

Paravertebral Collateral Arteries in Patients with Carotid Stenosis: Is There a Safe Space for Transforaminal Cervical Nerve Root Injections?

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Abstract

Aim Image-guided cervical nerve root injections can cause serious complications including spinal cord infarction. This risk may be increased in patients with carotid stenosis who develop collateral arteries. The aim of this study is to describe the prevalence, and anatomical location, of arterial collateral vessels in relation to the optimal needle tip position in cervical nerve root injections.

Materials and Methods This retrospective study included 25 patients who had > 70% stenosis on a carotid CT angiogram. For each foramen the position of collateral arteries and the most anterior point of the facet joint were recorded, as Cartesian coordinates, by two independent observers. Descriptive statistics were used to analyse and present the results.

Results 14 patients had unilateral and 11 had bilateral stenoses. A total of 85 collaterals were identified at all levels, the most common being C2/3. The median distance from collateral to optimal needle tip placement was 9.6 mm (95% CI median: 6.7–12.4, IQR: 5.6–15.6). The minimum distance was 2.9 mm. Inter-observer reliability was “substantial” (ICC 0.78, 95% CI 0.71–0.83).

Conclusion Collateral arteries were common in our cohort of patients with carotid artery stenosis and half lay within

10 mm of the optimal position for transforaminal cervical nerve root injection.

Keywords Cervical nerve root injections · Carotid stenosis · Cervical collaterals · Optimal needle tip position

Introduction

Cervical nerve root injections are both diagnostic and therapeutic in patients presenting with symptoms of cervical radiculopathy, which may be the result of disc herniation or foraminal stenosis [1]. The aim is to inject corticosteroid, with or without local anaesthetic, near the exiting nerve root at the affected level. This reduces the perineural inflammation, which is believed to be the cause of the patient’s discomfort [1–3].

The most serious reported complications include death, stroke, arrhythmias, sensory or motor loss, meningitis, bleeding, and seizure [3, 4]. Complications may arise from intra-arterial injection of particulate preparations of corticosteroids. These may cause cervical spinal cord infarction by embolising the feeding anterior radicular artery of the spinal cord. Such small vessels may not be seen during image-guided injection, whatever imaging method is employed, until appreciated by the absence of contrast medium after injection. There are published guidelines for the positioning of the tip of the needle that aim to minimise inadvertent arterial puncture but it is difficult to completely avoid such complications [4, 5].

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Variations in the arterial supply to the neck are common. Some are congenital and others acquired later in life. Anastomoses between the vertebral and carotid branches, and other variations, have been described in patients with multiple severe stenosis, or occlusions, of the carotid and extracranial cerebral arteries [6–8]. These acquired anastomotic variants occur in older patients (Fig. 1). These are the same age as the majority of patients undergoing image guided cervical nerve root injections.

The guidelines for safe positioning of needles for cervical nerve root injections are based on normal arterial anatomy. To date there is no published literature that describes the distribution of collateral arteries around the cervical neural foramina in patients with carotid stenosis or occlusions. This information may identify a source of risk in these patients.

The aim of this study is to describe the prevalence and position of arterial anastomotic vessels around the cervical neural foramina in patients with carotid stenosis.

Materials and Methods

This was a retrospective cross-sectional imaging study approved by the local research ethics board. The study population consisted of patients who have undergone a CT angiogram of the carotid arteries for carotid stenosis or occlusion and whose CT studies were available on the hospital PACS archive.

Studies were included in sequential chronological order if one or more carotid arteries were reported to have a greater than 70% stenosis and if at least one collateral artery was visible. A collateral artery was identified if the mean attenuation value for the vessel was greater than 120 Hounsfield units (HU) and less than 250 HU (this range includes contrast medium within vessels, but excludes calcification) and if the origin of the vessel could be traced

to the carotid or vertebral arteries. The HU was measured using an ovoid region of interest tool (Synapse (PACS)TM, Fujifilm Medical Systems). The optimal needle position was defined as the point at which a line drawn from the most anterolateral surface of the vertebral body touched the most anterolateral surface of the facet at the level of the intervertebral foramen [2] (Fig. 2). The positions of each arterial collateral artery, and the optimal needle position, were recorded as Cartesian coordinates. All measurements were performed independently by two radiology trainees under the direction of a supervising interventional musculoskeletal radiology consultant.

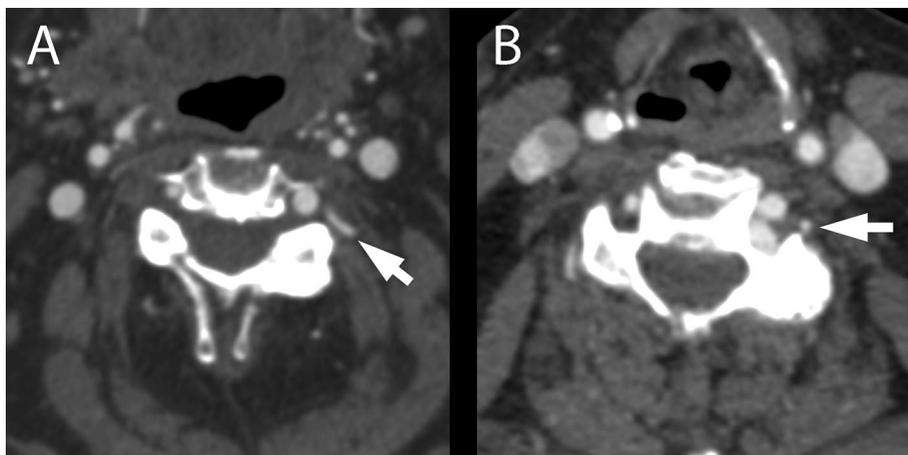
All measurements were corrected so that the coronal plane of the vertebra lay along the x -axis. This was performed by taking calculating the angle subtended by the A–B line to the x -axis using trigonometry. The angle was used to correct the angle of the diagonal from optimal injection point to collateral vessel and further trigonometry used to calculate the corrected x and y co-ordinates.

The sample size was calculated in order to ensure that the cohort was a representative of the population of patients being studied. The mean and standard deviation of measurements of collateral artery to optimal needle tip position were taken from 10 cases. The sample size n was calculated as the number of collaterals required to achieve a 95% confidence interval of 1.25 mm for the mean distance which gave a minimal sample size of $n = 39$ [9]. Descriptive and reliability statistics were performed using R [10].

Results

A total of 25 CT examinations were included in the study. 14 patients had unilateral and 11 had bilateral stenosis. The cohort comprised 12 men and 13 women with a median age of 77 years (range 47 to 95). A total of 85 collateral arteries

Fig. 1 Axial CT image at (A) C2/3 and (B) C4/5 with arterial phase iodinated contrast enhancement in a patient with a significant stenosis at the left carotid bifurcation demonstrating collateral arteries arising from the left vertebral artery (arrows) close to the intervertebral foramina at the optimal location for transforaminal injection



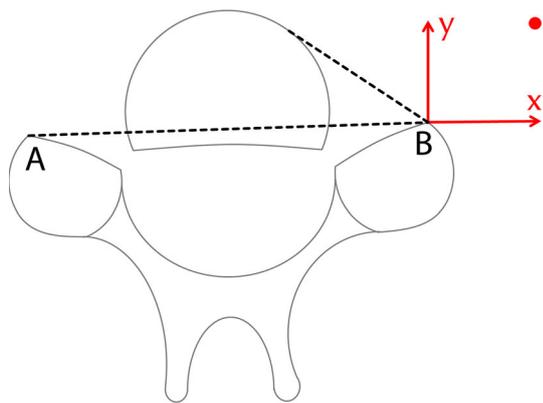


Fig. 2 Line drawing demonstrating the landmarks for primary endpoint measures. The *x*-axis was defined as a line between the anterior surface of the right and left facet joints (A–B). The position of each collateral artery (an arbitrary example is represented in this diagram by a red dot) was measured along *x* and *y* coordinates which were then corrected according to the slope of the A–B axis

were identified; 45 on the right and 40 on the left. The most prevalent level for the presence of a collateral artery was C2/C3 (*n* = 31, 36.5%). The frequency of collaterals at other levels was: C3/C4 (*n* = 22, 25.9%), C4/C5 (*n* = 11, 12.9%), C5/C6 (*n* = 9, 10.6%), C7/T1 (*n* = 8, 9.4%) and C6/C7 (*n* = 4, 4.7%) (Table 1).

Significantly more collaterals arteries were identified at the level of each disc in patients with bilateral carotid stenosis compared to those with unilateral stenosis (Wilcoxon signed rank test *p* = 0.034). In the 11 patients with bilateral carotid stenosis a total of 60 collateral vessels were identified at the axial level of the intervertebral foramina (median 2, Interquartile range 2–10) and of the 14 patients with unilateral carotid stenosis 25 collateral arteries were found (median 1, IQR: 1–2) (Fig. 3).

The one-way intraclass correlation coefficient for consistency (ICC = 0.78, 95% CI: 0.71–0.83) demonstrated a “substantial” [11] inter-rater agreement for the co-ordinates of both optimal injection point and position of collateral artery on the *x* and *y*-axes. The mean of the observed measured calculated and used for the following descriptive statistics.

Table 1 The number of collateral arteries identified at each cervical level from C1 to T1

Level	Right	Left
C1/2	0	0
C2/3	13	18
C3/4	13	9
C4/5	7	4
C5/6	4	5
C6/7	2	2
C7/T1	6	2
Total	45	40

The data describing the position of the artery, relative to the optimal needle tip position (the target), did not conform to a parametric distribution with both distance from, and angle to, the target position failing the Shapiro–Wilk test for normality (*p* < 0.001) and therefore the descriptive statistics are reported as median and interquartile ranges.

The median distance from target, for both right and left sided collateral arteries, was 9.6 mm (95% CI median: 6.7–12.4, IQR: 5.6–15.6). The median angular position was 60.3° (95% CI median: 51.5–69.1, IQR = 47.2–68.4). The minimum position from the target was 2.9 mm (Fig. 4).

Discussion

Previous authors have recommended an optimal needle tip position for safe paraforaminal cervical nerve root injections at a point where a line drawn at a tangent to the vertebral body and the facet touches the anterolateral facet joint [2, 4]. The results of this study suggest that this needle-tip position does not guarantee that the injection will avoid cervical collateral arteries in patients with significant carotid stenosis. Collateral arteries can be demonstrated, in patients with severe carotid stenosis (> 70%) at each cervical level but with decreasing cranio-caudal prevalence. The collaterals are located at a median distance of 9.6 mm anterolateral to this optimal injection point; in other words half of the collaterals were found within 10 mm. The minimum distance between a collateral artery and the optimal point needle tip position 2.9 mm however this does not represent a completely “safe” space. This is because the measurements were made from the centre of the collateral artery to the margin of the cortex of the facet this distance will be filled with half the diameter of the collateral artery, the periosteum and the margins of the facet joint capsule. Even so the risk of complications following arterial injection with non-particulate steroid is likely to be low.

While vertebrocarotid anastomotic collateral arteries have been documented with angiography, in patients with significant or occluded common carotid arteries [6, 7], this is the first study that relates the position of these vessels to the intervertebral foramen.

All the collateral arteries lie anterolateral to the optimal needle tip position. None were recorded posterior to the *x*-axis. This might suggest that a true lateral (decubitus) [12] or posterior [4, 13] approach might be safer than an anterolateral approach. However the problem being addressed is not that of inadvertent puncture of a collateral artery on the way in but of inadvertent injection after final positioning. When a cervical nerve injection is performed under CT guidance the injection itself is not imaged in real-time. Once the operator is satisfied with the location and a

Fig. 3 Frequency histograms comparing the number of collateral vessels identified at the level of the intervertebral foramina in patients with bilateral and unilateral carotid stenosis. In most patients only one vessel was identified but larger numbers of patients with bilateral stenosis had multiple collateral vessels

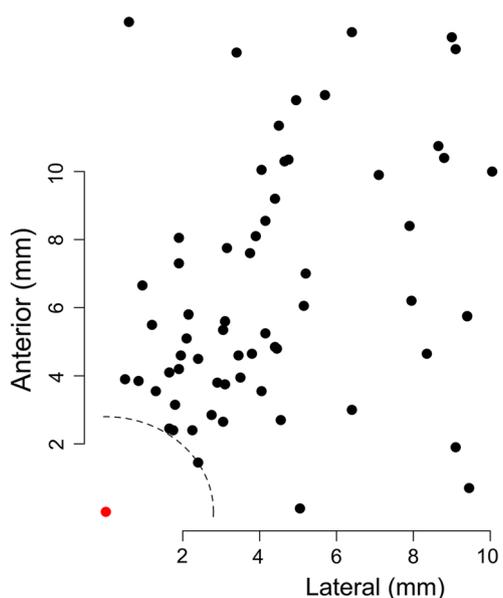
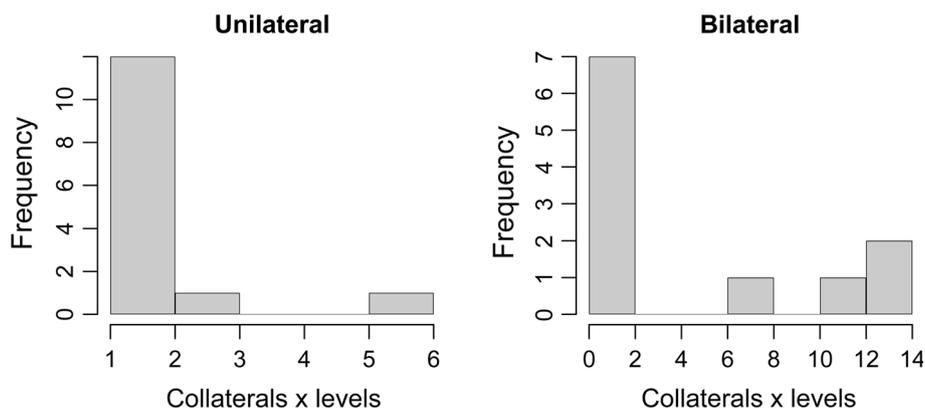


Fig. 4 Scatterplot demonstrating the anterolateral distribution of collateral arteries relative to the optimal needle position (red dot). This is a cumulative plot of all cervical levels, both right and left. The minimum distance from the optimal needle tip position to the centre of a collateral artery was 2.9 mm (dashed line)

satisfactory test injection of contrast medium has been performed then the steroid is injected slowly along with a further small amount of contrast medium. Therefore if the needle tip has moved between injections it is possible to inject the steroid into a collateral vessel and to not know until the final check CT is acquired. Performing nerve root injections under direct fluoroscopic control overcomes part of this problem in that an injection into a collateral vessel is soon apparent because of an absence of contrast medium visible on real-time fluoroscopy.

It is also not clear if it is the direct injection of a collateral artery that is the cause of spinal cord infarcts, or whether vasospasm induced by the nearby injectate may be responsible. Large case series of anterolateral injections suggest that this approach is as safe as others although none

of these studies specifically looked at the risk in patients with carotid stenosis or occlusion [14, 15].

Another way to minimize the risk of arterial puncture is an indirect approach to the cervical nerve root through the ipsilateral facet joint. Paraforaminal and epidural extension of injectate has been described in a cohort of 25 patients [16].

The narrow confidence intervals for the median suggest that the study was adequately powered and the “substantial” interobserver reliability indicates that the execution of the study was reproducible.

There are a number of limitations to this study. The study is limited by the phenotype of the population being studied. All patients in this cohort had symptoms attributable to the carotid stenosis and therefore the results might not be generalizable to patients with asymptomatic stenosis. The cohort is also susceptible to selection bias in that not all patients with severe carotid artery stenosis have CT angiography. Typically only those patients who are fit for an operation would have a CT carotid angiogram to assess the anatomy and document the degree of stenosis prior to surgery whereas this selection does not apply to patients having nerve root injections.

The study was performed by radiology trainees. This might be considered to be a limitation but in our institution most of the more than 500 CT guided nerve root injections performed each year are performed by our trainees supervised by a senior musculoskeletal radiologist. Therefore we consider them to be suitably qualified to perform this study particularly as their methodology was directly supervised and reviewed by the senior author.

The methodology leaves some questions unanswered. The study did not assess the accuracy of the observers’ ability to locate the optimal injection point, only the level of agreement in their observations. A study that measured their accuracy would require comparison with a third subjective observation because there is no absolute measure of location that can be used as a gold standard.

Therefore a study designed to measure accuracy would in effect be a similar inter-observer study.

The location of the collateral vessel was identified as the centre of the opacified vessel however it could be argued that the margin of the opacified lumen closest to the optimal injection point might be a more appropriate location to identify. The cross-sectional diameter of the collateral vessels is typically in the order of 1–2 mm and therefore this might have a small effect in reducing the median distance from injection point to collateral artery.

We would not make a formal recommendation that all patients with carotid artery stenosis or occlusion should have pre-procedural CT angiography because the results of this study do not provide evidence that will reduce the risk to these patients. However because collateral vessels were found commonly in our cohort of patients it may be that clinicians performing cervical nerve root injections consider performing CT angiography in patients with carotid stenosis or occlusion in order to inform the risk of arterial collateral puncture.

In conclusion collateral arteries were common in our cohort of patients with severe carotid artery stenosis. They were found at all levels but with decreasing frequency from C2 to T1. Half of all collateral arteries lay within 10 mm of the optimal needle tip position for paraforaminal nerve root injection and may constitute an increased risk for ischaemic spinal cord injury.

Author's Contribution APT: Guarantor of integrity of the entire study. APT, AF: Study concepts and design. AM: Literature search. Clinical studies—N/A. AM, AES: Experimental studies/data analysis. APT: Statistical analysis. AM, AES, APT: Manuscript preparation APT: Manuscript editing.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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