Anatomy

The nerve root exits from the lower aspect of the neural foramen, above its corresponding vertebral body. The anatomic relations of the neural foramen and the foraminal zone are shown in Figure 1. The lateral margin of the foraminal zone is demarcated by a line from the anterolateral vertebral body to the lateral aspect of the articular facet. The posterior aspect of the foraminal zone is the most appropriate site for cervical transforaminal steroid injection. At this location, the needle tip is immediately anterior to the convexity of the articular facet, posterior to the cervical nerve root, and posterior to the vertebral artery.

Cervical radiculopathy debilitates millions of people annually [1]. Radiculopathy is a clinical syndrome of radicular pain, numbness, or weakness secondary to nerve root inflammation and is most commonly caused by disk herniation or degenerative foraminal stenosis. When conservative treatments fail, an effective pain management option is cervical transforaminal steroid injection [2]. Delivering steroids close to a compressed cervical nerve reduces inflammation, which might be involved in the pain [3]. Some authors propose that reducing inflammation can also decrease the size of the swollen nerve and minimize the degree of compression. Local anesthesia is injected in combination with a steroid for immediate acquisition of diagnostic information about the appropriate level of injection.

Cervical transforaminal steroid injection can be guided by conventional fluoroscopy or CT fluoroscopy. The anatomic relations in the neck are better visualized with CT fluoroscopy. Careful technique, however, continues to be essential to avoiding serious complications [4, 5]. We describe the anatomy of the neural foramen and a technique of CT fluoroscopy–assisted cervical transforaminal steroid injection. We also discuss the role of contrast material in CT guidance and illustrate the contrast appearances of appropriate and inappropriate needle locations.

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Understanding of arterial anatomy is critical to prevention of intravascular injection (Fig. 2). Radiculomedullary arteries originate from the vertebral artery to supply the nerve roots and provide variable supply to the spinal cord via anastomoses with the spinal arteries. Because the radiculomedullary artery and the vertebral artery are anterior to the spinal nerve root, injection posterior to the nerve is preferred. The posterior foraminal zone is not avascular, however; variable arterial branches are present. These branches originate from...
the deep cervical artery and ascending cervical artery and can have feeding branches to the vertebral and radiculomedullary arteries. Rich venous plexuses around the neural foramen also are present (Fig. 2).

**Technique**

**Preparation**

A brief history and consent are obtained. The patient is asked to score the preprocedural pain level on an 11-point numerical scale (0, no pain; 10, worst pain imaginable) [6, 7]. Other important information is duration of pain, dermatomal distribution of symptoms, and history of injections. Previous relevant images are reviewed.

Patients are positioned on the CT scanner in the supine position with the head neutral or turned away from the side of injection. A radiopaque skin marker is placed on the lateral aspect of the neck, approximately at the plane of the earlobe. A planning unenhanced CT scan of the cervical spine is obtained, and the injection approach is planned. The approach includes determining a pathway that avoids the carotid sheath and vertebral artery and marking the skin for the needle entry site from the radiopaque marker (Fig. 3). Even without contrast administration, the interventionalist can identify the vertebral and carotid arteries by following these vessels on consecutive axial images. Noting the depth from the skin entry point to the foramen helps to identify the length of needle needed.

**Tip**—The interventionalist should consider whether symptoms and imaging findings correspond to the level requested for injection. The dermatomal distribution of pain is useful for identification of a specific cervical nerve root. If the injection requested does not match the distribution of radicular pain and imaging findings, an alternative injection level can be discussed with the referring physician.

**Needle Placement**

The skin is sterilized, draped, and anesthetized with 1% lidocaine. With intermittent CT fluoroscopic guidance, a 22-gauge 1.5- or 3.5-inch needle is advanced into the skin and directed to the posterior foraminal zone (Fig. 3). CT fluoroscopic images are displayed with bone windows so that the bony landmarks and needle can be appreciated with less artifact. The fluoroscopic capabilities allow switching of window displays during the injection to verify the position of the vertebral artery.

**Tip**—Heme can accumulate in the needle hub if the needle penetrates vascular structures. Blood can be cleared with gauze or a saline injection. Injection should not be performed until the aspirate is heme negative.

**Tip**—Microbore tubing connected to the needle hub can be used throughout the procedure to avoid inadvertent needle movement during syringe changes.

**Trap**—Use of needles smaller than 22-gauge can increase the risk of vascular access and decrease the ability to detect heme.

**Contrast Administration**

When the aspirate is clear, 0.2–0.5 mL of diluted contrast material is slowly injected with the bevel of the needle directed ventrally (Fig. 3). If there is evidence of inappropriate contrast distribution, the interventionalist can reposition the needle.

**Tip**—Injection of 1% lidocaine (~0.25 mL) before positioning of the tip in the posterior foraminal zone will clear the needle and tube apparatus of air and reduce patient discomfort.

**Trap**—Undiluted contrast material can obscure the needle tip and make repositioning the needle difficult. We favor the dilution ratio of 2 mL of sterile saline solution to 1 mL of iopamidol (Isovue-M 200, Bracco).

**Injection of Drugs**

The contrast syringe is detached, and a syringe containing 1 mL of betamethasone (3 mg/mL) (Celestone, Bayer HealthCare) and 1 mL of bupivacaine (2.5 mg/mL) is connected without introduction of air. After initial heme-negative aspiration, the solution is slowly injected. The needle is then removed, and manual pressure is applied. Although betamethasone does not self-aggregate into large particulates in solution (compared with methylprednisolone and triamcinolone), manual agitation of the solution is recommended immediately before injection because particulates can cause microvascular occlusion after intravascular injection [8]. The patient is observed for 30 minutes, and a postprocedural pain score is obtained before discharge.

**Tip**—Gentle intermittent aspiration should be performed throughout the injection to ensure extravascular positioning.

**Contrast Material**

Rare but serious complications of cervical transforaminal steroid injection, such as brainstem and spinal cord infarction, are thought to arise from three possible mechanisms of vascular occlusion: intraarterial corticosteroid injection, air embolism, and dissection [4, 5] (Figs. 4 and 5). The use of contrast material can reduce the risk of inadvertent intravascular injection, but it is important to note that neither contrast enhancement nor heme-negative aspiration alone is sufficient to exclude intravascular penetration [9, 10]. Contrast enhancement can also be helpful for optimizing needle position to maximize therapeutic response (Fig. 6) but must be used in combination with lower-gauge needles, microbore tubing, gentle aspiration, and air removal from the needle system to fully minimize risk. Using this technique, we have had no major complications of cervical transforaminal steroid injection.

Contrast enhancement alerts the interventionalist to inappropriate needle position. Extraforaminal injection results in accumulation of contrast material lateral to the foraminal zone (Fig. 7). Intravascular contrast injection washes away quickly and may appear as linear or focal enhancement around the vertebral artery or punctate enhancement in the paraspinal muscles (Fig. 8). Subperiosteal injection leads to accumulation of contrast material anterior to the facet joint with obtuse margins to bone (Fig. 9). Another indicator of subperiosteal injection is higher resistance during injection.

**Conclusion**

CT fluoroscopic guidance with contrast enhancement facilitates accurate positioning of the needle in the posterior foraminal zone for cervical transforaminal steroid injection. To maximize therapeutic response and minimize risk, the radiologist should be familiar with the complex anatomy of the neural foramen and the CT findings of appropriate needle positioning.

**References**

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Fig. 1—24-year-old man with history of neck pain after trauma shows normal anatomy of nerve root and neural foramen.

A and B, Three-dimensional surface-rendered (A) and axial (B) CT scans show neural foramen and its borders. Foramina are oriented anterolaterally 45° to sagittal plane. Neural foramen (asterisk, A) and foraminal zone (FZ) are bordered in anteromedial aspect by uncovertebral (UV) joints, posterolateral aspect by facet and facet joints, superior aspect by pedicle (P) of vertebra, and inferior aspect by pedicle (P) of lower vertebra. In medial aspect, foramina are formed by edge of vertebral body endplates and intervertebral disks. Ideal location of needle tip for cervical transforaminal steroid injection is posterior aspect of foraminal zone (dotted lines, B), immediately anterior to facet and posterior to vertebral artery (VA).

C, Axial CT myelogram shows intrathecal contrast enhancement in dural nerve root sleeve (white arrow) and contrast enhancement outlining ventral (arrowhead) and dorsal (black arrow) rami. Ventral and dorsal roots originate from spinal cord and unite in foramen to form cervical nerve root, which is surrounded by dural nerve root sleeve.

D, Axial T2-weighted MR image shows cervical nerve root (white arrow) and ventral (arrowhead) and dorsal (black arrow) rami.
CT Fluoroscopy for Cervical Steroid Injections

Fig. 2—35-year-old woman. Angiography for suspected arterial dissection shows normal vascular anatomy of neural foramen. VA = vertebral, IJV = internal jugular vein, CCA = common carotid artery, SCA = subclavian artery.
A, Axial maximum-intensity-projection CT angiographic image shows radiculomedullary artery (arrow), which branches from vertebral artery (VA) and anastomoses with anterior spinal artery (arrowhead).
B, Coronal maximum-intensity-projection CT angiographic image shows radiculomedullary arteries (arrows) feeding anterior spinal artery (arrowhead).
C, Axial CT angiographic image shows ascending cervical artery close to left neural foramen (white arrow) and branch of this artery (arrowhead) in left paravertebral muscle. Radiculomedullary artery (black arrow) is evident on right.
D, Coronal maximum-intensity-projection CT angiographic image shows ascending cervical arteries (arrows), which are branches of superior thyroid arteries originating from thyrocervical trunks. Right ascending cervical artery courses in neural foramen.
E, Coronal maximum-intensity-projection CT angiographic image shows bilateral deep cervical arteries (arrows) coursing in neural foramina. These branches originate from costocervical trunks.
F, Axial contrast-enhanced CT image shows anastomosis between foraminal venous plexus (arrowhead), anterior and posterior (black arrow) internal vertebral veins, and external vertebral venous plexus (white arrow).
Fig. 3—55-year-old man with left neck pain. Technique of cervical transforaminal steroid injection.

A, Photograph shows position of patient on CT scanner and radiopaque marker (arrow).

B, CT image shows planned pathway of needle to foraminal zone (1) and distance between skin entry site and radiopaque marker (2).

C, Photograph shows equipment on sterile tray. For shorter depths, 22-gauge 1.5-inch needle can be used.

D, CT fluoroscopic image shows needle in extraforaminal space. Needle must be advanced further.

E, CT fluoroscopic image shows needle in inappropriate position in posterior foraminal zone, anterior to facet.

F, CT fluoroscopic image after contrast injection shows needle and thin linear area of contrast enhancement (arrow) in posterior foraminal zone.
CT Fluoroscopy for Cervical Steroid Injections

Fig. 4—80 year-old woman with posterior circulation infarction after left cervical transforaminal steroid injection by another technique with large-particle steroid. A, Axial CT fluoroscopic image shows needle tip in region of left vertebral artery before injection of methylprednisolone (Depo-Medrol, Pharmacia & Upjohn) and bupivacaine. Normal right vertebral artery (arrow) is visible. Within several seconds after injection, patient became unresponsive, bradycardic, and hypertensive. IJV = internal jugular vein, CCA = common carotid artery. B, Axial T2-weighted MR image shows hyperintensity in left medulla (arrow) and cerebellum (arrowheads) consistent with acute infarction. C, MR angiogram shows normal left vertebral artery (VA) without dissection or occlusion. CCA = common carotid artery, SCA = subclavian artery.

Fig. 5—38 year-old woman with brainstem and spinal cord infarction after bilateral cervical transforaminal steroid injection of C6 by another technique with smaller-bore needle. A, Axial CT fluoroscopic image shows 22-gauge spinal needle in right foraminal zone. Left cervical transforaminal steroid injection was performed with 25-gauge needle. Left needle placement led to bloody ooze in needle hub, which was reported to cease before injection of triamcinolone (Kenalog, Apothecon) and bupivacaine. Patient reported severe headache immediately after injection, and upper and lower limb weakness developed. Minutes later patient experienced hypotension, bradycardia, and respiratory difficulty. B, Sagittal T2-weighted fat-saturated MR image of cervical spine shows hyperintensity and mass effect in medulla (arrow) and spinal cord (arrowheads) extending to C6 level. C, Axial T2-weighted MR image shows hyperintensity in spinal cord (arrow) that spares periphery; finding is consistent with acute infarction. Patient became permanently quadriplegic.
Fig. 6—Three different patients with left neck pain. Range of CT appearances of contrast enhancement in neural foramen. Appearance can vary depending on position of needle and volume of contrast material injected. CT appearance in Figure 3F is linear contrast. Other CT findings that indicate needle location is appropriate for injection are as follows.

A, CT fluoroscopic image shows contrast enhancement in foramen that outlines nerve root sleeve (arrow).

B, CT fluoroscopic image shows larger amount of contrast material filling most of neural foramen (arrow).

C, CT fluoroscopic image shows contrast material in foramen (white arrow) tracking into central epidural space (black arrow) in spinal canal. Locules of gas also are present.

Fig. 7—82-year-old woman with extraforaminal contrast accumulation after cervical transforaminal steroid injection. Axial CT fluoroscopic image shows needle tip to be extraforaminal and abutting facet. Contrast enhancement is predominantly extraforaminal (arrow). Cervical transforaminal steroid injection at this site can result in short-acting nerve block, but corticosteroids have not been delivered to site of nerve root compression and inflammation. Therefore, therapeutic potential of cervical transforaminal steroid injection is reduced. Needle must be repositioned so that tip is not abutting bone and can be advanced into foraminal zone.

Fig. 8—40-year-old man with intravascular contrast enhancement after cervical transforaminal steroid injection. Axial CT fluoroscopic image shows injection of contrast material around foramen (arrow) leads to enhancement of vessels (arrowheads) in paraspinal muscles. These vessels can be enhancing posterior vertebral veins or branches of ascending or deep cervical arteries.

Fig. 9—32-year-old man with subperiosteal contrast accumulation after cervical transforaminal steroid injection.

A, Axial CT fluoroscopic image shows subperiosteal contrast material hugging facet with obtuse margins to bone (arrow).

B, Axial CT fluoroscopic image shows contrast tracking along lamina (arrow) with greater volume of injection.