Carotid Endarterectomy with Twisted Internal Jugular Vein Located Anterior to the Common Carotid Artery

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Abstract

The knowledge of both normal and abnormal anatomy of the veins of the neck may be important for surgeons performing carotid endarterectomy (CEA), to avoid inadvertent injury to vascular structures. We present three cases of abnormal course of the internal jugular vein (IJV) which run anterior to the common carotid artery, named twisted IJV, that usually run posterolateral to the common carotid artery in patients undergoing CEA. These twisted IJV cases were detected by preoperative multidetector computed tomography angiography evaluation. During the CEA procedure, before identifying the common carotid artery, we dissected the retromandibular space to find the common facial vein. Then, dissection proceeded along the common facial vein caudally to find the IJV. After ligation and cutting of the common facial vein, a carotid sheath with the IJV turned laterally revealed the common carotid artery safely, and CEA was accomplished. Our clinical experience shows that knowledge of the anatomical anomaly of the IJV allows safe dissection of the carotid triangle avoiding inadvertent injury to the vasculature and vagus nerve.

Keywords
- internal jugular vein variant
- carotid triangle
- neck surgery

Introduction

Complications associated with neck surgery include hemorrhage,[1] nerve damage,[2] and chylous fistula.[3] Successful surgical management of carotid endarterectomy (CEA) patients is therefore predicated on recognizing patient-specific anatomic structures that may increase the risk of an adverse outcome. The internal jugular vein (IJV) is the largest caliber blood vessel in the head and neck. The anatomy of this vessel is considered to be relatively stable, so it serves as a major surgical landmark for adjacent structures (e.g., spinal accessory nerve, carotid artery, cervical lymph nodes). Anomalies of the IJV, including duplications and fenestrations, have been reported,[4,5] but few attempts have been made to characterize the prevalence of IJV location anomaly[6,7] in surgical cases. Variations in the location of the IJV may account for iatrogenic IJV injuries, and might lead to IJV ligation. Adverse effects after IJV ligation include transverse sinus thrombosis.[8] Therefore, understanding the anomalies of the IJV is important to avoid iatrogenic damage during CEA. We report three cases of IJV anomalies in patients undergoing CEA from 2020 to 2022 and discuss the clinical implications, operative management, and literature describing IJV location anomaly.

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Table 1 Cases with twisted internal jugular vein

Case no.	Age (y)	Sex	Stenosis (%)	Site	Comorbidity	Symptom
1	81	Male	90	Left	DM, DLp	–
2	75	Male	80	Left	HT	Amaurosis fugax
3	70	Male	50	Left	DLp	TIA

Abbreviations: DLp; dyslipidemia; DM, diabetes mellitus; HT, hypertension; TIA, transient ischemic attack.

Materials and Methods

Patient Assessment

We treated 60 consecutive patients with internal carotid artery stenosis by CEA from January 2020 to December 2022. Three-dimensional computed tomography arteriography + venography (3D CTA + V) data were obtained preoperatively, which detected twisted IJV located anterior to the common carotid artery (CCA) in three patients (5%). All three patients were men with left-sided IJV anomaly, as summarized in ►**Table 1**. All three patients underwent CEA.

Surgical Technique of CEA for Patients with Twisted IJV

Under general anesthesia, a transverse skin incision was made using the left neck crease at the level of the carotid bifurcation. After dissection of the skin flap under the platysma muscle along to the great auricular nerve and the external jugular vein and reaching the surface of the parotid gland, the retromandibular space was carefully dissected along to the investing layer of the deep cervical fascia to find the posterior belly of the digastric muscle (PBDGM). The PBDGM is dissected as far as possible until the white tendinous part of the anterior part of the PBDGM was revealed. The common facial vein (CFV) was found at the superficial and anterior part of the PBDGM. Then, dissection proceeded along to the CFV caudally to find the anterior part of the carotid sheath and IJV. After ligation and cutting of the CFV, the anterior part of the carotid sheath with the IJV was dissected and the CCA identified, then turned laterally to reveal the external carotid artery, CCA, and internal carotid artery, and CEA was accomplished.

Construction of 3D CTA + V

To obtain cervical arterial and venous information, we used a 64-row multidetector computed tomography (CT) scanner (Aquilion; Canon, Inc., Tokyo, Japan). CT was performed according to the following parameters, briefly described as follows: 0.5-mm collimation, 3.5-mm table increment per rotation (3.5 helical pitch), 0.75-second r gantry rotation speed, and 120 kV/300 mA. Before scanning commenced, 60 mL (350 mg I/mL) of iomeprol contrast medium (Eisai, Tokyo, Japan) was injected via the right antecubital vein using a power injector (Nemoto, Tokyo, Japan) at a rate of 4 mL/s. Initiation of scanning was set with an automatic or visual bolus-tracking program, which was used to start the first arterial phase scan after the injection of contrast medium. Six seconds after arterial phase data acquisition, venous phase data collection was started. For our scanner, the effective dose for the original CTA data are around 1.5 mSv, calculated according to the National Radiological Protection Board W67. Axial slices were reconstructed with a 0.5-mm slice thickness at 0.3-mm intervals. The images obtained were transferred and processed using a stand-alone workstation (Ziostation 2; Ziosoft, Inc., Tokyo, Japan).

3D CTA + V images were produced by a technician by subtracting bone density structures using a subtraction mode in a workstation. First, subtraction images were produced which enhanced CT image data by subtracting plain CT image data. Then, an arterial image using 3D CTA was generated by employing a threshold technique and editing the image manually to remove any remaining bone of the cranial base using the subtraction image. 3D CTV image was also generated in the same manner. Then, anterior and lateral views of the 3D CTA + V fusion image were constructed.

Case Presentation

Case 1

An 81-year-old man with diabetes mellitus and dyslipidemia was admitted for left carotid stenosis up to 90%. 3D CTA + V revealed the IJV running anteriorly to the CCA in the lateral view (►**Fig. 1A**). Left CEA was performed. The CFV was found and dissected caudally and revealed the IJV (►**Fig. 1B**). After ligation and cutting of the CFV (►**Fig. 1C**), the carotid sheath with the IJV turned laterally revealed the external carotid artery, CCA, and internal carotid artery (►**Fig. 1D**), and CEA was accomplished. The vagus nerve was found posterior to the CCA. No cerebral infarction occurred postoperatively. He was discharged on the eighth postoperative day without any complications.

Case 2

A 75-year-old man with hypertension presented with a 2-week history of left amaurosis fugax and was admitted for left carotid stenosis up to 80%. 3D CTA + V revealed the IJV running anteriorly to the CCA in the lateral view (►**Fig. 2A**). Left CEA was performed. The CFV was found and dissected caudally and revealed the IJV (►**Fig. 2B**). After ligation and cutting of the CFV (►**Fig. 2C**), the carotid sheath with the IJV turned laterally revealed the external carotid artery, CCA, and internal carotid artery (►**Fig. 2D**), and CEA was accomplished. The vagus nerve was found posterior to the CCA. No cerebral infarction occurred postoperatively. He was discharged on the seventh postoperative day without any complications.

Case 3

A 70-year-old man with dyslipidemia presented with a 1-week history of transient right hemiparesis for 1 hour

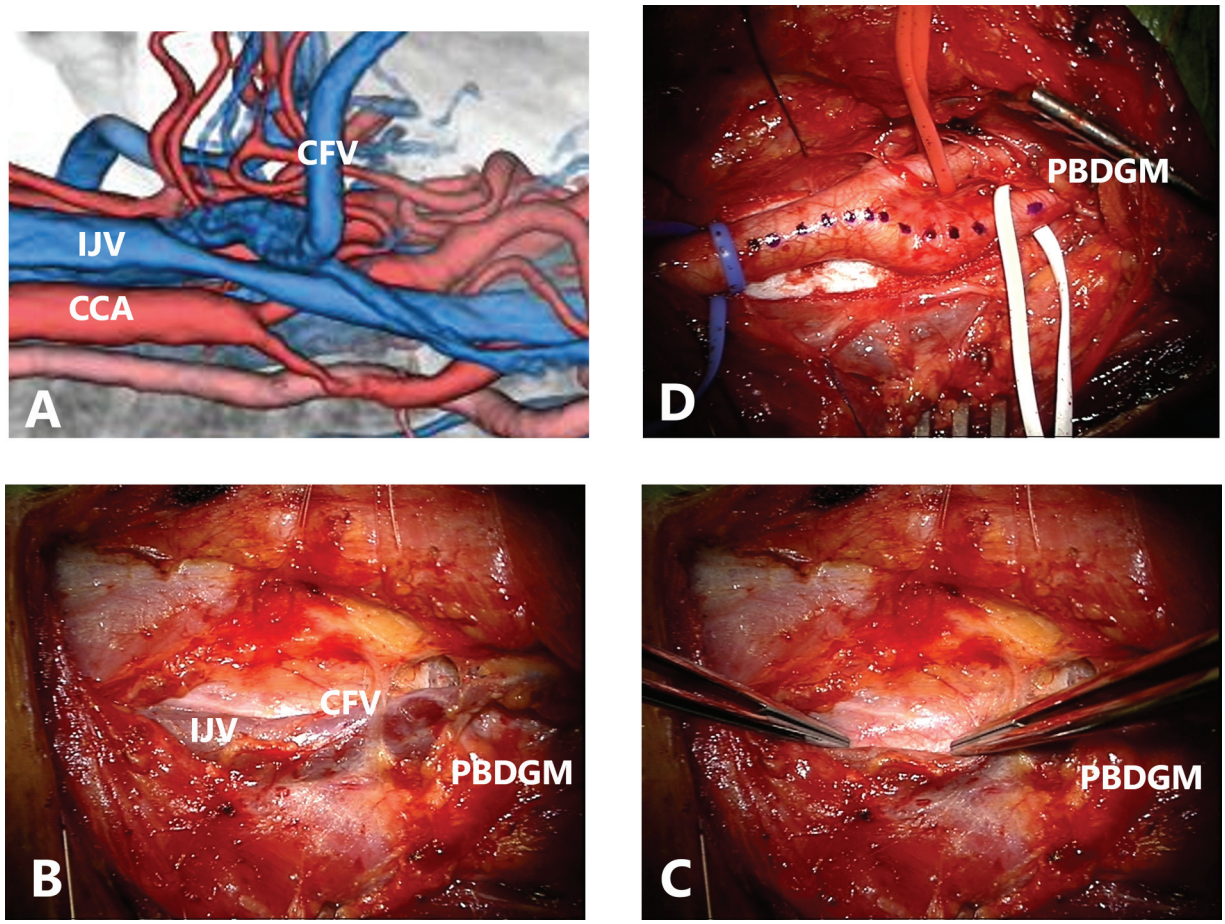

Fig. 1 Case 1. Three-dimensional computed tomography arteriography + venography, lateral view, revealed the left internal jugular vein (IJV) running anteriorly to the common carotid artery (CCA) (**A**). The common facial vein (CFV) was found and dissected caudally and revealed the IJV before carotid endarterectomy (**B**). After ligation and cutting of the CFV (**C**), the carotid sheath with the IJV turned laterally revealed the external carotid artery, CCA, and internal carotid artery (**D**). PBDGM, posterior belly of digastric muscle.

and was admitted for left carotid stenosis up to 50%. 3D CTA + V revealed the IJV located slightly anterior to the CCA in the lateral view (►**Fig. 3A**). Left CEA was performed. The CFV was found and dissected caudally and revealed the IJV (►**Fig. 3B**). After ligation and cutting of the CFV (►**Fig. 3C**), the carotid sheath with the IJV turned laterally revealed the external carotid artery, CCA, and internal carotid artery (►**Fig. 3D**), and CEA was accomplished. The vagus nerve was found posterior to the CCA. No cerebral infarction occurred postoperatively. He was discharged on the seventh postoperative day without any complications.

Discussion

Variations in the relationship between the IJV and CCA have been reported as the cause of unsuccessful IJV cannulations.[7,9] Two-dimensional ultrasonographic examinations of the right and left supraclavicular triangle in 219 adult individuals who had no history of neck surgery found an anterolateral location of the IJV to CCA was the most common configuration observed on both sides of the neck (84% right side and 91.8% left side), followed by the lateral (14.2% right and 6.4% left) and anterior (1.4% right and 1.8% left) locations.[6] Another study found the IJV was in the lateral and anterolateral positions in 86.66% of cases on the right and in 85% on the left.[10] Analysis of tomographic images identified an IJV medial of the CCA in 1.1% of cases.[11] We found a prevalence of 5.0% in our series, based on 3 of 60 neck dissections performed by a single surgeon at our institution from 2020 to 2022.

We usually performed CEA with the following procedure. The carotid triangle of the anterior cervical triangle is used as a landmark for the carotid arteries. The carotid triangle consists of three muscles, the sternocleidomastoid muscle, the omohyoid muscle, and the PBDGM. After skin incision, dissection is performed along to the anterior border of the sternocleidomastoid muscle to find the omohyoid muscle, and reveal the CCA in the carotid sheath at the lower corner of the carotid triangle. At this level, the carotid sheath encloses the CCA, IJV, and vagus nerve, of which the CCA is located anteromedial, the IJV posterolateral, and the vagus nerve posterior,[12] allowing the CCA to be secured without interference from the IJV or vagus nerve. However, in the case of the IJV located in unusual positions, such as anterior or medial to the CCA, the IJV is disturbed before reaching the CCA and may suffer injury. Furthermore, since the CCA is located posteromedial to the jugular vein, dissection behind the IJV may cause injury to the vagus nerve. The anatomical

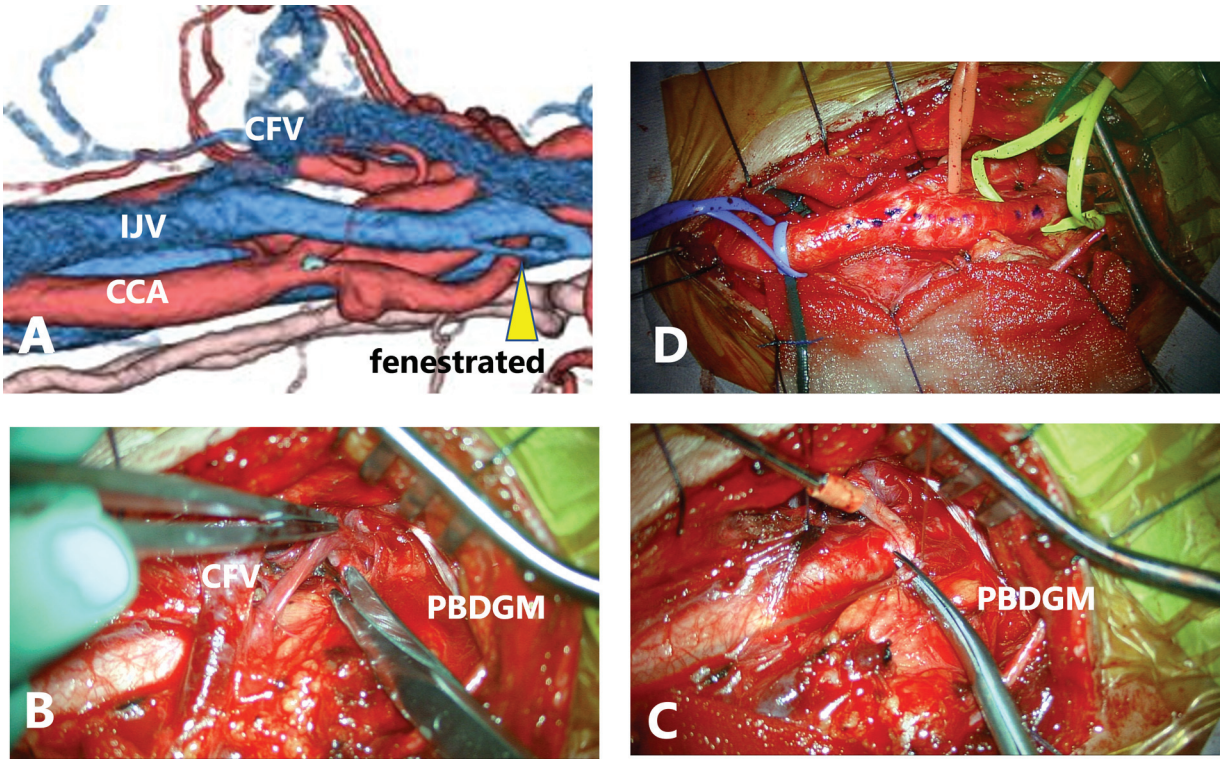

Fig. 2 Case 2. Three-dimensional computed tomography arteriography + venography, lateral view, revealed the left fenestrated internal jugular vein (IJV) (arrowhead) running anteriorly to the common carotid artery (CCA) (**A**). The common facial vein (CFV) was found and dissected caudally and revealed the IJV before carotid endarterectomy (**B**). After ligation and cutting of the CFV (**C**), the carotid sheath with the IJV turned laterally revealed the external carotid artery, CCA, and internal carotid artery (**D**). PBDGM, posterior belly of digastric muscle.

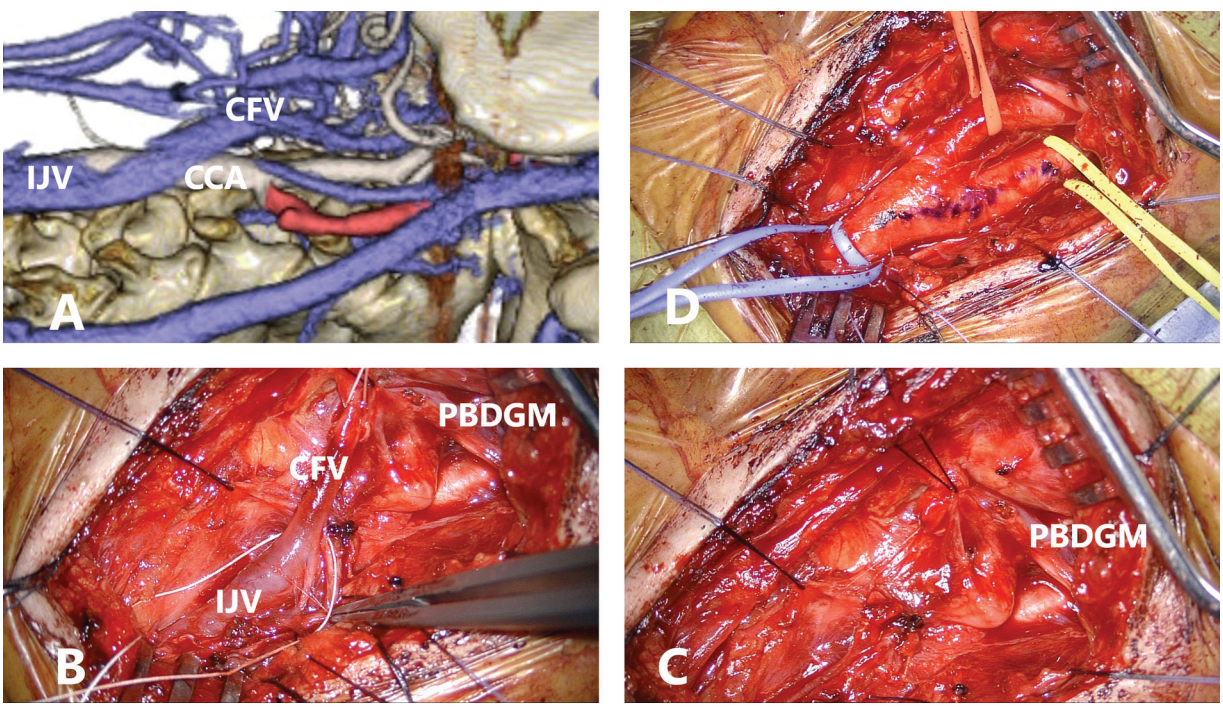

Fig. 3 Case 3. Three-dimensional computed tomography arteriography + venography, lateral view, revealed the left internal jugular vein (IJV) located slightly anterior to the common carotid artery (CCA) (**A**). The common facial vein (CFV) was found and dissected caudally and revealed the IJV (**B**). After ligation and cutting of the CFV (**C**), the carotid sheath with the IJV turned laterally revealed the external carotid artery, CCA, and internal carotid artery (**D**). CEA, carotid endarterectomy; PBDGM, posterior belly of digastric muscle.

position of the vagus nerve within the carotid sheath is usually posterior between the IJV and the CCA (posterolateral to the CCA).[13,14] Variations of the course of the vagus nerve are thought to be rare.[14] In our three cases, the vagus nerve was located normally, posterior to the CCA. On the other hand, recent reports have indicated that the vagus nerve course variations, anterior or medial between the IJV and CCA in the carotid sheath, are not so rare[15,16] and can be found more often in the left side.[13] Therefore, dissection of the IJV from in front of or behind the IJV carries some risk of affecting the vagus nerve. Since the vagus nerve does not exist in the carotid sheath at the site of CFV inflow to the IJV, the carotid sheath can be safely dissected by using this site as a guide to identify the IJV, enter the inside of the carotid sheath, and reach the CCA medial to the IJV.

Therefore, it is necessary to know the relationship between the IJV and the CCA before surgery. We also need to simulate how to reveal the CCA in the case of unusual course of the IJV. Consequently, we consider that 3D CTA + V simulation before surgery is useful.

In the case of unusual location of the IJV, we propose a different dissection method to find the carotid arteries. Dissection of the retromandibular space can reach the PBDGM. The CFV is located superficially at the anterior part of the PBDGM. No dangerous structure prevents reaching the PBDGM. Because the CFV flows out to the IJV, the CFV is considered a good landmark to find the IJV. After dissection and ligation of the CFV, dissection is continued anterior border of the IJV to find the CCA. In this manner, we have successfully performed CEA in three patients with unusual IJV location.

The posterior cervical triangle approach is an alternative approach, which is proposed for high carotid artery exposure for CEA[17,18] in the case of unusual location of the IJV. This technique can reveal the CCA without concern for the IJV, even if the IJV is located anterior to the CCA.

IJV anomaly such as bifurcation, duplication, fenestration, trifurcation, and posterior tributary have also been reported.[4] Three prior studies have assessed the prevalence of duplicated or fenestrated anatomical variations of the IJV. A prevalence of 3.3% was based on 4 cases of duplicated or fenestrated IJVs among 123 neck dissections in a Japanese population.[19] A prevalence of 0.4% was based on 3 cases of duplicated or fenestrated IJVs among approximately 750 neck dissections in France.[20] A prevalence of 1% was based on 3 cases of duplicated or fenestrated IJVs among 295 patients undergoing neck dissection in the United States.[21] IJV fenestration in our case 2 was identified preoperatively by 3D CTA + V. Whether such venous malformations are related to IJV location abnormalities is unknown, so our case 2 may have been an accidental complication, but more cases need to be accumulated in the future.

Conclusion

We conclude that there is a wide variation in the anatomical location of the IJV to the CCA and, because of this variation, routine techniques of CCA dissection may result in complications of the IJV or vagal nerve injury. Therefore, we recommend 3D CTA + V simulation to identify the IJV location before CEA.

Authors' Contributions

A.E. was responsible for the investigation and drafting of the original manuscript. T.T., K.F., S.T., T.Y., M.N., Y.O., and A.T. were involved in the investigation. K.W. contributed through conceptualization, supervision, and provided oversight for the review and editing of the manuscript, along with participation in the investigation.

Patients' Consent

All patients provided written consent for the publication of this case report.

Conflict of Interest

None declared.

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