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CASE REPORT

The impact of an anomalous third segment of the vertebral artery on bypass surgery: a case report and literature review

Yike Zhao[1]
Fangzhou Liu[1]
Fazheng Shen[2]
Jianing Liang[2]
Xinli Zhao[2]

Author details can be found at the end of this article

Correspondence to:
Yike Zhao (zyk824380900@163.com); Xinli Zhao (13782510911@163.com)[2]

Abstract

The horizontal part of the third segment (V3) of the vertebral artery (VA) is a critical anastomotic site for bypass procedures involving either donor or recipient vessels. It is rare for the V3 segment to deviate from its typical course of passing through the atlanto-transverse foramen. V3 anomaly encountered in occipital artery (OA)-V3 bypass surgery has not been previously reported. Here, we present a case involving a patient undergoing bypass surgery due to recurrent post-stent occlusion at the first segment (V1) of the left VA. During the operation, it was noted that the V3 horizontal segment could not be identified within the left VA groove, leading to initial suspicion of left V3 disuse atrophy attributed to prolonged chronic ischaemia. Consequently, there was a need to modify the operative method and to transition from an OA-V3 bypass to an OA-posterior inferior cerebellar artery bypass. Post-operative computed tomography angiography confirmed that indeed, the left V3 did not traverse through the transverse foramen of the atlas and instead entered the dural membrane between the first cervical vertebra (C1) and the second cervical vertebra (C2).

Key words: Atlanto-transverse foramen; Bypass; Occlusion; Stent; Vertebral artery

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Introduction

The third segment (V3) of the vertebral artery (VA) is a common site for bypass anastomosis as a donor or recipient vessel (Wang et al, 2019; Ota et al, 2021). The incidence of V3 variants is very low in the normal population. Xing et al (2021) found that the incidence of the V3 segment anomaly of VA was 0.94%, and that the V3 segment anomaly had a significant impact on surgery. Omotoso et al (2023) reported that 197 (1.8%) out of 10,820 patients had persistent first intersegmental arteries. To our knowledge, there have been no previous reports of V3 anomaly encountered in occipital artery (OA)-V3 bypass surgery. In the present case, intraoperative identification of the V3 level within the left VA groove was unsuccessful. This led to speculation that chronic ischaemia may have resulted in atrophic changes in the left V3 segment. Consequently, the procedure was modified from extracranial bypass to extracranial-intracranial bypass.

Case report

History

A 72-year-old Chinese female presented to the First Affiliated Hospital of Xinxiang Medical University with a 10-year history of intermittent dizziness and a medical background including stent placement for left VA stenosis. The patient's initial dizziness was insidious in onset and mild in intensity, prompting minimal concern at first. However, 3 years ago, as her symptoms progressed, she sought care at a local hospital where a diagnostic evaluation revealed a severe stenosis of the left VA orifice (the imaging data from that evaluation were not available for the present report). Subsequently, the first stent was placed at that hospital. 2 years ago, upon the recurrence of symptoms and imaging revealing re-narrowing of the left VA ostium, a second stent was placed at the same medical facility. Despite these procedures, the patient experienced an episode of syncope a year ago following another

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bout of dizziness. She regained consciousness spontaneously and received intravenous treatment at the above-mentioned hospital before being discharged. Six months ago, she presented with postural dizziness and was admitted to our department with a preliminary diagnosis of "cerebrovascular stenosis" following outpatient consultation. Before the bypass procedure, the patient had maintained intact cognition and activities of daily living despite her medical challenges. Additionally, she had managed hypertension for 8 years through consistent medication adherence (Nifedipine sustained-release tablets, 10 mg/day, qm and enalapril tablets, 10 mg/day, qn). This patient had no history of allergies, a history of one pregnancy and childbirth (a healthy male), cessation of menstruation at the age of 52, deceased parents with unknown cause of death, and one healthy brother.

Physical examination and laboratory tests

Upon neurological examination, the patient was alert and fully oriented with a normal gait and absence of ataxia. No abnormal eye movements or other pathological signs were noted. The laboratory findings revealed no abnormalities (Table 1).

Imaging examination

Digital subtraction angiography (DSA) findings revealed the following (Figures 1A–F): ①Occlusion was observed in the first segment (V1) of the left VA, with a metal stent approximately 44.38 mm in length. ②The right VA only supplied the ipsilateral posterior inferior cerebellar artery (PICA), and the distal part of the right fourth segment (V4) of the VA was absent. ③Three small branches of the left deep carotid artery were anastomosed with the second segment (V2) of the left VA and the vertical part of the left V3, respectively, to supply the vertebrobasilar arterial system with blood flow into bilateral superior cerebellar arteries (SCA), with no blood flow into the posterior cerebral artery (PCA). ④The left internal carotid artery (ICA) supplied the ipsilateral PCA, but did not provide supply to the basilar artery (BA) through the first segment of the PCA (P1). ⑤The right ICA supplied the ipsilateral PCA, but did not provide supply to the BA through P1. ⑥The left OA was well developed.

High-resolution magnetic resonance imaging (HR-MRI) demonstrated (Figures 2A–C): ①Thinning of the BA with thickening and roughness of its wall, resulting in slight narrowing of its lumen. ②Both sides of PCA originated from the ipsilateral ICA, with thickening of the arterial wall and slight narrowing observed in the left P1. ③Possible presence of unstable plaques on the left V3 and V4 arterial walls leading to mild luminal stenosis. ④The distal part of the right V4 was not visualised. The HR-MRI also indicated potential instability

Table 1. Laboratory findings

Item	Normal range	Test value
White blood cells (10^9/L)	3.5–9.5	4.60
Haemoglobin (g/L)	115–150	119
Platelets (10^9/L)	125–350	189
Haematocrit (%)	0.35–0.45	0.366
Total protein (g/L)	65–85	66.9
Albumin (g/L)	40–55	40.8
Creatinine (mmol/L)	41–81	47.2
Glucose(mmol/L)	3.89–6.11	5.09
Potassium (mmol/L)	3.5–5.3	4.69
Sodium (mmol/L)	137–147	141
Chlorine (mmol/L)	99–110	105.9

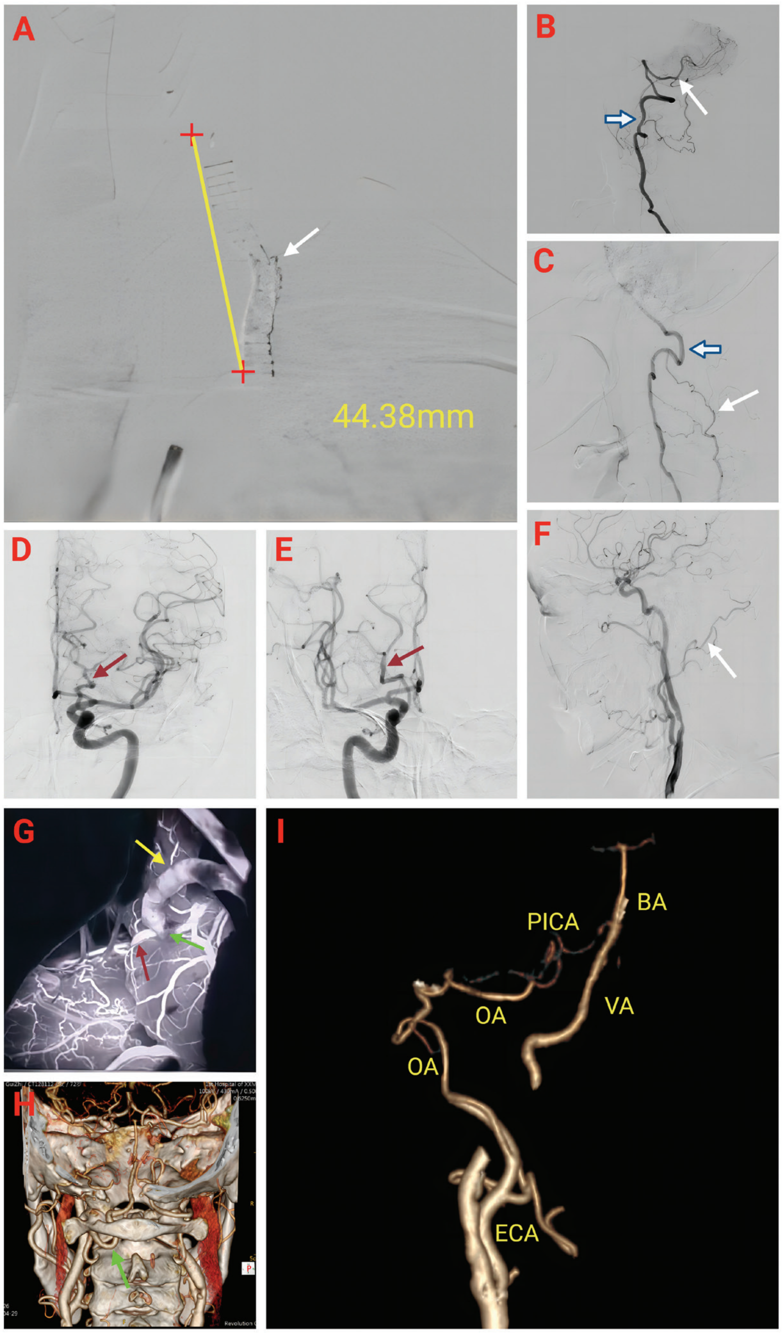

Figure 1. A. Occlusion was observed in the first segment (V1) (white arrow) of the left vertebral artery (VA), with a metal stent approximately 44.38 mm in length. B. The right VA supplied the ipsilateral posterior inferior cerebellar artery (PICA) (white arrow), and there was under development in the distal part of the fourth segment (V4) (blue arrow—right V3 vertical segment of VA). C. Three small branches of the left deep carotid artery (white arrow) were anastomosed with the left second segment (V2) and vertical segment of the left third segment (V3), respectively, to supply the vertebrobasilar arterial system with blood flow into the bilateral superior cerebellar arteries (SCA), with no blood flow into the posterior cerebral artery (PCA) (blue arrow—left V3 vertical segment of VA). D. The left internal carotid artery (ICA) supplied the ipsilateral PCA (red arrow) but did not provide supply to the basilar artery (BA) through the first segment of the PCA (P1). E. The right ICA supplied the ipsilateral PCA (red arrow) but did not provide supply to the BA through P1. F. The left occipital artery (OA) (white arrow) exhibited good development. G. Intraoperative indocyanine green angiography showed smooth anastomosis (yellow arrow-OA, red arrow-PICA, green arrow-anastomotic site). H. Postoperative computed tomography angiography (CTA) showed that the left VA (green arrow) did not pass through the left first cervical vertebra (C1) transverse foramen and ran between C1 and the second cervical vertebra (C2). I. Postoperative CTA showed unobstructed OA-PICA bypass. ECA, external carotid artery.

within certain areas such as possible plaque formation along the left V3 and V4 segments causing mild luminal stenosis.

Preoperative preparation

For the management of posterior circulation ischaemia, the family members declined intravascular stent treatment and opted for a bypass intervention after being informed of the imaging features in detail. Following meticulous preoperative preparation, comprehensive discussions, and formulation of the surgical plan, the patient and her family were apprised of the procedural details and potential risks. Informed consent was obtained to proceed with a left OA-V3 bypass.

Major surgical procedures

A left-far lateral approach was adopted. During the surgical procedure, following routine exposure of the left VA notch, only a faint pulse was observed in the tissues between the VA notch and the foramen magnum, with no discernible VA pulsation palpable. To confirm the patency of the VA, further dissection was performed along the entire length of the left atlanto-VA groove, extending outward to the atlanto-transverse foramen and exposing forward to the atlanto-occipital joint, upward to the foramen magnum, and deep to dura mater. It was ascertained that the VA coursed solely within the tissues between the posterior arch of the atlas and foramen magnum. The venous plexus was meticulously dissected layer by layer deep to the dura mater, revealing only a delicate greyish-white cable structure resembling cotton thread originating from the left transverse foramen and entering the dura mater near the midline, with weak pulsations at both ends. No dilation was noted after the application of a papaverine-soaked cotton pad, and no lumen was observed upon cutting. Given concerns that long-standing chronic ischaemia at the V3 level had led to atrophy, degeneration, and occlusion and that this posed a significant surgical challenge, preoperative imaging was carefully studied again and revealed a well-developed ipsilateral PICA suitable as a recipient vessel, prompting preparation for a left OA-PICA bypass which could be performed through the existing incisions. After discussion among surgical team members

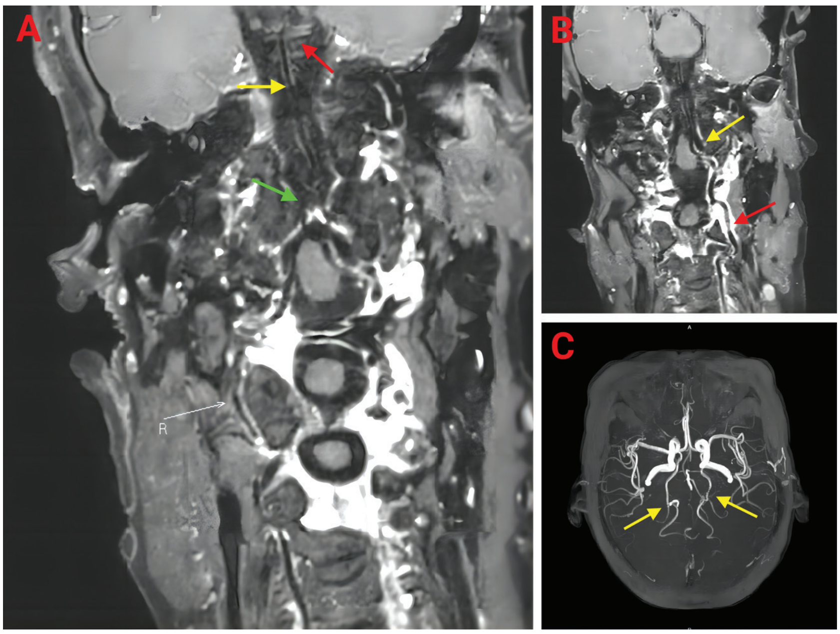

Figure 2. A. Thinning of the BA with thickening and roughness of its wall, resulting in a slight narrowing of its lumen (yellow arrow); Thickening of the arterial wall and slight narrowing observed in left P1 (red arrow); The distal part of the right V4 was not visualised (green arrow) (R long white thin arrow-right VA). B. Possible presence of unstable plaques on left V3 (red arrow) and V4 (yellow arrow) arterial walls leading to mild luminal stenosis. C. Both sides of PCA originated from ipsilateral ICA (yellow arrow).

and obtaining family consent with additional signatures acknowledging potential risks associated with the new surgical approach, the left OA-PICA bypass was performed, and intraoperative indocyanine green angiography showed anastomosis patency (Figure 1G).

Postoperative management

The OA-PICA bypass procedure was successfully executed and classified as a level 4 grade. Afterwards, the patient was transferred to the Neurosurgical Intensive Care Unit. On the first day post-surgery, the patient exhibited normal speech and limb movement while remaining alert. Computed tomography angiography (CTA) was performed and the findings were reviewed (Figures 1H,I). Subsequently, the patient was transferred back to the general ward. Discharge from the hospital occurred 10 days post-operation with prescribed oral aspirin 200 mg/day (half an hour before breakfast) and rosuvastatin 10 mg/day (before sleeping). Follow-up has been conducted for over 6 months without any emergence of new symptoms or signs.

Discussion

The posterior circulation is predominantly supplied by the vertebrobasilar artery system, with potential collateral support from the anterior circulation via the posterior communicating artery. In cases of normal bilateral VA supplying the BA, stenosis or occlusion of a single VA typically does not lead to posterior circulation ischaemia. However, in this specific case, there was a distal occlusion of the right V4 and a 44.38-mm-long intra-stent occlusion in the left V1 segment. The vertebrobasilar arterial system (to SCA) relied on three small anastomotic branches of the left deep carotid artery for blood supply. Bilateral ICA provided blood for ipsilateral PCA, but with no retrograde flow through P1 to the BA. Therefore, the clinical manifestations of posterior circulatory ischaemia such as dizziness, fall, and transient disturbance of consciousness were observed.

The standard surgical approach for treating posterior circulation ischaemia includes: ①The management of stenosis at the ostia of the VA, such as VA stenting, endarterectomy, and VA-common carotid artery transposition (Travers and Siddiq, 2021). ②Treatment through the distal VA, including external carotid artery (ECA)-V3 bypass, OA-V3 bypass (Wang et al, 2019), and facial artery-V2 bypass. ③Extracranial-intracranial bypass; for example, OA-PICA/anterior inferior cerebellar artery bypass (Ausman et al, 1990), superficial temporal artery-PCA/SCA bypass (Ausman et al, 1990; Sakamoto et al, 2023), and ECA-radial artery-PCA bypass (Zhang et al, 2023). In the present case, the distal end of the right V4 was occluded, and there was no retrograde blood supply to the BA through either side of the P1. The V1 segment of the left VA was occluded, and the left V2 to SCA segments were unobstructed. The three small branches of the left deep carotid artery were anastomosed with the left V2 and vertical segments of left the V3, respectively. The left OA was well developed. Therefore, the preoperative surgical plan was to perform a left OA-V3 horizontal segment bypass.

The prevalence of V3 variants varies across studies, ranging from 0.94% to 10% (Tokuda et al, 1985; Duntze et al, 2012; Xing et al, 2021; Omotoso et al, 2023), and exhibits geographical variation, with North Americans showing the lowest prevalence at less than 1% (Fortuniak et al, 2016). Furthermore, the occurrence of V3 variants is also closely associated with local anatomical variations in bone structure. Xia et al (2021) found the incidence of VA variations was 41% in patients with congenital cervical scoliosis. Hong et al (2016) reported the V3 segment anomaly was significantly common in cases with bony abnormality (29.2%). Lin et al (2021) reported that the total incidence of V3 segment anomaly in patients with bony abnormalities was 25.9%. The VA variations in the V3 segment mainly include persistent first intersegmental artery, fenestration, and the PICA branch originating from the C1/2 part (Vaněk et al, 2017). An additional variation involves anastomosis of the ECA and the V3 segment of VA (Uchino et al, 2018). In the present case, the patient's V3 anatomical anomaly involved a persistent first intersegmental artery. During the surgical procedure, it was challenging to locate the V3 horizontal segment in the left VA notch. Initially, it was misinterpreted as V3 disuse atrophy resulting from prolonged chronic ischaemia. Consequently, it was necessary to transition from an extracranial bypass to an extracranial-intracranial bypass. Subsequent postoperative CTA examination revealed (Figures 1H,I): ①A smooth OA-PICA anastomosis. ②The intact V3 did not traverse through the transverse foramen of C1 but instead entered the dural membrane between C1 and C2.

Reviewing the preoperative DSA of the patient, it was observed that the imaging had already indicated a significant length discrepancy between the left and right V3 vertical segments (Figures 1B,C blue arrow). However, due to sequential and separate angiography of the bilateral VA, visualisation of both sides' V3 segments was not on the same image, making direct comparison challenging. This disparity was overlooked. This underscores the importance for neurosurgeons, in future work involving V3, to pay attention to whether DSA examination results show symmetrical or asymmetrical bilateral V3, and to consider if further investigation is necessary.

During the surgical procedure, no bone abnormalities such as atlantolateral process, incomplete posterior arch, or retrotransverse foramen and atlantoaxial joint dislocation were found (Hong et al, 2008; Sanchis-Gimeno et al, 2018; Salunke et al, 2020; Xia et al, 2021). However, due to limited experience, we overlooked the possibility of V3 course abnormalities occurring in normal bone conditions. Post-surgery CTA revealed no abnormal bone structure in the local area of the atlanto-occipital region but did detect a V3 anomaly under the posterior arch of the atlas. This highlights the need for enhanced literature review of local anatomical structures associated with V3, in order to obtain a deeper understanding of local anatomical variations and to ensure smooth progress in future surgeries.

Conclusion

The V3 horizontal segment of the VA is typically the anastomotic site for bypass donors or recipients, and it is uncommon for the V3 segment to not traverse the atlanto-transverse foramen. If the V3 horizontal segment cannot be found in the VA groove during surgery, consideration should be given to the possibility of V3 variation, and separation of the V3 between C1 and C2 can be performed for extracranial bypass. This article presents only one case, and we are aware of no other cases of V3 bypass surgery involving V3 course abnormalities that have been reported until now. Further research is needed to investigate the impact of V3 anomaly on posterior cerebral ischaemia and the influence of V3-involved bypass procedures.

Learning points

- Before the operation, it is essential to have a comprehensive understanding of the local anatomical structure of the bypass.
- There should be alternative options available for bypass surgery.
- In the event that the V3 horizontal segment is not identified within the VA notch intraoperatively, it is imperative to contemplate the potential presence of a variant course of the V3 segment.

Author details

[1]Queen Mary School, Jiangxi Medical College, Nanchang University, Nanchang, Jiangxi, China

[2]Department of Neurosurgery, The First Affiliated Hospital of Xinxiang Medical University, Xinxiang, Henan, China

Availability of data and materials

All the data of this study are included in this article.

Author contributions

YKZ and XLZ were responsible for the design of the work. XLZ, FZS and JNL performed the research. FZL provided help and analyzed the data. YKZ drafted the manuscript. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the First Affiliated Hospital of Xinxiang Medical College (EC-024-364), and was conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki and informed consent obtained from the patient.

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Conflict of interest

The authors declare no conflict of interest.

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