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Brief Research Report

Vertebral Artery Anatomical Variations as They Relate to Cervical Transforaminal Epidural Steroid Injections

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Abstract

Objective. To identify and categorize anatomical anomalies of the vertebral artery and determine the relationship of these unexpected variations to the site for cervical transforaminal epidural steroid injections (CTESI).

Design. The cervical region and course of the vertebral arteries was dissected in 10 cadavers. Anatomical anomalies of the vertebral arteries were identified and documented. Those that could increase the risk of intra-arterial injection during fluoroscopically guided procedures are detailed.

Results. Twenty percent of vertebral arteries were found to have anatomical variations including accessory vessels and lateral loops. These variations placed arterial segments in a portion of the posterior neural foramen where they could be at risk for cannulation during CETSI. In addition, 20% of the vertebral arteries entered the transverse foraminal column at a level other than C6.

Discussion. CTESI have become a mainstay in the treatment algorithm for painful cervical radiculopathy. Described techniques take extreme care to avoid cannulation of the vertebral artery during this procedure. Unexpected deviation of the artery, or an arterial segment, into the posterior neural foramen, the target zone for CTESI, increases the risk of intra-arterial cannulation during injection. Accordingly, the practitioner must be aware of variant anatomy of the vertebral artery and take all precautions to avoid potential complications that may arise as a consequence.

Key Words. Cervical Transforaminal Epidural Steroid Injection; Vertebral Artery; Cervical Radiculopathy

Introduction

Cervical Transforaminal Epidural Steroid Injection (CTESI) has proven to be a valuable and successful component of the treatment algorithm for painful cervical radiculopathy. When performed with caution and precision, current techniques have proven to be safe, however, risks do exist, as with any interventional procedure. Some authors prefer the interlaminar approach, while others prefer the transforaminal approach [1]. One previously documented hazard of the transforaminal approach is cannulation and subsequent injection of particulate steroid into the vertebral artery (VA) [2]. To date, no catastrophic complications are attributed to instillation of non-particulate steroids with CTESI.

This study aims to determine the type and frequency of anatomical anomalies in the course of the V2 segment of the VA, and discuss the likelihood that these variations could increase the risk of intra-arterial injection.

Methods

Ten cadavers in residence at the college of medicine for educational and research purposes were used in this study. At the time of death, the cadavers ranged in age from 61 years to 100 years old. There were five women and five men. (see Table 1). Nine of the 10 cadavers had been used in a basic science anatomy dissection course for first year medical students prior to being included in this study. These nine cadavers had undergone disarticulation at the C0-C1 level, but, despite this, the musculature and deep tissues surrounding the cervical spine had not been disturbed. Therefore, these specimens were appropriate for inclusion in this study. The head and neck region of the 10th cadaver had not been dissected prior to this study.

The dissection approach for cadaver no.10 utilized a midline anterior cervical incision to expose the deep musculature of the cervical spine. The subsequent dissection sequence and methods for all 10 specimens followed an identical protocol.

The deep cervical musculature was removed leaving the bony cervical spine intact. Care was taken to not disturb exiting nerve roots associated with the cervical and brachial plexuses. The neural foramina at the C3, C4, C5, C6, and C7 levels were examined bilaterally in each cadaver, for a total of 100 foramina. The subclavian arteries were identified bilaterally, and the origin of right and left VAs was documented in all 10 cadavers (N = 20). Beginning at the origin of each VA, the costal (anterior) components of the cervical vertebrae were carefully removed using rongeurs until the entire anterior surface of the intact vertebral artery was observable in the transverse foraminal column. The vertebral level of entrance was recorded and each VA was examined along the entire length of the cervical spine. Care was taken to observe and document the proximity of the VA to the neural foramen where the cervical spinal nerve is protected cephalad and caudad by adjacent transverse processes at each intervertebral level. Particular interest was given to any anomalous course of the artery as well as any atypical arterial segments.

Table 1 List of study cadavers with corresponding age and sex at time of death

Cadaver Number	Age at Time of Death	Sex
1	91	Female
2	88	Female
3	81	Male
4	97	Female
5	86	Male
6	100	Female
7	72	Male
8	61	Male
9	92	Male
10	71	Female

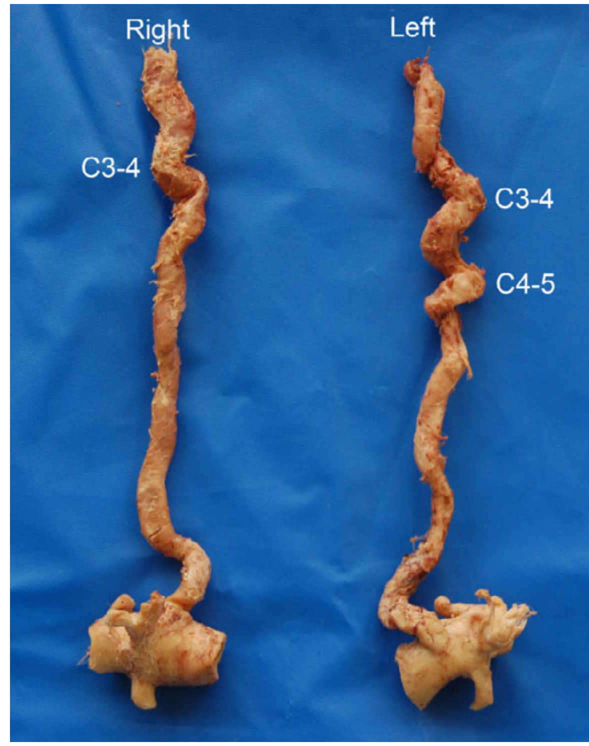

Figure 1 Photographic image of bilateral vertebral arteries removed from cadaver no.1 showing lateral loops at the C3-4 level (right artery) and C3-4, C4-5 levels (left artery).

Results

Two types of clinically significant anatomical anomalies were observed: lateral loops and accessory arteries. In cadaver no. 1, both vertebral arteries were tortuous along their V2 path and lateral loops emerged from the transverse foraminal column between adjacent transverse processes and protruded into the posterior aspect of the neural foramen (Figures 1, 2, 3A & 3B). On the right side, a lateral loop was observed in the neural foramen at the C3 vertebral level, while on the left two lateral loops were noted, one in the C3 neural foramen and the other in the C4 neural foramen. At all three sites, the looping segment of artery occupied the posterolateral area of the neural foramen posterior to the exiting nerve root.

Of 100 foramina studied, one lateral loop was noted in a right C3 foramen, one in a left C3 foramen, and the final in a left C4 neural foramen. This yields a prevalence of 3% with a 95% confidence interval (CI) = 0–6%.

The second type of variation, accessory vertebral artery, was observed in cadaver no.5 bilaterally. On the right, the

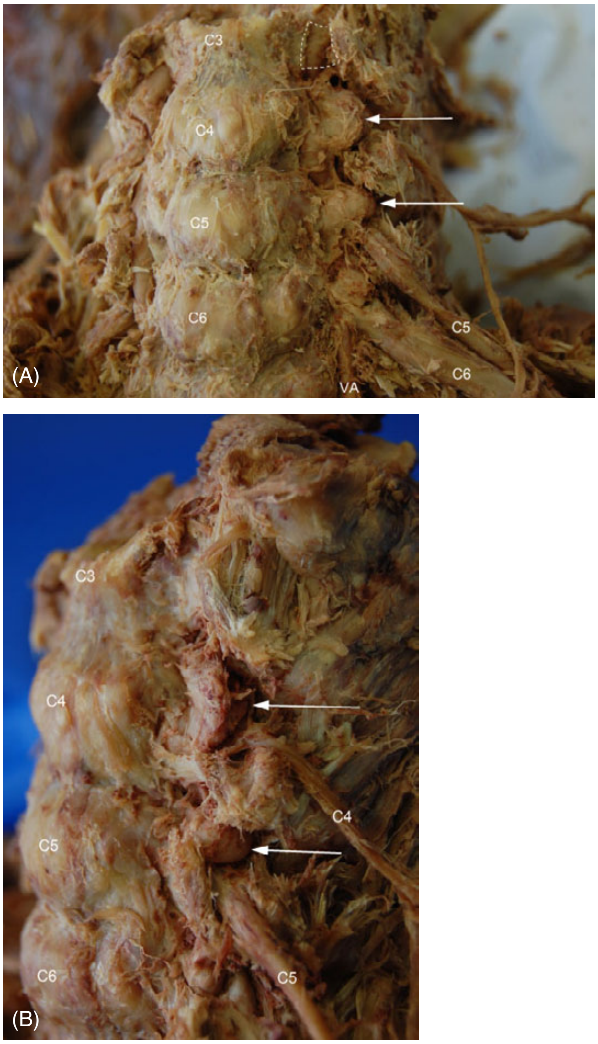

Figure 2 (A) Left vertebral artery of cadaver no.1. Anterolateral view with lateral loops bulging into the neural foramina (white arrows). The loops are visible because the costal elements of the transverse processes have been removed at all levels. Dashed white box illustrates area where the costal element was removed at C3. VA = Vertebral Artery; (B) Left vertebral artery of cadaver no.1. Lateral view showing posterior position of lateral loops.

accessory VA originated from the subclavian artery adjacent to the origin of the vertebral artery (Figure 4A). On the left, it originated from the thyrocervical trunk. Both anomalous arteries traveled cephalad in an anterolateral position relative to the vertebral bodies. On the right, the anomalous artery entered the C5 neural foramen, passing posterior to the exiting C6 nerve root (Figure 4B). At that point, it joined the ascending right vertebral artery. On the left side, the accessory artery entered the C4 neural foramen. Before doing so, it gave rise to a small branch that entered the C5 neural foramen. Both the C5 branch and the accessory artery traveled posterior to the exiting nerve roots and medially through the neural foramen before joining the main VA. In total, two accessory vertebral arteries were observed out of 20 VA's examined, which yields a 10% prevalence with 95% CI of 0–23%.

In addition to lateral loops and accessory arteries, four of the 20 VAs entered the transverse foraminal column at a level other than C6. In the 100 possible levels of entrance observed in this study, there was an 80% prevalence of entry at C6, with a 95% CI of 72–88%. The prevalence of entry at C3 and C4 was 0%. Both the C5 and C7 vertebral levels entry points for two vertebral arteries, for a prevalence of 10% at each level with a 95% CI of 4–16%.

Discussion

Typically, the vertebral arteries arise from the subclavian arteries and deliver blood to the cervical region and brain [3]. After passing through the cervical transverse foraminal column, each vertebral artery crosses the foramen magnum to enter the cranium [4].

Clinically, the VA is described as having four discreet segments [5]. The first segment (V1) begins at the origin of the VA from the subclavian artery and extends to the level of the C6 transverse process. The second segment (V2) runs in the transverse foraminal column from C6 to C2. The

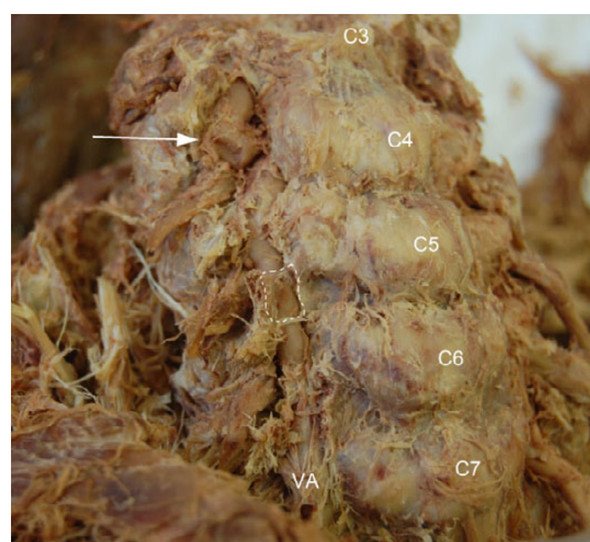

Figure 3 Right vertebral artery of cadaver no.1. Anterolateral view showing lateral loop (white arrow) of the vertebral artery (VA). White dashed box outlines area of the excised costal element which was removed at each level in order to expose the vertebral artery.

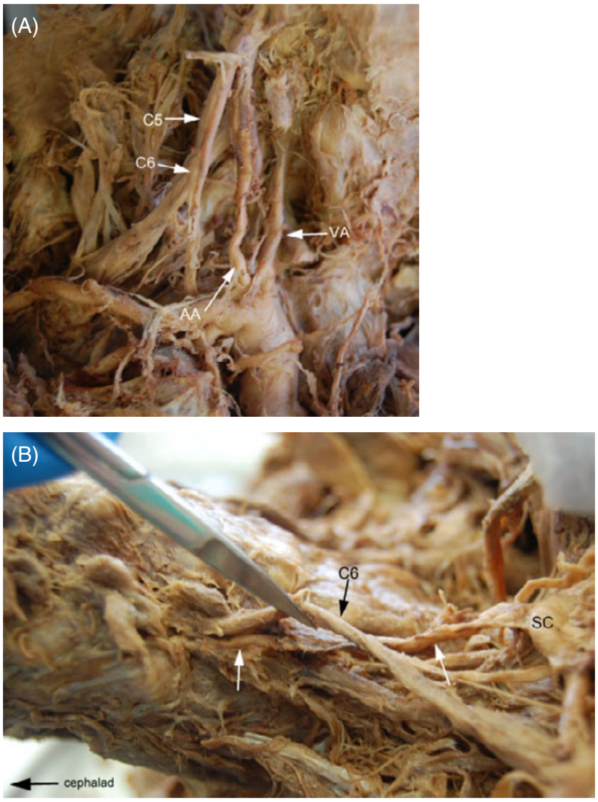

Figure 4 (A) Right accessory artery (AA) of cadaver no.5. Anterolateral view demonstrating an accessory artery (AA) originating lateral to the vertebral artery (VA) from the subclavian artery; (B) Right accessory artery (AA) of cadaver no.5. Lateral view showing an accessory artery (white arrows) originating from the subclavian artery (SC), entering the C5 neural foramen posterior to the exiting C6 nerve root (black arrow).

third segment (V3) extends from the C2 transverse foramen to the foramen magnum, and the fourth segment (V4) from the foramen magnum to the formation of the basilar artery.

The majority of CTESIs are performed along the V2 segment of the VA, which typically enters the C6 transverse foramen and remains within the protection of the bony column of cervical transverse processes throughout its length [6]. The safe target area for CTESIs, which is described in relation to the normal pathway of the vertebral artery, is located in the posterior aspect of the neural foramen. To avoid cannulating the VA, interventionalists are taught to direct their needle, using an oblique view under image guidance, toward the superior articular process while maintaining a posterior approach. After touching periosteum, the needle is directed slightly anteriorly and advanced medially into the neural foramen taking care not to pass beyond the midpoint of the articular pillar in the anteroposterior view [7]. Extreme care is used to keep the needle tip positioned in the posterior aspect of the neural foramen at all times (Figure 5). In a patient with normal anatomy, these guidelines should keep the needle from puncturing the exiting nerve root, vertebral artery, or dural sac.

The normal path of the VA in the cervical transforaminal column is immediately anterior to the CTESI target zone. In the present study, 20% of vertebral arteries exhibited anatomical anomalies that placed an arterial segment posteriorly into the CTESI target zone. Appreciating the close proximity of the VA to the target zone is critical because injections into the artery carry multiple risks, including seizures, stroke and death [8]. Intimate knowledge of normal VA anatomy, as well as awareness of possible anatomical variations, is essential.

The looped or "corkscrew" morphology of the VA, observed bilaterally in cadaver no.1, placed portions of the artery herniating into the posterolateral aspect of several neural foramina. When the artery expands laterally from the transverse foraminal column, it can impinge on neural structures in the foramen causing a compressive radiculopathy resulting in pain, which may lead to referral for a CTESI. Posterolateral displacement of the artery positions it directly into the injection target zone where it is

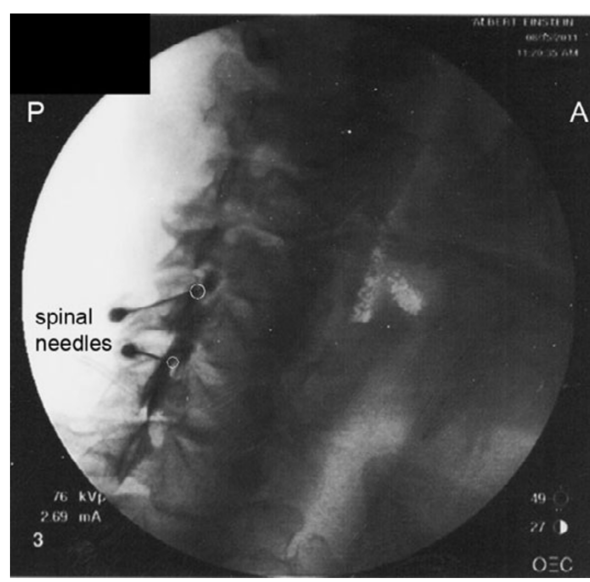

Figure 5 Right oblique fluoroscopic image demonstrating final needle position in the neural foramen with the needle tip remaining in the posterior aspect of the C4-5 and C5-6 neural foramina (as seen in white circles). Contrast dye has been injected at both levels somewhat filling each neural foramen. P = posterior, A = Anterior.

at risk for intra-arterial injection. An important finding is that lateral loops can occur at more than one vertebral level in a given artery, as they did in the left artery of cadaver no.1.

Studies of this phenomenon are few. Paksoy et al. [9] evaluated 173 patients with complaints of cervicobrachial pain, 13 of whom were found to have vertebral artery loop formation compressing nerve roots. Both medial and lateral loops were identified, but whether or not they entered the CTESI target zone was not discussed. Bruneau et al. [4] studied 500 VAs using computed tomography and magnetic resonance imaging (MRI) and described only medial loops of the vertebral artery although they mentioned in their discussion that lateral loops can occur. In 2010, Fink et al. [10] reported a patient in whom lateral loops of the vertebral artery resulted in painful radiculopathy but did not describe a treatment protocol. Sakaida et al. [11] described a case in which left radicular symptoms were attributed to nerve root compression caused by a medial loop of the VA. This anomaly was surgically repaired.

Anomalous loops are of concern to both spinal interventionalists and spine surgeons but for different reasons. The spine surgeon is more concerned with medially projecting loops that interfere with the surgical approach [12], while the interventionalist is more concerned with lateral loops that invade the injection target zone creating the risk of intra-arterial injection.

Accessory VAs can also increase the inherent risk of a properly performed CTESI. In the case of cadaver no.5, the bilateral accessory arteries entered the neural foramina posterior to the exiting nerve roots placing them directly in the injection target zone. Takasato et al. [13] described a case in which angiography confirmed the presence of two right vertebral arteries, along with a left accessory artery originating from the thyrocervical trunk. In their case, both the vertebral and accessory arteries traveled in the transverse foramina, never coursing through the neural foramen. Although the anomalies described by Takasato et al. differ anatomically from our findings, their documentation of anomalous vertebral arteries supports the notion that multiple types of accessory vertebral arteries exist. The present study shows that some of these may encroach upon the CTESI target zone.

In addition to lateral arterial loops and accessory vertebral arteries, we observed four instances (20%) of variation in the level of entrance of the vertebral artery to the transverse foraminal column. These variations are not uncommon [14] and when present do not increase the risk of intra-arterial injection during a CTESI. They are, however, evidence that the VA frequently exhibits a variant pathway.

Conclusion

This study has shown that anatomical variations of the vertebral artery, including accessory vessels and lateral loops, may place arterial segments in the posterior portion of the neural foramen, the target zone for cervical transforaminal epidural steroid injections. This aberrant location of the VA increases the risk for arterial cannulation during CTESI.

CTESI, when performed in the proper setting, can be an extremely useful tool in the management of painful cervical radiculopathy. As with any invasive procedure, even when performed properly, CTESI comes with inherent risks. For example, safe technique cannot account for anatomical variability that may exist from patient to patient and from artery to artery. In addition to using appropriate procedural technique, other safety measures such as digital subtraction are currently available and should always be employed. Pre-procedure MRIs should be examined closely to evaluate, if possible, the course of the VA. The sensitivity of using non-contrast MRI to determine the in vivo course of the vertebral artery has not been studied or demonstrated. Despite this, using MR images to evaluate the VA as well as the neural, osseous and ligamentous structures can only be helpful.

While the sample size in this study was small, the risk posed by anatomical variation was clearly demonstrated. It is important that physicians who perform cervical transforaminal epidural steroid injections be aware not only of safe technique and normal anatomy but of possible anatomical variations of the vertebral artery and surrounding tissues in order to most effectively avoid complications.

Acknowledgments

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