REVIEW ARTICLE

Review of Venous Anatomy for Venographic Interpretation in Chronic Cerebrospinal Venous Insufficiency

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ABSTRACT

Chronic cerebrospinal venous insufficiency (CCSVI) represents a recently described condition that may potentially contribute to the symptoms experienced by patients with multiple sclerosis. The evaluation of a prospective patient for CCSVI often involves an invasive evaluation with venography of the internal jugular and azygos veins. The purpose of this article is to review the normal anatomy of the internal jugular, vertebral, and azygos veins, as an understanding of these veins is necessary for appropriate interpretation of the venograms obtained to evaluate patients for CCSVI.

ABBREVIATIONS

AJV = anterior jugular vein, AP = anteroposterior, CCSVI = chronic cerebrospinal venous insufficiency, EJV = external jugular vein, IJV = internal jugular vein, LAO = left anterior oblique, RAO = right anterior oblique, SVC = superior vena cava

Chronic cerebrospinal venous insufficiency (CCSVI) represents a recently described condition that may potentially contribute to the symptoms experienced by patients with multiple sclerosis (1). The evaluation of a prospective patient for CCSVI and possible treatment with venous angioplasty involves a noninvasive evaluation with Doppler ultrasound (US) and/or magnetic resonance venography and an invasive evaluation with selective catheterization and venography of the internal jugular and azygos veins (2,3). Although interventionalists have significant experience with venous access and catheter placement in the internal jugular vein (IJV), the indications for, and therefore the experience with, selective catheterization and venography of the internal jugular and azygos veins are limited. The purpose of this article is to review the normal and variant venous anatomy of the head, neck, and azygos systems. As the efficacy of venography and angioplasty is unproven in the evaluation and treatment of multiple sclerosis, a thorough understanding of this anatomy is essential in the safe pursuit of this important research.

INTERNAL JUGULAR VEIN

The IJV is the dominant outflow vein from the brain, beginning as the continuation of the transverse and sigmoid sinuses in the jugular foramen. The superior bulb of the IJV, which is an area of mild venous dilation, is located in the jugular foramen. Immediately below the jugular foramen, it is common for the posterior wall of the vein to rest against the anterior surface of the transverse process of C1 (4). In some patients, the transverse process can indent or kink the posterior wall of the IJV (Fig 1), possibly causing an increase in intracranial venous pressure if it occurs on the side of the dominant transverse and sigmoid sinus (4). Below the transverse process of C1, the IJV runs lateral and slightly anterior to the internal carotid artery, typically within 1 mm of the artery (5). This may result in compression along the medial aspect of the IJV proximal to the carotid bifurcation (Fig 2). The vein then passes below the sternocleidomastoid muscle to join the subclavian vein (6). Anomalies of the IJV are rare. Duplication of the IJV has been reported and is estimated to occur in approximately four per 1,000 unilateral neck dissections (7,8).

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whereas, in US screening studies, a valve was found in one or both of the IJVs in 72%–96% of patients (12–14). In patients with a valve on only one side, 80% are located on the right side (12). The cusps of the IJV valve are thin, translucent structures (15). Most of the valves are bicuspid with anterior and posterior leaflets, although uni-
Figure 3. (a) RAO view from a right IJV venogram with ipsilateral head rotation demonstrates luminal narrowing (arrow). A fixed stenosis just above the confluence of the IJV with the subclavian vein is seen as well. (b) RAO view from the right IJV venogram in the same patient with contralateral head rotation demonstrates maximization of the luminal diameter in the previously narrowed area. The fixed stenosis of the IJV (asterisk) is still present.

Figure 4. Anteroposterior (AP) view (a) and lateral view (b) from left IJV venograms performed in different patients demonstrate the cavernous sinus (CAV) and its drainage into the IJV via the inferior petrosal sinus (IPS) and inferior petroclival vein (IPV). ACV = anterior condylar vein, MEV = mastoid emissary vein, SS = sigmoid sinus.
cusp and tricuspid valves have been reported as well (10,11,13). The valves are located in the distal IJV, just proximal to the jugular bulb (12). Physiologically, complete valve closure occurs once during diastole, to prevent the transmission of pressure from the right atrium and superior vena cava (SVC) into the IJV (16).

There is significant variability of the size and symmetry of the normal IJVs. Using US at the level of the cricoid cartilage, Lin et al (17) found that the normal venous diameter ranged from 9.1 mm to 10.2 mm, but that a small IJV (< 5 mm in diameter) can be seen in 13.5% of patients on the right and in 10.6% of patients on the left. Taal et al (18) found clinically significant anatomic abnormalities in as many as 30% of patients undergoing dialysis with no history of previous catheter placement. The use of CT scans to measure the diameters of the right and left IJV showed that 80.5% of individuals have a smaller IJV on the left (5,19). The diameter of the IJV is independent of age and sex (20).

There are many factors that can determine the size of the IJV. These include hydration status, cardiac status and intrathoracic pressure, head position, and anatomic compression by adjacent structures in the neck (21). Certain positional maneuvers can maximize the cross-sectional area of the IJV, including head rotation to the contralateral side (Fig 3) and placement of the patient in the Trendelenburg position (22,23). In fact, head rotation to the ipsilateral side causes a significant reduction of the mean diameter of the ipsilateral IJV, even approaching complete occlusion (23). The size of the IJV can be further complicated by the occurrence of jugular phlebectasia, which is defined as focal dilation of the inferior jugular bulb, or the area of the vein located inferior to the valves (21). This is more common on the right than the left because intrathoracic pressure may be more directly transmitted to the right side than to the left, possibly because of the shorter length of the right brachiocephalic vein and the possible presence of valves in the left brachiocephalic vein (24).

There are many known tributaries draining into the IJV as it runs caudally in the neck from the jugular foramen to the subclavian vein. The inferior petrosal sinus is the major source of drainage from the cavernous sinus and arises from its posterosuperior aspect (Fig 4) (25). It communicates with the basilar plexus, the anterior and lateral condylar veins, the anterior condylar confluence, and the vertebral venous plexus before draining into the superior jugular bulb or the IJV at the level of the hypoglossal canal or lower (26,27). The connection of the inferior petrosal sinus to the jugular bulb occurs through a single vessel, multiple vessels, or a plexiform network of vessels (25). In rare cases, the inferior petrosal sinus drains directly into the vertebral venous plexus. The inferior petroclival vein (also referred to as the inferior petrooccipital vein or petrooccipital sinus) is a rarely described entity that originates from the posterolateral aspect of the cavernous sinus. It runs just lateral and inferior to the inferior petrosal sinus along the inferior petroclival fissure, ultimately draining into the anterior condylar confluence or the medial aspect of the jugular bulb (Fig 4) (27–29).

The common facial vein (Fig 5) is another tributary that commonly enters the IJV at the angle of the mandible. It receives variable drainage from the anterior facial vein, anterior branch of the posterior facial vein (or retromandibular vein), lingual vein, and communicating vein to the anterior jugular vein (AJV). Anastomoses between the common facial vein and superior thyroid vein are also seen with high frequency. The anterior facial vein is the direct continuation of the angular vein. It runs superficial and lateral to the submandibular gland. The posterior facial vein is formed by the superficial temporal and internal maxillary veins within the parotid gland. Whereas the anterior branch of the posterior facial vein joins with the anterior facial vein to form the common facial vein, the posterior branch joins with the posterior auricular vein to form the external jugular vein (EJV). The superior and middle thyroid veins are other tributaries draining directly into the ipsilateral IJV, with the former entering the IJV more cranially (30). The inferior thyroid veins often join together and terminate unpaired into the left brachiocephalic vein, but they can drain directly into the jugular venous arch (Fig 6) (31). The lingual and pharyngeal veins are the other tributaries of the IJV.
Figure 6. (a) AP view from a left IJV venogram demonstrates the superior (STV) and middle thyroid veins (MTV) with the anastomotic connections between the two veins. (b) AP view from a left IJV venogram in a different patient demonstrates the middle and inferior thyroid veins with the anastomotic connections between the two veins. The inferior thyroid vein (ITV) can be seen draining directly into the left brachiocephalic vein (BV). SV = subclavian vein.

Figure 7. (a) AP view from a left IJV venogram demonstrates the formation of the EJV by the posterior branch (PB-PFV) of the posterior facial vein (PFV) and the posterior auricular vein (PAV). The EJV in this patient drains into the confluence of the IJV and subclavian vein (SV). (b) RAO view from a right IJV venogram in a different patient demonstrates the drainage of the EJV into the subclavian vein (SV). AB-PFV = anterior branch of the posterior facial vein, CFV = common facial vein.
Figure 8. (a) AP view from a left IJV venogram demonstrates the communication of the EJV with the AJV. (b) AP view from a left IJV venogram in a different patient demonstrates the communication of the IJV with the right and left AJV. The jugular venous arch is well seen in this patient. (c) AP view from a left IJV venogram in a different patient demonstrates a large left AJV draining predominately via the jugular venous arch (JVA) into the contralateral confluence of the right IJV and subclavian vein (SV). Diminutive drainage into the left EJV is seen as well. BV = brachiocephalic vein.

Figure 9. AP (a) and lateral (b) views from the left IJV venogram demonstrate the vertebral vein (VV) and deep cervical vein receiving inflow from the mastoid emissary vein (MEV; originating from the sigmoid sinus and draining into the suboccipital venous plexus [SVP]) and the posterior condylar vein (PCV; originating from the jugular bulb).
EXTERNAL JUGULAR VEIN

The EJV is formed by the confluence of the posterior branch of the posterior facial vein and the posterior auricular vein (Fig 7a). It then descends superficial and lateral to the sternocleidomastoid muscle, terminating into the confluence of the subclavian and IJVs (60%), the subclavian vein (36%), or the IJV (4%; Fig 7b) (32). There is an inverse correlation between the diameters of the EJV and IJV (21,33). There are typically two pairs of valves in the EJV. The lower pair is at the confluence of this vein with the subclavian or jugular vein and the upper pair is approximately 4 cm above the clavicle (34). Anomalies of the EJV are rare, but duplication has been reported (35).

ANTERIOR JUGULAR VEIN

The AJVs begin above the level of the hyoid bone after receiving blood from superficial veins, the EJVs (Fig 8a), the facial veins, or the IJVs (Fig 8b). The AJVs typically descend between the midline and the anterior border of the sternocleidomastoid muscle. They usually end in the subclavian vein (54%) or EJVs (46%; Fig 8c) (32). Most frequently, there are two AJVs, but a single vein positioned in the midline is possible (31). The right and left AJVs may communicate via the jugular venous arch (also known as the anterior jugular arch), which is located just above the sternum (31,36). This arch receives tributaries from the thyroid gland via the inferior thyroid veins.

VERTEBRAL VEINS

The vertebral veins represent a distal continuation of the vertebral artery venous plexus (37). They receive inflow from the sigmoid sinuses via the mastoid emissary veins, the condylar veins, and the marginal sinus surrounding the foramen magnum (29,35). The mastoid emissary vein originates from the transverse portion of the sigmoid sinus and runs posteriorly to drain into the suboccipital venous plexus, which drains into the deep cervical veins or the vertebral artery venous plexus via an anastomotic vein (Fig 9) (38,39). The posterior condylar vein originates from the superior jugular bulb and connects this structure to the deep cervical veins and vertebral artery venous plexus (Fig 9) (40,41). The lateral condylar vein most commonly arises from an anastomotic branch connecting the IJV with the anterior condylar confluence and serves to join the latter to the vertebral artery venous plexus.
plexus (27). The anterior condylar vein arises from the anterior condylar confluence, joining this structure to the internal vertebral venous plexus (27).

More inferiorly, the vertebral artery venous plexus continues as two or three vertebral veins, which enter the transverse foramen of C1 and descend as a plexus of veins surrounding the vertebral artery (34,37). The deep cervical and vertebral veins are considered the external component of the vertebral venous plexus (Fig 10). Intervertebral veins connect the vertebral vein with the internal vertebral venous plexus within the spinal canal (Fig 11) (42,43). The vertebral vein exits the transverse foramen at C7 as a single trunk, which enters the posterior portion of the brachiocephalic vein (Fig 11). The deep cervical vein terminates in the distal vertebral vein or the brachiocephalic vein. The vertebral venous plexus is another major route for intracranial outflow, particularly when the body is in an upright position and when intraabdominal or intrathoracic pressure is increased (42–45).

**AZYGOS VEIN**

The azygos system of veins provides outflow from the intercostal and paravertebral veins within the posterior aspect of the chest (36). The ascending lumbar veins form the origin of the azygos system. These veins communicate with the common iliac veins via the iliolumbar veins (46). The ascending lumbar vein may be continuous with the iliolumbar vein or may become a plexus of smaller veins in the midlumbar region (Fig 12).

Figure 12. AP view of a pelvic venogram demonstrates the iliolumbar vein (ILV) and ascending lumbar vein (ALV) in a patient with incidental May–Thurner syndrome. CIV = common iliac vein.

Figure 13. Lateral view of the azygos vein (AV) demonstrates contour irregularity along its posterior margin by the thoracic vertebral bodies.

Figure 14. Left anterior oblique view from an azygos venogram demonstrates the azygos arch (AA) as it runs superior to the right mainstem bronchus to communicate with the SVC. AV = azygos vein, RBV = right bronchial vein, RMB = right mainstem bronchus.
On the right side, the azygos vein typically begins at the level of L3 from the ascending lumbar and subcostal veins (47). As it ascends from the abdomen into the chest through the aortic hiatus and within the right paravertebral space, it receives all the right posterior intercostal veins and right bronchial vein, as well as esophageal, mediastinal, and pericardial veins (34). It may show slight localized anterior displacement by osteophytes as it ascends along the spine (Fig 13) (48). At the level of T4–T5, the azygos arch begins as the vein turns anterior and travels superior to the right mainstem bronchus and the right pulmonary artery (Fig 14). It then joins with the left superior intercostal vein, which receives the upper (ie, 2nd to 4th) left posterior intercostal veins and ultimately empties into the left brachiocephalic vein (Fig 16) (56).

The normal size of the azygos vein is variable but has been reported as measuring 3–6 mm at the level of the diaphragm, 5–10 mm at the level of T8, and 8–14 mm at the horizontal portion of the azygos arch (51). Enlargement of the azygos vein can be seen when there is increased venous flow caused by collateral circulation or fistula formation, or by increased right atrial pressure (47). Common causes include azygos continuation of the IVC, congestive heart failure, obstruction of the SVC or IVC, and splenic or portal vein thrombosis with portal hypertension (47,51).

CONCLUSIONS

The anatomy of the jugular and azygos system of veins is complex. The evaluation of multiple sclerosis patients for CCSVI has brought selective venography of the internal jugular and azygos veins to the forefront as a diagnostic modality for this entity. Although the link between CCSVI and multiple sclerosis remains unclear, an understanding of this anatomy...
will undoubtedly aid researchers in exploring a potential link between CCSVI and the pathologic basis of this devastating disease.

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