

Understanding the Course of Vertebral Artery at Craniovertebral Junction in Occipital Assimilation of Atlas: Made Simplified Using Conventional Angiography

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Abstract

Introduction Preoperative assessment of vertebral artery (VA) is important to avoid its injury during surgery at craniovertebral junction (CVJ). The main concern is the course of third segment of VA (V3) while performing instrumentation at CVJ, that is, segment of VA from its course through transverse foramen of C2 to its course along the posterior arch of C1. This segment of VA includes its passage through C1 transverse foramen as well. This observational study was done to analyze the course, curvature, and termination of VA in patients with occipital assimilation of atlas at CVJ, a complex congenital anomaly, and compared with the normal course for better understanding especially by young neurosurgeons and spine surgeons.

Materials and Method This is an observational study that included patients with occipitalized C1 with or without associated anomalies. Out of 30 patients of CVJ anomalies, 16 patients had occipitalized atlas. Digital subtraction angiography was done in all cases. It was done by selectively catheterizing the VA using standard Seldinger's technique and both anteroposterior and lateral projections were taken.

Results The course of VA was not identical on either side in any individual. It was lengthened and tortuous in all patients. Different types of anomalous course were encountered like bypassing transverse foramen of C1, close relation with C1–2 facet joints, variable course along the posterior arch of C1, abnormal termination and fenestration of VA.

Conclusion Craniovertebral junction anomalies are not only bony or neural, but are vascular too. Complex CVJ anomalies are associated with higher incidence of anomalous course of the VA, an important surgical consideration.

Keywords

- ▶ assimilation of atlas
- ▶ C2-segmental type of vertebral artery
- ▶ vertebral artery (VA)
- ▶ anomalous course
- ▶ digital subtraction angiography (DSA)

Introduction

Preoperative assessment of course of vertebral artery (VA) is crucial in the management of craniovertebral junction (CVJ) anomalies to avoid injury to it. There are studies regarding

bony suitability for screw insertion in C1 and C2 vertebrae^{1,2} and few about vascular suitability for instrumentation at this region.³ In this study, course of VA at CVJ in patients with occipital assimilation of atlas with or without other bony segmentation defects was evaluated and compared with

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normal course of VA for better understanding by neurosurgeons as described in standard textbook of neuroradiology.⁴ Occipitalization of C1 was preferred, because it is one of the commonly encountered complex bony CVJ anomalies, in which posterior arch of atlas is partially or completely assimilated with basi-occiput and related with lateral mass screw insertion.

Materials and Method

A total of 30 patients were subjected to digital subtraction angiography (DSA) by neurosurgeons trained in neuroangiography and neurointervention. The angiograms were done to evaluate the course of VA at C1 to C2 level. Out of 30 patients, 16 had occipitalization of atlas. Six patients had basilar invagination, six had Klippel–Feil anomaly and basilar invagination, three had hypoplastic C2, and single patient had glomus jugulare mass (Table 1). Patients with atlantoaxial dislocation without occipitalization of atlas were excluded from the study. Neurological deficits were in the form of spastic quadriparesis and/or cerebellar signs, cranial nerve palsy, and occipital neuralgia. Patients with glomus jugulare tumor had no neurological deficit but had short neck and were subjected to angiography to look for vascularity of the tumor.

Radiological workup of all patients was done by means of dynamic X-rays of CVJ and cervical spine, 5-mm thick CT scan slices, and MRI.

Informed consent for the procedure, sensitivity to injection xylocaine, and omnipaque dye were ensured in all. Angiogram was done by cannulating the femoral artery as per standardized protocol described by Seldinger.⁴ Five or four French catheter was used to cannulate the VA depending on the diameter of the VA. Dye was injected manually and ~5 to 6 mL of omnipaque dye for each injection was used, maximum of six injections needed.

The normal course of VA based on DSA is described in **Fig. 1** for understanding the abnormal course better.

Results

Course, length, and curvature of VA were not identical on both the sides in any of the angiogram. Lengthening and/or tortuosity of VA was seen in all the patients and was described when there was more than one loop on lateral angiogram. The radiological anatomy and angiographic findings are tabulated in **Table 1**.

In 8 out of 16 patients, VA was forming first corner of the square but not the second corner of the square of V3 segment of VA on one side and in two patients both the sides. In all these patients, the vertical limb of V3 was also medially deviated rather than vertical straight as shown in normal AP VA angiogram. In these patients, the artery was taking medial course after emerging from the transverse foramen of the C2 vertebra but not passing through the transverse foramen of C1 vertebra. It was in close relation to the posterior aspect of C1–2 facet joint (**Figs. 2, 3, 4, 5**).

Patients with basilar invagination had variable termination of the VA. Two patients had fenestrated terminal part of

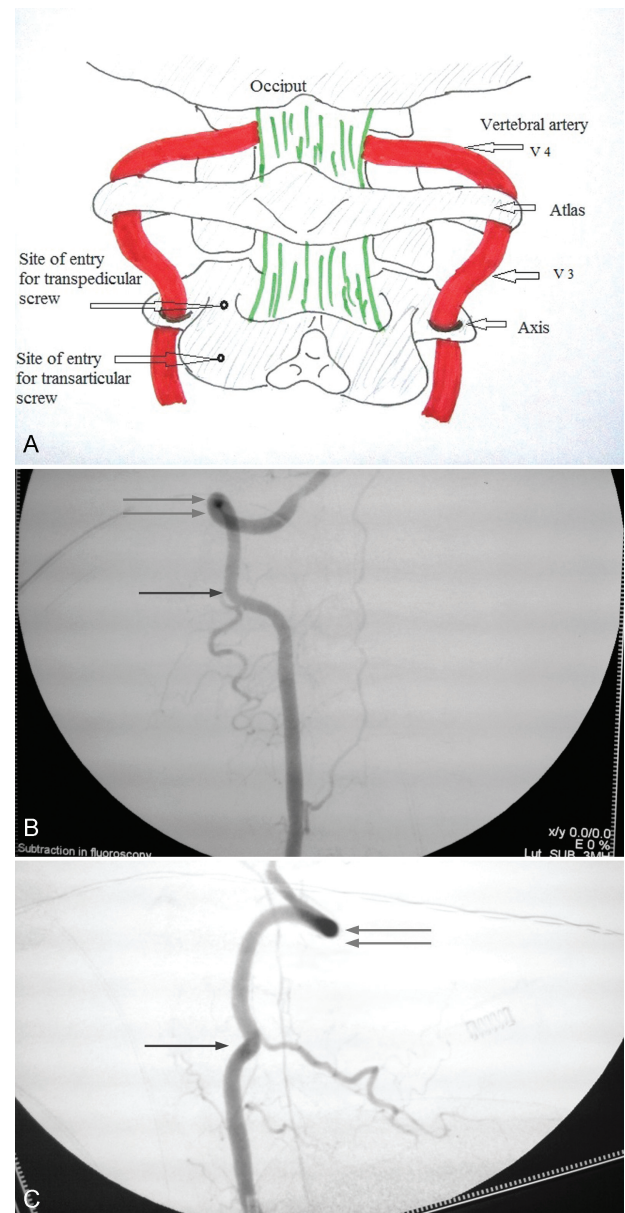


Fig. 1 (A) Diagrammatic presentation of normal course of the vertebral artery traversing both atlas and axis transverse foramen and site of entry of screws. The normal course of vertebral. Normal course of the vertebral artery as seen in DSA, AP view (B) and lateral view (C). In AP view, the course of third segment of VA (V3) appears like half a square (from double arrow to single arrow). At first corner of square it exits from C2 transverse foramen, and at second corner it runs along the posterior arch of atlas and in between two arrows it traverses through C1 transverse foramen. In lateral view, when it exits from C1 foramen, it appears like "hair pin."⁴ The normal course of vertebral.

VA extending into basilar artery (**Fig. 6**). One patient had aplastic left VA and another patient had one-sided VA terminating into two branches, that is, posterior inferior cerebellar artery and occipital artery (**Fig. 7**).

In all the patients except four, normal hair pin-like appearance of VA, which is formed along the posterior arch of atlas, was missing. Four patients had variable course of VA along the posterior arch of atlas. In three patients, there was

Table 1 Patient's data depicting radiological and angiographic findings

| S. no | Age/sex | Radiological finding | Angiographic finding |
|-------|------------|---|---|
| 1 | 18 years/M | Occipitalized posterior arch of C1 with BI | Left VA bypassing C1 transverse foramen |
| 2 | 25 years/M | Occipitalized posterior arch of C1, Klippel Feil anomaly with BI | VA bypassing C1 transverse foramen bilateral, tortuous anterior convex curve of VA |
| 3 | 55 years/M | Occipitalized posterior arch of C1 with BI | Left VA bypassing C1 transverse foramen |
| 4 | 25 years/M | Occipitalized posterior arch of C1 with BI | Bilateral tortuous vertebral artery |
| 5 | 28 years/F | Occipitalized posterior arch of C1, Klippel Feil anomaly with BI | Left vertebral artery making a loop on the medial aspect of C1–2 joint, stagnation of dye, right VA bypassing C1 transverse foramen |
| 6 | 35 years/M | Occipitalized posterior arch of C1 with BI | Vertebral artery is tortuous, left VA by passing C1 transverse foramen, pin-shaped loop along the posterior element of C2 rather than along C1 |
| 7 | 30 years/F | Occipitalized posterior arch of C1 with BI | Left VA bypassing C1 transverse foramen, tortuous, dissection of vertebral artery at C2–3 in the form of stagnation of dye |
| 8 | 18 years/M | Occipitalized posterior arch of C1, Klippel Feil anomaly with BI | Right VA bypassing transverse foramen of C1, stagnation of dye |
| 9 | 25 years/M | Occipitalized posterior arch of C1, Klippel Feil anomaly with BI | Left VA bypassing C1 transverse foramen, duplicated vertebral artery |
| 10 | 23 years/M | Occipitalized C1, posteriorly directed C2, hypoplastic C2, AAD | Left vertebral artery making tortuous loop in spinal canal, right vertebral artery not occupying posterior arch of atlas |
| 11 | 16 years/F | Occipitalized C1, posteriorly directed C2, foramen magnum narrowing | Left VA bypassing C1 foramen, tortuous, right vertebral artery with large PICA, and abnormal communication with occipital artery |
| 12 | 13 years/M | Occipitalized C1, reducible anomaly, C2–3 and C3–4 partly fused | Right vertebral artery not occupying posterior arch of atlas, left vertebral artery terminating into PICA, both vertebral arteries tortuous and lengthened left more than right |
| 13 | 46 years/F | Occipitalized C1, foramen magnum narrowing | Lengthened and tortuous vertebral artery |
| 14 | 25 years/F | Occipitalized C1, glomus jugulare mass | VA bypassing C1 transverse foramen |
| 15 | 18 years/M | Occipitalized C1, BI | VA bypassing C1 transverse foramen, convex anteromedial loop along the anterior aspect of body of axis vertebra |
| 16 | 18 years/M | Occipitalized C1 with AAD and Klippel Feil anomaly | VA bypassing C1 transverse foramen bilateral |

Abbreviations: AAD, atlantoaxial dislocation; BI, basilar invagination; VA, vertebral artery.

stagnation of dye in arterial phase after clearance of the dye from the venous sinuses and jugular vein.

Discussion

The reported incidence of VA injury in CVJ anomalies during instrumentation is 4.1% by Wright and Lauryssen.⁵ The incidence of variations in the course of VA is 2 to 3% in normal population and up to 20% in patients with CVJ anomalies.^{6,7} In this study, 66.6% of individuals with occipitalized C1 posterior arch with or without associated anomalies showed abnormal course of VA, as if C1 arch decides the course of VA. Vertebral artery was in close relation to the posterior aspect of the C1 to C2 facet joint and was not occupying the C1 transverse foramen. Sato,⁸ Tokuda et al,⁹ and Sardhara et al³ have

reported its incidence to be 0.6%, 0.7%, and as high as 64%, respectively. Their study was based on CT or MR imaging. In this anomaly, the transverse foramen of atlas exists but is occupied by a vertebral vein and lacks artery.¹⁰ After emerging from the C2 transverse foramen, VA normally courses in the spinal canal between C1 and C2, and ascends in anterior two-third of the spinal canal to join its counterpart. On angiogram, if the second corner of the square made by the V3segment of VA is found to be missing on anteroposterior projection of angiogram, it is described as C2-segmental type of VA anomaly.

The screw trajectory described for transarticular C1–2 screw fixation is medial, away from transverse foramen of atlas.^{11,12} However, in the above-described anomalous course of VA, since the artery is in close relation to C1–2 facet joint



Fig. 2 Lateral view showing left VA that is not passing through the C1 transverse foramen. The V4 segment is lengthened making antero-medial loop at C2 body and entering into the spinal canal, going superomedial to form basilar artery (basilar invagination, occipitalized C1 both sides).



Fig. 3 Lateral view showing left VA that is not passing through transverse foramen of atlas (basilar invagination, occipitalized C1).

and bypassing the transverse foramen, transverse foramen of C1 may be considered as a landmark to direct the screw rather than avoiding it. At the same time, the artery would be encountered medially during the dissection at C1 and C2. Moreover, VA is in close proximity to C1–2 facet joints; the hub of the screw may compromise the vessel and C1–2 fixation is not without danger of injuring the VA.^{13–15}

Out of 16 individuals with occipitalized atlas, VA was not passing over the posterior arch of C1 in 12 individuals, that is, in 75% cases. Francesco et al⁶ and Tubbs et al¹⁶ have described the same in 57 and 67% of the normal subjects, respectively. This shows that even in normal subjects also, the typical

normal course still has variations along the posterior arch of atlas which has higher incidence in patient with occipitalized atlas.

Tortuous and lengthened VA was a consistent finding. There was evidence of slowing of circulation in few patients, an indicator of VA dissection. The acute VA angulations in the presence of an occipitalized atlas, its stretching due to presence of AAD, and its medial deviation due to C1–2 facet asymmetry may lead to an earlier compression of the VA during axial neck movements and perhaps would have predisposed to early vascular changes in the form of intimal trauma manifesting as stagnation of dye, that is, slowing of circulation.^{3,17}

Other reported VA anomalies such as abnormal termination were also found in few of the patients. Persistent first intersegmental artery and fenestration occur in 0.67 and 1%, respectively, patients without CVJ anomaly but with bony anomalies—like occipitalization of atlas, Klippel–Feil syndrome or os odontoideum incidence is 19 and 36.4%, respectively.^{7,9,18}

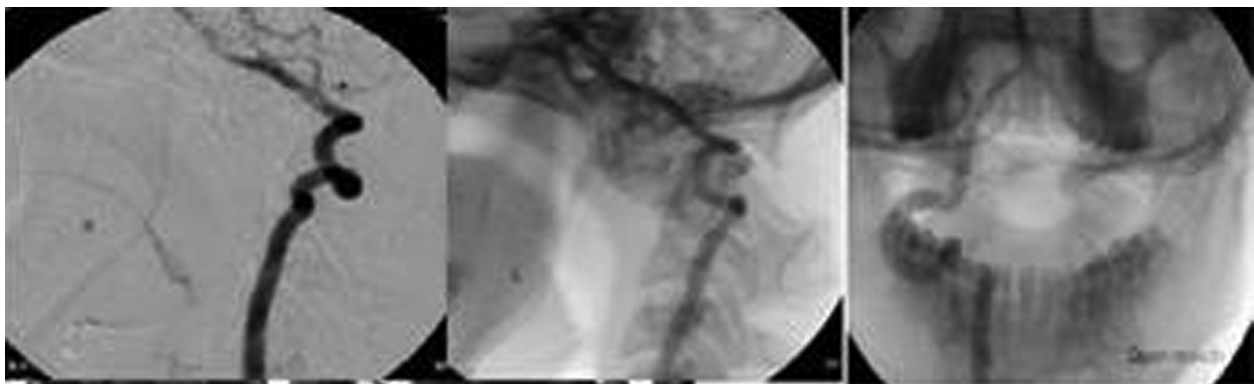


Fig. 4 Lateral and AP views of left vertebral angiogram showing lengthened VA, bypassing transverse foramen of C1.

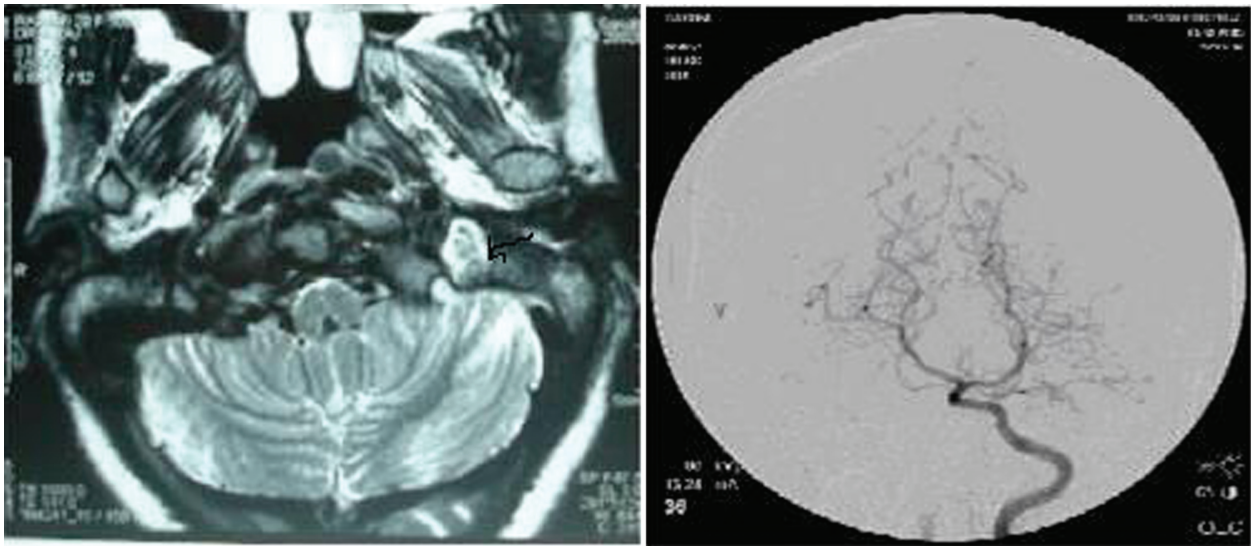


Fig. 5 MRI T2 axial cut of foramen magnum of a patient with asymptomatic occipitalized atlas and left glomus jugulare tumor shown by an arrow. DSA AP view of same patient showing C2 segmental artery.



Fig. 6 AP view of DSA showing fenestrated terminal part of vertebral artery and proximal portion of basilar artery with reversed medial projection of part of vertebral artery between C1 and C2. Left C2 segmental type of vertebral artery patients with basilar invagina.



Fig. 7 Lateral view of DSA showing vertebral artery terminating into occipital artery and PICA, remaining vertebral supply is from contralateral artery. One patient had aplastic left.

of VA. The trajectory of screw placement needs to be modified based on the course of VA at C1 and C2.

Conclusion

Congenital CVJ anomalies are not only bony or neural anomalies but vascular anomalies as well. Symptomatic or asymptomatic individuals with occipitalized atlas have a very high incidence of abnormal course of VA especially the third segment and perhaps C1 posterior arch decides the course

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