or should be spared in the process of coil occlusion of the aneurysm.

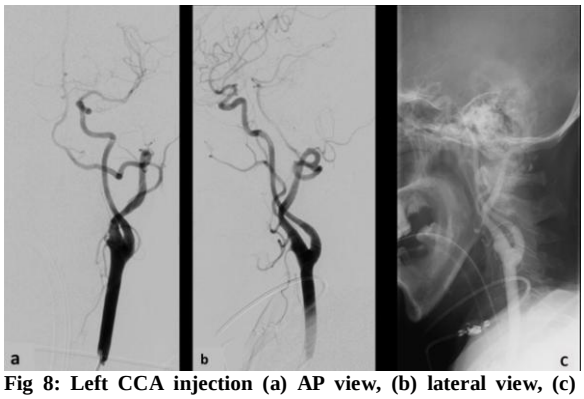

Fig 8: Left CCA injection (a) AP view, (b) lateral view, (c) unsubtracted lateral view show proatlantal intersegmental artery type II (black arrow). ICA (white arrow), ECA (open arrow).

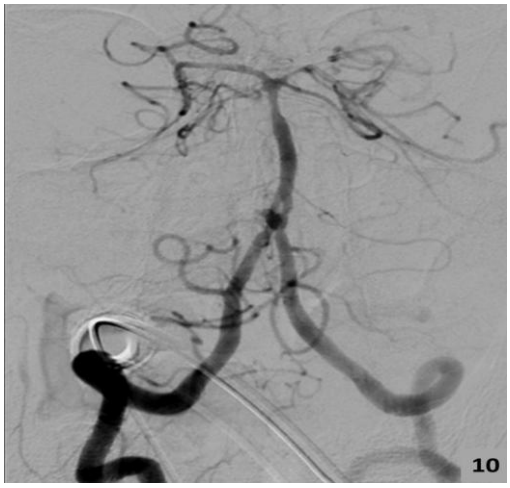

Fig 9: Right VA injection straight AP view shows the fenestration at the vertebro-basilar junction. Fenestrations are usually associated with aneurysms – as is noted here.

CONCLUSION

In summary, anatomic variants of vertebral artery in neck have been documented well in the literature. However, awareness of these anomalies during routine diagnostic cerebral angiography is crucial when searching for a vessel that doesn't arise in its usual position. Whenever there is doubt regarding the origins of the great vessels of the neck during diagnostic cerebral angiogram, a pigtail injection of the arch followed by selective injections as indicated, is mandatory. Knowledge of normal anatomy and variations of vertebral artery is of utmost importance while performing any endovascular procedure in order to prevent any iatrogenic injury as this vessel supply the vitals structures of the brain.

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