SPINE INTERVENTIONAL

Guidelines to Imaging Landmarks for Interventional Spine Procedures: Fluoroscopy and CT Anatomy

Alessandro Cianfoni, Daniel J. Boulter, Zoran Rumboldt, Tyler Zapton, and Giuseppe Bonaldi

ABSTRACT

Many diagnostic and therapeutic spine procedures can be performed percutaneously under fluoroscopic imaging guidance. Knowledge of radiographic and cross-sectional anatomy, together with strict adherence to procedural technique, is key for safety and success. This article reviews the fundamental principles of imaging guidance with fluoroscopy. The concepts behind the basic fluoroscopic views are discussed, including the EF and level-specific orthogonal views. Regional spine anatomy and a step-by-step approach for the most common percutaneous spine accesses are reviewed by comparing percutaneous needle access on the standard fluoroscopic views with their 3D and cross-sectional CT anatomy correlates.

ABBREVIATIONS KEY

AP = antero-posterior
CC = craniocaudal
EF = en face
ESI = epidural steroid injection
LL = lateral-lateral
LOR = loss of resistance
RL = right-left

Received February 3, 2011; accepted after revision March 23.

From the Medical University of South Carolina, Department of Radiology, (A.C., D.J.B., Z.R., T.Z.), Charleston, South Carolina; Ospedali Riuniti di Bergamo (G.B.), Bergamo, Italy

Please address correspondence to Daniel J. Boulter, MD, Medical University of South Carolina, 169 Ashley Ave, MSC 322, Charleston, SC 29418 e-mail: boulter@musc.edu

DOI 10.3174/ng.1110004

INTRODUCTION

Fluoroscopic imaging guidance permits precise and safe performance of a wide variety of percutaneous spine procedures, including injections for diagnosis and treatment of back pain, spinal and paraspinal biopsies, cement augmentation of vertebral fractures, and ablation of vertebral tumors.[1] Thorough knowledge of imaging guidance principles and spine anatomy, including both fluoroscopically visible bony landmarks and complex regional anatomy visible on CT, is critical for spine interventionalists. The purpose of this article is to review fundamental fluoroscopic image-guidance principles and techniques for the most common percutaneous spinal accesses. Fluoroscopic imaging landmarks for each access are displayed with their CT correlates to improve understanding of the relevant anatomy. For each spine access, sample images from a real case are also shown.

For sake of consistency, in all descriptions, the patient is assumed to be prone.

FLUOROSCOPY GUIDANCE PRINCIPLES

The spine has multiple curves; therefore, each vertebral body has a different spatial orientation (Fig 1). These level-specific orientations do not conform to the traditional concept of AP and LL views as defined by the straight orthogonal position of the fluoroscopy imaging unit (from now on referred as to the C-arm). For fluoroscopically guided spine procedures, AP and LL views should be defined differently for each individual vertebral level of interest (Fig 2), dependent on the unique physiologic and pathologic curvature of the patient.

Obtaining a Level-Specific AP and LL View

Obtaining precise orthogonal AP and LL views of the spine at the level of interest is a prerequisite to achieving the optimal view for needle insertion. At the target level, the C-arm angle is adjusted along the 2 axes: RL and CC, both in AP and LL positions (Fig 3).

AP View. Start from the AP position and rotate the spinous process of the target vertebral body into the midline by using RL C-arm adjustments. Profile the vertebral disk endplates until they appear as a single line, with disk spaces clearly visible, by using CC C-arm adjustments. When done correctly, the vertebral body has a "box"

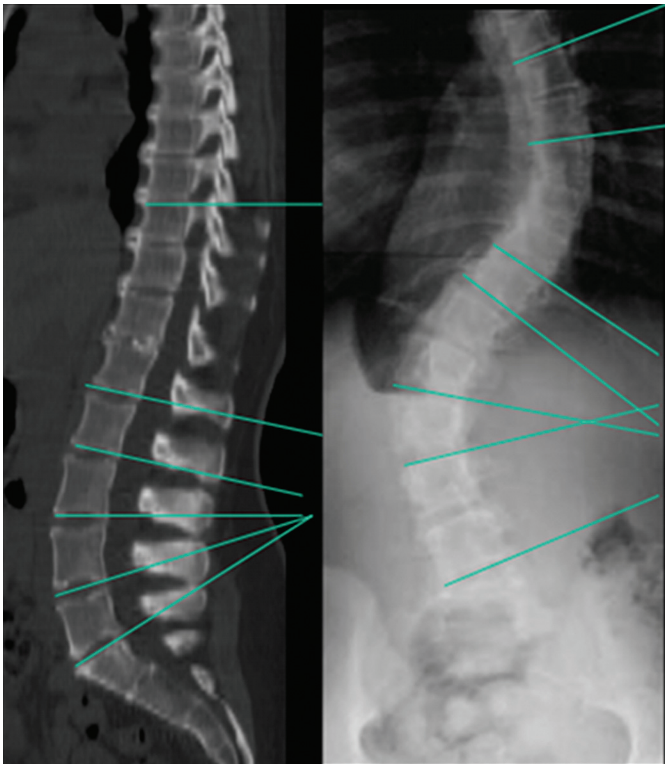

Fig 1. Vertebral bodies.

Each vertebral body has an individual orientation in space, with unique AP and LL axes, due to physiologic and pathologic spine curves. Even adjacent vertebral bodies or disk spaces can have different axes.

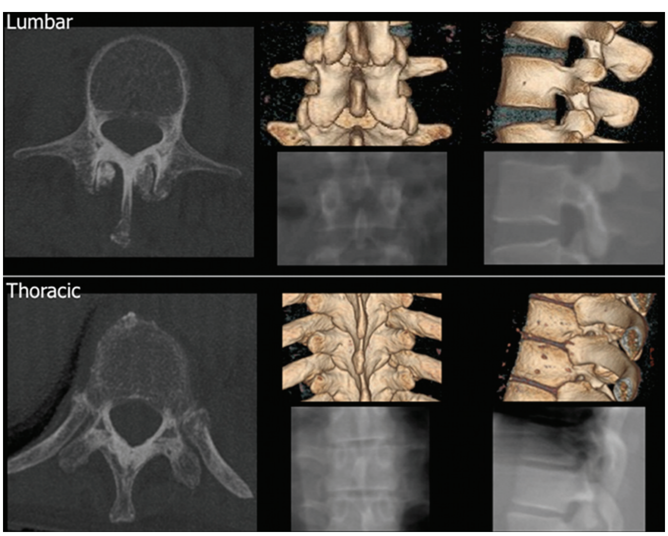

Fig 2. Pedicles.

Lumbar spine pedicles are straight and are projected on the superior half of vertebral body in the AP projection. Thoracic spine pedicles are oblique and are projected partially on the disk space in the AP projection. Ribs articulate with pedicles at the level of disk space.

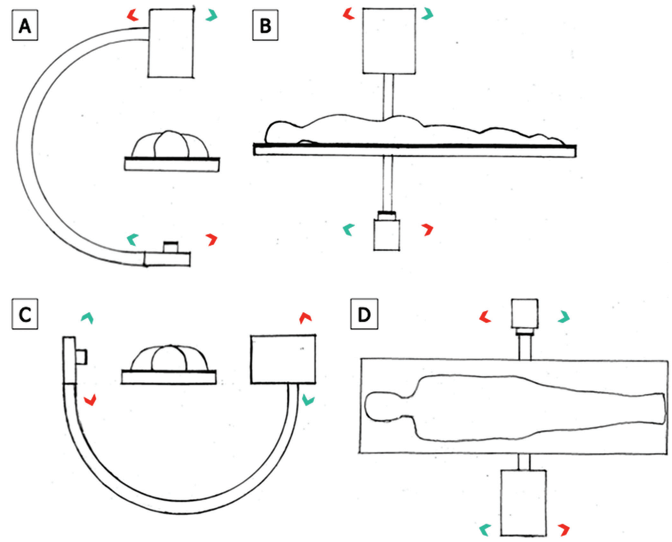

Fig 3. Elementary axes of C-arm rotation.

The AP view has 2 axes of rotation: LL (*A*) and CC (*B*). Red and green arrows denote the opposing directions of tube rotation. CC axes (*B*) are termed cephalocaudal (red) and caudocephalad (green). The LL view has 2 axes of rotation: RL (*C*) and CC (*D*).

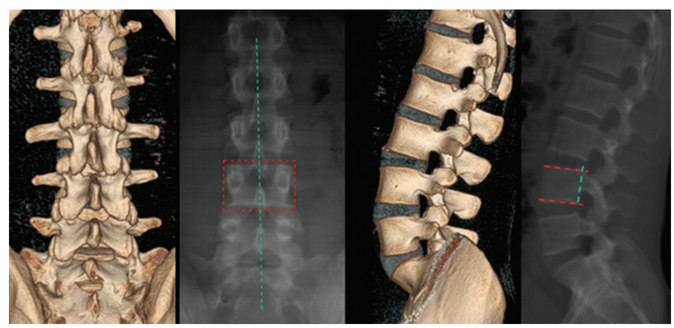

Fig 4. True AP and LL views at L4.

AP view shows the vertebral body appearing as a box with spinous processes in the midline. The LL view shows profiled disk endplates and the posterior vertebral wall. Note the superimposition of the posterior articular processes and the well-profiled foramina on the LL view. In obtaining an LL view at a thoracic level (not shown), fluoroscopic superimposition of the ribs should also be pursued.

appearance, with the spinous process along the midline (Fig 4).

LL View. Rotate the C-arm into the LL position, profile the disk endplates, and superimpose the pedicles by using CC C-arm adjustments. Profile the posterior wall and superimpose the articular processes by using RL C-arm adjustments. When done correctly, the vertebral body has a box-appearance and the foramina are clearly visible (Fig 4). A doubled appearance of the endplates and/or posterior vertebral body walls suggests an incorrect LL view, which may cause misjudgment of the underlying anatomy and dangerously wrong needle placement.

Obtaining AP and LL views at the level of interest may assume complex oblique angles of the C-arm, depending on the degree of curvature (physiologic and pathologic). The level of interest needs to be positioned in the center of the image to avoid parallax and to be appropriately collimated to reduce irradiation and scatter. Magnification might be obtained when necessary at a cost of increased radiation exposure.

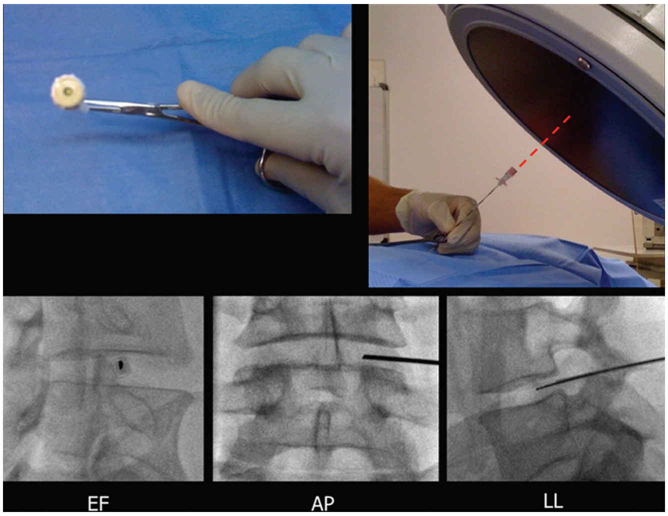

Fig 5. EF technique.

Once the desired fluoroscopic view is obtained, the needle is aligned along the image-intensifier-tube axis, seen EF by the x-ray beam, and it appears as a single radiopaque dot superimposed on the fluoroscopic target (disk space in this example). The AP and LL views are necessary to intermittently determine the exact location of the needle tip.

EF Technique

For safe and precise insertion of needles, the EF technique (also called "parallel," "bull's eye," or "down the barrel") is used (Fig 5). With the EF technique, the C-arm is angled precisely in line with the projected path of the needle from the skin to the target. The needle is then inserted parallel to the x-ray beam, appearing as a single radiopaque dot superimposed over the target. Intermittent orthogonal AP and LL views serve to determine the exact instrument-tip location during needle insertion and at the final desired needle placement.

Scottie Dog View

Percutaneous procedures in the lumbar spine often require oblique fluoroscopic views necessitating knowledge of the bony landmarks of the so-called "Scottie Dog" (Fig 6).To obtain a Scottie Dog view, first obtain a standard level-specific AP view ("box"), oblique the C-arm toward the desired access side until the appearance of the Scottie Dog with a well-profiled ipsilateral pedicle (eye) and superior articular process (ear).

COMMON LUMBAR AND THORACIC SPINE PERCUTANEOUS ACCESSES

Lumbar Interlaminar Access

The lumbar interlaminar access is used for both epidural injections and lumbar puncture (Fig 7A, -B).

Fluoroscopic EF View. First, obtain a level-specific AP view. Oblique the C-arm slightly in a CC direction, parallel to the orientation of the spinous processes. Oblique the C-arm slightly in a RL direction toward the desired access side, to open up the interlaminar space. The fluoroscopic target is the interlaminar space, either slightly lateral to the spinous process and below the spinolaminar junction or the inferior border of the lamina at the spinolaminar junction.

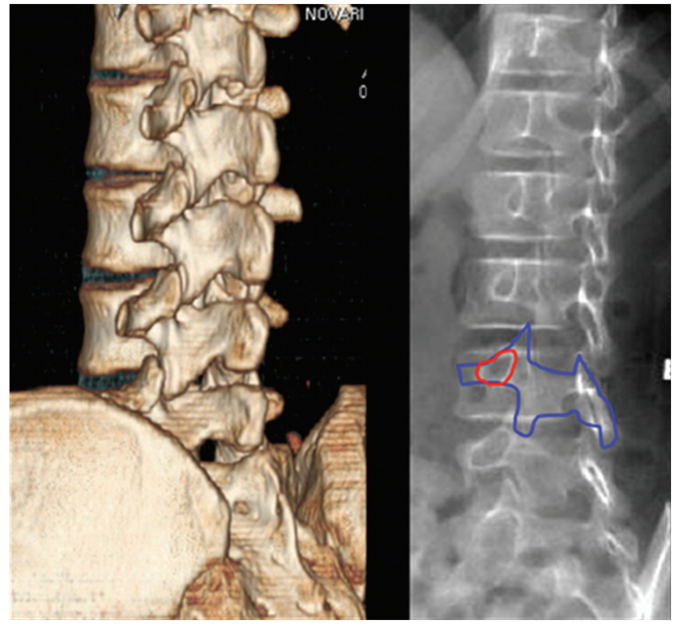

Fig 6. Scottie Dog view.

Oblique view of the lumbar spine provides an easily recognizable set of landmarks resembling a dog. The eye of the dog corresponds to the pedicle; the nose, to the transverse process; the ear, to the superior facet; the anterior leg, to the inferior facet; the body, to the lamina; and tail and posterior leg, to the spinous process.

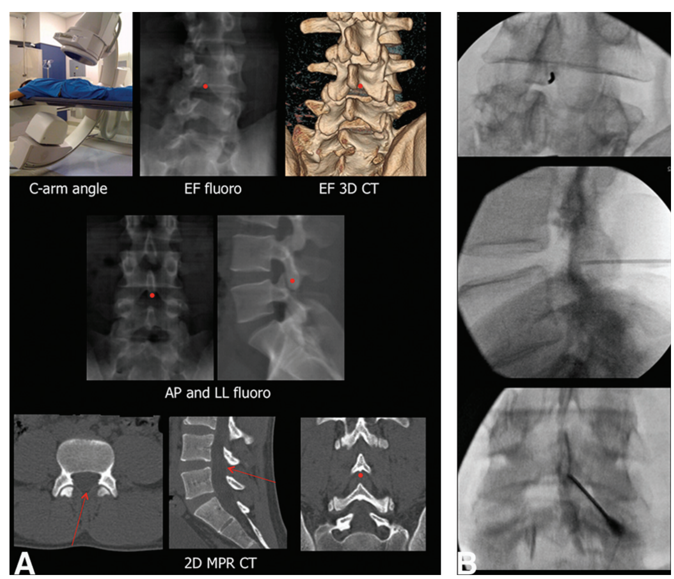

Fig 7. Right L4–L5 interlaminar access.

A, Caudocranial and minimal lateral obliquity of the C-arm opens the interlaminar space. The interlaminar space along the midline is the target. Bone contact can be made with the inferior edge of the lamina at the groin of the Scottie Dog. The needle can then be walked off the bone to pierce the yellow ligament. *B*, Epidural injection at L4–L5 through an interlaminar access. Note the EF view with the needle EF and the epidural contrast spread on the LL and AP views.

Needle Advancement. If the inferior border of the lamina has been targeted, once bone contact is obtained, the needle tip can be gently "walked off" the bone inferiorly and inserted in the ligamentum flavum. The needle tip traversing the ligamentum flavum is perceived by the operator as having increased resistance and a tactile "gritty" sensation as the needle is slowly and gently advanced.

Fluoroscopic AP and LL Views. AP view reveals the needle tip midline, just below the spinous process. The LL view shows the needle tip superimposed on the dorsal aspect of the inferior articular processes.

Procedural Details. If the thecal sac is the target, the needle tip is advanced to the center of the canal where free flow of CSF from the needle should be obtained.

If the epidural space is the target, the operator first passes through the ligamentum flavum by using the LOR technique. This technique exploits the difference in compliance of the thick fibrous ligamentum flavum and the epidural space, detected by the operator as decreased resistance to injection once the epidural space has been reached. The LOR technique was first described in 1933 by Dogliotti[2] by using a saline-filled syringe; however, modified LOR techniques using air or a combination of saline and air are described.[3,4] We suggest using a dedicated LOR syringe filled with sterile preservative-free saline and air.[4] The operator manipulates the syringe, so that air rises toward the plunger and intermittently applies gentle pressure on the plunger during careful advancement through the ligamentum flavum. If the needle tip is within the ligamentum flavum, the air meniscus within the syringe will compress and the plunger will bounce backward. Once the needle tip passes the inner margin of the ligament, entering the epidural space, the operator feels the loss of resistance to the plunger resulting in easy and effortless injection of saline. Contrast should then be injected under real-time fluoroscopy to confirm epidural needle tip placement, first on LL and then on AP views.

Lumbar Foraminal Access

The lumbar foraminal access is used for selective nerve root block and intraforaminal epidural steroid injection (Fig 8A, -B).

Fluoroscopic EF View. First, obtain a level-specific AP view. Oblique the C-arm in an RL direction toward the desired access side, until the superior articular process (the ear of the Scottie Dog in fluoroscopy) is superimposed over the superior disk space approximately two fifths of the length of the disk endplate line posterior to the anterolateral vertebral body margin. The classic fluoroscopic target is below the 6 o'clock position of the pedicle (eye of the Scottie Dog), assuming that an imaginary clock face is superimposed on the pedicle within the so-called "safe triangle." See below for a brief discussion of the controversy surrounding the safe triangle.

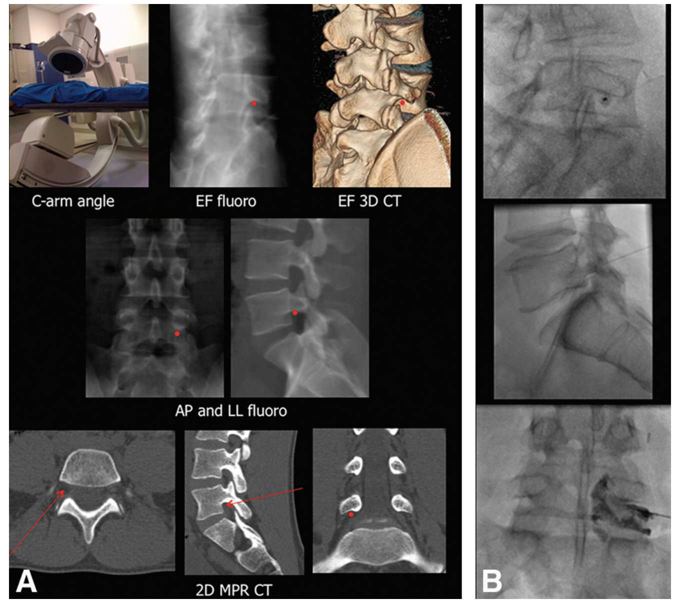

Fig 8. Right L5–S1 foraminal access.
A, If one targets an area below 6 o'clock of the eye of the Scottie Dog, the needle is placed just superior to the exiting nerve root (see coronal 2D CT image). *B*, Right L5–S1 transforaminal epidural injection. Precise EF view ensures accurate needle placement as confirmed by the desired spread of contrast on the AP view, which outlines the exiting L5 nerve root and adjacent epidural space.

Needle Advancement. Advance the needle slowly, lateral and ventral to the articular mass, until the needle tip is in the mid or anterior portion of the neuroforamen on the LL view or until the patient experiences radicular paresthesia. Occasionally, a loss of resistance to the needle advancement can be felt on entering the epidural space of the foramen.

Fluoroscopic AP and LL Views. AP view shows the needle tip below the pedicle lateral to an imaginary line joining the medial cortex of the pedicles to avoid puncturing the thecal sac. The LL view shows the needle tip in the upper and anterior quadrant of the neuroforamen.

Procedural Details. The operator should inject contrast under real-time fluoroscopy, first on the AP and then on the LL view, to rule out vascular runoff, keeping in mind the presence of the radicular arteries in the foramen, and to confirm spread of contrast along the exiting nerve sheath and/or adjacent epidural space. In doubtful cases, digital subtraction can be used before anesthetic or steroid injection to increase the sensitivity for vascular runoff.

Debate over the Safe Triangle Access. Although access to the safe triangle is the most widely recognized and used fluoroscopic target for intraforaminal injections, extremely rare but devastating complications, such as spinal cord infarctions, resulting in paraplegia, have occurred during such

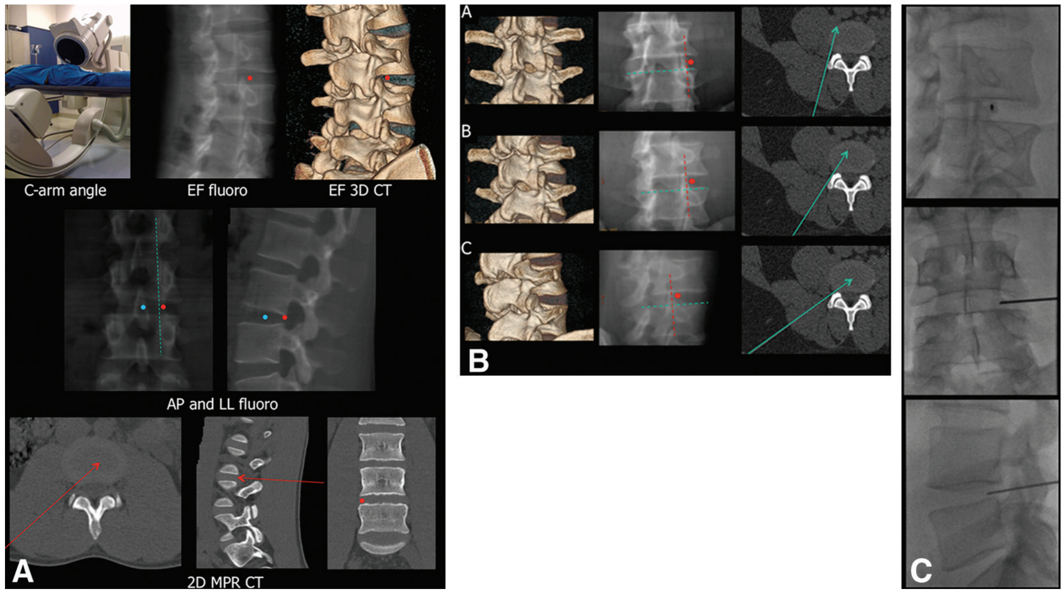

Fig 9. Right L3–L4 disk access.

A, Precise profiling of the disk endplates ensures accurate needle placement along the central axis of the disk space. The target is just anterior to the L4 superior articular process (ear of the Scottie Dog). The green dashed line on the AP view, connecting the medial borders of the pedicles, represents the lateral boundary of the central canal. The needle tip should never be advanced medial to this imaginary line, unless the LL view shows the needle tip at the posterior aspect of the disk space (*red dots*). The final position of the needle tip is marked by blue dots. *B*, Degrees of obliquity for disk access. The obliquity of the EF view determines the access to the central portion of the disk. The EF view obliquity is gauged by the position of the ear of the Scottie Dog relative to the disk endplate (*green dashed line*). (*A* and *B*) The ear of the dog projects too anteriorly along the disk endplate, leading to potential nerve root injury and incorrect lateral access to the disk. *C*, Correct obliquity of the EF view, with the ear of the dog at the midpoint of the disk endplate, allows safe and correct access to the center of the disk. Right L4–L5 disk access. On the EF view, the ear of the dog bisects the L5 superior disk endplate. The target is just anterior to the L5 superior articular process with the needle placed EF. Intermittent AP and LL views are used to determine depth of the needle. The AP and LL views demonstrate the needle tip inserted in the disk, just within the annulus fibrosus.

procedures.[5] The most likely explanation for such complications is embolization, vasospasm, or direct vascular injury to the radicular arteries supplying the spinal cord, which can be found at any thoracolumbar level, with unpredictable interindividual variability. Anatomic and angiographic studies have demonstrated that radicular arteries supplying the spinal cord, most notably the arteria radicularis magna or artery of Adamkiewicz, though variable in the foraminal level of entry into the thecal sac, almost invariably course in the upper and midportion of the neuroforamen along the exiting nerve root. This course has prompted some authors to debate the safety of this widely taught approach to the upper portion of the foramen[5,6,7] and to propose a safer and equally efficacious access to the thoracolumbar foramina in the inferior third portion, similar to a disk access (see below). The LL view is used to adjust depth of the needle tip, to prevent disk penetration.

Lumbar Disk (L1-L2 to L4-L5) Access

The lumbar disk access is used to perform disk biopsy, disk decompression, disk injection, and discography (Fig 9A–C).

Fluoroscopic EF View. First, obtain a level-specific AP view. Then, precisely profile the disk endplates on both sides of the target disk space by adjusting the C-arm in the CC direction. Oblique the C-arm in the RL direction toward the desired access side, until the ear of the Scottie Dog (the superior articular process) bisects the disk endplate at its midportion (Fig 9B). A lesser degree of obliquity may result in nerve injury and incorrect peripheral/annular disk access. More pronounced obliquity carries the risk of violation of the thecal sac but allows a more posterior access to the disk if desired. If the degree of obliquity is limited by imaging equipment, patient positioning, or body habitus, a coaxial technique can be used, in which a curved-tip inner needle is inserted through a larger bore outer needle. The fluoroscopic target is just anterior to the superior articular process in the center of the disk space.

Needle Advancement. Advance the needle slowly, by using the LL view and align the needle to the central axis of the disk to avoid the disk endplates. In case of radicular paresthesia or pain, the needle needs to be retracted and generally redirected slightly medial and inferiorly, toward the "safe zone" described by Kapoor et al,[8] to avoid the exiting nerve root. Needle tip position needs to be verified on the AP and LL views before entering the annulus. The needle passing through the annulus fibrosus is perceived by the operator as an increased firm/elastic gritty tactile sensation and as a subsequent loss of resistance at the annulus-nucleus junction.

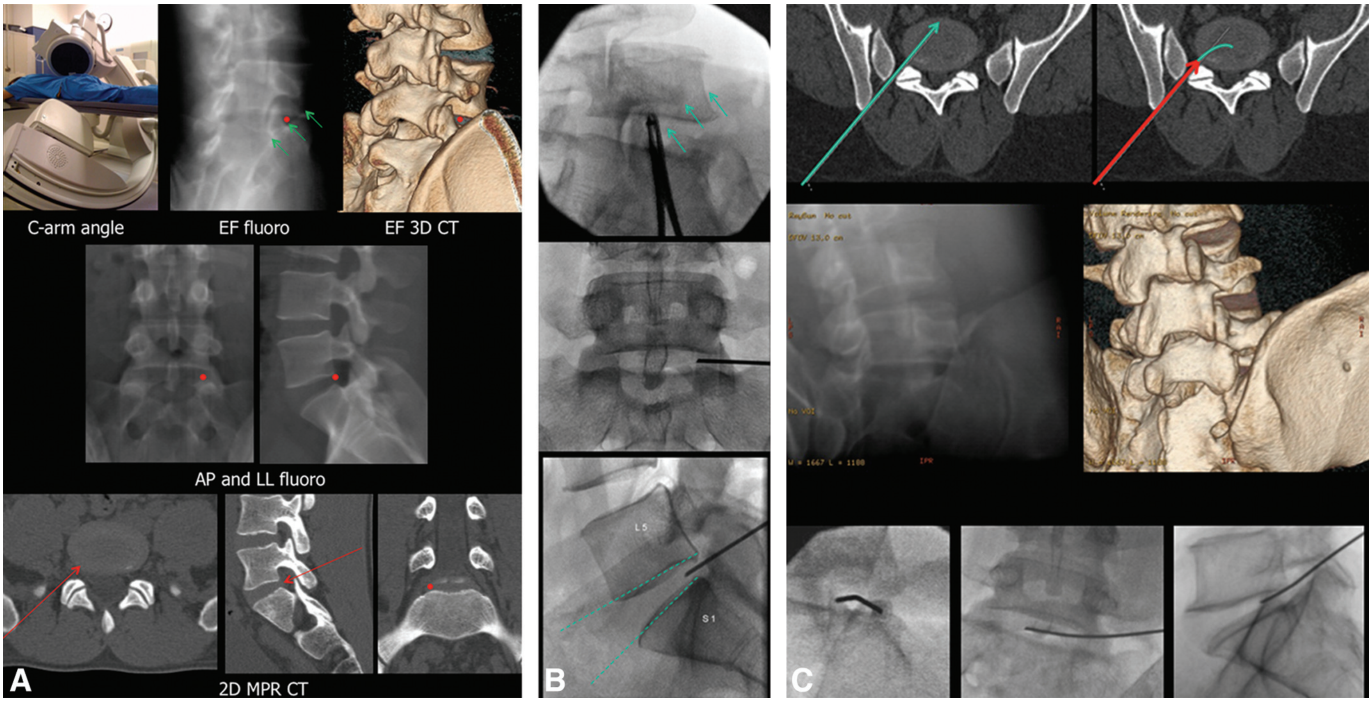

Fig 10. Right L5–S1 disk access.

A, Prominence of the iliac crest (green arrows) and the degree of lordotic angle at L5–S1 can be a challenge. The iliac crest tends to limit the desired oblique access to the disk space, best appreciated on the EF 3D CT and axial 2D CT images. The coronal CT image shows the target at the posterior aspect of the disk, just inferior and medial to the exiting nerve root. *B*, Right L5–S1 disk access. The needle is placed EF, with the help of a needle holder superimposed on the narrow radiolucent triangle target. Note the curvilinear shadow of the iliac crest on the EF view (*green arrows*) forming the lateral border of the triangle. AP and LL views show the needle tip within the disk space, aligned along its major axis and bisecting the imaginary angle between the divergent disk endplate profiles on the LL view (*green dashed lines*). *C*, Curved-needle access to the L5–S1 disk space. When a prominent iliac crest limits the obliquity of the EF view and access to the L5–S1 disk (*green arrow*), a curved-needle access to the disk center can be performed by using a curved needle passed over a straight k-wire, previously placed with a standard approach, as shown in the real-case example. Alternatively, a smaller caliber curved coaxial needle can be passed through a straight cannula.

Fluoroscopic AP and LL Views. The AP view obtained just before entering the disk space shows the needle tip superimposed on the lateral disk space above the pedicle of the inferior vertebral body. The needle tip should be lateral to an imaginary line connecting the medial borders of the pedicles, representing the lateral margins of the central canal and of the dural sac. The LL view shows the needle in the lower part of the foramen, at the posterior disk margin. Once the needle is advanced into the disk, the needle tip will be in the center of the disk space on the AP and LL views.

Procedural Details. The use of general anesthesia or local anesthesia into the foramen is contraindicated because patient feedback of radicular sensation is critical to avoid nerve injury. Local anesthesia is not to be administered deep to the posterior articular processes. With penetration of the annulus fibrosus, a sharp nonradicular low-back pain sensation is generally reported by the patient.

Lumbar L5-S1 Disk Access

The lumbar disk access for the L5-S1 level is unique due to the narrow anatomic window of access between the iliac crest, superior articular process of S1, and the inferior endplate of L5 (Fig 10A–C).

Fluoroscopic EF View. First, profile the L5-S1 disk endplates in the AP view by adjusting the C-arm in the CC direction. Note that the disk endplates at L5-S1 are usually divergent anteriorly due to the lordotic curvature and, therefore, cannot be profiled fluoroscopically on the same AP view. If one adjusts the C-arm obliquity in the CC direction, the profile of the inferior L5 disk endplate will appear first; then, if one progresses to further obliquity, the profile of the superior S1 disk endplate will appear. The optimal CC obliquity of the C-arm for the L5-S1 disk access is intermediate between these 2 landmarks. Oblique the C-arm in the RL direction toward the access side until the S1 superior articular process bisects the midpoint of the S1 superior disk endplate. The iliac crest is fluoroscopically projected as a curved line lateral to the S1 articular process.

The fluoroscopic target is a radiolucent small triangle bordered superiorly by the L5 inferior disk endplate, medially by the S1 articular process, and laterally by the iliac crest, representing a window of access to the disk space.

C-arm angles can be very pronounced to obtain this fluoroscopic view. During RL adjustment of the C-arm, the medial border of the iliac crest will progressively narrow the

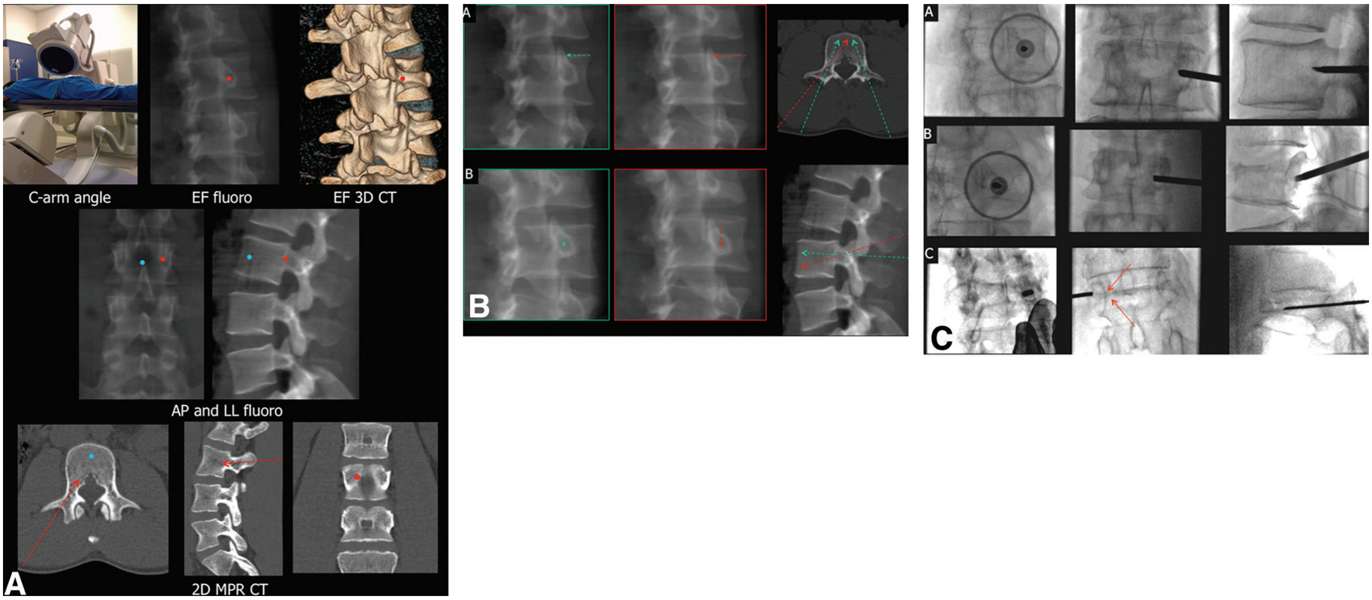

Fig 11. Right L3 pedicular access.

A, The EF target is the center of the eye of the Scottie Dog. While advancing the needle in the pedicle, one should take care not to breach the medial pedicle cortex. Check intermittently the AP and LL views during needle advancement. The medial cortex of the pedicle is the safety margin on the AP view until the posterior vertebral wall is passed on the LL view (*red dots*). Once the posterior vertebral wall is reached, the needle is advanced toward the midline and the safety margin is the junction between the mid and anterior thirds of the vertebral body (*blue dots*). *B*, Degrees of obliquity for pedicular access. Access to the ipsilateral half or midline of the vertebral body is determined by RL adjustments in the degree of EF obliquity (*A*). Lesser obliquity (green arrow) is chosen for a bipedicular access. Greater obliquity (red arrow) is best for unipedicular access. Using RL tube adjustments, the pedicle can be superimposed more peripherally or centrally within the vertebral body, determining access to the lateral portion or center of the vertebra, respectively. Access to the upper or lower half of the vertebral body is determined by craniocaudal adjustments in the degree of EF obliquity. Lesser obliquity (*green arrow*) is chosen for upper-half access; greater obliquity (*red arrow*) is chosen for lower-half access. With CC tube adjustments, the pedicle can be superimposed more superiorly or centrally within the vertebral body, determining access to more cranial or caudal portions of the vertebra, respectively. *C*, Three real-case examples of vertebral pedicular access with increasing craniocaudal obliquity from *A* to *C*, as required by the moderate compression deformity of the vertebral body in *B* and complete collapse (vertebra plana) in *C*. The correct EF view for access to a collapsed vertebra is obtained by superimposing the pedicle on the anterior vertebral body wall (*arrows in C*) between the collapsed anterior margins of the endplates.

target (radiolucent triangle), at times limiting the obtainable degree of obliquity.

Needle Advancement. The needle advancement is the same as that for L1-L4 to L4-L5 disk access.

Fluoroscopic AP and LL Views. The fluoroscopic AP and LL views are the same as those for L1-L4 to L4-L5 disk access.

Procedural Details. Depending on the degree of lumbosacral lordosis, the needle skin entry point can be more cranial for L5-S1 than for L4-L5 access, and the lateral distance from the midline increases with the size of the patient. The iliac crest may obstruct desired oblique access, therefore necessitating a lesser degree of RL obliquity. Lesser obliquity limits access to the central and posterior portions of the disk and increases the risk of nerve root injury. A coaxial technique with a curved needle can be used to circumvent the bone. Alternatively lateral decubitus positioning can be attempted, with a bolster under the contralateral recumbent iliac crest, to tilt the ipsilateral iliac crest and widen the desired anatomic access. Male patients generally have high-riding iliac crests, which result in more difficult access compared with females.

Lumbar Transpedicular Vertebral Body Access

The lumbar pedicular access is used for vertebral body biopsy, vertebroplasty, and kyphoplasty (Fig 11A–C).

Fluoroscopic EF View. First, obtain a level-specific AP view (box view of the vertebral body) with CC adjustments of the C-arm. Oblique the C-arm in an RL direction toward the desired access side until a view of the Scottie Dog is obtained. The fluoroscopic target is the center of the eye of the Scottie Dog. The margins of the eye of the Scottie Dog represent the cortical margins of the pedicle. In the lumbar spine, the pedicle is fluoroscopically superimposed on the upper half of the vertebral body, contained within the boundary of the superior disk endplate. Depending on the desired final position of the needle tip within the vertebral body, the C-arm can be angled to various degrees in the CC and RL directions. Adjustments in the CC direction superimpose the pedicle on the upper or lower half of the vertebral body, which will respectively result in access to the superior or inferior portion of the vertebral body. Adjustments in RL obliquity will determine access to the ipsilateral half, to the midline, or to the contralateral half of the vertebral body.

Needle Advancement. Once the needle tip is docked in bone, it can be advanced into the pedicle and vertebral body manually or by gentle mallet tapping, while intermittently checking its exact position in the AP and LL views.

AP and LL Fluoroscopic Views. AP and LL views, respectively, show the needle tip just lateral to the outer margin of the pedicle (AP) and in the posterior third of the pedicle (LL), when the needle is just docked in bone; within the center of the pedicle (AP) and in the middle third of the pedicle (LL) when the needle is advancing in the pedicle; just medial to the inner margin of the pedicle (AP) and just ventral to the posterior vertebral wall (LL) when the needle is entering the vertebral body; and along the midline (AP) and at the anterior third of the vertebral body (LL) when the needle is completely inserted into the vertebral body.

While the needle tip is being advanced within the pedicle, it can inadvertently cross the medial border of the pedicle (the safety landmark), indicating pedicular cortical breach and central canal penetration. When the needle tip is within the vertebral body, it should not be advanced past the junction of the middle and anterior thirds in the LL view to avoid anterior wall cortical breach and injury to the retroperitoneal organs. Accordingly, advancement of needle within the pedicle has to be performed under AP fluoroscopic control, while advancement within the vertebral body has to be performed under LL fluoroscopic control.

Procedural Details. Slight adjustments of the CC and RL obliquity of the EF view are crucial while precisely directing the needle toward a specific area of the vertebral body, as is the case in biopsies of focal lesions or when obliged by distorted anatomy, such as in compression fracture deformities. As a general rule, when visible, the final target should be superimposed on the pedicle on the EF fluoroscopic view.

Thoracic Extrapedicular Vertebral Body Access

The extrapedicular approach can be useful to access the thoracic vertebral body, especially above T8, when small size and straight AP orientation of the pedicles prevent sufficiently oblique pedicular access to reach the midline of the vertebral body (Fig 12 A, -B).

Fluoroscopic EF View.- First, obtain a level-specific AP view, with a box appearance of the vertebral body, by using CC C-arm adjustments. The pedicles in the thoracic spine are oriented obliquely in a CC axis, and the AP projection of the pedicles is usually partially superimposed on the adjacent cranial disk space. Oblique the C-arm in a CC direction, toward the head, until the pedicles are superimposed on the vertebral body, slightly cranial to the transverse process. Oblique the C-arm in an RL direction toward the desired access side until the pedicle is between the lateral

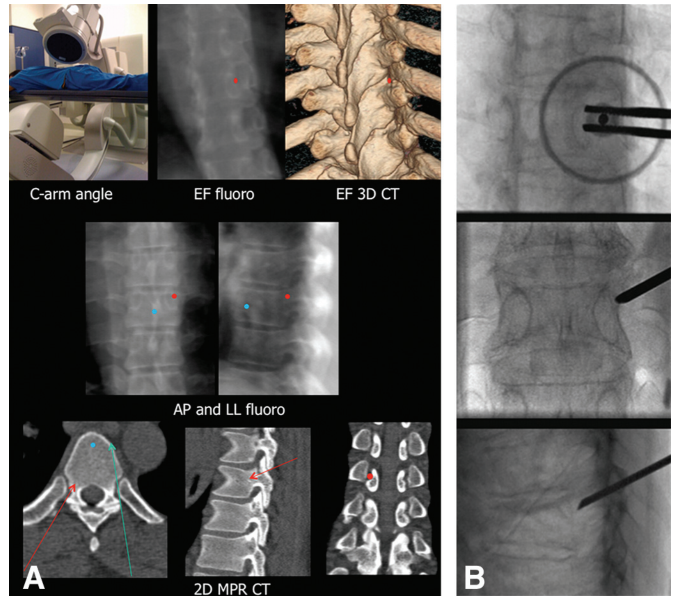

Fig 12. Right T7 extrapedicular access.

A, On the EF view the target is the costovertebral joint at 2 o'clock relative to the pedicle. Keep the needle tip medial to the rib head and pleural line. The needle passes the posterior vertebral wall lateral to the pedicle (*red dots*). The rib head keeps the needle in place. The final position is the anterior vertebral body, along the midline (*blue dots*). Note on the axial 2D CT image that due to the sloping anterior wall of the thoracic vertebral body, the needle can be advanced to the anterior half of the vertebral body only when a good obliquity toward midline is obtained; otherwise the anterolateral cortex can be breached (*green arrow*). *B*, Right T7 extrapedicular vertebral access. The target with the EF technique is 2 o'clock relative to the pedicle, with the needle placed EF between the pedicle and the rib head. The AP and LL views show the needle tip at the posterosuperolateral corner of the vertebral body, directed craniocaudally. From this position, the needle can be advanced toward the anterior half of the vertebral body along the midline.

one third and the medial two thirds of the vertebral body and/or the costovertebral joint is profiled. The target is the costovertebral joint, located at the superolateral aspect (2 o'clock for a right access, 10 o'clock for a left access) of the pedicle.

Needle Advancement. The needle tip should strictly remain medial to the rib head and pleural line. The needle will slide above the transverse process along the lateral aspect of the pedicle and the medial aspect of the rib head, in the so-called costopedicular junction. This is often felt as a fibrous firm nonosseous structure, until true bone contact is made with the posterosuperolateral aspect of the vertebral body. Once bone contact is made, the needle can be advanced into the anterior one third of the vertebral body toward its midline.

Fluoroscopic AP and LL Views. The AP view shows the needle tip just lateral to the outer border of the pedicle. The LL view shows the needle tip at the posterior vertebral wall. When the needle enters the vertebral body, the safety margin is the midline on the AP view and the junction of middle and anterior thirds of the vertebral body on the LL view.

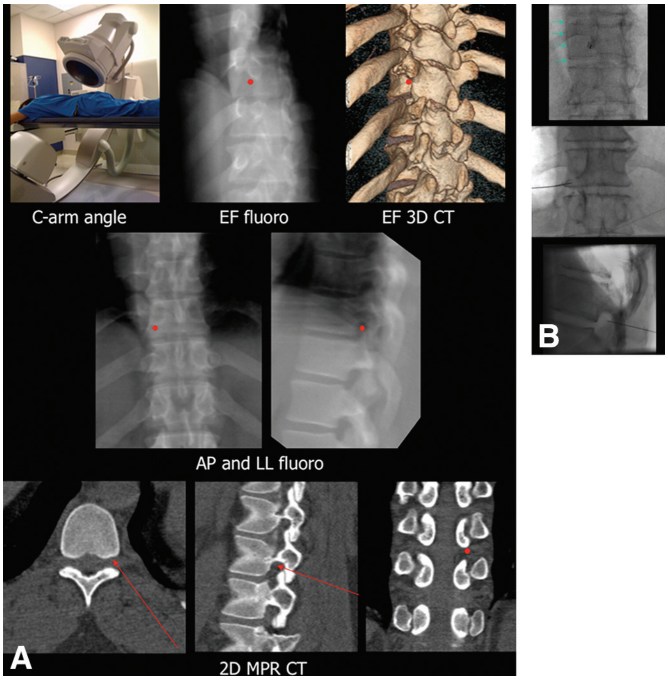

Fig 13. Left T10–T11 foraminal access.

A, The EF view and the needle access have a caudocranial obliquity to pass under the transverse process. The pedicle should be fluoroscopically superimposed on the disk space above. The target is 7 o'clock relative to the pedicle. On the AP view, the needle tip must be lateral to the medial cortex of the pedicle to avoid puncturing the thecal sac. Inject contrast to rule out vascular runoff. *B*, Left T10–T11 transforaminal injection. The needle is placed EF below the pedicle, medial to the pleural line (*green arrows*), until radicular intercostal paresthesia is elicited. Contrast injection is mandatory to rule out vascular runoff, due to the presence of radicular arteries. On the AP view, contrast spread is seen in the foraminal epidural space.

Procedural Details. At the higher thoracic levels, the fluoroscopic EF view and needle access have a steep cephalocaudal direction to slide above the transverse process. The vertebral body entry point is usually at the superior and posterolateral corner of the vertebral body, pointing toward its anteroinferior portion. If the needle is not near the midline on the AP view, it should not be advanced past the midportion of the vertebral body on the LL view so as not to risk breach of the anterolateral cortex, due to the sloping of the anterior vertebral wall in the upper thoracic spine.

Thoracic Foraminal Access

The thoracic foraminal access is used for thoracic selective nerve root blocks and intraforaminal thoracic epidural injections (Fig 13A, -B).

Fluoroscopic EF View. First obtain a level-specific AP projection (box appearance) of the vertebral body by using CC C-arm adjustments. Oblique the C-arm further in the CC direction toward the feet, until the pedicles are completely superimposed on the cranial disk space. Oblique the C-arm in an RL direction toward the desired access side until the pedicle is between the lateral one third and the medial two thirds of the vertebral body. The target is below the inferolateral aspect of the pedicle at 5 o'clock for right access and 7 o'clock for left access.

Needle Advancement. Advance the needle slowly under EF fluoroscopic view, keeping the needle tip medial to the pleural line to avoid pneumothorax. Advance until the needle tip is in the midportion of the foramen on the LL view or the patient experiences radicular paresthesia.

Fluoroscopic AP and LL Views. The AP view shows the needle tip below the pedicle lateral to the medial cortex of the pedicle. The LL view shows the needle tip at the superior portion of the foramen.

Procedural Details. Strict fluoroscopic control during needle advancement is required to avoid pleural puncture. The operator should inject contrast under real-time fluoroscopy to exclude vascular runoff, first on the AP and then on the LL view, keeping in mind the presence of the radicular arteries in the foramen and to confirm spread of contrast along the exiting nerve sheath and/or the adjacent epidural space. In doubtful cases, to increase sensitivity, digital subtraction can be used to rule out vascular runoff before anesthetic or steroid injection.

As in the lumbar spine, the thoracic intraforaminal needle access and injection carry the risk of embolization and injury to the radicular arteries, and the debate over the safe triangle applies to the thoracic procedures as well. Some authors propose as safer and equally efficacious an access to the inferior portion of the neuroforamen (see above in "Lumbar Foraminal Access").

CONCLUSIONS

Thorough knowledge of imaging guidance principles and regional anatomy is a necessary requisite for the spine proceduralist. Comparison of standard fluoroscopic projections for commonly performed spinal accesses, with their correlate multiplanar 2D and 3D CT images, may aid understanding of the principles of fluoroscopic views and the underlying relevant complex spinal anatomy.

REFERENCES

1. Mathis JM, Golovac S, eds. *Image-Guided Spine Interventions.* 2nd ed. New York: Springer-Verlag; 2010
2. Dogliotti AM. **A new method of block anesthesia: segmental peridural spinal anesthesia.** *Am J Surg* 1933;20:107–18
3. Segal S, Arendt KW. **A retrospective effectiveness study of loss of resistance to air or saline for identification of the epidural space.** *Anesth Analg* 2010;110:558–63
4. Goodyear P. **Identification of epidural space using air and normal saline.** *Anaesthesia* 2001;56:397–98
5. Glaser SE, Shah RV. **Root cause analysis of paraplegia follow-**

ing transforaminal epidural steroid injections: the 'unsafe' triangle. *Pain Physician* 2010;13:237–44
6. Ruan X, Chiravuri S. **Truly a critical review: root cause analysis of paraplegia following transforaminal epidural steroid injections—"unsafe" triangle.** *Pain Physician* 2011;14:E82–83
7. Murthy NS, Maus TP, Behrns CL. **Intraforaminal location of the great anterior radiculomedullary artery (artery of Adamkiewicz): a retrospective review.** *Pain Med* 2010;11:1756–64
8. Kapoor V, Rothfus WE, Grahovac SZ, et al. **Radicular pain avoidance during needle placement in lumbar diskography.** *AJR Am J Roentgenol* 2003;181:1149–54