Anatomical Variations of the Vertebral Artery in the Upper Cervical Spine
Clinical Relevance for Procedures Targeting the C1/C2 and C2/C3 Joints

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Background and Objectives: Accidental breach of the vertebral artery (VA) during the performance of cervical pain blocks can result in significant morbidity. Whereas anatomical variations have been described for the foraminal (V2) segment of the VA, those involving its V3 portion (between the C2 transverse process and dura) have not been investigated and may be of importance for procedures targeting the third occipital nerve or the lateral atlantoaxial joint.

Methods: Five hundred computed tomography angiograms of the neck performed in patients older than 50 years for the management of cerebrovascular accident or cervical trauma (between January 2010 and May 2016) were retrospectively and independently reviewed by 2 neuroradiologists. Courses of the VA in relation to the lateral aspect of the C2/C3 joint and the posterior surface of the C1/C2 joint were examined. For the latter, any medial encroachment of the VA (or one of its branches) was noted. The presence of a VA loop between C1 and C2 and its distance from the upper border of the superior articular process (SAP) of C3 were also recorded. If the VA loop coursed posteriorly, its position in relation to 6 fields found on the lateral aspects of the articular pillars of C2 and C3 was tabulated.

Results: At the C1/C2 level, the VA coursed medially over the lateral quarter of the dorsal joint surface in 1% of subjects (0.6% and 0.4% on the left and right sides, respectively; P = 0.998). A VA loop originating between C1 and C2 was found to travel posteroinferiorly over the anterolateral aspect of the inferior articular pillar of C2 in 55.5% of patients on the left and 41.9% on the right side (P < 0.001), as well as over the SAP of C3 in 0.4% of subjects. When present in the quadrant immediately cephalad to the C3 SAP, VA loops coursed within 2.0 ± 1.5 and 3.3 ± 2.5 mm on the left and right sides, respectively, of its superior aspect (P < 0.001).

Conclusions: The VA commonly travels adjacent to areas targeted by third occipital nerve procedures and more rarely over the access point for lateral atlantoaxial joint injections. Modifications to existing techniques may reduce the risk of accidental VA breach.

METHODS

After obtaining ethics committee approval (McGill University Health Center, Montreal, Quebec, Canada; August 12, 2016), we retrospectively identified 500 CTAs performed at the Montreal General Hospital between January 2010 and May 2016 for the management of cerebrovascular accident or cervical trauma. We restricted CTAs to those carried out in patients older than 50 years. Exclusion criteria included the lack of opacification of blood vessels, poor-quality imaging (due to patient movement or beam hardening artifacts), evidence of instrumentation from previous surgery, and tumors and fractures of the upper cervical spine (C1/C2 or C2/C3). Images were acquired with one of two 64-slice multidetector scanners (Philips Ingenuity [Philips Healthcare, Markham, Ontario, Canada] and a GE VCT [GE Healthcare, Mississauga, Ontario, Canada]) or a Toshiba Aquilion 320-slice scanner (Toshiba Medical Systems, Markham, Ontario, Canada), using a slice thickness varying from 0.625 to 1 mm. Because of its retrospective nature, this study was not registered.

Two neuroradiologists independently reviewed the V3 segment of the VA using the Inteleviewer PACS software (Intelerad Medical Systems, Montreal, Quebec, Canada), which allows true sagittal reformating. The courses of the VA in relation to the lateral aspect of the C2/C3 joint and the posterior surface of the C1/C2 joint were examined. For the latter, any medial encroachment...
of the VA (or one of its branches) was noted (Fig. 1). The presence of a VA loop between C1 and C2 and its distance from the upper border of the superior articular process (SAP) of C3 (DL) were also recorded (Fig. 4). If the VA loop coursed posteriorly, its position in relation to 6 fields found on the lateral aspects of the articular pillars (APs) of C2 and C3 was tabulated (Fig. 4). This was accomplished by identifying the arterial loop in a sagittal view and scrolling medially to visualize the AP in order to assess which field(s) it overlapped. An average of the measurements recorded by the 2 independent observers was tabulated for the DL.

Statistical analysis was performed using SPSS version 21 statistical software (IBM Corp, Armonk, New York). Findings from the left and right sides were compared using the Mann-Whitney U test (DL) or McNemar test (proportion of patients with a VA in a given field). Interobserver agreement was assessed with Spearman correlation coefficient. All P values presented are 2-sided, and values inferior to 0.05 were considered significant.

RESULTS

Our inclusion and exclusion criteria yielded a total of 500 CTAs. A vascular loop was absent in 14 (left or right) sides, and imaging artifacts obscured the atlantoaxial joint in 6 patients. Thus, the C1/C2 level was assessed bilaterally in 494 patients. For the C2/C3 level, the left and right sides were evaluated in 492 and 494 subjects, respectively. Patients presented at a mean age 69.1 ± 11.2 years, and 56.1% were male.

The VA was found on the dorsal aspect on the C1/C2 joint in 3 (0.6%) and 2 patients (0.4%) on the left and right sides, respectively, where it remained confined to the lateral quarter of the joint. Results pertaining to the C2/C3 joint, including statistical comparisons between right and left sides, are presented in Figure 5. In patients in whom a descending VA loop coursed posteriorly onto the inferior articular process of C2 (quadrant D or E) (Figs. 3 and 4), the DL displayed a smaller size on the left compared with the right side (2.0 ± 1.5 vs 3.3 ± 2.5 mm, P < 0.001), indicating a closer proximity of the loop to the tip of the C3 SAP on the left side. A significant correlation was observed between age and DL (r = −0.132; P = 0.003). Analysis for interobserver agreement revealed that DL measurements were highly correlated between the 2 independent observers (r = 0.805; P < 0.001). The proportion of patients in whom the VA overlay the left and right quadrants is presented in Figure 5. Significant

FIGURE 1. Anteroposterior radiograph of the upper cervical spine. Left side of the image demonstrates the currently recommended point for lateral antlantoaxial access (star) in the middle of the lateral third of the joint. The area of interest (rectangle) used to define a positive finding (medially coursing VA) is also illustrated. Right side of the image shows the expected course of the VA (black line) on the lateral aspect of the bony contour. A medially coursing VA is depicted (gray line) encroaching on the posterior aspect of the joint. This variant was identified in 0.6% and 0.4% of patients (left and right sides, respectively). A modified target point for joint entry, which could reduce the risk of VA breach, is illustrated (white dot at the junction of the medial and lateral thirds of the joint).

FIGURE 2. Lateral radiograph of the upper cervical spine demonstrating the trajectories and target points for TON procedures. A, The 3 injection target points (black dots) for TON block are shown. The course of a straight VA (black line), which was observed in 2.8% of patients is shown. The majority of subjects were found to have some degree of tortuosity, with a loop originating between C1 and C2 coursing posteriorly toward the lateral aspect of the C2/C3 zygapophyseal joint (gray line). B, A reference grid delineating the study fields has been drawn over the APs of C2 and C3. The 3 transverse cannula (C) placements targeting the SAP of C3 for RF ablation of the TON are shown. Final cannula tip positions for the parasagittal (Ps) and oblique (Ob) passes are shown (broken lines).
Differences were found between the 2 sides for A, B, and D (all \( P < 0.007 \)).

**DISCUSSION**

Our retrospective imaging study reveals that VA loops commonly course posteriorly onto the AP of C2 but rarely onto the AP of C3 (Fig. 5). While the upper fields of C2 were most frequently involved, a VA was nonetheless present in the antero-inferior quadrant (D) in half of subjects. Furthermore, a significant difference was found between right and left sides. This finding mirrors the results of Giuffre and Sherkat, who previously reported increased tortuosity of the V2 VA on the left side. At the C1/C2 level, we observed that the VA coursed medially over the lateral quarter of the dorsal joint surface in 1% of the subjects (0.6% and 0.4% on the left and right sides, respectively). Although it remained confined to the outer quarter of the joint in all cases, the VA could still be punctured by a needle placed at the recommended target point for joint access (ie, middle of the lateral third). Procedures targeting the C2/C3 zygapophyseal joint include diagnostic blocks, as well as RF ablation of the third occipital nerve (TON). Fluoroscopy-guided TON blocks target 3 sites in the midline of the AP including the C2–C3 joint line, cephalad quarter of C3, and caudal quarter of C2 (Fig. 2A). These injection points overlap quadrants E and H in which the presence of a VA loop was identified in 5.5% to 7.9% and 0.2% of CTAs, respectively. Radiofrequency ablation of the TON requires multiple lesions using both oblique and parasagittal passes to target the C3 SAP (Fig. 2B). The most cephalad trajectory overlaps quadrants E and D, in which a VA was noted in 7.9%/5.5% and 55.5%/41.9% of patients, respectively (left/right). Parasagittal and oblique passes differ in their final cannula tip position, as the latter target a more anterior point of the SAP, thereby conferring a greater risk of VA breach. This possibility seems most significant for needle placements on the rostral aspect of the C3 SAP, adjacent to quadrant D, where a VA was present in half of CTAs and where loops descended within 2.0 to 3.3 mm of the SAP tip.

Our patient selection requires discussion. The external validity of any survey inherently depends on the fact that the prevalence of the studied condition in the sampled population mirrors that of the population at large. For this reason, our survey included only subjects older than 50 years, as previous studies examining the V2 VA segment had found that increasing age and spondylosis were associated with greater vascular tortuosity. Further, older patients are more frequently afflicted by cervicogenic headaches and commonly require blocks that would target the upper cervical joints. Our results suggest a similar trend for the V3 VA segment as for its V2 counterpart in older patients, as we found a significant (negative) correlation between age and DL, indicating an increase in VA tortuosity with age.

Preprocedural imaging can reduce the risk of VA breach by identifying anatomical variations in the latter’s course. The use of magnetic resonance imaging to examine the V2 VA segment before cervical transforaminal injections has been described and could be similarly used to assess the V3 VA before C1/C2 or C2/C3 procedures. Ultrasound (US) imaging is readily available and can dependably identify arteries along the cervical spine.

**FIGURE 3.** Three-dimensional volume reconstruction created from a CT angiogram demonstrating a VA loop between C1 and C2, which courses caudally and posteriorly over the anterolateral aspect of the C2/C3 zygapophyseal joint. The rectangular frame corresponds to the area of the explanatory inset: transverse process of C1 (1), C1/C2 joint (2), VA loop (3), transverse process of C2 (4), inferior articular process of C2 (5), C2/C3 zygapophyseal joint (6), C3 AP (7), C3 transverse process (8), C3/C4 zygapophyseal joint (9).

**FIGURE 4.** Lateral radiograph of the upper cervical spine demonstrating the fields used to report the position of posterior coursing VA loops over the lateral aspects the C2 and C3 APs (A–L). The distance from the inferior border of the loop to the anterosuperior edge of the C2/C3 joint (DL) is also illustrated.
Although its use at the C1/C2 level has not been formally investigated, TON blocks can be reliably performed with US guidance.\textsuperscript{17} Thus, adjunctive US could theoretically be used to identify posteriorly coursing VA loops before fluoroscopy-guided TON RF ablation procedures (Fig. 6).

Based on our findings, the risk of VA breach could be further reduced with simple modifications of currently recommended techniques. For instance, for lateral atlantoaxial access, entering the joint slightly more medially (ie, junction of the lateral and medial thirds) would avoid the VA in all our study subjects (Fig. 1), although this could increase the risk of encountering the C2 dorsal root ganglion during needle insertion. For TON RF procedures, omitting the oblique passes can significantly reduce the risk of VA puncture. Although such omission could theoretically reduce clinical efficacy, the true benefits of oblique passes (within the context of cervical medial branch RF ablation) have been questioned recently.\textsuperscript{18} In addition, the common practice of injecting local anesthetics and steroids through the RF cannula (without confirmatory use of contrast agent and subtraction angiography) should be reconsidered because it could lead to significant morbidity should an unrecognized VA breach occur.

In conclusion, our retrospective imaging study reveals that in patients older than 50 years the VA commonly travels adjacent to areas targeted by TON procedures and more rarely over the access point for lateral atlantoaxial joint injections. Modifications to existing techniques may reduce the risk of accidental VA breach. Further investigation is required to determine if our findings are applicable to a younger patient population.

REFERENCES


