Lumbar Epidural Injections

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Introduction

Low back and lower extremity pain may be secondary to degenerative disc disease with disc disruption, disc herniation, disc protrusion, and disc extrusion; central or foraminal stenosis; discogenic pain without disc herniation, facet joint pain, or sacroiliac joint pain; and post-lumbar surgery syndrome amenable to appropriate diagnosis and management with surgical and nonsurgical interventions. However, disc herniation resulting in lumbar radiculopathy is seen in only 9.8 per 1000 cases. Surgery is indicated most commonly for three conditions including disc herniation, spinal stenosis, and spondylolisthesis but also performed frequently for discogenic pain.

Multiple conservative nonsurgical modalities have been utilized. Access to the epidural space is available by caudal, interlaminar, and transforaminal approaches [1, 2]. The development of epidural injections in managing chronic low back and lower extremity pain started with caudal epidural injections, followed by the development of interlaminar and transforaminal approaches utilizing local anesthetics with steroids and multiple other drugs. Thus, the literature described substantial differences in techniques and outcomes among the three approaches [1, 2]. Due to the inherent variations, differences, advantages, and disadvantages applicable to each technique, including the effectiveness and outcomes, the three procedures are considered as separate entities. Further, response to epidural injections for various pathological conditions is also variable with outcomes assessed based on pathology for each approach.

History

The first description of epidural injection being placed spinally was by Corning in 1885 [3]. In 1901, caudal epidural injections were described by Sicard [4], Pasquier and Leri [5], and Cathelin [6] independently for the relief of sciatica or lumbago [4], for surgical procedures [5], and for the relief of pain due to inoperative carcinoma of the rectum [6]. The extension of caudal epidural injections for the treatment of sciatica has been attributed to Caussade and Queste in 1909 [7], Viner in 1925 [8], Evans in 1930 [9], Brown in 1960 [10], and Cyriax from 1937 to the 1970s [11, 12].

Interlaminar epidural injections were described in 1933 by Dogliotti [13] introducing the loss of resistance technique, with a lubricated glass or plastic syringe partially filled with air or saline and with a hanging-drop technique by Gutierrez [14].

The earliest description of corticosteroids by epidural administration coincides with the development of the transforaminal approach [15, 16]. Robecchi and Capra [15] administered periradicular injection of hydrocortisone into the first sacral nerve root in 1952, reporting relief of lumbar and sciatic pain in a woman, published in Italian literature. Lievre et al. [16], in 1953, reported transforaminal epidural injection of steroids into the first sacral nerve root in the French literature.

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L. Manchikanti et al. (eds.), *Essentials of Interventional Techniques in Managing Chronic Pain*,
https://doi.org/10.1007/978-3-319-60361-2_11

The initial review of the use of corticosteroids via the caudal epidural space was conducted by Cappio in 1957 with a literature review [17]. The first large American study was published in 1961 by Goebert et al. [18] with their report of 113 patients, with 86 of them receiving caudal epidural injections, with 72% obtaining greater than 60% relief of their pain. Since then, the evidence for all three approaches of lumbar epidural injections has been published with multiple randomized trials and systematic reviews [1, 2, 19–22].

Pathophysiology

- Tissues in the lower back capable of transmitting pain include the disc, nerve root dura, muscle, ligament, fascia, and facet joint [23].
- Pain from lumbar disc herniation can arise from nerve root compression and stimulation of nociceptors in the annulus or posterior longitudinal ligament (Fig. 11.1).
  - Mixter and Barr [25] in 1934 described intervertebral disc herniation, which led many practitioners to assume that intervertebral disc herniation is the most common cause of back problems.
- A simple ideological explanation of compression, or mass effect, lacks practical application [1, 26].
  - As many studies have indicated, there are asymptomatic individuals present with disc herniations that are evident on computerized tomographic axial scans or on magnetic resonance imaging scans [1, 27].
- A multitude of mechanisms have been proposed to explain radicular pain, which include partial axonal damage, neuroma formation, focal demyelination, intraneural edema, impaired microcirculation, chemical irritation, and inflammation [1]
  - Inflammatory reactions between the nucleus pulposus and nerve roots have been suggested as playing an important role in disc herniation with sciatica [1, 26].
- Intervertebral disc without herniation has been implicated as a source of spinal pain based on decades of preclinical, clinical, and epidemiological research, though the precise mechanisms still continue to be debated as the literature evolves [1].
  - Low back pain without disc herniation was described by Mixter and Ayers [28] soon after the description of disc herniation [25].
  - Based on diagnostic discography [1], lumbar intervertebral discs showed the prevalence of internal disc disruption in 39% [29] and a 42% [30] with discogenic pain in 26% [31].
- Spinal stenosis implying narrowing of the spinal canal has been defined as any type of narrowing of the spinal canal, nerve canals, or intervertebral foramina (Fig. 11.2). It may be local, segmental, or generalized and congenital or acquired [33].
  - Spinal stenosis may result from disc bulging, protrusion, and herniation, ossification and thickening of ligamentum flavum, ossification of posterior longitudinal ligament (PLL), osteophytosis, and arthritic changes of facet joints.
  - Spinal stenosis is a multifactorial disorder with pathogenesis of neurogenic claudication in lumbar spinal canal stenosis explained by:
    - Mechanical force (compression with occlusion of the subarachnoid space)
    - Circulatory disturbances with venous congestion and injury to the nerves with Wallerian degeneration
- Lumbar postsurgery syndrome is one of the causes of continued persistent pain and disability with low back and lower extremity pain, reported with a reoperation rate of 9.5–25% [1].
  - The unremitting pain and disability in the low back and lower extremities following lumbar spine surgery have been hypothesized to be secondary to multiple causes including epidural fibrosis, sacroiliac joint pain, disc herniation, discogenic pain, spinal stenosis, arachnoiditis, and facet joint pain [1, 34].
- The underlying mechanism of action for epidurally administered local anesthetic and steroids has been described, even though it continues to evolve [1].
  - The various modes of action of corticosteroids include membrane stabilization, inhibition of neural peptide synthesis or action, blockade of phospholipase A2 activity, prolonged suppression of ongoing neuronal discharge, and suppression of sensitization of dorsal horn neurons.
    - Local anesthetics also have been shown to have significant effect in relieving low back and lower extremity pain, both in experimental and clinical settings [1, 2, 12, 35, 36].
  - Local anesthetics have been postulated to provide relief by multiple mechanisms which include suppression of nociceptive discharge, the blockade of sympathetic reflex arc, the blockade of axonal transport, the blockade of sensitization, and anti-inflammatory effects.

Evidence Base

Evidence of effectiveness is determined based on best evidence synthesis ranging from Levels I to V, with Level I evidence being the highest level of evidence obtained from multiple relevant high-quality, randomized controlled trials (RCTs) [37].

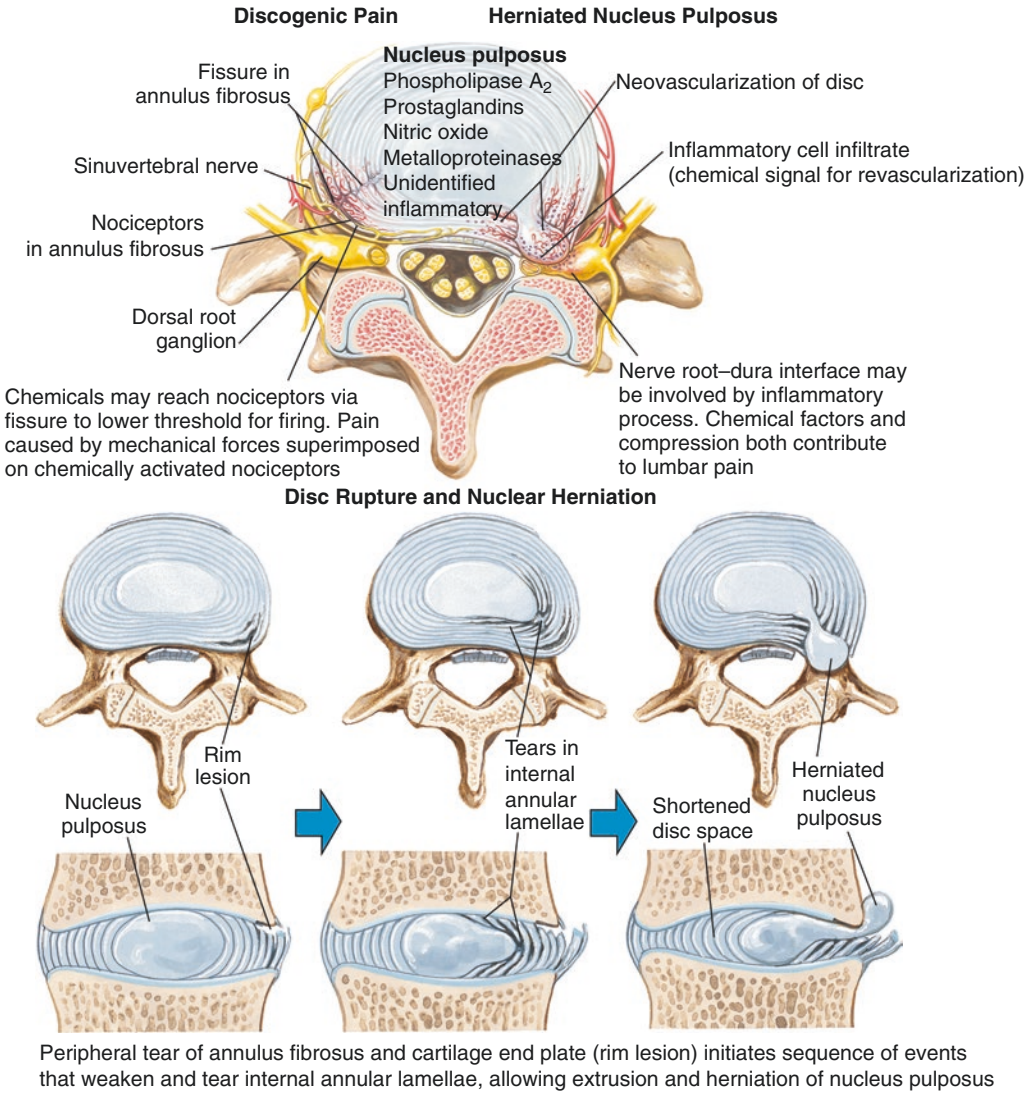

Fig. 11.1 Pathophysiology of lumbar disc degeneration, disc herniation, and discogenic pain (From Greene [24]; with permission) Netter Orthopedic

Level II describes the evidence obtained from at least one relevant high-quality randomized controlled trial or multiple relevant moderate or low-quality randomized controlled trials.

Level III incorporates not only the evidence from randomized trials but also from nonrandomized studies, whereas Level IV and V evidence is based on observational studies and consensus.

- Disc herniation
  - Based on the multiple, relevant, high-quality randomized trials, there is Level I evidence of short-term improvement of less than 6 months and Level II evidence for long-term improvement with caudal, interlaminar, and transforaminal epidural injections in managing chronic low back and lower extremity pain of disc herniation as shown in Table 11.1 [38–45], with lack of evidence from some trials [51, 52].
- Discogenic pain
  - In managing discogenic pain without disc herniation, or facet joint pain, or sacroiliac joint pain, the evidence is Level II for caudal and lumbar interlaminar epidural injections as shown in Table 11.1 [46, 47].
- Central spinal stenosis
  - In managing central spinal stenosis, the evidence is Level II for interlaminar and caudal epidural injections as shown in Table 11.1 [48, 49].
- Post-lumbar surgery syndrome
  - In managing post-lumbar surgery syndrome, the evidence is Level II for caudal epidural injections as shown in Table 11.1 [50].

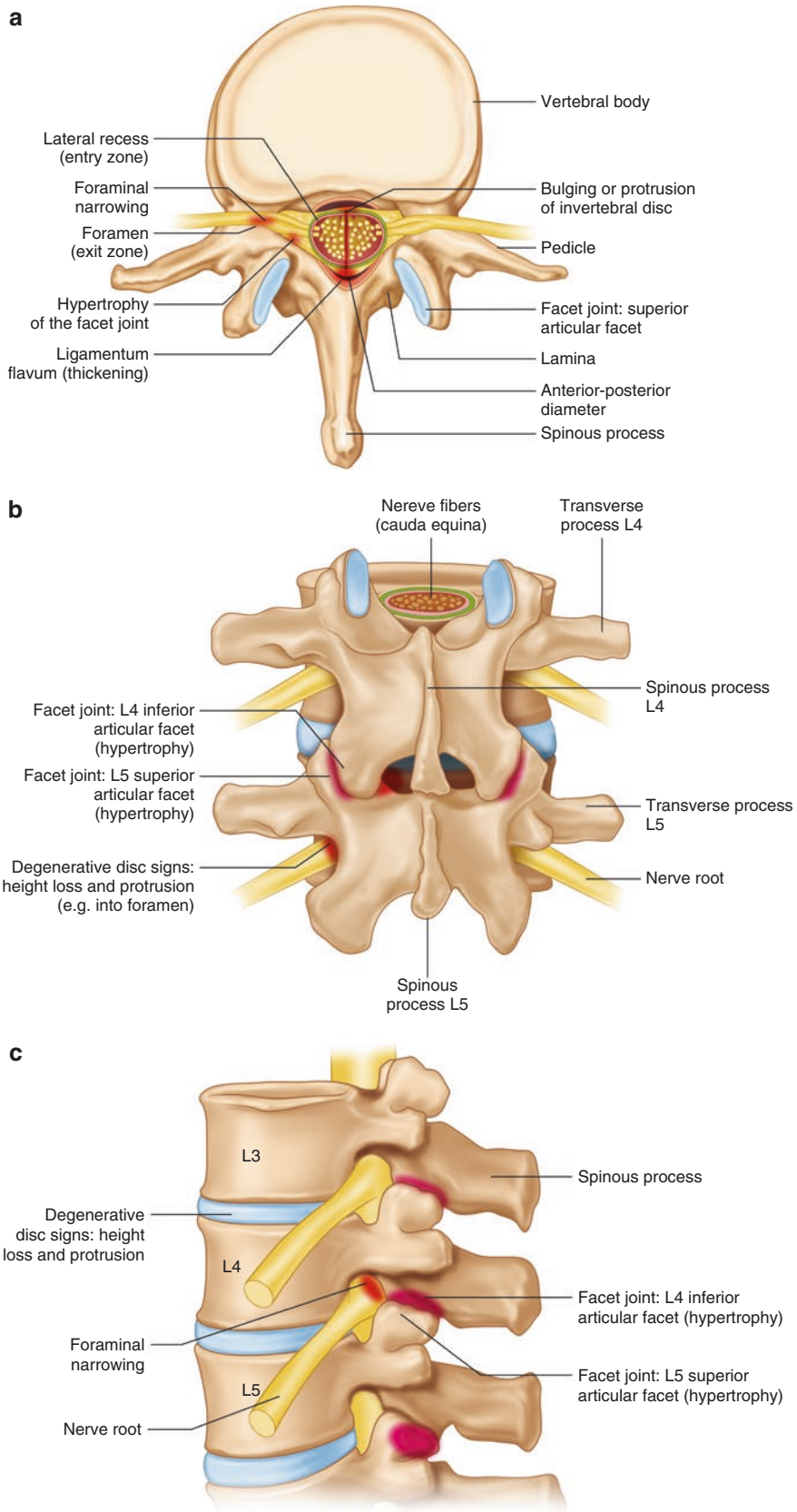

Fig. 11.2 Pathoanatomical illustration of lumbar spinal stenosis. (**a**) Coronal view of lumbar spine showing stenosis. In a coronal view, distinct stenosis areas are depicted in *red*. Ventral compression can be caused by medially bulging or protrusion of intervertebral discs. Lateral stenosis can be caused by lateral prolapse, stenosis of the neuroforamen, or hypertrophy of the facet joints.(**b**) Posterior view of lumbar spine showing stenosis. In posterior view of lateral stenosis (*red dots*) caused by hypertrophic facet joints and narrowing of the neuroforamen. (**c**) Lateral view of lumbar spine showing stenosis. In lateral perspective of narrowed neuroforamen causing a lateral stenosis (Adapted from Siebert et al. [32])

Table 11.1 Evidence of lumbar epidural injections

	Evidence	Systematic reviews/guidelines	Therapeutic trials
Disc herniation	Short term: Level I Long term: Level II for caudal, interlaminar, and transforaminal epidural injections	Manchikanti et al. [1, 2, 26, 36] Pinto et al. [20] Kaye et al. [21]	Manchikanti et al. [38–40] Tafazal et al. [41] Dashfield et al. [42] Ghahreman et al. [43] Jeong et al. [44] Riew et al. [45]
Discogenic pain	Level II for interlaminar and caudal epidural injections, whereas it is Level III or IV for transforaminal epidural injections	Manchikanti et al. [1, 26, 36] Kaye et al. [21]	Manchikanti et al. [46, 47]
Central spinal stenosis	Level II for interlaminar and caudal epidural injections, whereas it is Level III or IV for transforaminal epidural injections	Manchikanti et al. [1, 22, 26, 36] Kaye et al. [21]	Manchikanti et al. [48, 49]
Post-lumbar surgery syndrome	Level II for caudal epidural injections, whereas it is Level IV or V for transforaminal epidural injections	Manchikanti et al. [1, 26, 36] Kaye et al. [21]	Manchikanti et al. [50]

Indications

- Indications for lumbar epidural injections (caudal, interlaminar, or transforaminal) are as follows:
  - Chronic low back and/or lower extremity pain of moderate to severe pain of at least 3 months duration which has failed to respond or poorly responded to noninterventional and nonsurgical conservative management resulting from:
    - Disc herniation/lumbar radiculitis
    - Lumbar spinal stenosis
    - Axial or discogenic low back pain without facet joint or sacroiliac joint pain or disc herniation
    - Post-lumbar surgery syndrome
  - Lumbar interlaminar may be performed in postsurgery syndrome only if the access to the epidural space is obtained above or below the scar.
  - Caudal epidural is the modality of choice for postsurgery syndrome based on the level of pathology.
  - Indications have not been established with transforaminal for axial or discogenic pain.

Anatomy

- The human spine consists of 33 vertebrae, with 7 cervical vertebrae between the thorax and the skull, 12 thoracic vertebrae between the cervical spine and lumbar spine, and 5 lumbar vertebrae inferior to the thoracic vertebrae, along with 5 sacral vertebrae fused into 1 single bone, followed by 4 coccygeal vertebrae fused into a single small triangular bone called the coccyx.
  - Figures 11.3 and 11.4 show the spinal vertebrae and the regional differences between cervical, thoracic, and lumbar vertebrae.
  - In the intact spine, the vertebral foramina of the vertebrae are aligned to form a continuous channel, which is referred to as the vertebral canal (Figs. 11.3 and 11.4).
- The lumbar vertebral canal anteriorly is formed by the posterior surfaces of the lumbar vertebrae, the intervening discs, and the posterior longitudinal ligament (Fig. 11.5).
  - The posterior wall is formed by the laminae of the vertebrae and intervening ligamentum flava.
  - The lateral walls of the vertebral canal are formed by the pedicles of the lumbar vertebrae.
  - The deficiency in the lateral walls between the pedicles where the superior and inferior vertebral notches oppose one another forms the intervertebral foramina.
  - Each intervertebral foramen is bounded anteriorly by an intervertebral disc, the adjacent lower third of the vertebral body above, and uppermost portion of the vertebral body below, posteriorly by vertebral lamina and a facet joint, and above and below by a pedicle.
- The spine is often divided anatomically into the anterior, neuraxial, and posterior compartments (Fig. 11.6).
  - The anterior compartment consists of the vertebral body and intervertebral disc.
  - The neuraxial compartment includes all structures within the osseous and ligamentous boundaries of the spinal canal, including the posterior longitudinal ligament, ligamentum flavum, epidural, and epiradicular membranes.
  - The posterior compartment consists of facet joints and associated bony vertebral arch structures.
  - The dural sac resting on the floor of the vertebral canal is anteriorly on the backs of the vertebral bodies and the intervertebral discs; covering these structures is the posterior longitudinal ligament.

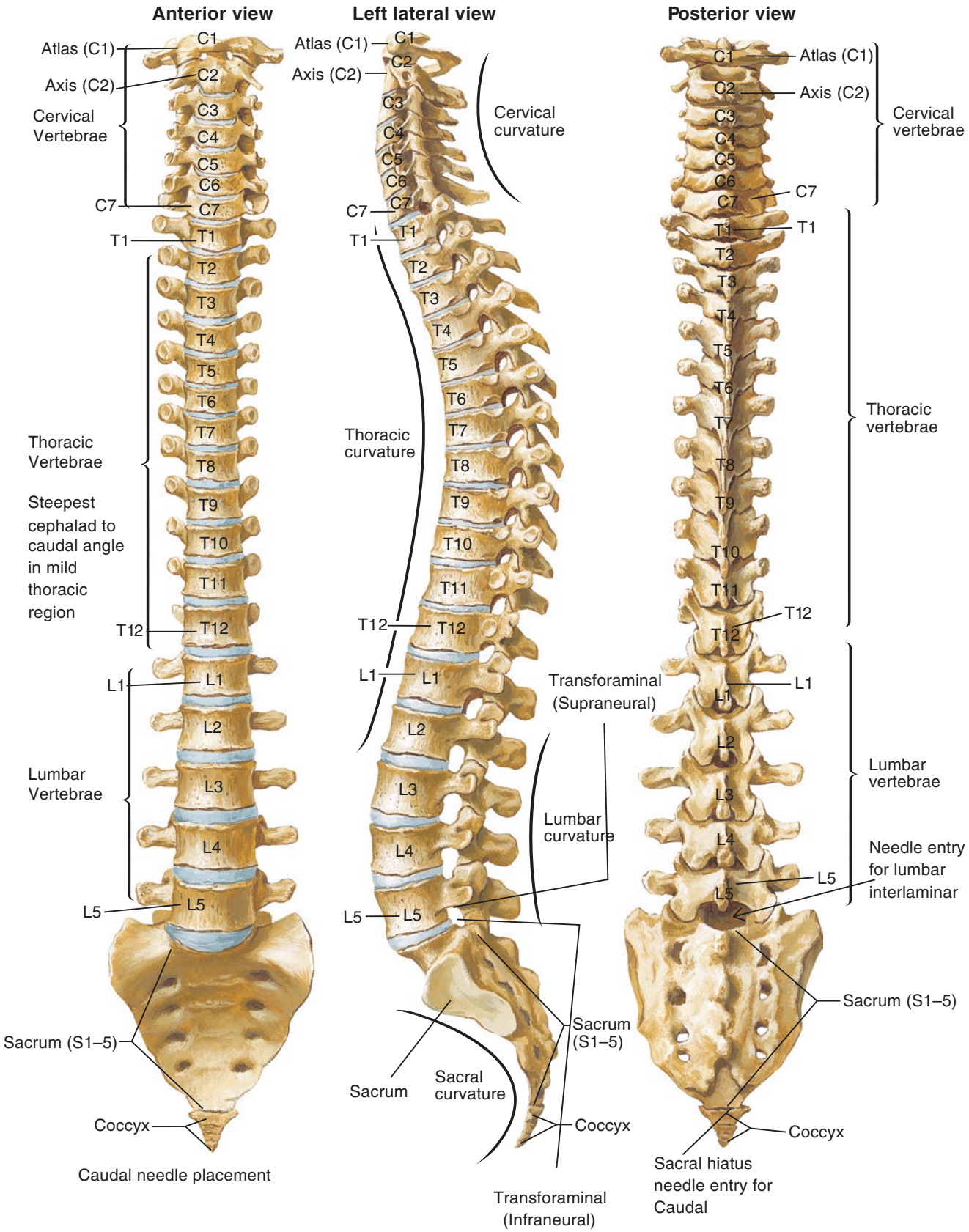

Fig. 11.3 Anatomy of vertebral column (Adapted from Netter (2006). Reproduced Netter Medical Illustration used with permission of Elsevier)

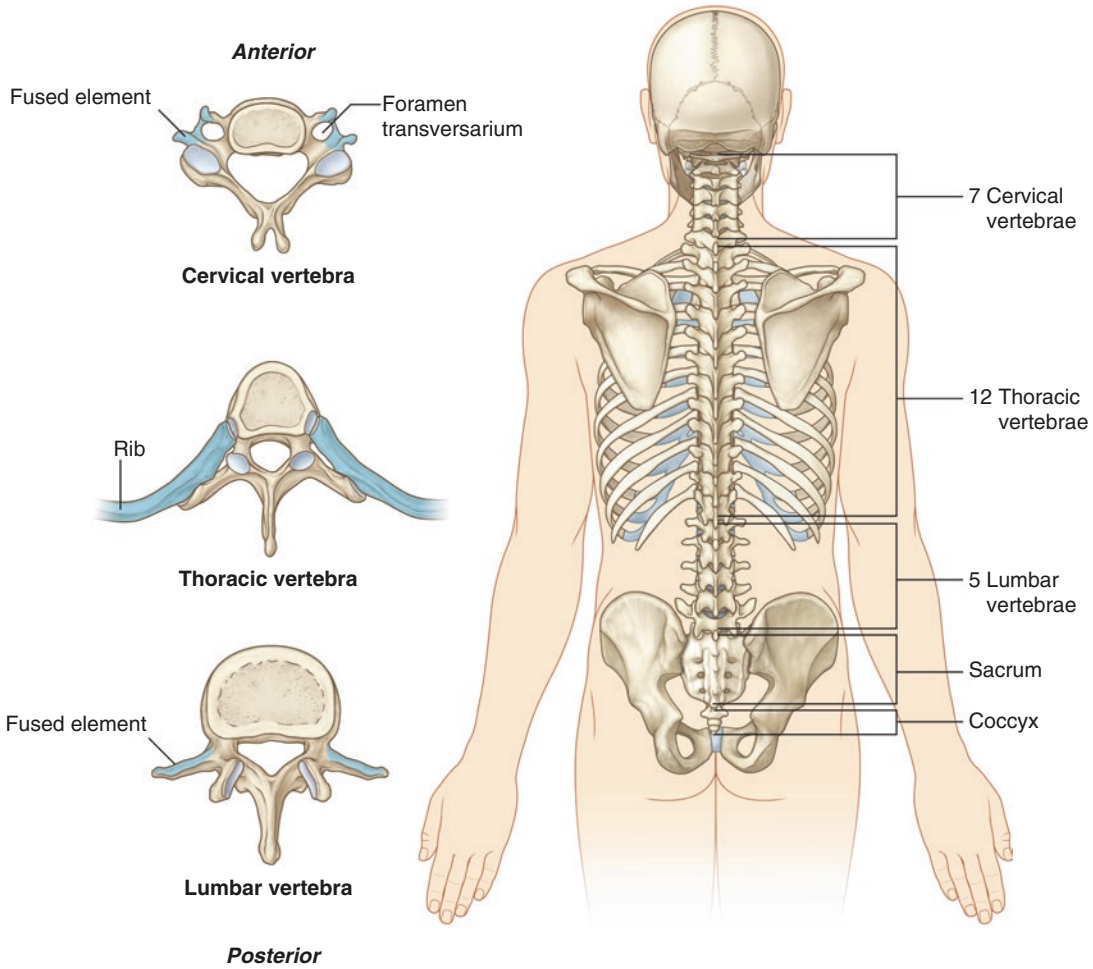

Fig. 11.4 Anatomy of vertebral column with cranium, ribs, and pelvis, with descriptive characteristics of cervical, thoracic, and lumbar vertebrae (From Drake et al. [53]. Reproduced from Gray's Anatomy for Students, Drake, ©2004, with permission from Elsevier)

  - Thus, anterior spinal arteries and sinuvertebral nerves run across the floor of the vertebral canal and are located anterior to the dural sac.
  - The dural sac posteriorly is related to the roof of the vertebral canal, the laminae, and the ligamentum flava.
- The size of the spinal canal is approximately twice the size of the cord but variable, with its largest diameter in the cervical and lumbar regions, corresponding to enlargements in the spinal cord measuring 18 mm in the anterior and posterior dimension at C4 to C6, with a transverse diameter of 30 mm, 17 mm in both anterior and posterior (AP) and transverse measurements in the thoracic region, and 23 mm in the AP diameters and 18 mm in the transverse diameter in the lumbar region (Fig. 11.7).
  - The canal in cross section appears triangular in the lumbar region. The spinal cord ends at L1 or L2 in adults and the dural sac continues to the spinal cord and conus, running down to the level of S2 (Fig. 11.7).

Epidural Space

- The epidural space is the space intervening between the dural sac and the osseo-ligamentous boundaries of the vertebral canal, which is a narrow space (Fig. 11.7).
  - The epidural space surrounds the dural sac and is bordered posteriorly by the ligamentum flavum and periosteum, anteriorly by the posterior longitudinal ligament and vertebral bodies, and laterally bordered by the pedicles and intervertebral foramina.
    - The epidural space is widest in the midline underneath the junction of the lamina and narrows laterally beneath the zygapophysial joint. The actual size and shape of the epidural space is determined by the manner of attachment of the dural sac to the walls of the spinal canal, as well as the shape of the spinal canal at different levels.
    - The size of the lumbar epidural space is 4.0–6.0 mm and sacral is 3.0 mm.

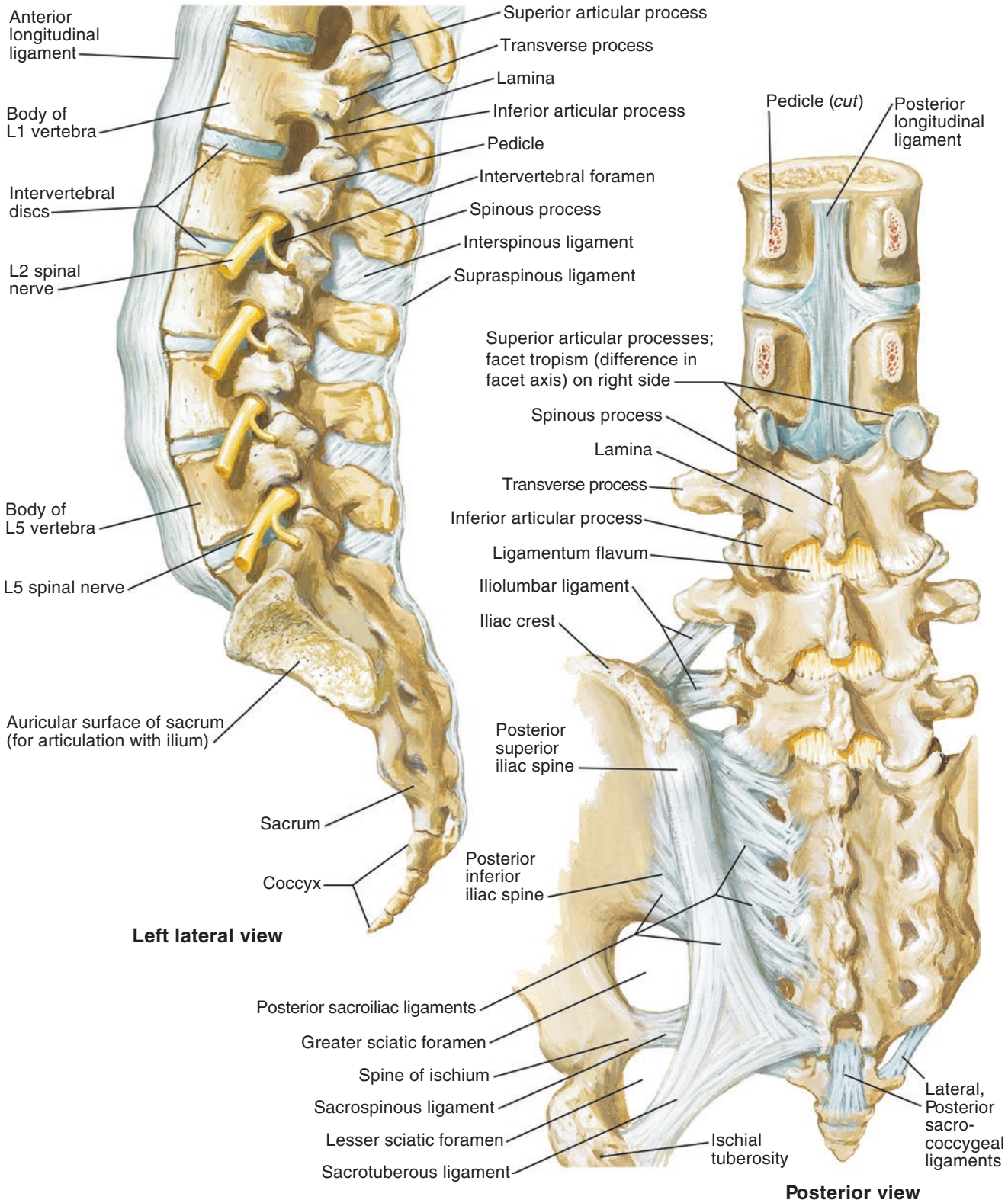

Fig. 11.5 Anatomic features of the lumbosacral spine (From Netter (2006). Reproduced Netter Medical Illustration used with permission of Elsevier)

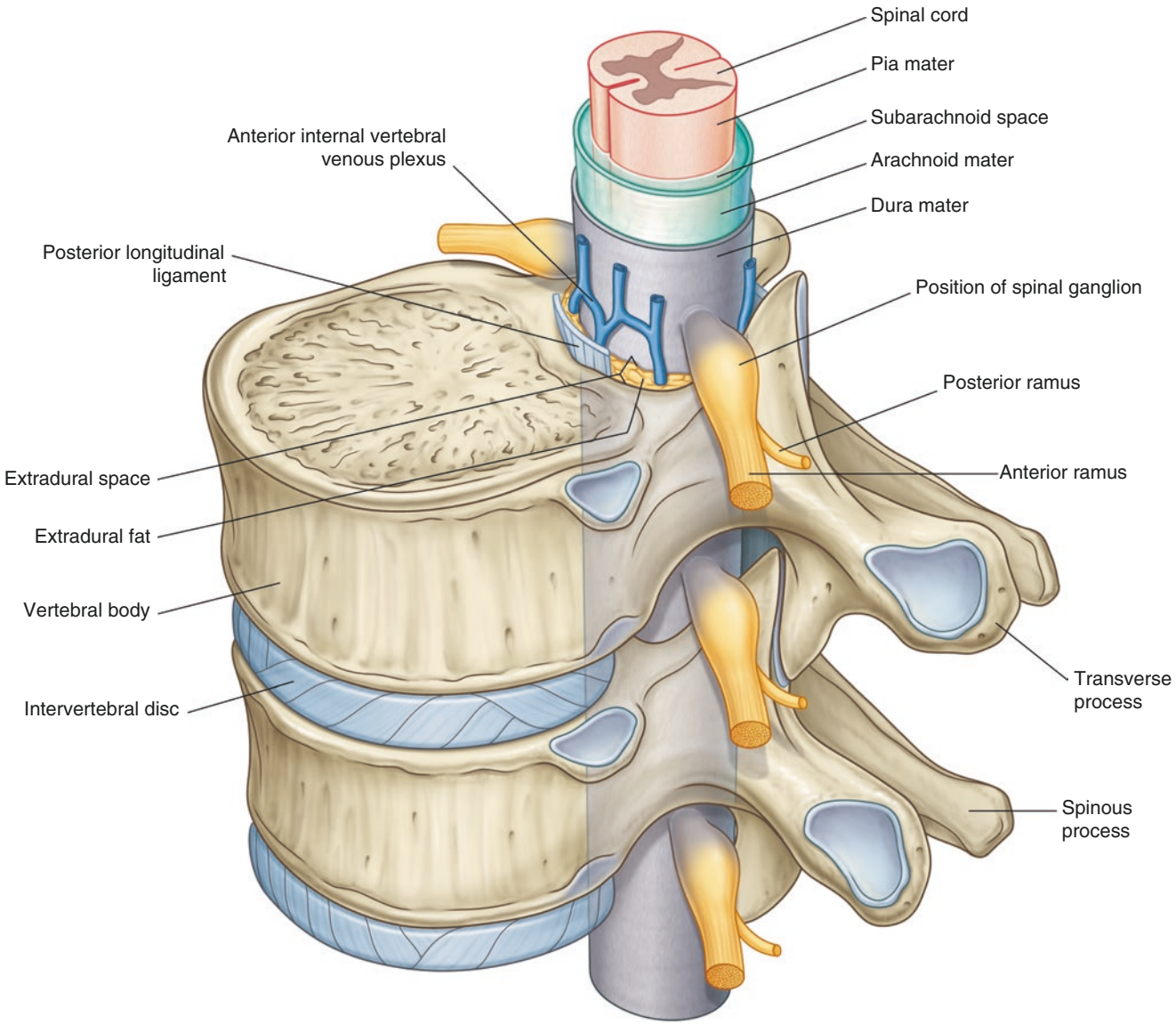

Fig. 11.6 Lumbar vertebral canal and its contents, showing anterior, neuraxial, and posterior compartments (From Drake et al. [53]. Reproduced from Gray's Anatomy for Students, Drake, ©2004, with permission from Elsevier)

- Contents of the epidural space include the vertebral venous plexus, the spinal branches of the segmental arteries, the lymphatics, and the dura arachnoid projections that surround the spinal nerve roots, along with abundant fat.

- The ligamentum flavum has been proposed to be joined in the midline. There appears to be a paired nature to the ligament having both a right and left portion (Fig. 11.8).
  - Cryomicrotome sectioning performed on the epidural space has shown that there is a variable degree of fusion of the ligamentum flavum in the midline.
  - The ligamentum flavum in the lumbar spine is thicker than in the cervical and thoracic spine.

Nerves

- The anatomy of the spinal nerve and vertebral canal is of crucial importance.
  - Ventral and dorsal segmental roots of spinal nerve root join to form the segmental spinal nerve that traverses the neural foramen, the spinal nerves dividing into the dorsal and ventral rami, outside the foramen (Figs. 11.5, 11.6, and 11.9).
    - Figure 11.9 illustrates relation of spinal nerve roots to vertebrae.
- Spinal nerve roots leave the dural sac, just above the level of each intervertebral foramen by penetrating the dural

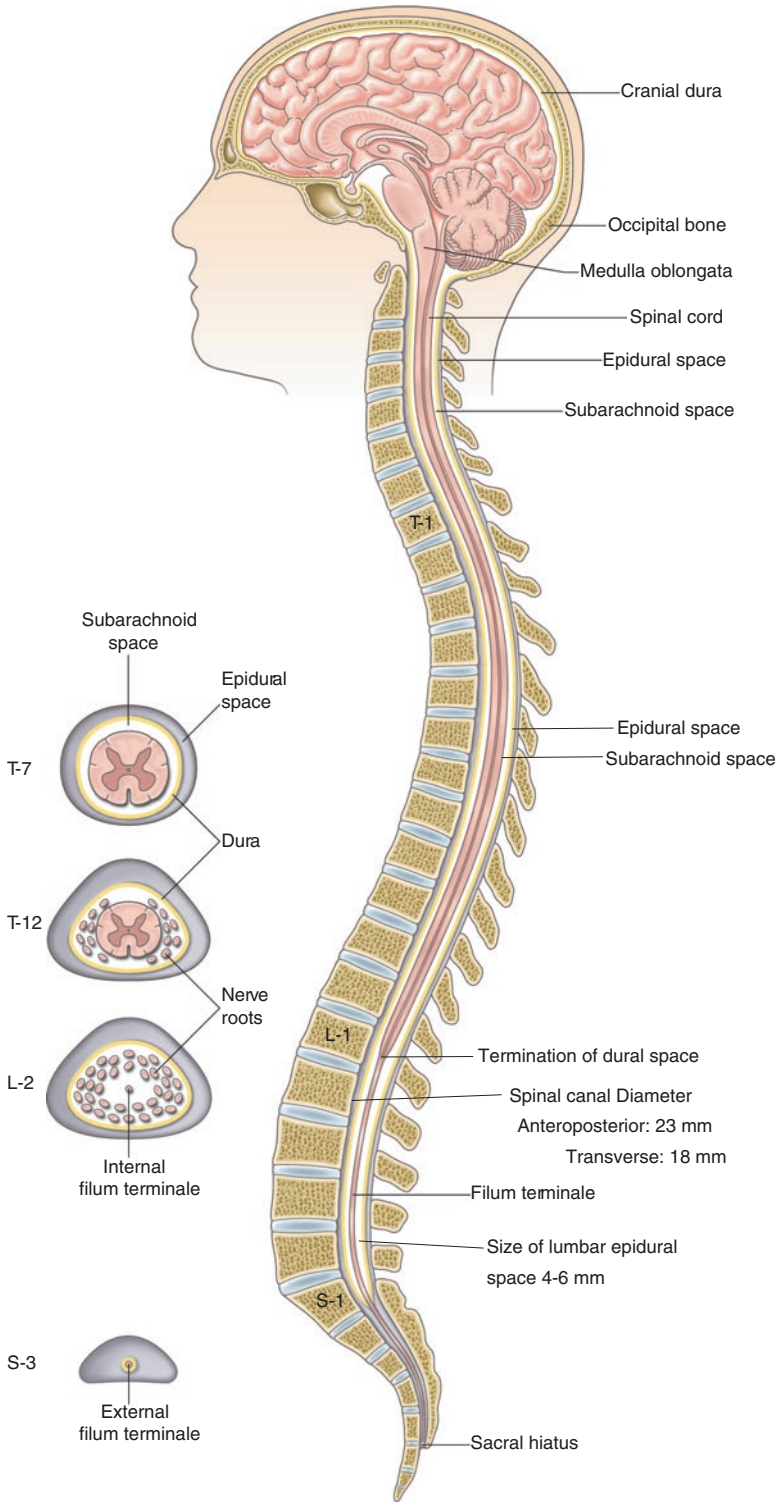

Fig. 11.7 Illustration of contents of the vertebral canal and epidural space (Adapted from Standring [54]. Reproduced from Gray's Anatomy, 39th ed, Standring. ©2005, with permission from Elsevier)

sac in an inferolateral direction, taking with them an extension of dura mater and arachnoid mater referred to as the dural sleeve.

- Immediately proximal to its junction with the spinal nerve, the dorsal root forms an enlargement, the dorsal root ganglion, which contains the cell bodies of sensory fibers in the dorsal root.
- The angle at which each pair of nerve roots leaves the dural sac varies, as the L1 and L2 root sleeve of the dural sac leaves at an obtuse angle but the dural sleeves

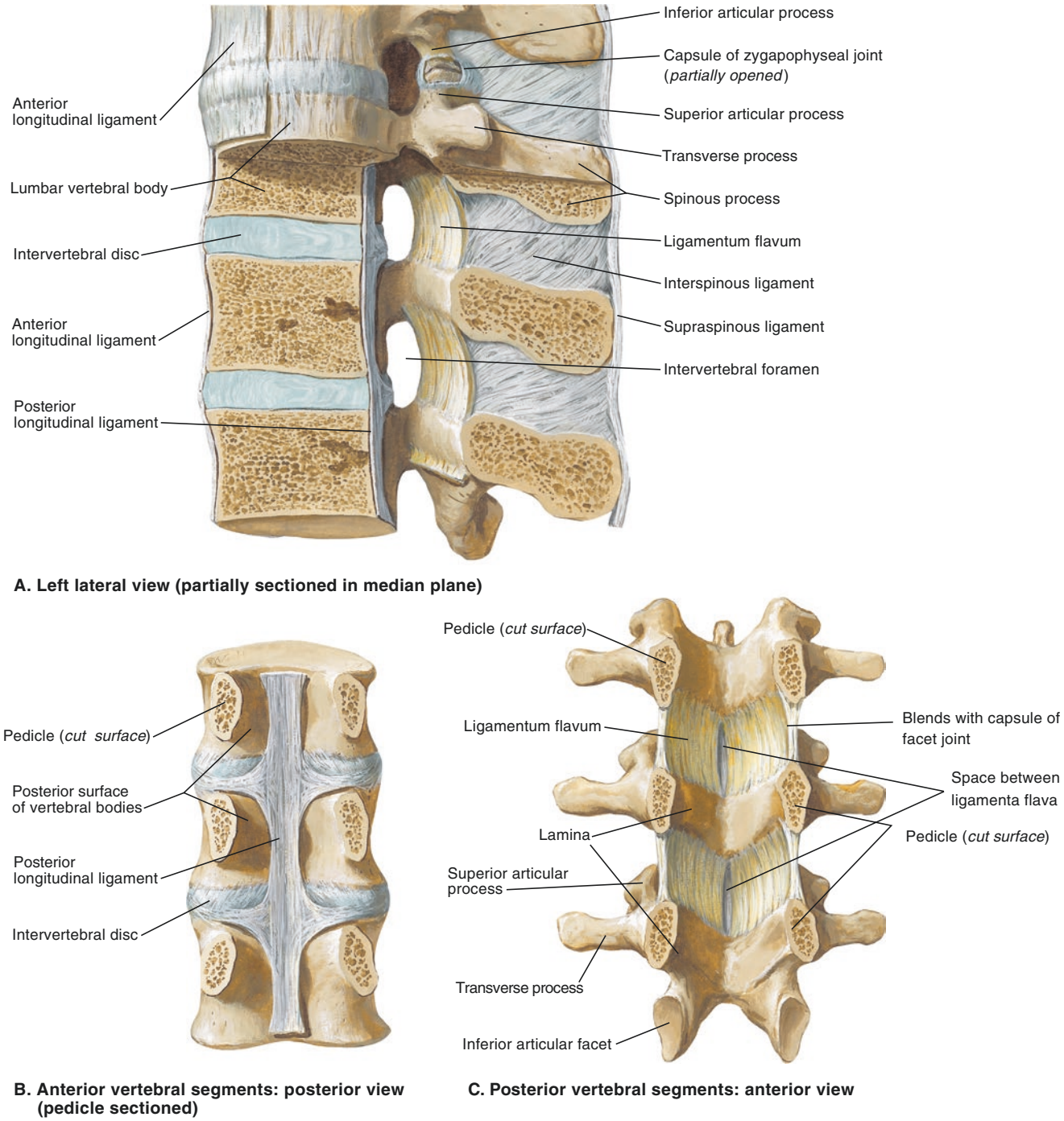

Fig. 11.8 (**a–c**) Lateral, posterior, and anterior views of lumbar spinal segments (Adapted from Netter (2006). Reproduced Netter Medical Illustration used with permission of Elsevier)

of the lower nerve roots form increasingly acute angles with the lateral margins of the dural sac [55] (Figs. 11.6 and 11.9).

– The angles formed by the L1 and L2 roots are about 80° and 70°, whereas the angles of the L3 and L4 roots are each about 60°, with the angle of the L5 root around 45°.

Vasculature

- Epidural arteries are present in the epidural space and supply the surrounding bony and ligamentous structures as well as the spinal cord. Segmental radicular vessels enter the epidural space through the intervertebral foramina.

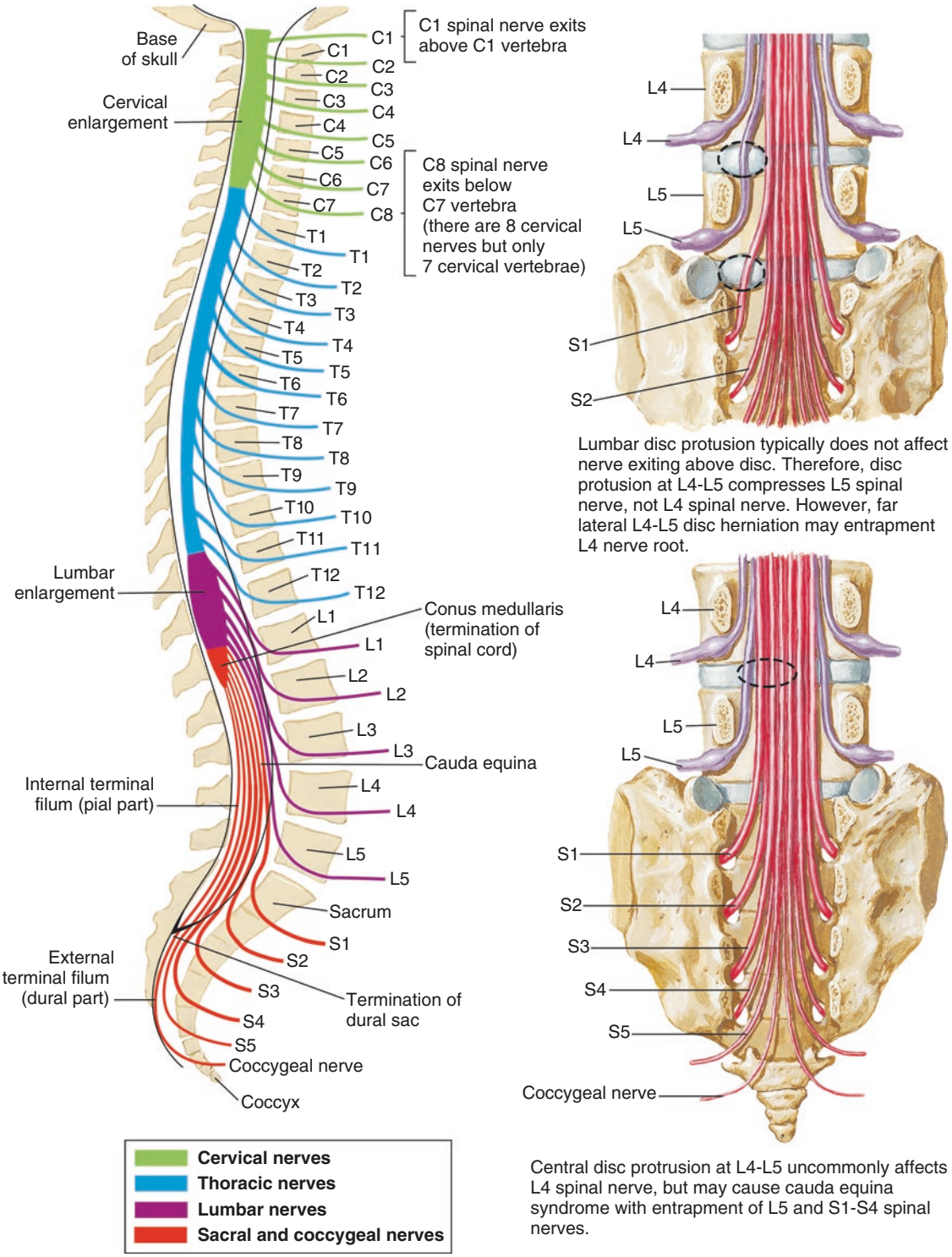

Fig. 11.9 Illustration of vertebral canal, spinal cord, and relation to spinal nerve roots to vertebrae (From Netter (2006). Reproduced Netter Medical Illustration used with permission of Elsevier)

  - These segmental arteries are derived from the aorta, subclavian, and iliac arteries (Fig. 11.10).
- The spinal cord receives its blood supply through both longitudinal and segmental vessels, which produce an anastomotic longitudinal network of arterial vessels which surround the cord [56].
  - Many of the arterial vessels that supply blood to the cord are end arteries, and collateral blood supplies are lacking throughout much of the cord.
- Multiple epidural veins are located in the lower lumbar epidural space (Fig. 11.11) [56].
  - The vertebral venous plexus drains through multiple segmental epidural veins, which exit the spinal canal through the intervertebral foramen, thus allowing venous return to the inferior cava and azygous vein via the thoracic and abdominal veins.

Technical Aspects

Lumbar epidural injections are administered by three approaches, interlaminar, transforaminal, and caudal, each different with its own technical approaches [57–59]. Fluoroscopy must be used for all three approaches in chronic pain management settings.

Lumbar Interlaminar Epidural Injections

- In the lumbar spine, the spinous processes are directly above the widest portion of the interlaminar space, allowing both a midline and a paramedian approach to be relatively easy.
- Lumbar interlaminar epidural injections have been performed with or without fluoroscopy. For all chronic pain settings, fluoroscopic guidance for epidural procedures is essential.
  - Incorrect needle placement utilizing a blind approach (without fluoroscopy) has been reported by multiple authors ranging from an 8% to 30% occurrence rate [1].
  - Assessment of epidurography patterns showed ventral spread of the contrast in 36% of the patients and the unilateral filling pattern in 84% of the patients. The mean number of levels of flow contrast cephalad from injections site was one to two segments, and caudally it was one segment [1].
  - Interlaminar approach with parasagittal technique has been shown to reach the ventral epidural space in the majority of the cases [1, 60].
- Among the multiple types of needles utilized in performing lumbar interlaminar epidural injections, the Tuohy needle is the most common using a loss of resistance technique (Fig. 11.12).
  - The needles' orifices align nearly perpendicular to the shaft to direct the needle, catheter, or solutions through the needle along the plane of the epidural space.
- Utilizing fluoroscopy, the epidural space is identified by loss of resistance technique introduced by Dogliotti [13] in 1933, with a lubricated glass syringe partially filled with air or saline [61].
  - Potential complications such as pneumocephalus, subcutaneous emphysema, or venous air embolism can occur with loss of resistance to air technique.
- The patient is placed in the prone position with firm padding under the abdomen with appropriate sterile preparation.
  - The desired interlaminar space is identified in PA view, with the rotation of the C-arm toward the patient's right side or left side until the spinous process is exactly equidistant from the right and the left pedicle with the cranial or caudal angulation until the desired interlaminar space is maximally opened.
    - In many cases, cranial or caudal angulation is not required, especially if the L5–S1 space is chosen.
    - Typically the L5–S1 space is the widest, as the interspaces are smaller, superior to L4–L5 and L3–L4. T12–L1 and L1–L2 are again easily accessible.
  - The midline, paramedian, or parasagittal technique is performed at the interspace most closely associated with the patient's level of pain, with identification of the space with fluoroscopy.
- The skin is anesthetized with preservative-free lidocaine 1%.
  - The Tuohy needle with or without a wing tip is placed in the midline or parasagittal or paramedian position (Fig. 11.13).
    - A parasagittal or paramedian approach is best utilized in patients with unilateral radicular pain syndromes.
  - Intermittent pressure is applied on the syringe plunger with advancement of the needle, with intermittent fluoroscopic visualization, until loss of resistance is felt or needle position is observed in the epidural space (Fig. 11.14).
  - As the needle is advanced through the interspinous ligament and is noted to be in direct midline or paramedially, the fluoroscope is positioned in a lateral view in order to ascertain the needle depth (Fig. 11.14).
  - The needle is then advanced into the ligamentum flavum and subsequently into the epidural space, while intermittent lateral fluoroscopic views are obtained.

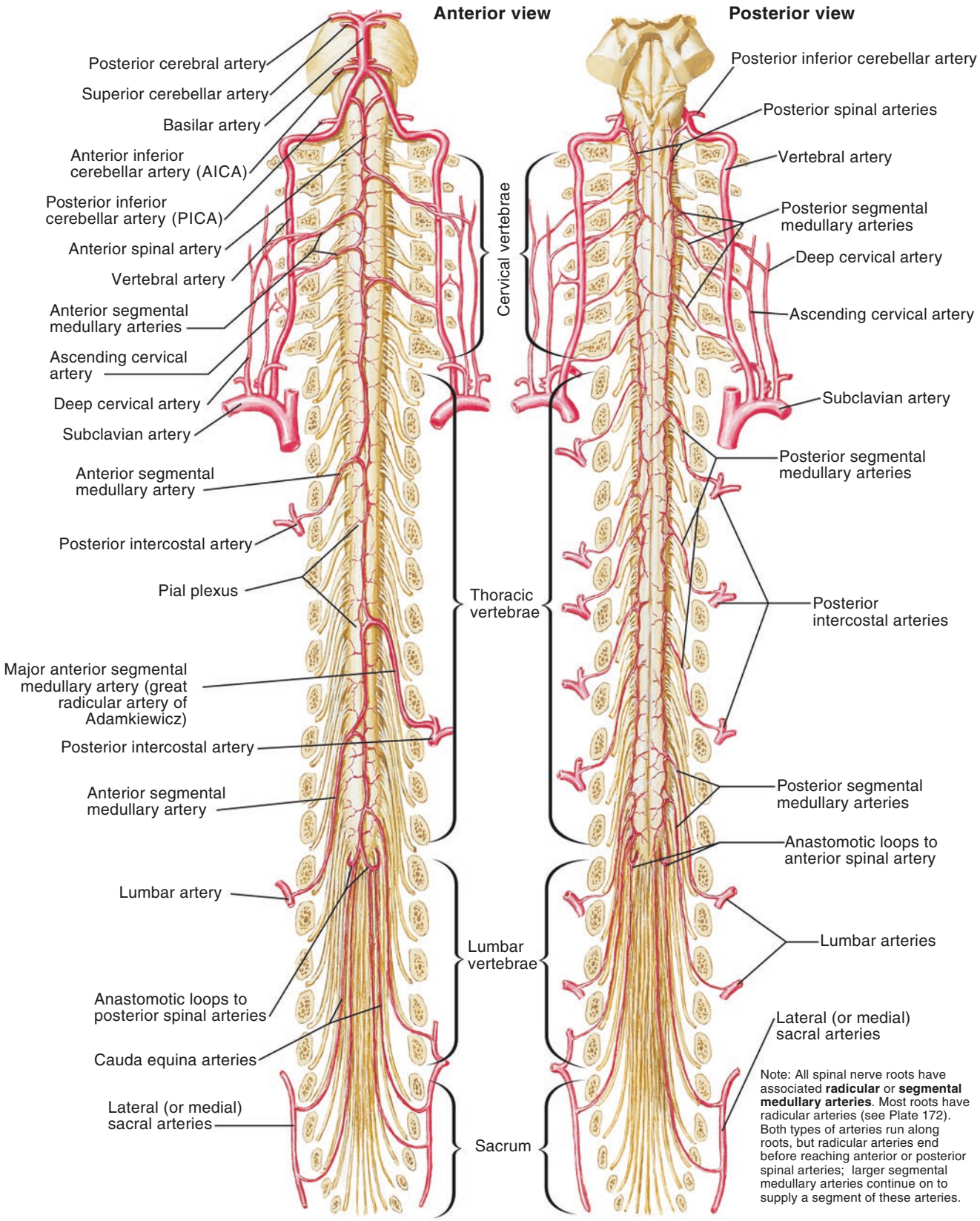

Fig. 11.10 Vascular supply of the spinal cord (From Netter (2006). Reproduced Netter Medical Illustration used with permission of Elsevier)

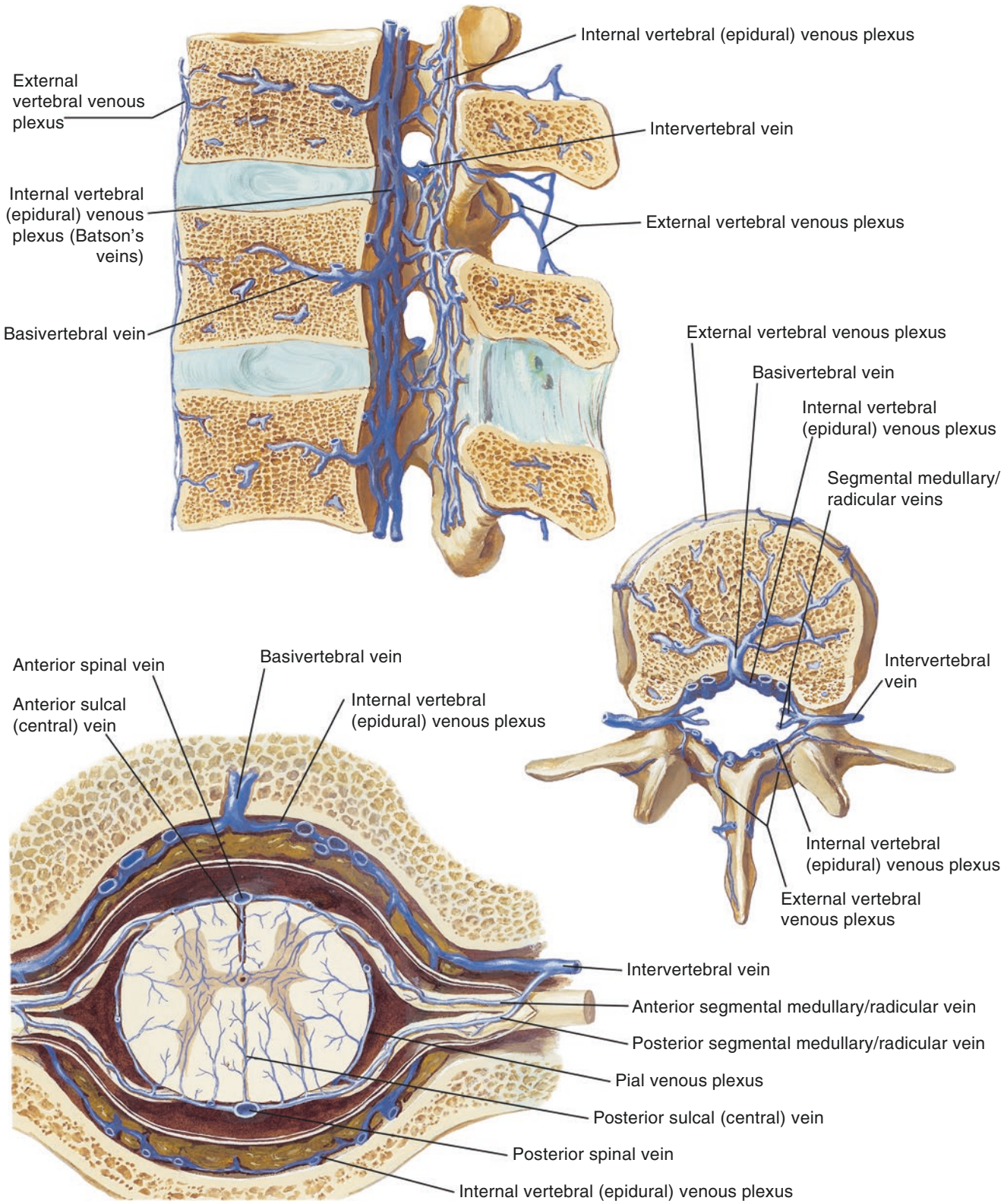

Fig. 11.11 Veins of the spinal cord and vertebral column (From Netter (2006). Reproduced Netter Medical Illustration used with permission of Elsevier)

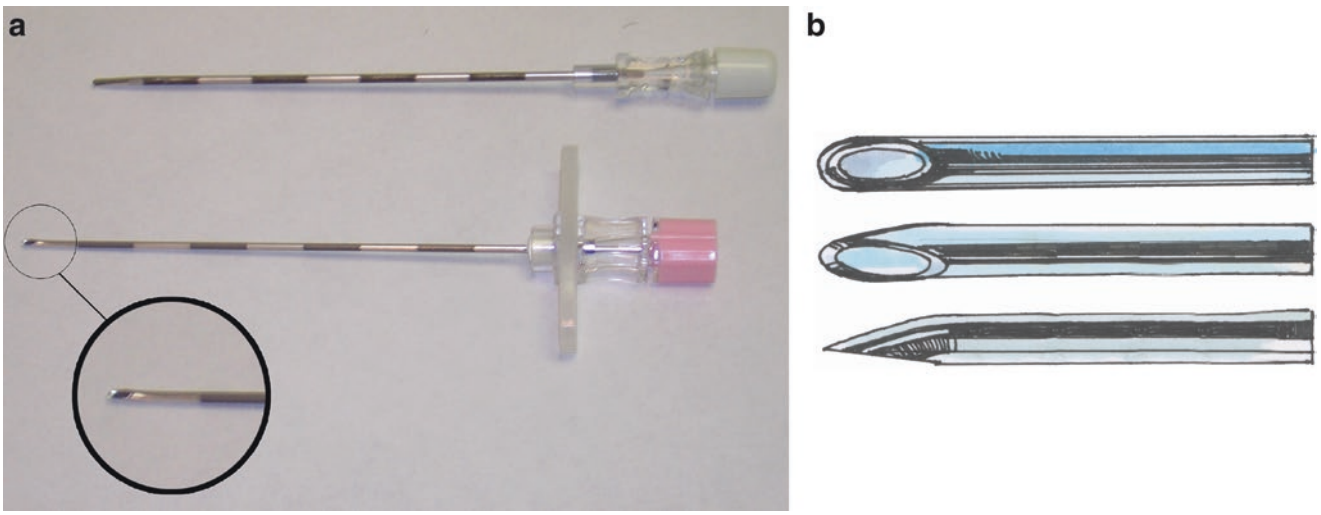

Fig. 11.12 Display of Tuohy needles. (**a**) An 18 gauge, nonwinged (*top*) and winged (*bottom*) Tuohy needle with centimeter graduations. (**b**) Front, oblique, and lateral views of Tuohy needle

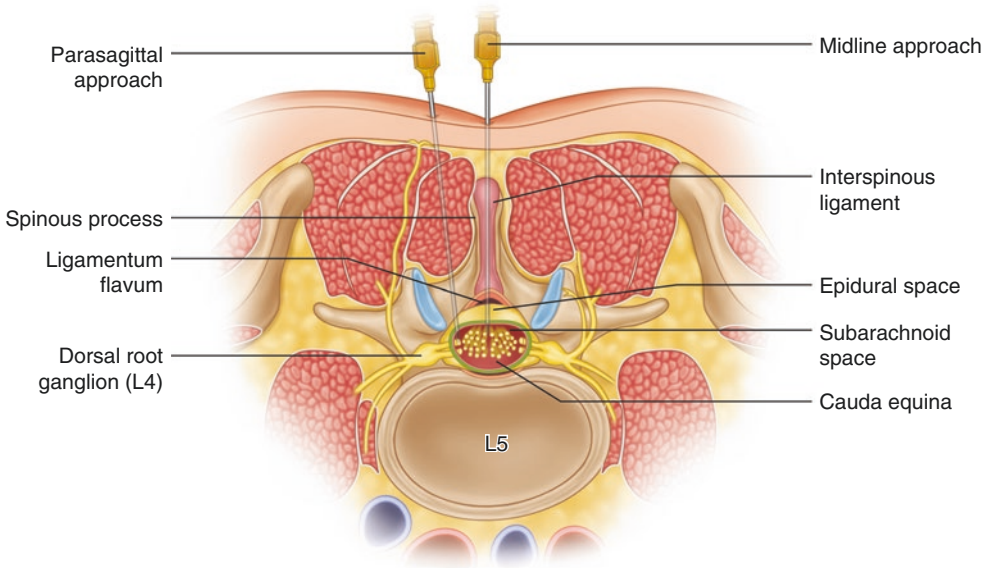

Fig. 11.13 Axial diagram of lumbar interlaminar epidural injections: needle position with midline and paramedian (sagittal) approaches

- For parasagittal approach, using the fluoroscope, the needle may be advanced toward the upper edge of the inferior lamina at the target interspace.
  - The needle is advanced superiorly into the ligamentum flavum and subsequently into the epidural space, utilizing a loss of resistance technique.
- Once the needle has reached the epidural space with appropriate loss of resistance to either air or saline, nonionic contrast 3–5 mL (Omnipaque or Isovue) is injected to confirm epidural placement.
  - Posteroanterior (PA) and lateral fluoroscopic images are obtained (Fig. 11.14).
  - The contrast spread may have an areolar appearance (Figs. 11.14, 11.15, and 11.16).
    - If no extra-epidural (intravascular, or subarachnoid, or soft tissue contrast pattern) is appreciated with negative aspiration with 3–5 mL of contrast, an injectate of local anesthetic preservative-free lidocaine 0.5%, or another local anesthetic alone or with steroid of 6 mL with 6 mg of betamethasone, 40 mg of methylprednisolone, or 40 mg of triamcinolone, is injected into the epidural space.
- In an ideal PA epidurogram, the nerve roots are clearly outlined by contrast as they exit the intervertebral foramina,

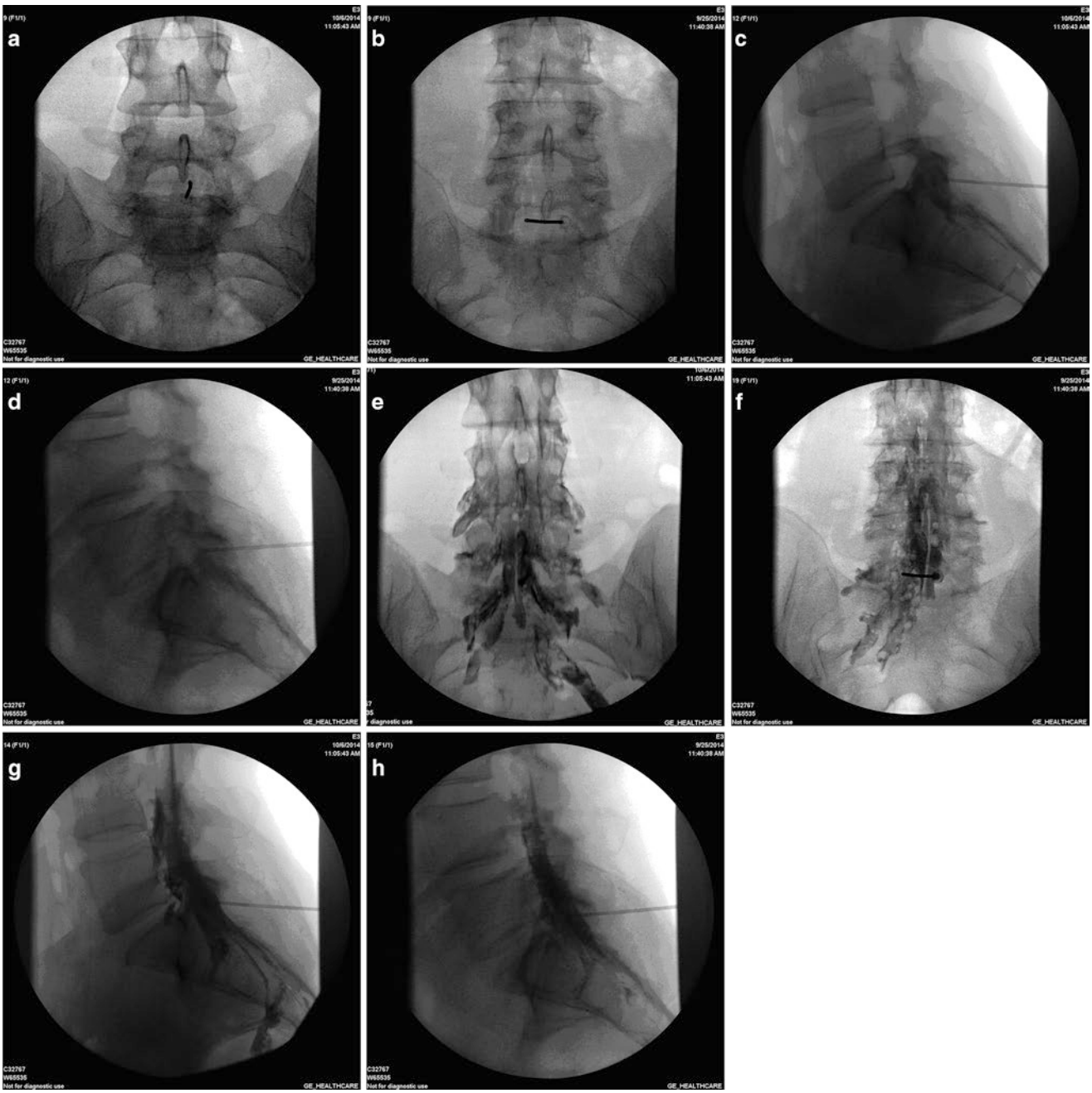

Fig. 11.14 Lumbar interlaminar epidural injections with midline (**a**, **c**, **e**, **g**) and paramedian or parasagittal (**b**, **d**, **f**, **h**) approach. (**a**) Needle tip in PA view with placement in midline between L5 and S1 and slightly lateral to L5 spinous process. (**b**) PA view with needle position to paramedian or parasagittal between L5 and S1 interspace. (**c**) Needle tip in PA view in posterior epidural space after penetrating the ligament flavum demonstrated by loss of resistance. (**d**) Needle position in lateral view after penetration of the ligamentum flavum into posterior epidural space. (**e**) PA view with injection of contrast with bilateral filling with typical illustration of nerve roots and air bubbles with a Christmas tree appearance. (**f**) Contrast filling pattern observed in PA view with typical nerve root filling at multiple levels predominantly on the left side with filling of epidural space and multiple nerve roots including L5, S1, and S2, with partial filling noted on the right side. (**g**) Lateral view of the epidural filling pattern illustrating double-line railroad pattern showing ventral as well as dorsal epidural space. (**h**) Lateral view with contrast filling predominantly with dorsal filling; however with railroad track pattern, also with ventral filling

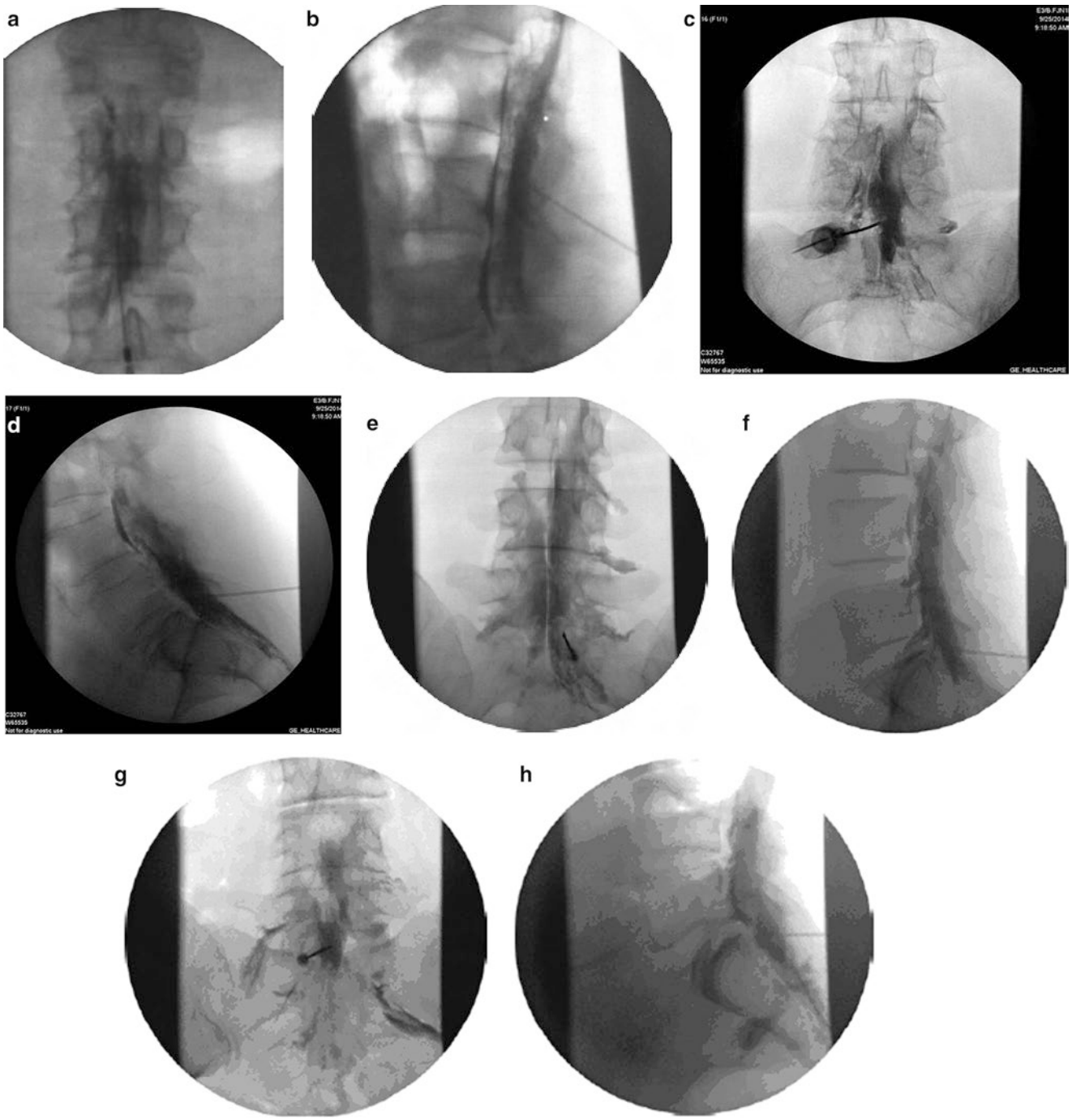

Fig. 11.15 Contrast display patterns of lumbar interlaminar with midline approach. (**a**) PA view with contrast injection with outlining of nerve roots with midline approach at L3 and L4. (**b**) Lateral view with ventral and dorsal contrast filling with double-line or "railroad track" pattern. (**c**) PA view of contrast display patterns of midline approach at L5 and S1. (**d**) Lateral view with contrast display pattern with predominantly dorsal filling pattern. (**e**) PA view of lumbar epidurography with needle placement between L5 and S1, somewhat to the right with excellent nerve root filling and epidural filling seen bilaterally. (**f**) Lateral view of L5 and S1 lumbar epidurogram with double-line "railroad track" pattern along with nerve root filling noted. (**g**) PA view of lumbar epidurography with needle placement between L5 and S1 with bilateral nerve root filling. (**h**) Lateral view of epidurography with needle entry between L5 and S1 contrast flow showing predominantly dorsal filling despite excellent nerve root filling noted in PA view

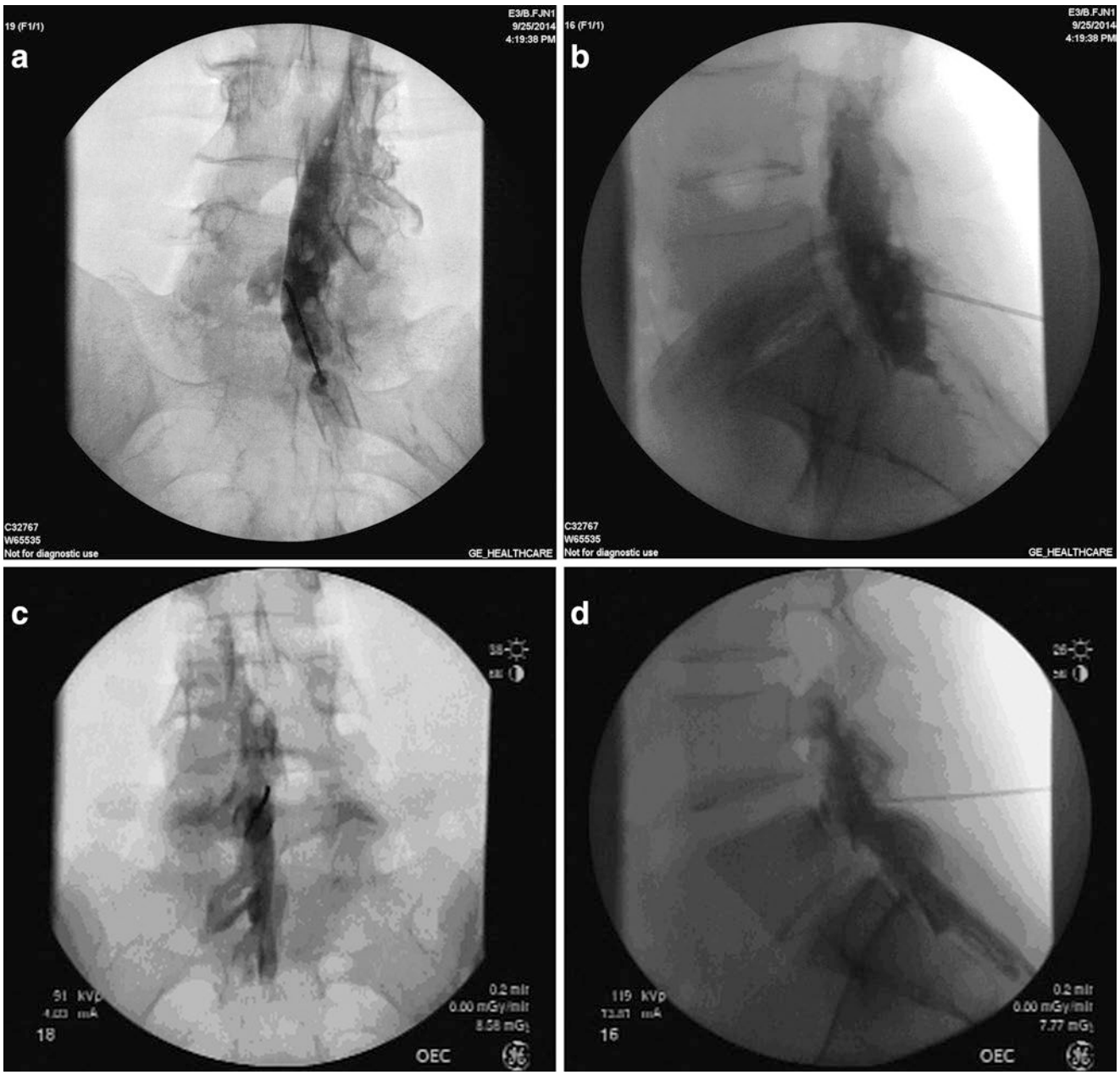

Fig. 11.16 Unilateral epidural filling patterns with midline approach. (**a**) PA view with needle placement in midline. Bevel facing left side with only right-sided filling with outlining of nerve roots. (**b**) Lateral view with dorsal filling despite excellent nerve root outlining in PA view. (**c**) AP view with contrast filling with needle between L4 and L5 epidural space with needle tip located slightly to the right side and the bevel facing the right side, with left-sided only filling, along with nerve root filling. (**d**) PA view showing predominantly dorsal filling despite nerve root filling with attempted ventral filling

and in a lateral view, contrast extends along both the anterior and posterior aspects of the epidural space on the lateral radiograph producing a "double line" or "railroad track" appearance characteristic of epidural localization of the contrast (Figs. 11.14, 11.15, 11.16, and 11.17).

  - However, this is not always the case. Thus, one should correlate PA and lateral views confirm epidural filling patterns.
- Figure 11.15 shows various types of epidural filling patterns with midline approach.

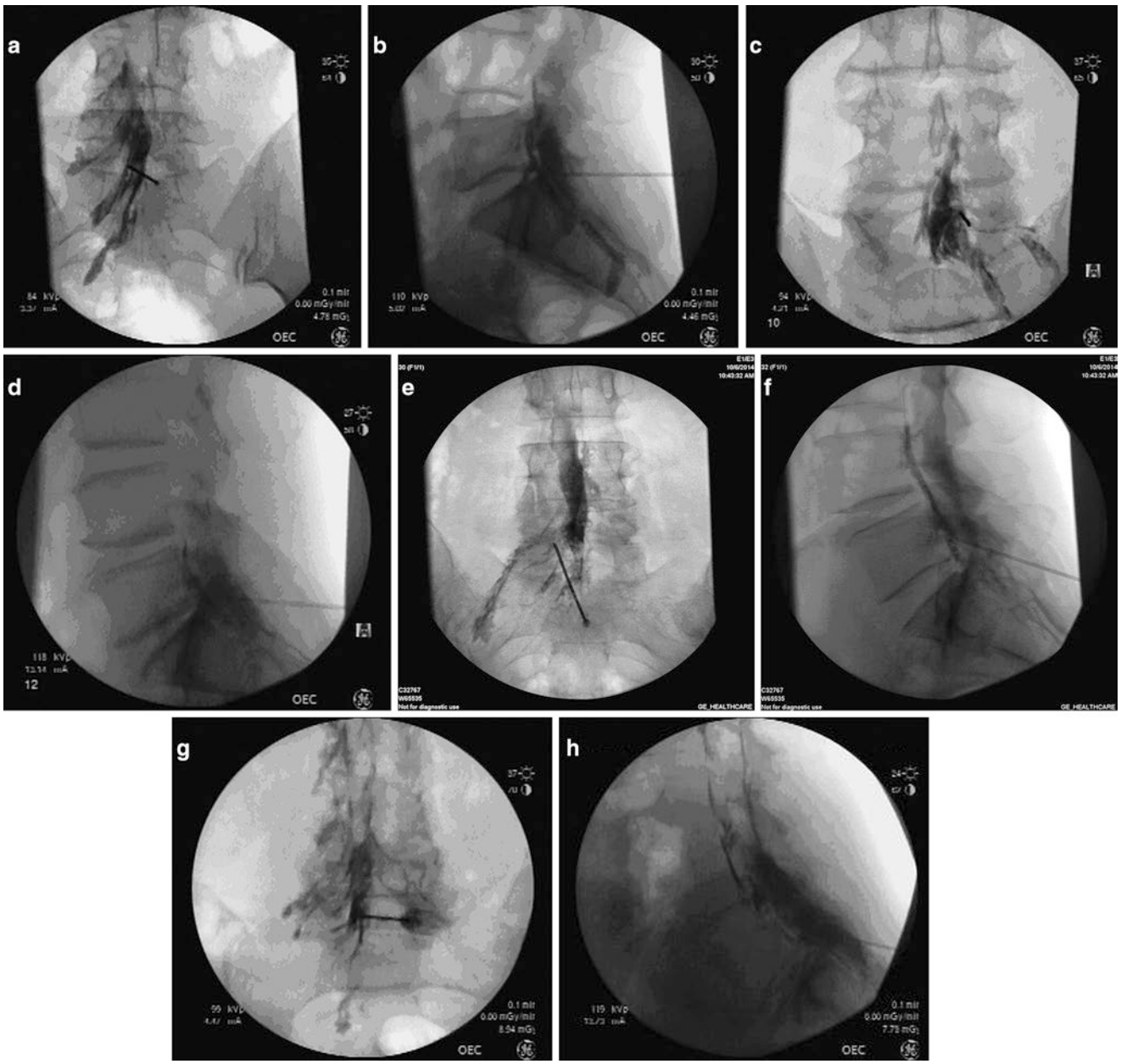

Fig. 11.17 Multiple types of epidural filling patterns with paramedian or parasagittal approach. (**a**) PA view of left paramedian approach at L5 and S1 with excellent nerve root outlining at L5, S1, and S2, and some filling of L4. (**b**) Lateral view of left paramedian interlaminar epidural at L5 and S1 showing predominantly ventral filling pattern. (**c**) PA view of right paramedian approach between L5 and S1 epidural space with outlining of L5 and S1 nerve roots. (**d**) Lateral view showing dorsal and ventral epidural filling with double-line railroad track pattern with contrast injection after entering the epidural space with loss of resistance technique. (**e**). PA view of left paramedian approach with contrast filling showing excellent nerve root filling of left L5 nerve root and associated filling of epidural space extending up to L3, as well as attempted filling of S1 nerve root. (**f**) PA view of left parasagittal approach with predominantly ventral filling. (**g**) PA view of left paramedian approach at L5 and S1 with nerve root filling at multiple levels. (**h**) Lateral view of left paramedian approach at L5 and S1 with display of ventral and dorsal filling with double-line or "railroad track" pattern

- Figure 11.16 shows unilateral filling patterns or without nerve root filling despite midline position of the needle.
- Figure 11.17 shows multiple filling patterns with paramedian or parasagittal approach.

Extra-epidural Placement

- Subarachnoid puncture and injection or subarachnoid myelographic contrast patterns are observed in 0.8% with lumbar epidural injections [62].
  - Myelographic and subarachnoid patterns demonstrate contrast within the thecal sac (Fig. 11.18).
  - PA radiographic view of lumbar spine after intrathecal placement of contrast media for myelogram may outline the lumbar thecal nerve roots within the thecal sac as they travel laterally toward the intervertebral foramina (Fig. 11.18).
    - However, this feature is much more common in myelography rather than unintended placement of subarachnoid contrast during an epidural injection (Fig. 11.18).
- Subdural contrast patterns are very rare but more commonly seen with interlaminar approach rather than caudal or transforaminal approaches as shown in Fig. 11.19 [63].
  - As shown in Fig. 11.19, pattern is of a banana type, specifically in the lateral view.
    - However, the pattern may be atypical with development of clinical symptoms and signs of subdural injection with patient developing only numbness without weakness almost 30–45 min following the injection.

Lumbar Transforaminal Epidural Injections

- Lumbar transforaminal epidural injections are considered target specific because injectate is placed over the relevant nerve root which may maximize drug concentration and possibly inject toward the ventral epidural space of the nerve root and dorsal root ganglion related to symptoms.
  - Selective nerve root block entails injection over the ventral nerve root below the dorsal root ganglion or over anterior primary ramus of spinal nerve.
    - Figure 11.13 shows supraneural and infraneural approach to transforaminal epidural injections.
  - Due to the multiple described advantages, transforaminal epidural injections have been performed more frequently and now exceed interlaminar and caudal epidural injections combined [64].
    - Lumbar transforaminal epidural injections are associated with rare catastrophic complications [65].
  - Traditionally, a neural safe triangle approach has been utilized as described by Bogduk and International Spine Intervention Society (ISIS) (Fig. 11.13) [65–67].
    - Figure 11.20 shows nerve root anatomy and implications of supraneural (safe triangle) and infraneural (Kambin's triangle) approaches of transforaminal and interlaminar epidural needle placement.

Critical Anatomy

- Understanding of anatomy of the nerve root and its relation to vasculature is critically important in avoiding major neurovascular complications [65, 68].
- The segmental radicular medullary arteries are variable in number and location.
  - The segmental radicular medullary arteries course through various neural foramina as they carry oxygenated blood from various cervical, thoracic, and lumbosacral arteries into the longitudinal anterior spinal artery system and ultimately into the parenchyma of the spinal cord (Figs. 11.10 and 11.21).
    - The size of the radicular artery is less than 0.2 mm, whereas the size of the medullary artery is 0.2–0.8 mm.
- The largest of these arteries is called the great anterior segmental medullary artery of Adamkiewicz and is found in the thoracolumbar region where it carries blood from an intercostal, subcostal, or lumbar artery or thoracic or lumbar neural foramen to supply a large portion of the middle and lower spinal cord [53, 69, 70].
- An ascending sacral radicular artery and a second thoracic radicular artery may also contribute to thoracolumbar cord blood supply.
- Figures 11.21 and 11.22 show relationship of various structures in the intervertebral foramen.
  - The main stem of the lumbar artery courses backward, with anterior and posterior radicular arteries, running upward along the nerve root before penetrating the dural sleeve just medial to the vertebral pedicle.
- Review of anatomical studies shows that the radicular artery seems to be located predominantly in the superior part of the neural foramen [65].
  - Alleyne et al. [71] in a cadaveric study found that the artery of Adamkiewicz was consistently found at the superior or middle portion of the foramen, ventral and slightly rostral or ventral to the dorsal root ganglion-ventral root complex (DRG-VR).

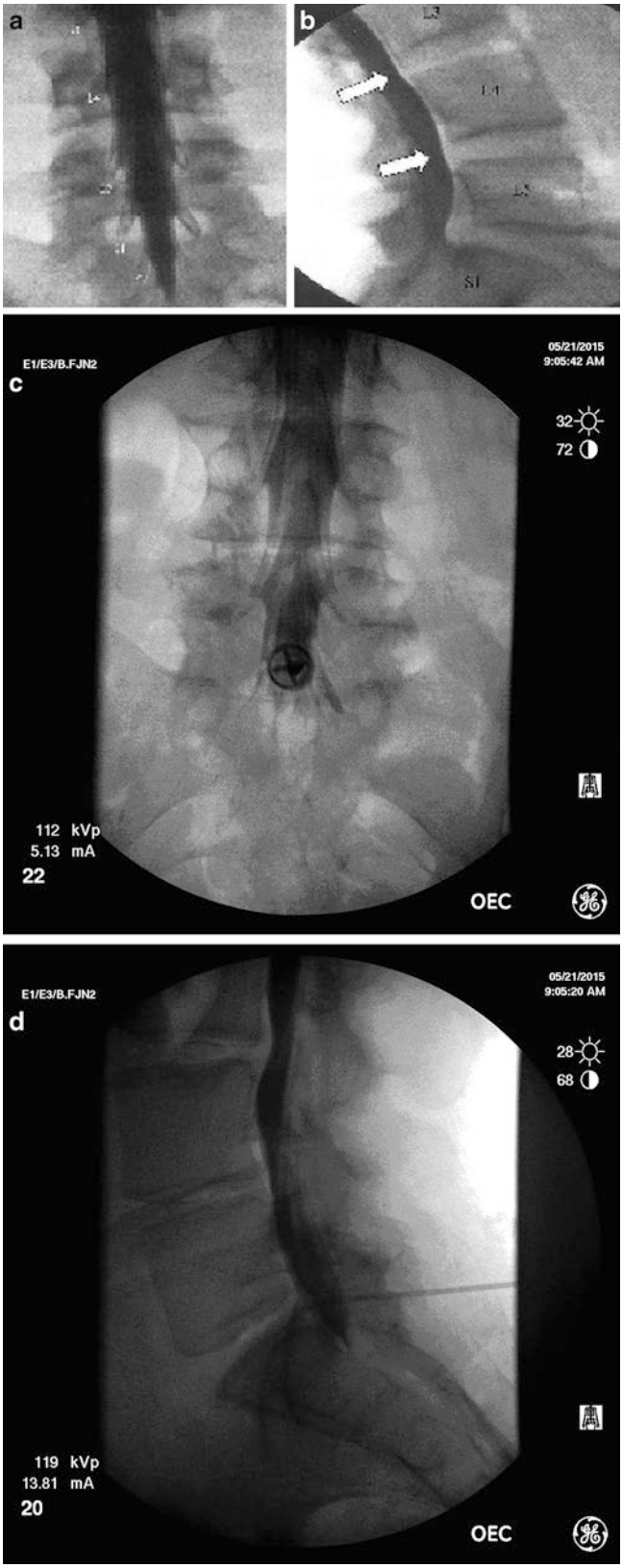

Fig. 11.18 Myelographic and subarachnoid filling patterns during an epidural procedure. (**a**, **b**) Typical myelographic contrast patterns. (**a**) Anterior and posterior view of lumbar myelogram demonstrating normal nerve root filling. Nerve roots identified by white numbers. (**b**) Lateral view of lumbar myelogram demonstrating ventral deformities (*white arrows*) of the thecal sac at the L3/L4 and L4/L5 levels. (**c**, **d**) Subarachnoid placement during epidural injection. (**c**) PA view of subarachnoid filling pattern. Nerve root filling not clearly identified as in myelogram. (**d**) Lateral view of subarachnoid placement of contrast demonstrating ventral deformities (*white arrows*) of the thecal sac at the L3/L4 and L4/L5 levels (From Botwin [58], with permission)

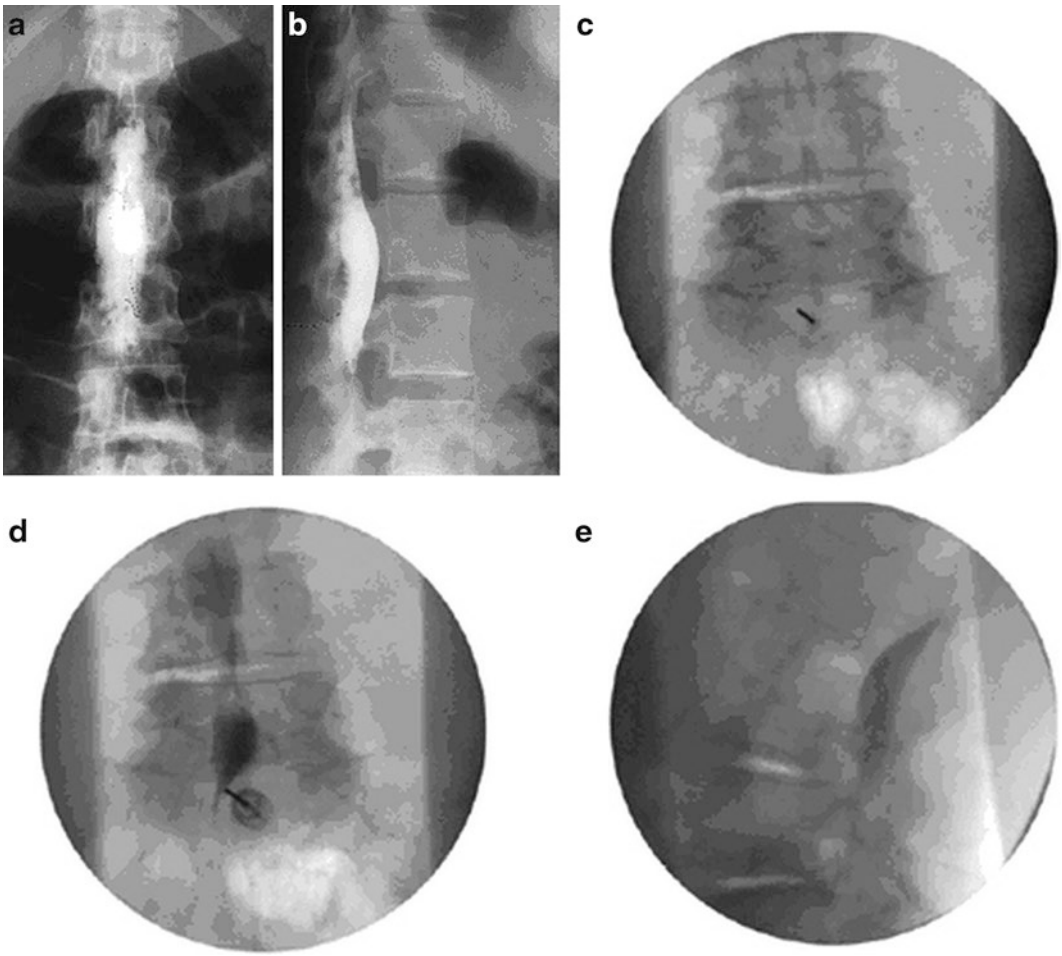

Fig. 11.19 Subdural contrast patterns. (**a**, **b**) Typical subdural compartment with contrast filling. (**a**) PA radiograph of the lumbar spine with subdural contrast media. The dense collection of contrast media is confined to the central portion of the spinal canal and does not extend to outline the exiting spinal roots laterally or in the inferior portion of the thecal sac. (**b**) Lateral radiograph of the lumbar spine with subdural contrast media. The dense collection of contrast media is confined to the posterior aspect of the spinal canal. The posterior border of fluid collection is linear (the dura mater), while the anterior border is somewhat more irregular (the arachnoid mater). (**c**–**e**). Subdural filling patterns during lumbar interlaminar epidural injections. (**c**) Needle placement with loss of resistance technique and appropriate localization under fluoroscopy. (**d**) Contrast pattern of subdural in PA view. (**e**) Lateral view of subdural contrast pattern

- Kroszczynski et al. [72] showed in a cadaveric study that the artery of Adamkiewicz and radicular arteries were predominantly located in the upper one-third of the foramen, anterosuperior or anterior to the DRG-VR complex (74%) with 23% in the mid one-third and 3% in the inferior one-third.
  - Figure 11.23 shows position of radicular artery in intervertebral foramen with needle placement with safe triangle approach.
- Rauschning [73] reported that the nerve root complex (root sleeve, ganglion, and nerve trunk) invariably lies in the "subpedicular notch" (which is the superior part of the foramen) together with the branches of lumbar artery implying superior location.
- van Roy et al. [74] in an anatomical review stated that the radicular artery follows the cranial aspect of the spinal nerves which reside in the large upper part of the foramen.
- Murthy et al. [75] in a retrospective review showed 97% of the radiculomedullary arteries are located in the superior one-half of neural foramen as opposed to only 9% and 2% for mid and inferior third, respectively, as shown in Fig. 11.24.
  - The artery of Adamkiewicz was located in the upper one-half of the foramen 97% of the time (110/113) and was never seen in the most inferior one-fifth of the foramen.

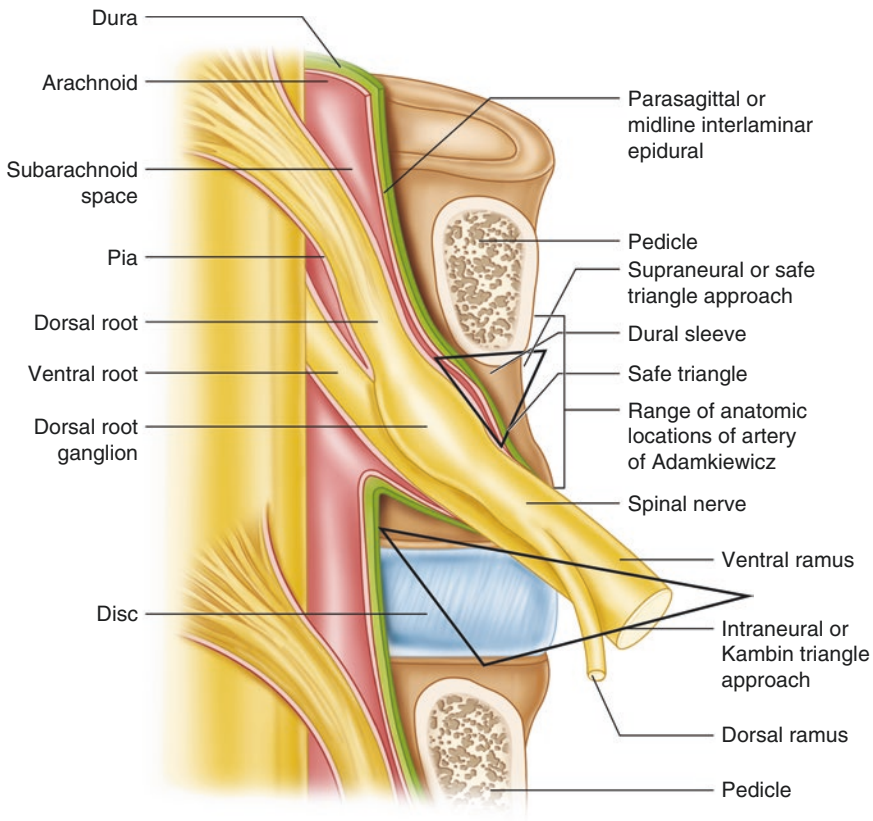

Fig. 11.20 Nerve root anatomy and implications of positioning needles for transforaminal and interlaminar epidural injections (Adapted from Standring [54]. Reproduced from Gray's Anatomy, 39th ed, Standring. ©2005, with permission from Elsevier)

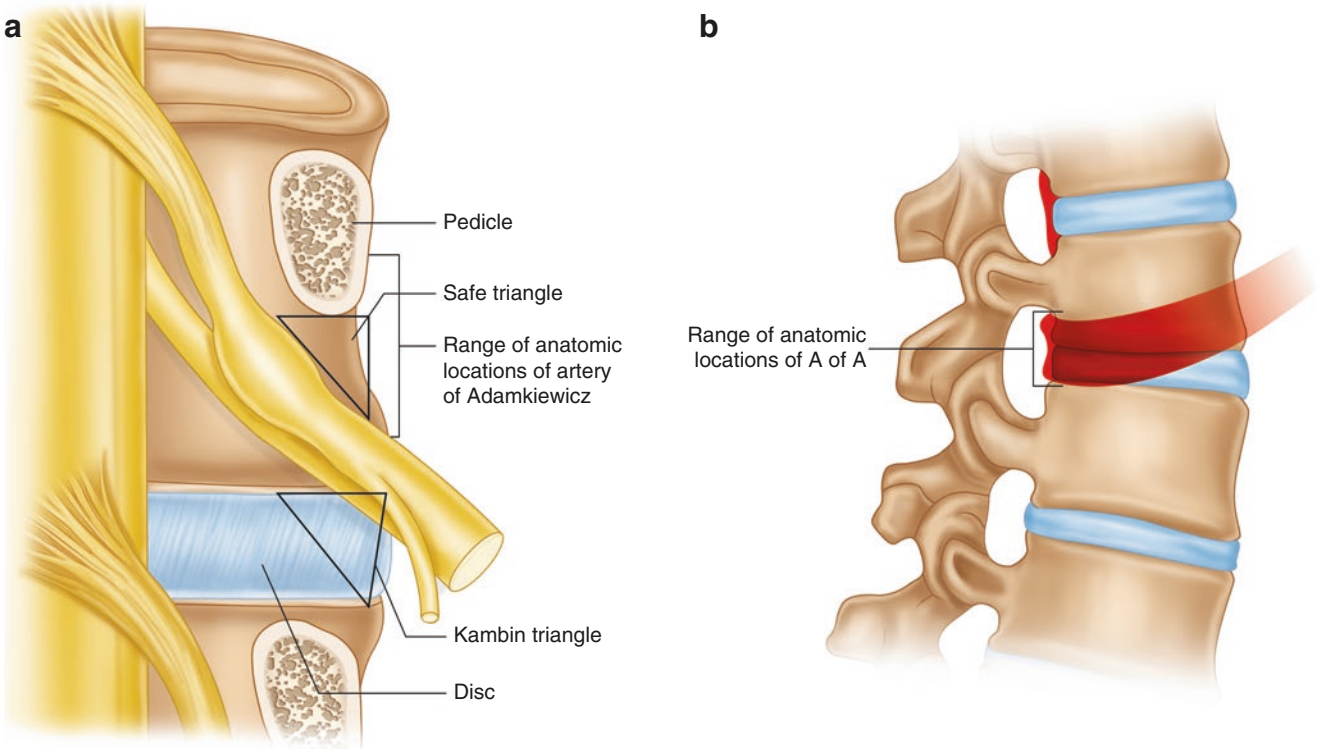

Fig. 11.21 (**a**, **b**) Relationship of arteries supplying the spinal cord with nerve roots. A of A – artery of Adamkiewicz

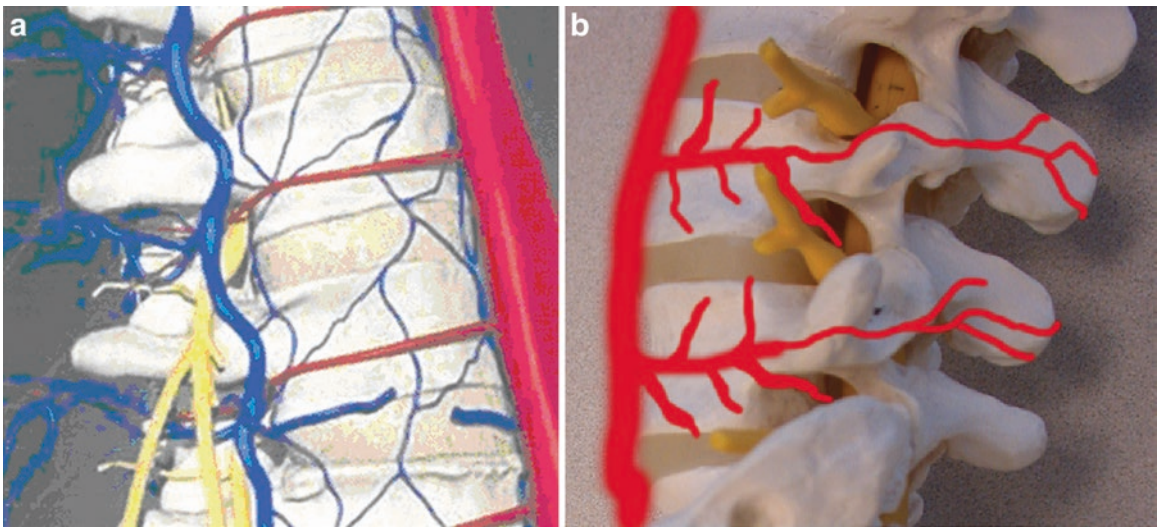

Fig. 11.22 Relationship of nerves and blood vessels in intervertebral foramen. (**a**) Typical course of arterial blood supply to spinal cord around waist of vertebra into the anterior and superior aspect of the intervertebral foramen, the location of the "safe triangle." (**b**) Relationship of arteries to nerves located in "safe triangle"

Technical Implications

- A safe triangle described by Bogduk [66] corresponds to three sides with the horizontal base of the pedicle, the outer vertical border of the intervertebral foramen, and the connecting diagonal nerve root and dorsal ganglion (Figs. 11.13, 11.20, 11.21, and 11.23).
  - Thus, a needle placed into the safe triangle will lie above and lateral to the nerve root. In this method, the injection needle is progressed toward the safe triangle under inferior surface of the pedicle to locate the spinal nerve at the superolateral aspect.
  - This approach has been favored because agents can be injected into the ventral epidural space – the inflammatory site between the back of the herniated intervertebral disc and the anterior nerve root dural sleeve. It also reduces the risk of damaging dura mater, as the injection needle goes through the border of the lateral upper intervertebral foramen.
    - The radiculomedullary arteries are located in this location in 97% [65, 72, 75].
    - It has been postulated that the odds of performing a procedure in the lumbar or thoracic foramen containing the artery of Adamkiewicz is 3.8% or 1 of 26 procedures [76, 77].
- Multiple risk reduction initiatives have been proposed to mitigate the risk of paraplegia through identification of intra-arterial needle placement. These include live fluoroscopy, digital subtraction angiography (DSA), local anesthetic test doses, and non-particulate steroids.
  - However, many of the risk mitigation strategies are based on assumption that the only mechanism of injury is the distal embolism of steroid particles which eventually cause obstruction to blood flow.
  - These strategies also assume an artery can be entered, contrast and/or local anesthetic injected, and then exited without local sequelae secondary to damage to the artery.
  - There are multiple other concerns with this theory in addition to the evidence that damage and obstruction to blood flow do occur secondary to other mechanisms of injury [76, 77].
  - Additionally, these risk mitigation strategies suffer from multiple flaws.
  - The local anesthetic test dose suffers from difficulty in measuring outcomes parameters.
  - Live fluoroscopy and DSA are based on the subjective interpretation of the individual pain physician [78, 79].
  - Differentiation between arterial and venous dispersion of dye is difficult [78, 79].
  - Multiple other mechanisms of injury include [78, 79]:
    - Mechanisms based on local phenomena with penetration and damage to the artery itself.
    - Intimal flaps, vasospasm, thrombosis, and transection of the artery. Of note, the outer diameters of the artery in the foramen and a 22 gauge needle are quite similar [78, 79].
    - There now is angiographic evidence of obstruction to flow through an injured radiculomedullary artery (right L2) 3 transforaminal epidural steroid injection [80].
- Multiple alternate approaches have been described with variations with infraneural placement of the needle called Kambin's triangle approach, inferior triangle approach, inferior ganglion approach, and retrodiscal approach.

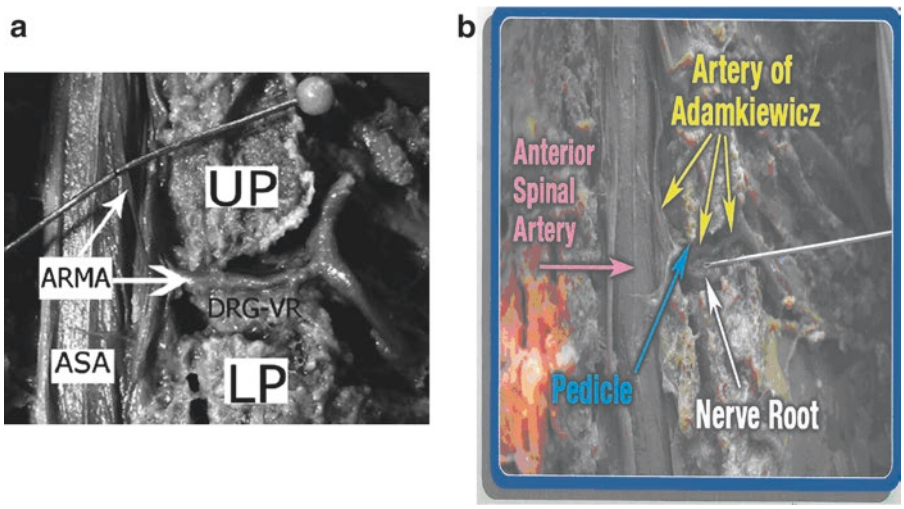

Fig. 11.23 Location of thoracolumbar anterior medullary arteries underneath pedicle and relative similarity in diameter of this vessel to a 22 g needle. (**a**) Longitudinal cross section of the thoracic vertebrae segment. *UP* upper pedicle, *LP* lower pedicle, *DRG-VR* dorsal root ganglion-ventral root complex, *ASA* anterior spinal artery, *ARMA* anterior medullary artery. (**b**) Relationship of Artery of Adamkiewicz to nerve root in safe triangle (From Kroszczynsi et al. [72], with permission)

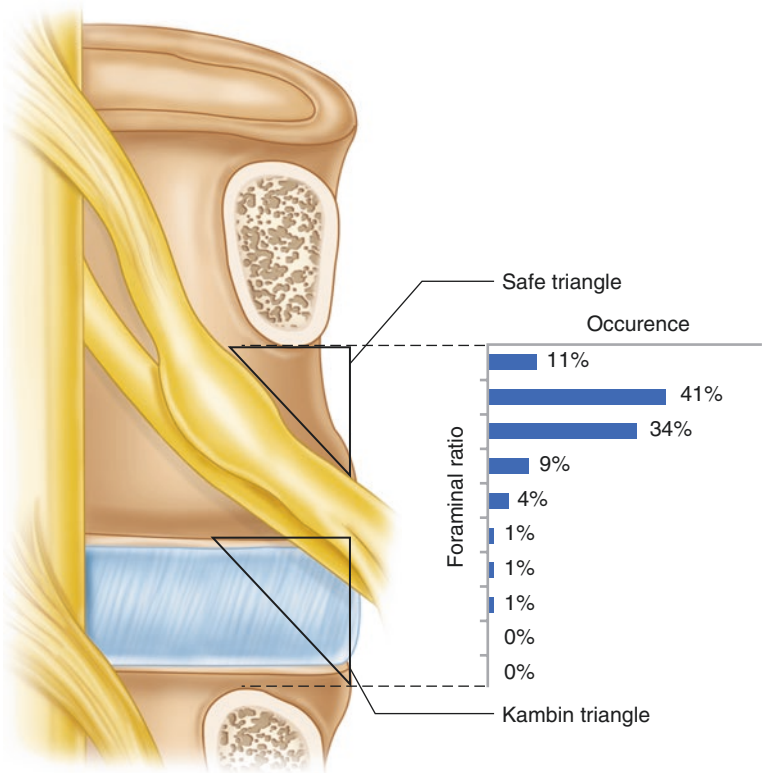

Fig. 11.24 Location of radicular medullary arteries, as determined at the mid-pedicular plane, is graphically depicted using the foraminal ratio, in 0.10 increments (Adapted from Murthy et al. [75])

- Based on the analysis of the available anatomical studies and radiological studies, Atluri et al. [65] have identified the "inferior triangle." The boundaries of the inferior triangle in the oblique fluoroscopic view are as follows: lateral border of the superior articular process forms one side of the triangle and the transverse process is the base, with hypotenuse traversing nerve root forming the other side of the triangle.
- In a PA view for the posterior approach, the triangle is formed with the inferior two-thirds or middle half of the triangle formed by the inferior margin of the superior pedicle and the superior margin of the inferior pedicle (Figs. 11.13 and 11.24).
- These approaches incorporate similar approaches with directing the needle placement in the inferior foramina avoiding radicular artery (Figs. 11.13 and 11.24).

• Kambin's triangle approach for transforaminal epidural injections, which is synonymous to inferior foraminal approach, has been popularized in recent years [65, 67, 81].
- In 1972, Kambin introduced endoscopic intervertebral discectomy by posterolateral approach, defining

Kambin's triangle as the site to approach the intervertebral disc [82].
  - Kambin's triangle is defined as a right triangle over the dorsolateral disc with the hypotenuse being the exiting nerve root, the base (width) the superior border of the caudal vertebra, and the height the dura/traversing nerve root as shown in Figs. 11.20, 11.24, and 11.25.

Safe Triangle Approach

- Safe triangle approach has been widely used with oblique or posterior approach [66].
  - For the posterior approach, the patient is placed in the prone position with firm padding under the abdomen and the fluoroscopy unit positioned with the spinous process in the center of the spine.
  - A diamond-tipped, Quincke, Whitacre, Bella-D Coudé®, or blunt needle is inserted into the skin over the lateral border between the two adjacent transverse processes at the target interspace, closer to the upper transverse process.
  - The needle is advanced toward the lower edge of the transverse process, near its junction with the superior articular process, or may be directed toward the edge of the transverse process, at which time the needle may be retracted slightly and redirected toward the base of the appropriate pedicle and advanced very slowly to the final position or the needle may also be directed toward the pedicle without this intermediate step.
  - The needle position may be observed in lateral view. A small volume of contrast is injected and the pattern of dispersion into the nerve root is noted.
    - If the needle has penetrated the epiradicular membrane surrounding the nerve root, an appropriate and positive image of the nerve root will be seen on fluoroscopy, with appropriate dispersion of the contrast, as shown in Fig. 11.26.
    - The needle tip may also be repositioned several millimeters inferior to the pedicle sometimes to appropriately position the needle into the epiradicular membrane. A classic contrast pattern with a dispersion showing a neurogram is not always achieved.
- In an oblique approach, the patient and the fluoroscopy unit are rotated as needed to provide an oblique projection of the pedicle on the side of the targeted nerve root (Fig. 11.26).
  - The oblique position is achieved by fluoroscopic imaging with adjustment until the superior articular process is seen between the anterior and posterior edge of the vertebral body, and the base of the articular process is in line with the pedicle.
  - A needle is inserted slightly above the superior articular process and directed toward the base of the pedicle, advancing slowly until contact is made with the bone below the pedicle (Fig. 11.26).
- Following the placement of needle, contrast is injected slowly and the dispersal pattern of the nerve root is assessed. If paresthesia is observed, the needle must be withdrawn approximately a millimeter or so and contrast is injected.

Inferior or Kambin's Triangle Approach

- The procedure may be performed with Kambin's triangle approach, either with posterior or oblique approach (Figs. 11.20, 11.24, and 11.25).
  - Atluri et al. [65] proposed to place the needle as inferior and as posterior as possible in the neural foramen, which corresponds to the inferomedial part of this inferior triangle.
- For posterior approach, the patient is placed in the prone position, and the fluoroscopy unit is positioned with the spinous process in the center of the spine (Figs. 11.27 and 11.28).
  - A diamond-tipped, Quincke, Whitacre, Bella-D Coudé, or a blunt needle is inserted into the skin over the lateral border between the two adjacent transverse processes at the target interspace, two-thirds below the upper transverse process.
  - The needle is advanced toward the inferior aspect of the foramen observing the needle position in posterior or in lateral views, with injection of a small volume of contrast, and the pattern of dispersion into the nerve root is noted.
    - If the needle has penetrated the epiradicular membrane surrounding the nerve root, an appropriate and positive image of the nerve root will be seen on fluoroscopy, with appropriate dispersion of the contrast, as shown in Figs. 11.27 and 11.28.
    - However, a classic contrast pattern with a dispersion showing a neurogram is often not achieved with this approach.
- For oblique approach, the patient is placed in the prone position, and the fluoroscopy unit is positioned into oblique position ipsilaterally until the "target point" is identified.
  - The target point is the junction of superior articular process (SAP) and transverse process (TP) (Figs. 11.27 and 11.28). If this landmark is not

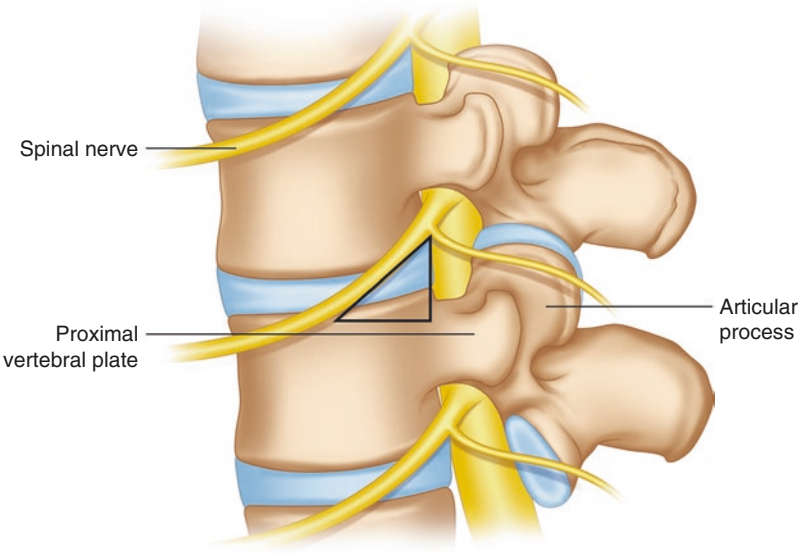

Fig. 11.25 Anatomic depiction of Kambin's triangle (Adapted from Park et al. [81])

clearly visualized, alternatively the inferolateral part of the SAP can be targeted. Craniocaudal angulation of the C-arm may be required to "crisp up" these target points.

- Targeting either of these points is critical as it will ensure inferior placement of the needle in the foramen. If not, the likelihood of the needle placement in the midzone of the foramen increases. This is not ideally desirable as up to 23% of the time, the radicular artery lays in the midzone of the foramen [74].

– If an L4 transforaminal epidural is planned, the target point is the junction of the SAP with TP at L5 level and not L4; the needle is advanced to contact the junction of SAP and TP (or the inferolateral part of SAP) (Fig. 11.28).

- After contacting either one of the above landmarks (this will ensure posterior placement of the needle and also decrease the chances of inadvertently entering the disc), walk off the bone slightly into the foramen (Fig. 11.28) and check the lateral view and advance the needle if necessary until it is in the posterior part of the foramen (Fig. 11.28).
- The needle tip must be observed in the PA view at the lateral aspect of the pedicle, followed by contrast injection (using PA views) for any vascular spread and also for medial epidural spread (Fig. 11.28).
- If the desired medial neural or epidural spread is not achieved, then the needle may be advanced slightly (needle bent may be maintained medially if using a curved needle) with repeat injection until good medial epidural spread is obtained (needle position medial to the 6 o'clock of the pedicle is not recommended as it will increase risk of subdural/intrathecal or intradiscal placement).
- As soon as the initial medial contrast spread is seen (even though lateral spread is noted), further needle advancement may be ceased because staying as lateral as possible in the PA view will ensure posterior placement of the needle in the foramen. Although in most cases medial contrast spread can be achieved in the posterior part of the foramen, sometimes the needle may have to be advanced to the anterior part of the foramen (Fig. 11.28).
- If the needle is in the anterior part of the foramen, it is pertinent that it should be in the inferior part. If not, the needle has to be repositioned. After negative aspiration for blood and cerebrospinal fluid and also negative vascular and intrathecal/subdural contrast spread, inject the medication.

- After satisfactory contrast dispersion pattern is observed, local anesthetic alone (1% preservative-free lidocaine 1–2 mL or another local anesthetic) or with corticosteroid (3 mg of betamethasone or 20 mg of methylprednisone or 20 mg triamcinolone or 8 mg of Decadron) is injected.
  – If supraneural or safe triangle approach is utilized, based on the recent research, it is recommended to avoid particulate steroids [83–85].
- Park et al. [81] studied Kambin's triangle approach of lumbar transforaminal epidural injections and compared it with safe triangle approach with outcomes in spinal stenosis. They concluded that the Kambin's triangle approach was as efficacious as the safe triangle approach for short-term effect and Kambin's triangle approach offered considerable advantages with less spinal nerve irritation during the procedure.

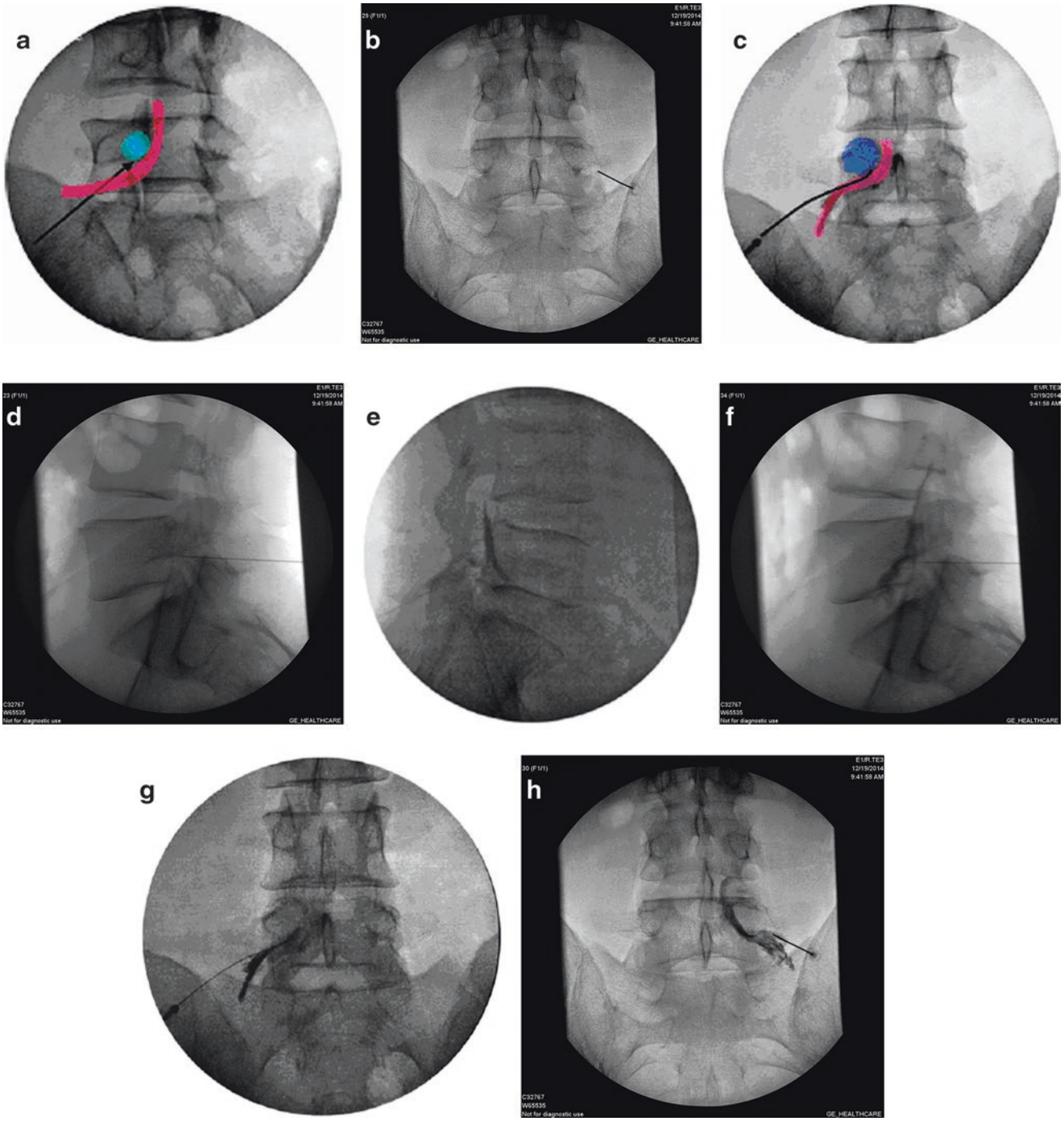

Fig. 11.26 Transforaminal epidural at L5, utilizing safe triangle approach with oblique (**a**, **c**, **e**, **g**) or posterior (**b**, **d**, **f**, **h**) approach. (**a**) "Scotty dog" and location of needle placement with illustrative anatomy of L5 – oblique approach. (**b**) Placement of needle at L5 with posterior approach in PA view. (**c**) Illustration of nerve root, pedicle, and needle in PA view. (**d**) Lateral view of L5 needle placement. (**e**) Lateral view of nerve root filling partially into epidural space. (**f**) Contrast display pattern at L5 in lateral view. (**g**) Nerve root filling noticed after contrast injection at L5 in PA view contrast into the nerve root. (**h**) Contrast display pattern of L5 nerve root in PA view

First Sacroiliac Transforaminal

- For the transforaminal approach for the S1 nerve root, the patient is in the prone position, and the S1 foramen is visualized under fluoroscopy which appears as a small radiolucent circle just below the oval S1 pedicle (Fig. 11.29).
- It may be necessary to direct the fluoroscopic beam in a cephalocaudal direction for the alignment of anterior and posterior foramina, in some cases about 30 degrees.

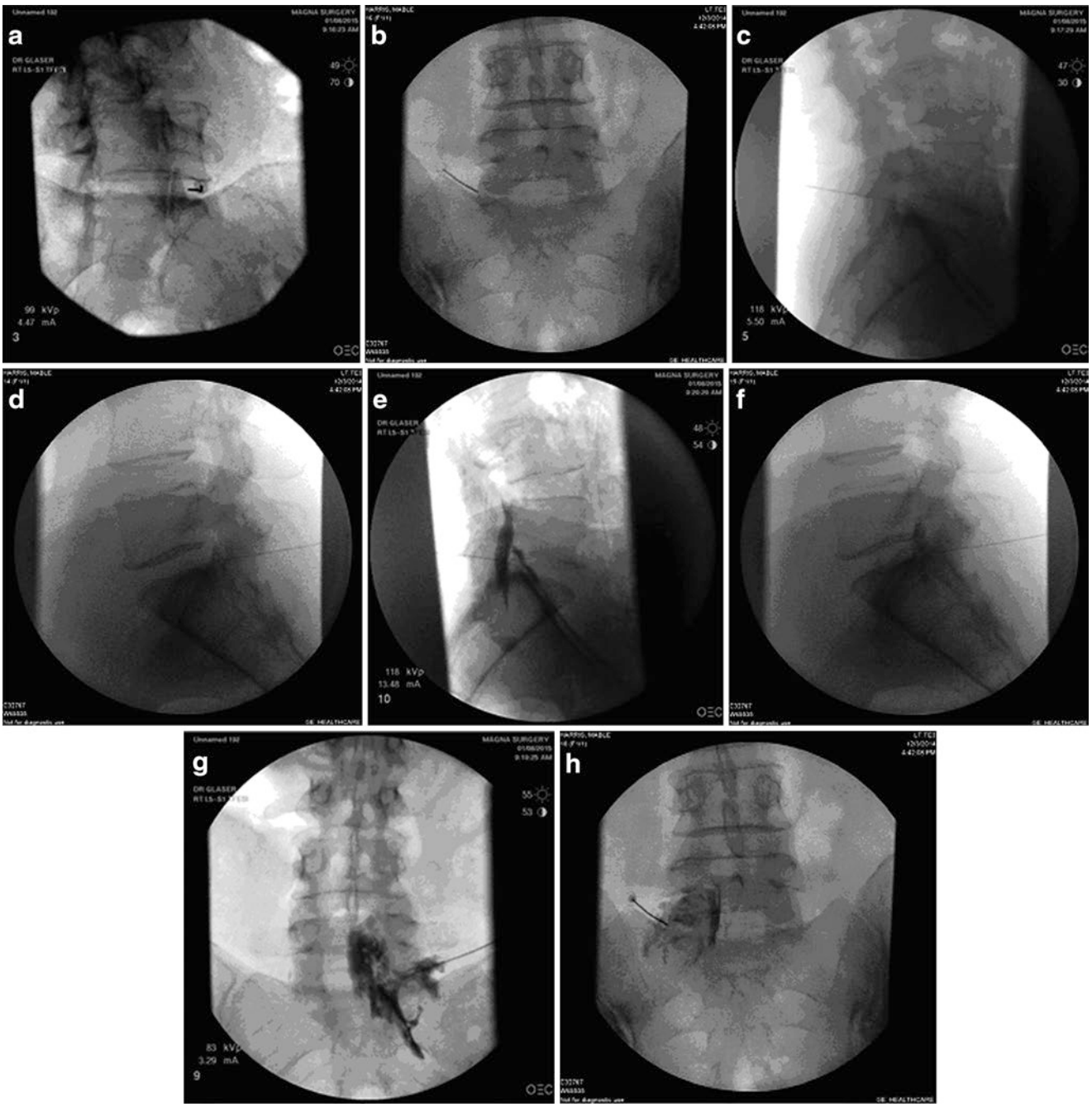

Fig. 11.27 Transforaminal epidural injection with Kambin's triangle approach with oblique (**a**, **c**, **e**, **g**) or posterior (**b**, **d**, **f**, **h**) approach at L5. (**a**) Oblique L5 transforaminal epidural injection. (**b**) PA view with needle placement at L5 – posterior approach. (**c**) Lateral L5 transforaminal epidural injection. (**d**) Lateral view with needle placement L5. (**e**) Lateral with contrast L5 transforaminal epidural injection. (**f**) Lateral view of L5 with contrast injection. (**g**) PA view of L5 transforaminal epidural injection with contrast. (**h**) PA view with contrast injection

- The needle is inserted slightly lateral and inferior to the S1 pedicle and advanced slowly through the posterior foramina to the medial edge of the pedicle.
- Extreme caution must be exercised to avoid advancing the needle through both the posterior and anterior S1 foramina and into the pelvis.

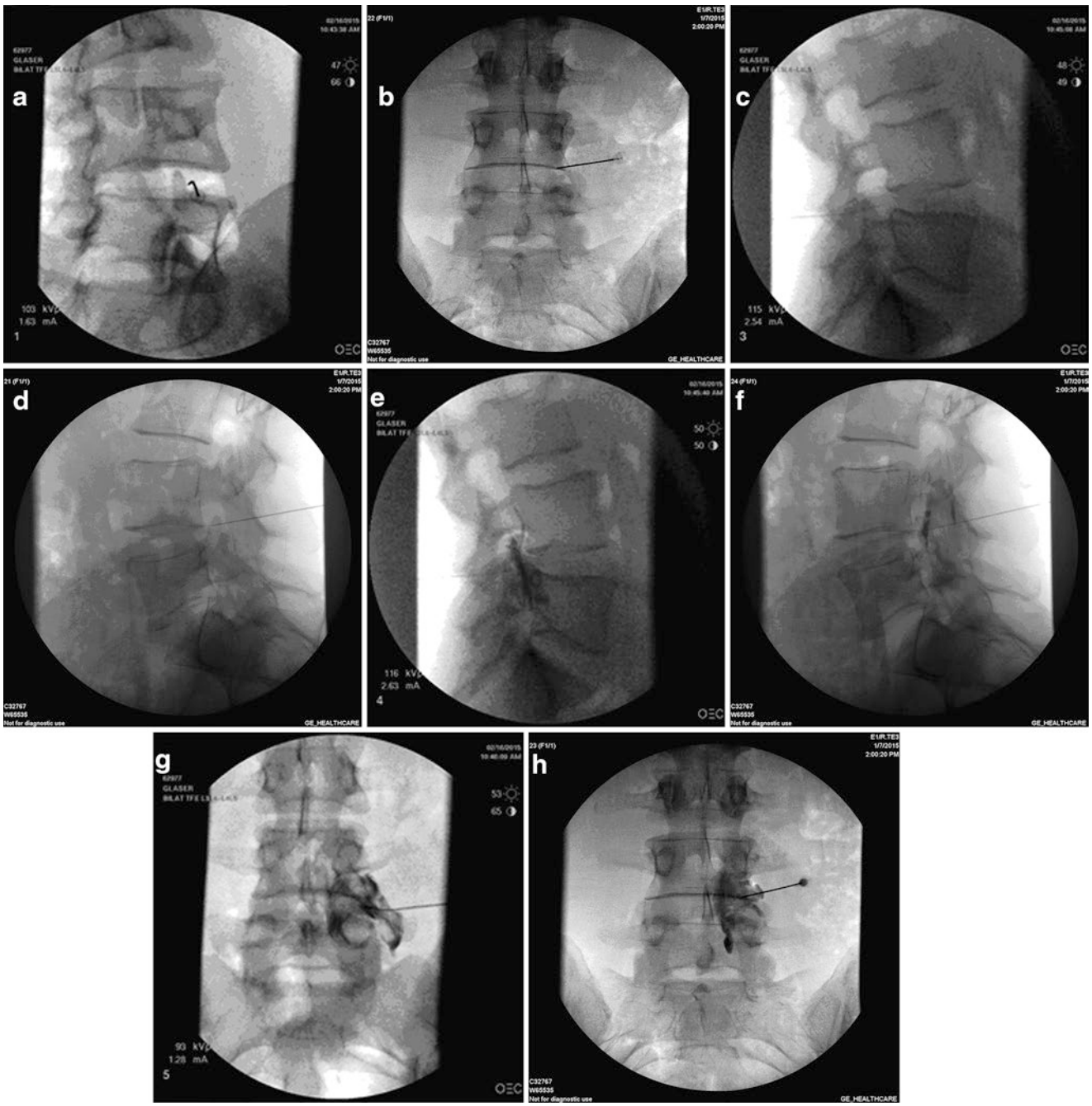

Fig. 11.28 Transforaminal epidural injections with Kambin's triangle approach with oblique (**a**, **c**, **e**, **g**) or posterior (**b**, **d**, **f**, **h**) approach at L4. (**a**) Oblique right L4 transforaminal epidural injection. (**b**) PA view with needle placement at L4 transforaminal epidural injection – posterior approach. (**c**) Lateral right L4 transforaminal epidural injection. (**d**) Lateral view with contrast injection at right L4 transforaminal epidural injection. (**e**) Lateral view with contrast injection at right L4 transforaminal epidural steroid injection. (**f**) Lateral view with contrast injection at right L4 transforaminal epidural injection. (**g**) PA view with contrast of right L4 transforaminal epidural injection. (**h**) PA view with contrast injection at right L5 transforaminal epidural injection

- First contacting the posterior sacral bone prior to entering the S1 foramina provides the depth and direction of the needle.
- Following appropriate placement of the needle, once again dispersion of the contrast is observed.
- If it is appropriate, local anesthetic and corticosteroid solution is injected similar to the lumbar transforaminal epidural injection.
  - Multiple injection contrast display patterns are shown with infraneural (Kambin's triangle) approach utiliz-

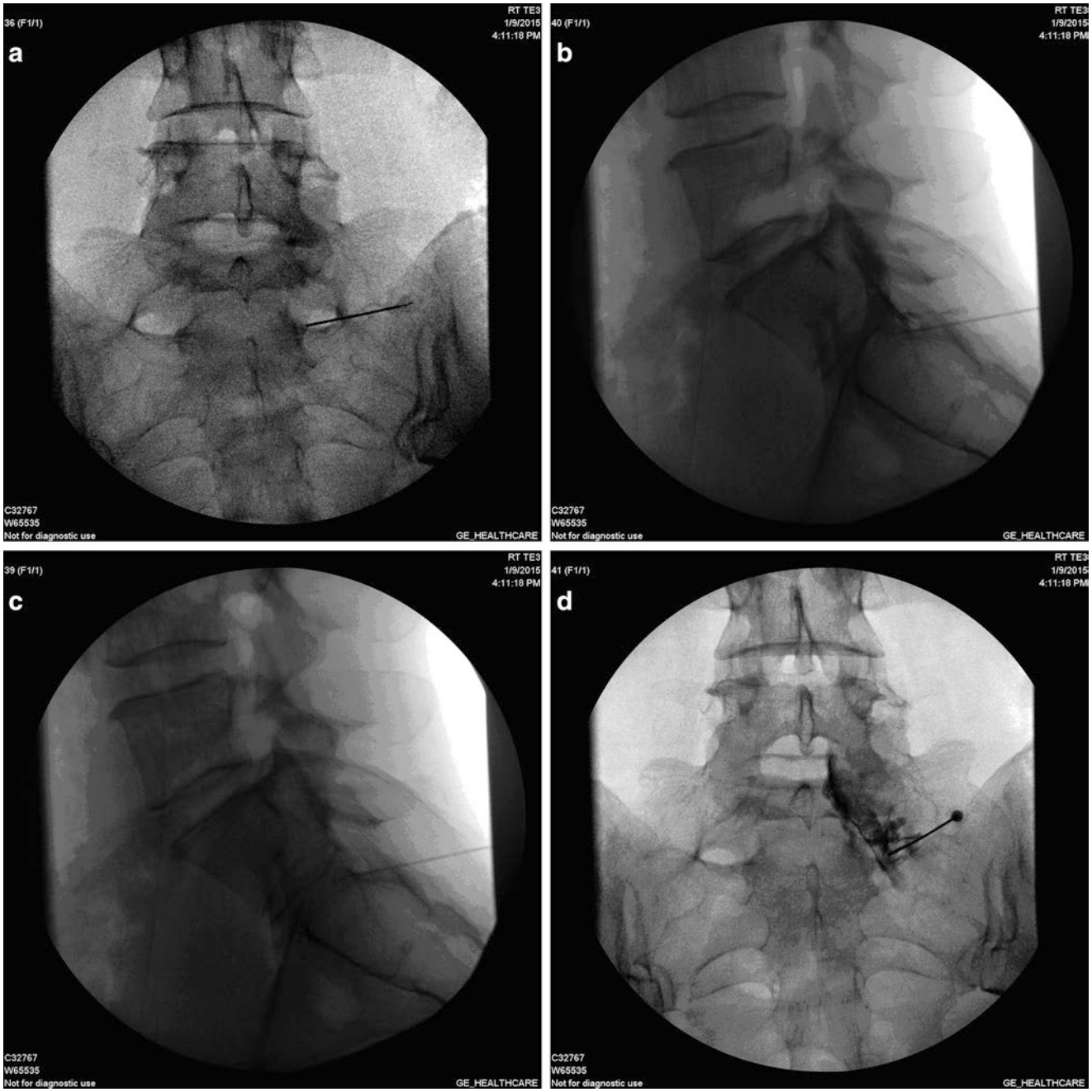

Fig. 11.29 First sacral transforaminal epidural injection with postero-anterior approach on right side. (**a**) Needle placement at right S1 for transforaminal in a PA view. (**b**) Needle placement at right S1 with contrast display in lateral view. (**c**) Needle position in lateral view prior to contrast injection. (**d**) Contrast display at S1 in PA view

ing posterior approach (Figs. 11.30 and 11.31) for lumbar transforaminal epidurals.

– Figure 11.32 shows comparison of supraneural and infraneural needle placement with posterior approach.
  - Nerve root filling patterns are similar with both approaches.
– Figure 11.33 shows multiple injection display patterns of sacral one transforaminal.

Extraneural Placement of Needle

- Intravascular placement of the needles with transforaminal epidural injections is much higher than lumbar interlaminar and caudal epidural injections [62, 80, 81]. The range of intravascular penetration in the lumbosacral region has been shown to be as high as 15% at lumbar levels and 46% at sacral levels.

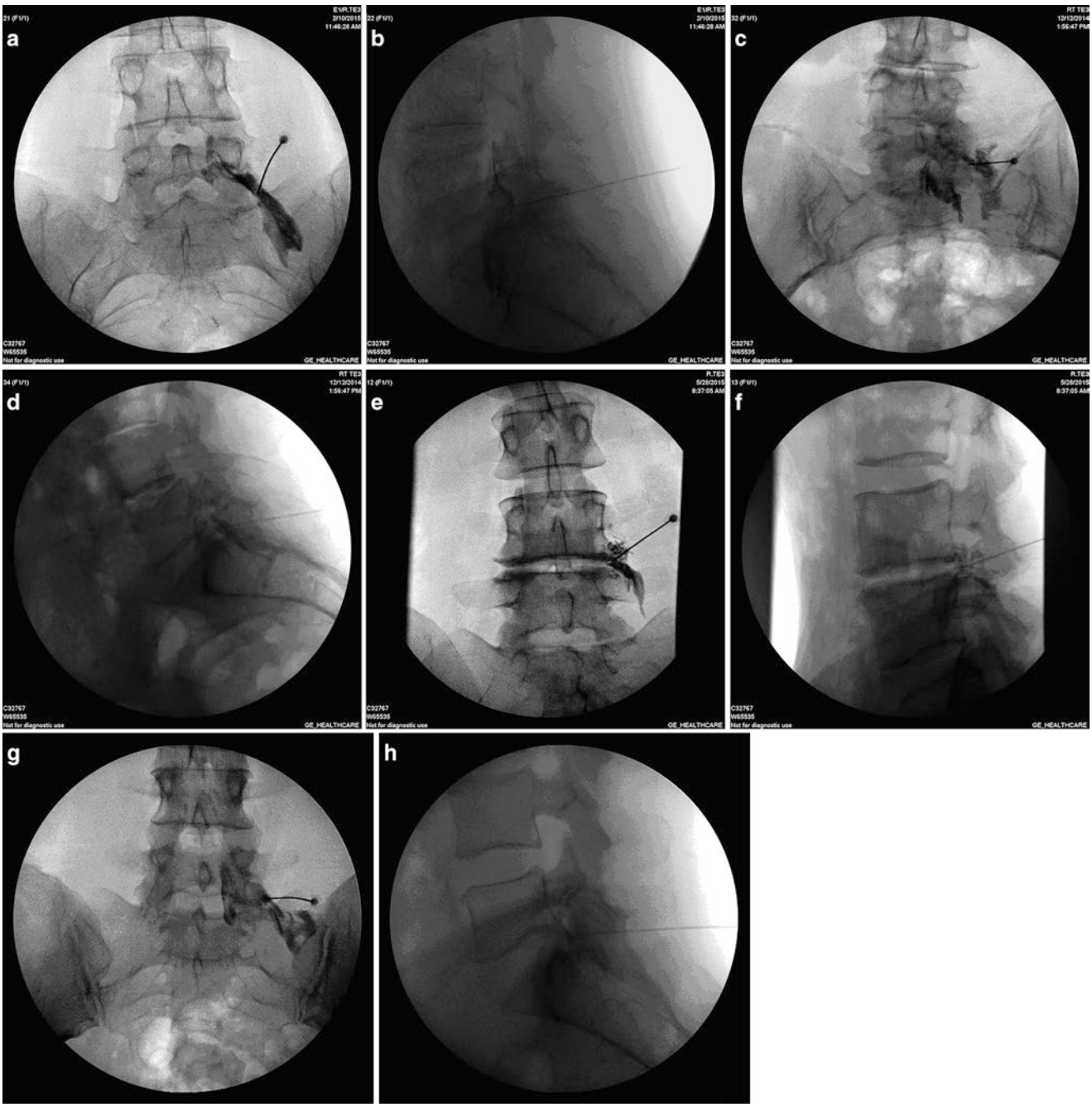

Fig. 11.30 (**a–p**) Contrast display patterns with posterior approach utilizing infraneural or Kambin's triangle approach. (**a, c, g, i, k, m, o**) Infraneural needle placement at L5 in PA view. (**b, d, h, j, l, n, p**) Infraneural needle placement at L5 in lateral view. (**e**), Infraneural needle placement at L4 in PA view. (**f**) Infraneural needle placement at L4 in lateral view

  - Use of DSA has been described to provide higher accuracy, specifically with intra-arterial injections.
    - However, a case report discussed the possibility of DSA missing intra-arterial needle placement [82].
- Figure 11.34 shows intravascular placement with L5 and S1 transforaminal epidural injections.
- Subdural filling patterns are more common with lumbar interlaminar epidural injections and catheterization with caudal epidural injections; however, they have been reported with transforaminal epidural injections also.
  - Figure 11.35 shows subdural filling patterns during L5 transforaminal epidural needle placement.

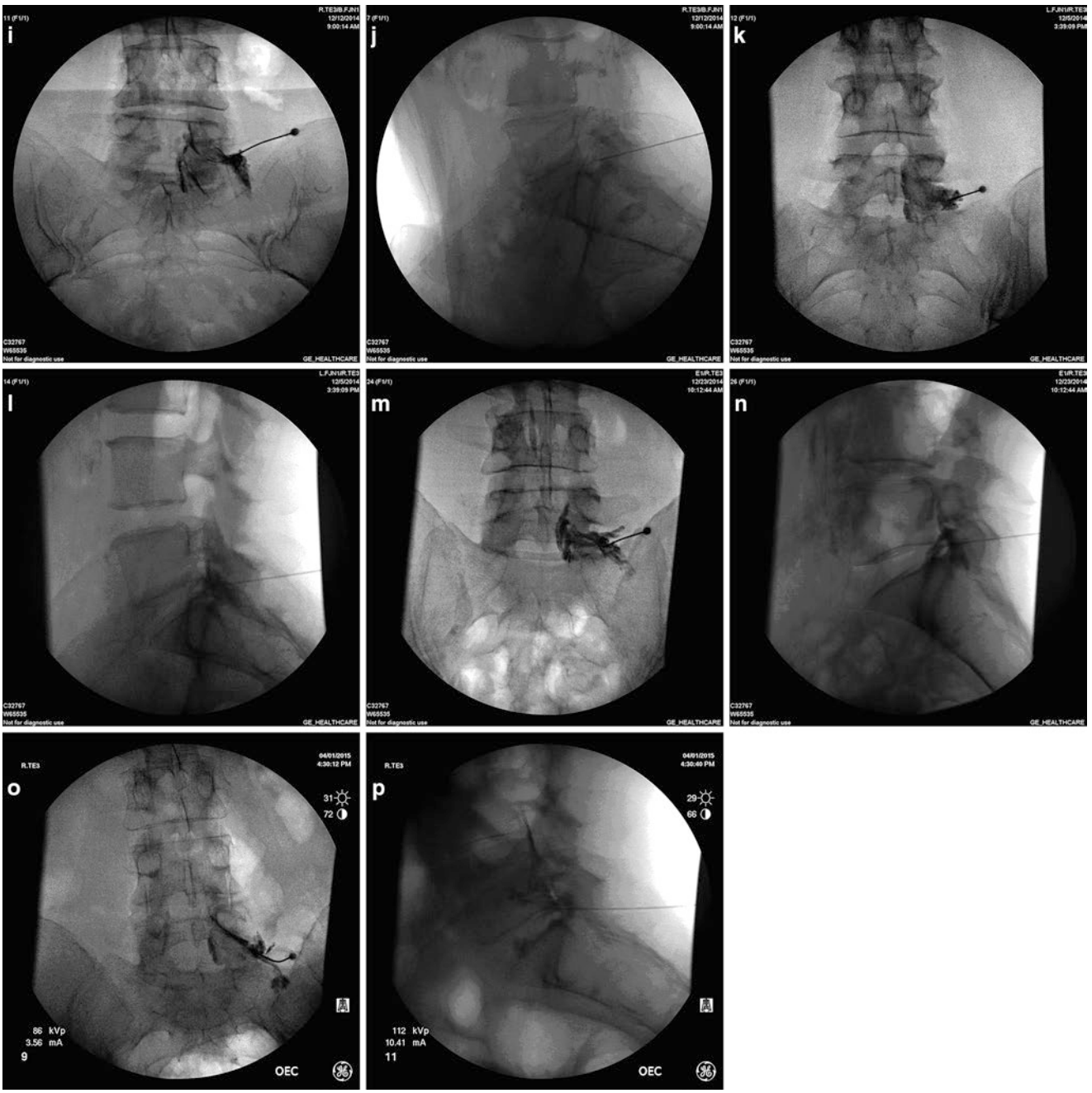

Fig. 11.30 (continued)

- Intradiscal placement has been described commonly with transforaminal epidural injections than interlaminar epidural injections, specifically utilizing infraneural approaches.
  - Figure 11.36 shows intradiscal placement of contrast during L5 transforaminal epidural injection.

Caudal Epidural Injections

- Among the three approaches to the epidural space, caudal epidural injections are the oldest, safest, and easiest to perform, even though they are considered nonspecific. Caudal epidural injections must be performed with

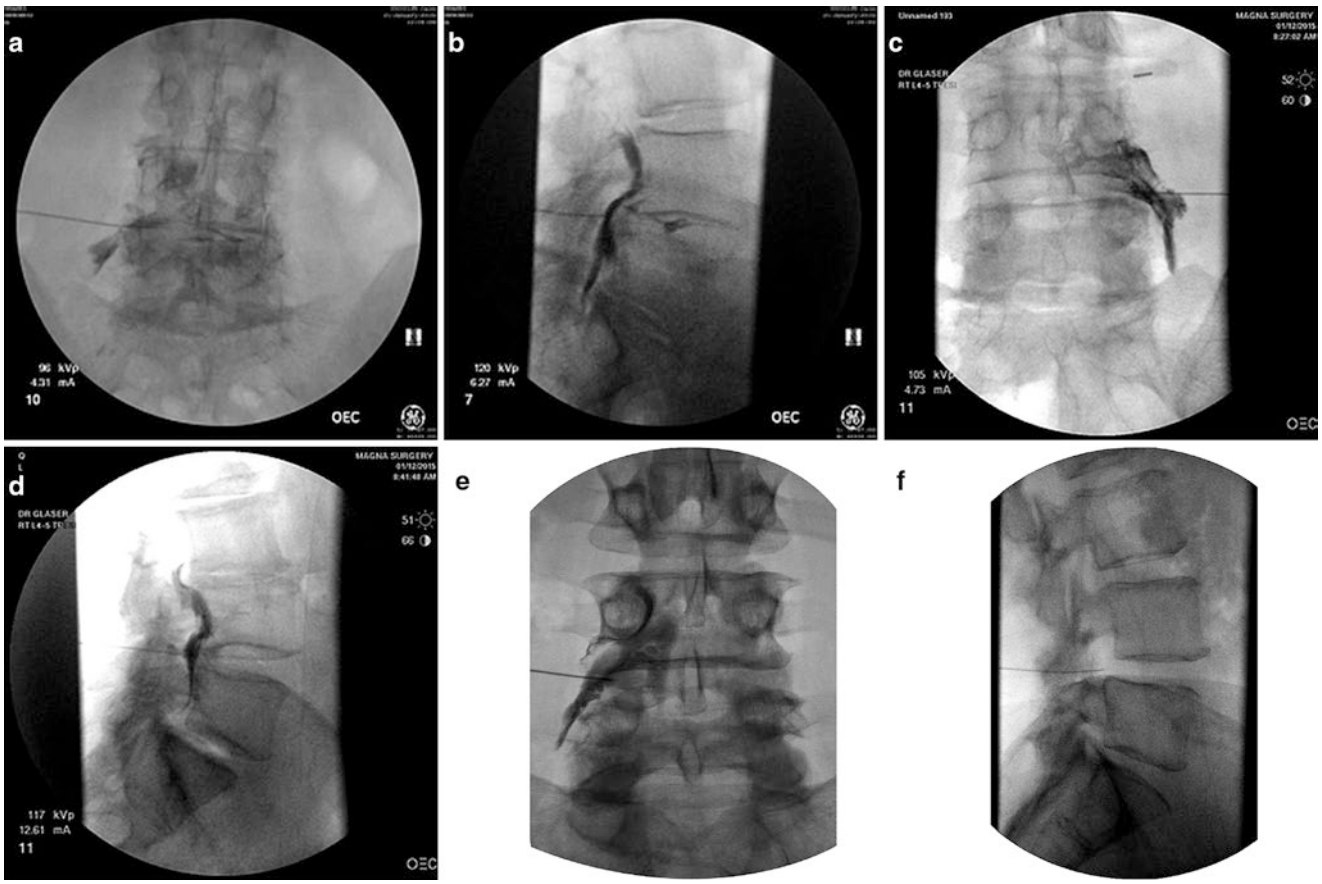

Fig. 11.31 (**a–f**) Contrast display patterns with oblique approach utilizing infraneural or Kambin's triangle approach. (**a, c**) Infraneural needle placement at L4 in PA view. (**b, d**) Infraneural needle placement at L4 in lateral view. (**e**) Outlining of L4 nerve root with contrast injection in PA view. (**f**) Needle placement similar to discography in lateral approach for L4 nerve transforaminal epidural injection

fluoroscopy. Failure to use fluoroscopy increases the prevalence of extra-epidural placement of the needle and injections [1, 86].
  - Overall, inaccurate placement has been shown to range from a low of 8% to a high of 38% in experienced hands with unrecognized intravascular placement ranged from 3.7% to 14%.
- The technical aspects of caudal epidural injections are distinctly different from lumbar interlaminar and transforaminal epidural injections.
  - The caudal epidural procedure is performed with the patient in the prone position with placement of firm padding under the pelvis, with the patient's head turned away from the operator and with appropriate tilting of the pelvis to make the sacral hiatus more prominent.
  - The abduction of legs and heels may prevent heightening of the gluteus muscles, which will facilitate identification of the sacral hiatus.
- Following the preparation of a wide area of skin with an antiseptic solution followed by appropriate draping, a C-arm is brought over the lumbosacral area and is positioned in either PA or lateral position.
- Understanding of the anatomy of sacrum is crucial for successful placement of needle.
  - The sacrum is a triangular bone, dorsally convex, that consists of the fused five sacral vertebrae articulating cephalad with the fifth lumbar vertebra and caudad with the coccyx as shown in Figs. 11.3, 11.4, and 11.37.
  - In the midline, there is a median crest with three or more, but commonly four, prominent tubercles which are variable, representing the sacral spinous processes.
  - The remnants of the S5 inferior articular processes are prominent and palpable through the skin and constitute the sacral cornua and, together with adjacent coccygeal cornua which they abut, are key landmarks for

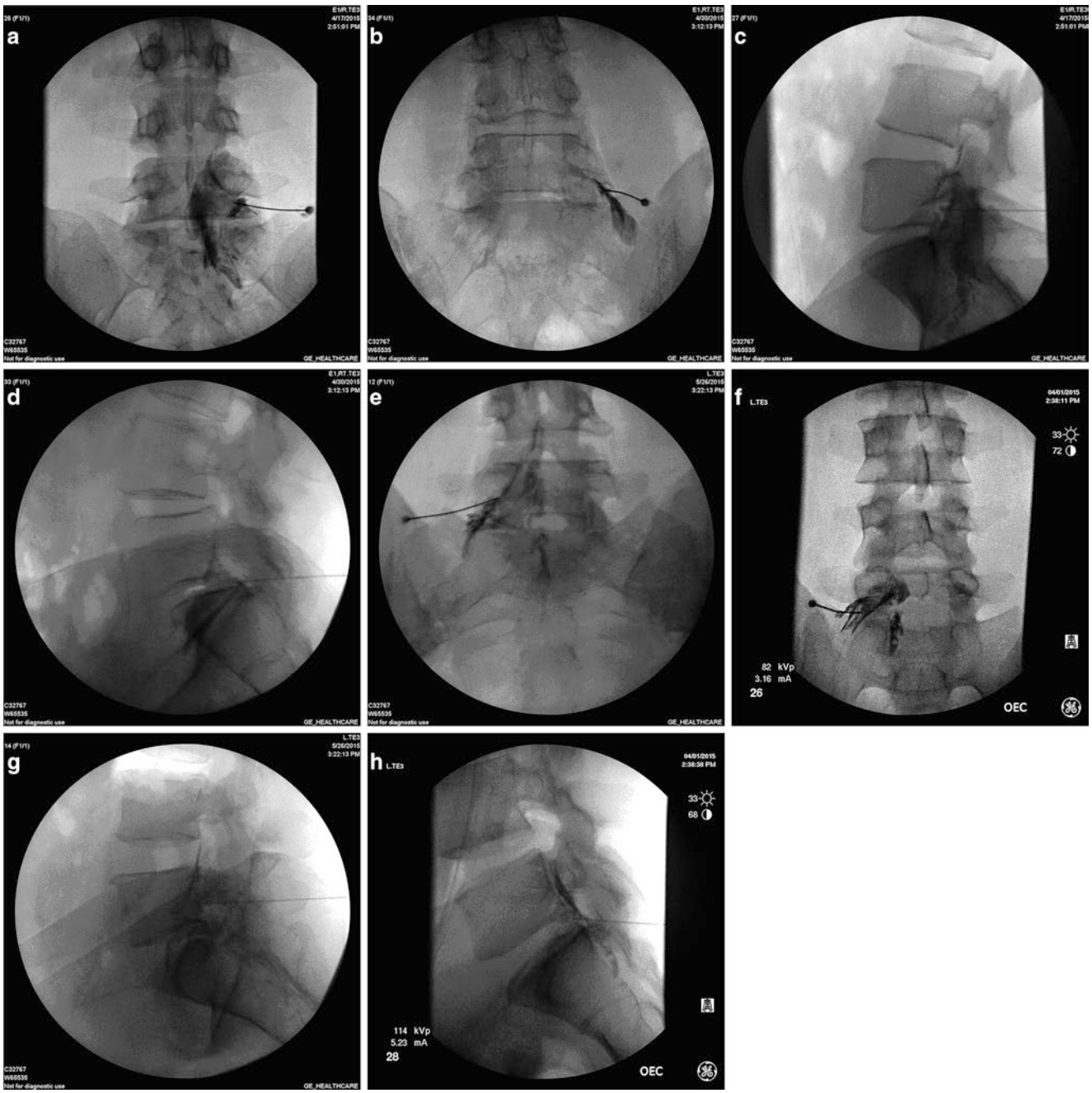

Fig. 11.32 Comparison of display patterns of supraneural (**a, c, e, g**) and infraneural (**b, d, f, h**) approaches of needle placement. (**a**) PA view at right L5 – supraneural. (**b**) PA view at right L5 – infraneural. (**c**) Lateral view at right L5 – supraneural. (**d**) Lateral view at right L5 – infraneural. (**e**) PA view at left L5 – supraneural. (**f**) PA view at left L5 – infraneural. (**g**) Lateral view at left L5 – supraneural. (**h**) Lateral view at left L5 – infraneural

identification of the sacral hiatus and successful caudal blockade.

- The coccyx is a small triangular bone consisting of three to five fused rudimentary vertebrae (Figs. 11.3, 11.4, and 11.37).
  - The coccyx attaches to the lower part of the sacrum. The tip of the coccyx is an important landmark.
- The sacral hiatus is a defect in the lower part of the posterior wall of the sacrum, formed by the failure of laminae of S5, and usually part of S4, to meet and fuse in the median plane.
  - Thus, a variable space is left which is described as an inverted U or V, covered by the thick fibrous posterior sacral coccygeal ligament.

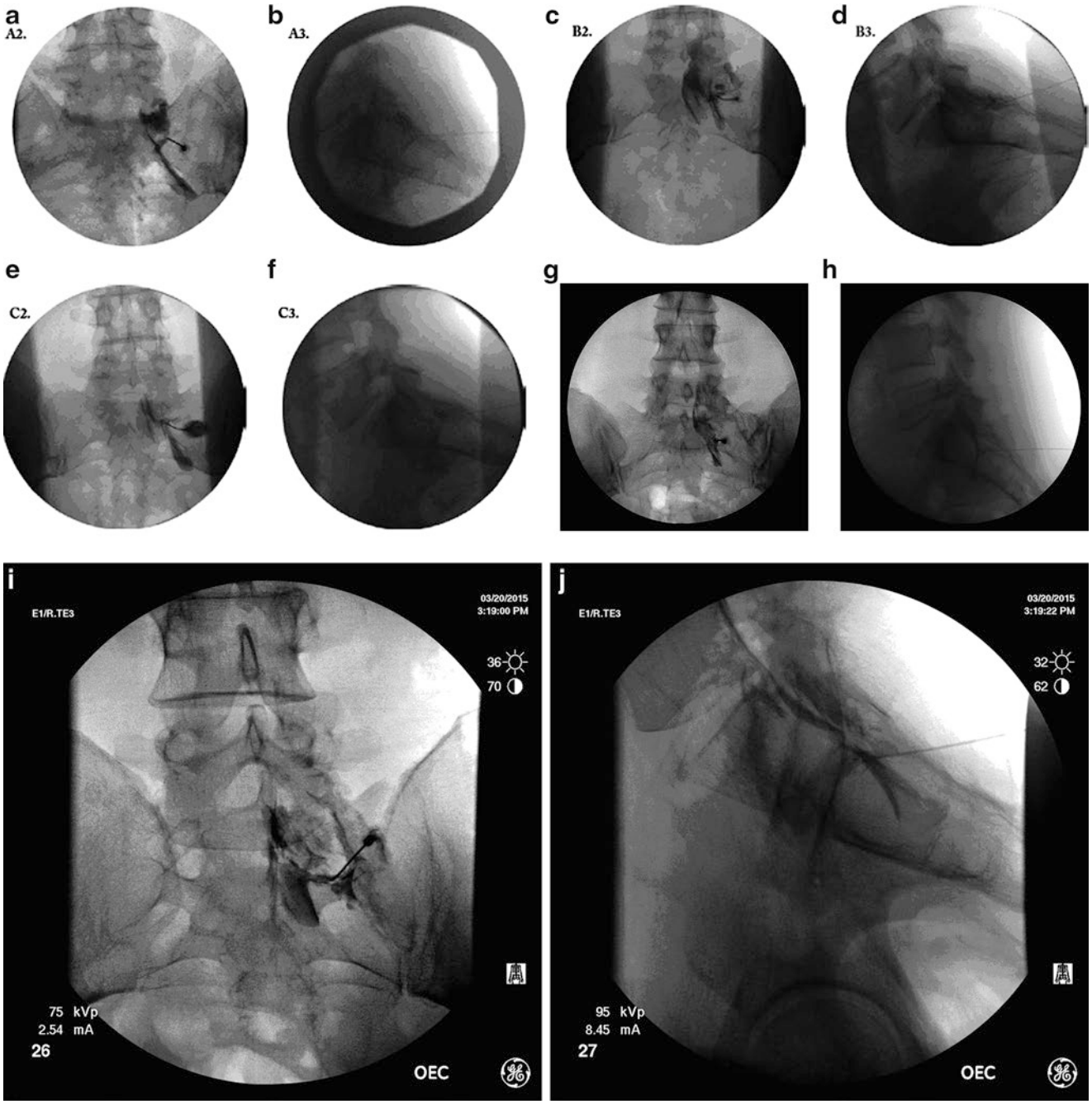

Fig. 11.33 Illustration of various dispersal patterns of SI transforaminal injection. (**a, c, e, g, i**) PA views with contrast. (**b, d, f, h, j**) Lateral views with contrast

- Direct access to the caudal canal is obtained by penetration of the sacrococcygeal ligament.
- There is significant variation in the normal anatomy in this area, with widely and highly variable sacral hiatus in size and shape.
- The hiatus lies higher than the lower one-third of the S4 in about 50% of specimens.
- The distance between the tip of the dural sac and the apex of the hiatus is also highly variable, from 20 to 45 mm.
- Sacral spina bifida is also seen in 1% of specimens, along with absent hiatus in approximately 7% of specimens, and very small AP diameter of the canal at the apex of the hiatus which is less than 2 mm in 5% of specimens.

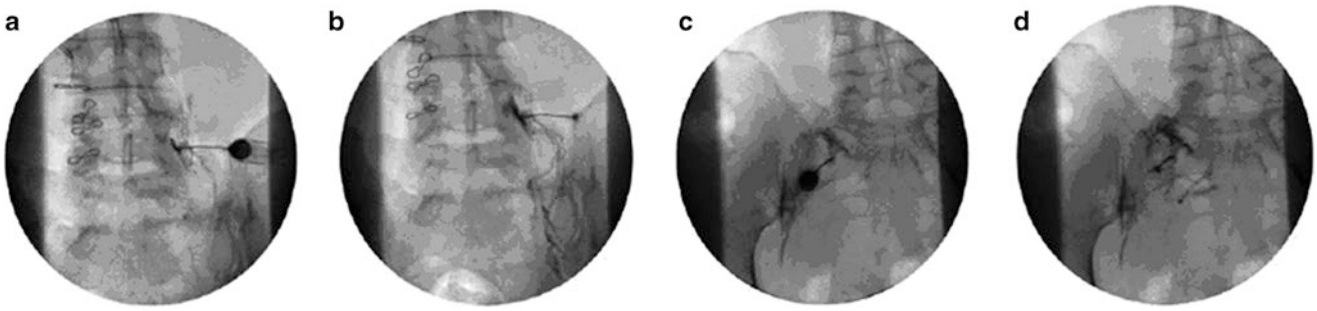

Fig. 11.34 Intravascular placement at L5 (**a, b**) and S1 (**c**, **d**)

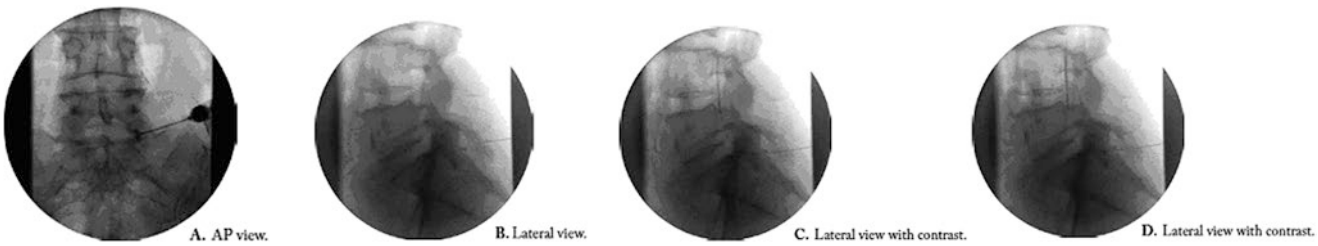

Fig. 11.35 (**a**–**d**) Illustration of subdural dispersal pattern of contrast during L5 transforaminal injection

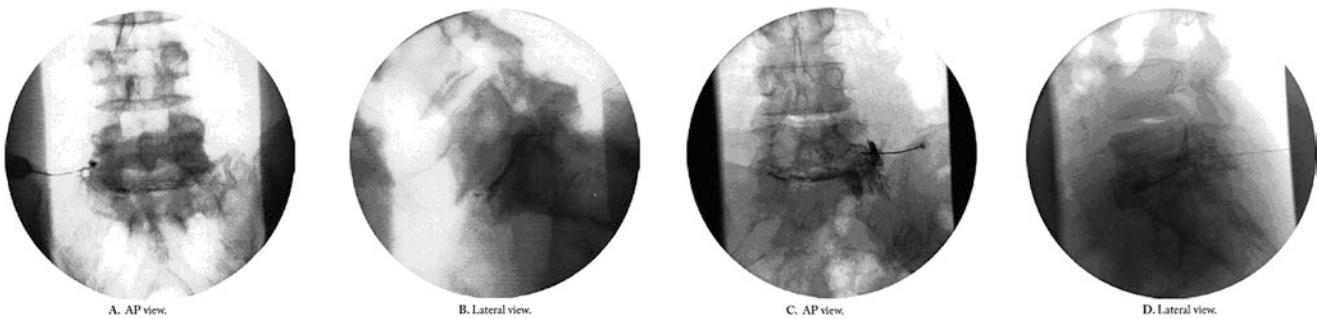

Fig. 11.36 (**a**–**d**) Intradiscal placement of contrast during L5 transforaminal epidural injection

  - However, while some anatomical features make the procedure easier rather than more difficult, absent hiatus actually makes the block impossible.
  - The quoted incidence of 7% may be excessive; this pessimistic figure takes no account of differences with advancing age.
  - In practice, absent hiatus is probably seen in less than 1% of patients.
  - Then the coccyx and sacral hiatus may be palpated, which can be located by using the needle as the marker (Fig. 11.37), and appropriate local anesthetic infiltration is carried out.
- Subsequently, an epidural needle (either 18 or 20 gauge Tuohy as shown in Fig. 11.12) is inserted as shown in Fig. 11.38 with injection of contrast observing under fluoroscopy.
  - After ascertaining the epidural placement, lack of return of blood or CSF, and appropriate filling pattern, as shown in Fig. 11.38, if the physician is satisfied, a choice of local anesthetic (0.5% preservative-free lidocaine) alone or with steroid (3 mg of betamethasone or 20 mg of methylprednisone or 20 mg triamcinolone or 8 mg of Decadron) is injected into the epidural space, with a total volume of 10 mL (5–15 mL).
- In a PA view of the epidurogram, the nerve roots are clearly outlined by contrast as they exit the intervertebral foramina, and in a lateral view, contrast extends along both the anterior and posterior aspects of the epidural space on the lateral radiograph occasionally producing a "double line" or "railroad track" appearance characteristic of epidural localization of the contrast (Fig. 11.39).
  - Multiple caudal epidural patterns are shown in Fig. 11.40.

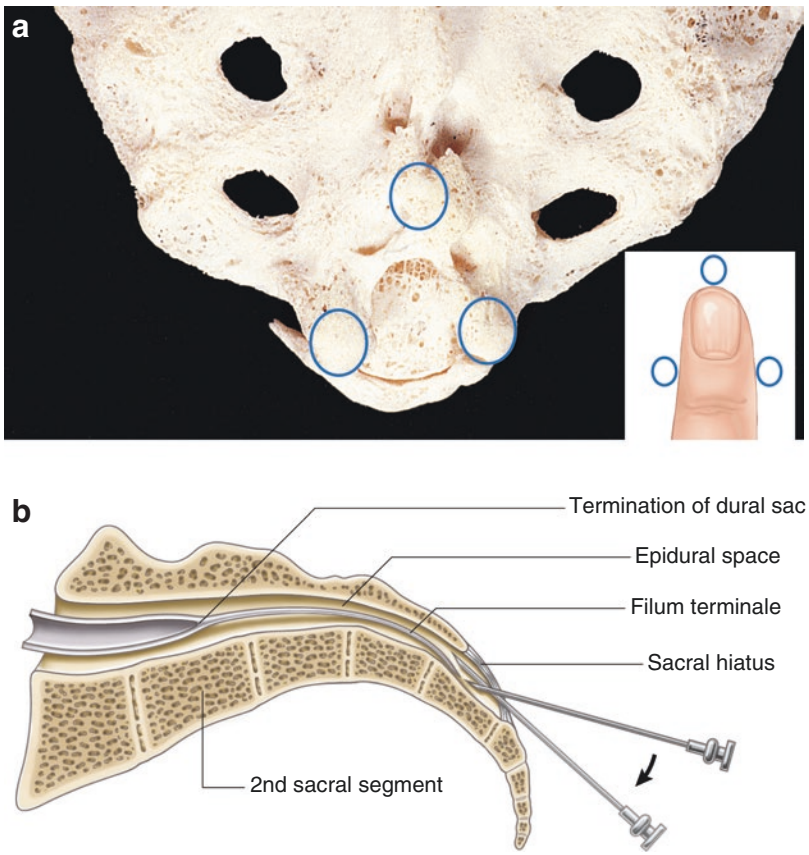

Fig. 11.37 Illustration of palpation of sacral cornua (**a**) and needle position for caudal epidural (**b**) (From Standring [54]. Reproduced from Gray's Anatomy, 39th ed, Standring. ©2005, with permission from Elsevier)

Extra-epidural Placement

- Incorrect or extra-epidural needle placement and contrast injection are observed frequently with soft tissue placement, intravascular entry, and subdural or subarachnoid placement [1, 62, 86].
  - Cotton-ball appearance, irregular or without nerve root fillings, indicates that the needle is extra-epidural and extravascular, whereas a pattern which shows rapid filling and disappearance of the vascular pattern indicates intravascular injection.
  - Myelographic or subarachnoid patterns are observed with caudal epidural injections, though less frequently than lumbar interlaminar epidural injections.

Side Effects and Complications

Side effects and complications of epidural injections including caudal, interlaminar, and transforaminal epidural injections in the lumbar spine are either related to the needle placement or drug administration and rare [1, 19, 62, 65, 66, 87–89]. However, occasional complications may become worrisome specifically with transforaminal epidural injections with neural trauma, vascular trauma, and intravascular injection leading to paralysis and death. Complications related to epidural injections are shown in Table 11.2.

In addition, other complications described in recent years, such as fungal infections in compounded steroids leading to devastating sequelae [90] and the FDA warning on April 23, 2014, concerning injecting corticosteroids into the epidural space of the spine resulting in rare but serious adverse events, have led to further controversy and discussions [68, 91–94].

- Side effects related to the administration of steroids are generally attributed either to the chemistry or the pharmacology of the steroids [1, 87].
  - The major theoretical complications of corticosteroid administration include suppression of pituitary adrenal axis, hypercorticism, Cushing's syndrome, osteoporosis, avascular necrosis of the bone, steroid myopathy, epidural lipomatosis, weight gain, fluid retention, and hyperglycemia.
  - The most commonly used steroids in neural blockade in the United States are methylprednisolone acetate, triamcinolone acetonide, and betamethasone acetate

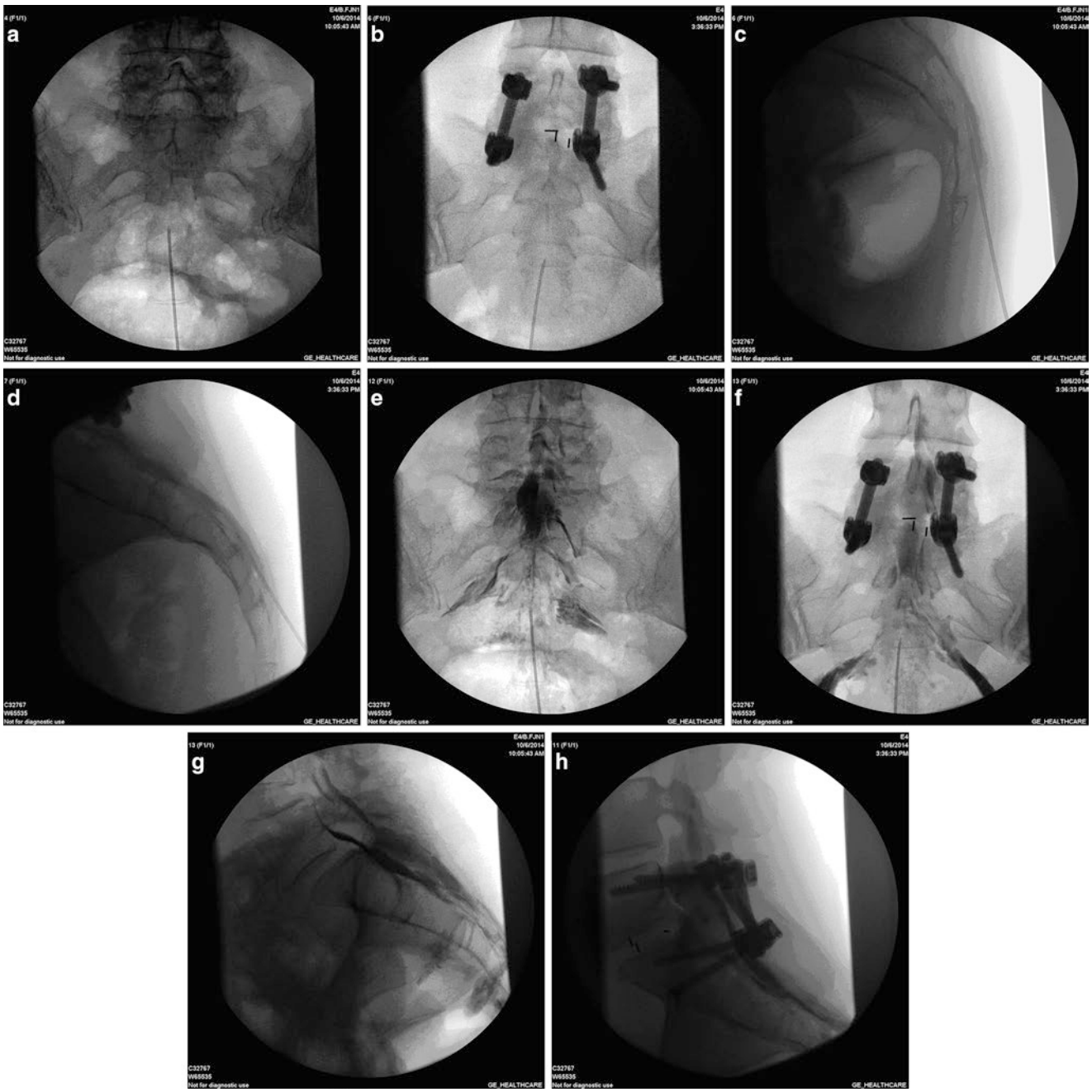

Fig. 11.38 (**a**–**h**) Steps in performing caudal epidural injections in patients with (**b**, **d**, **f**, **h**) and without (**a**, **c**, **e**, **g**) fusion. (**a**, **b**) PA view of the placement of the needle into sacral hiatus. (**c**, **d**) Lateral view of needle placement into the sacral hiatus. (**e**) Contrast injection into the epidural space showing epidural filling pattern, along with outlining of multiple nerve roots with a typical Christmas tree pattern. (**f**) PA view with good epidural filling pattern despite surgical intervention with no significant nerve root filling noted. (**g**) Lateral view showing a double-line pattern with double lines with ventral and dorsal filling pattern. (**h**) Lateral view of the caudal epidural filling with predominantly dorsal epidural filling pattern with some ventral epidural filling pattern

and phosphate mixture that have all been shown to be safe at epidural therapeutic doses in both clinical and experimental studies.

– It has been shown that if therapeutic doses of epidural steroids are administered, complications were not noted.

Precautions

- Relative contraindications to interventional techniques, specifically epidural injections, have been described in patients receiving treatment with antithrombotics and anticoagulants [1, 88, 89, 95–101].

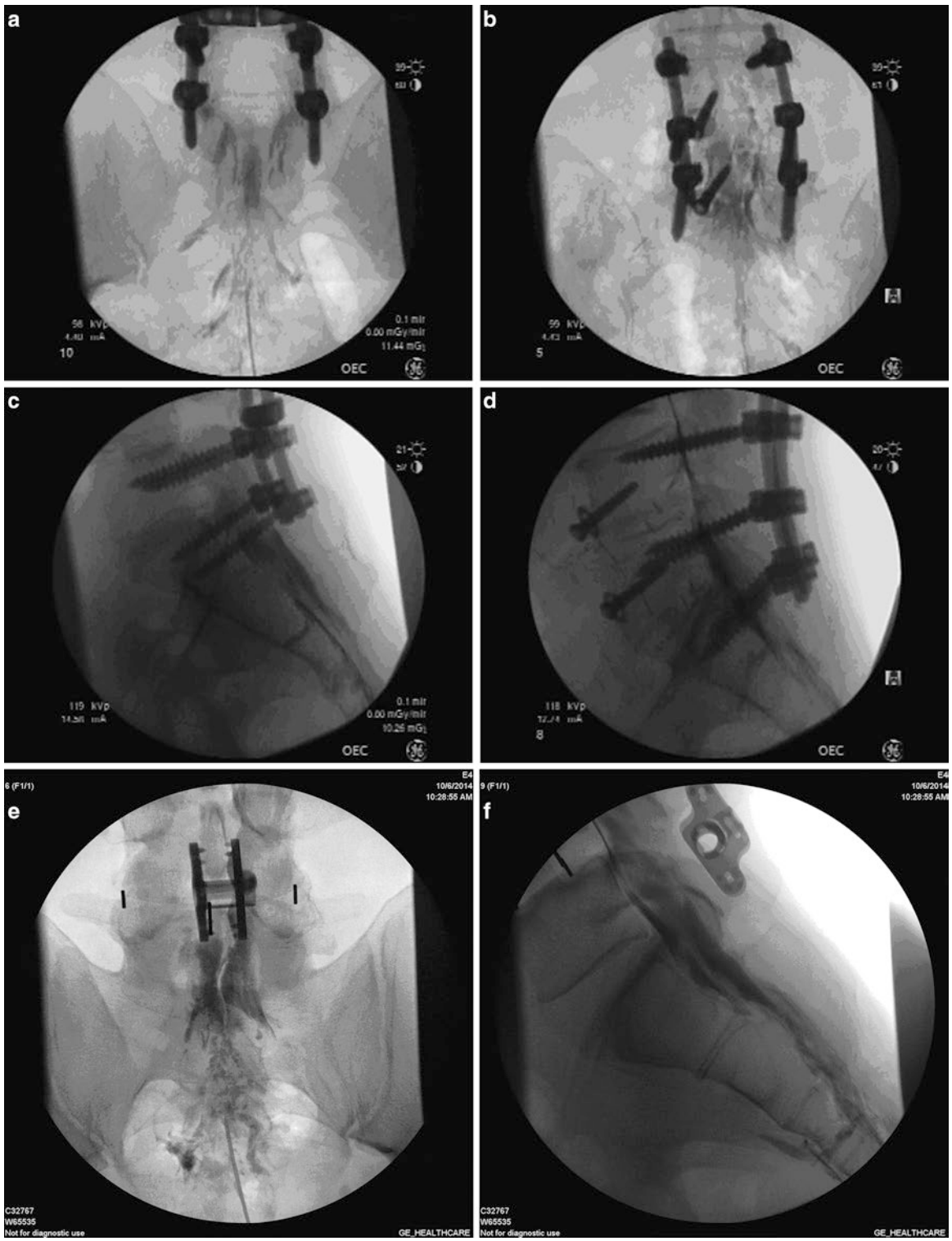

Fig. 11.39 (**a–f**) Caudal epidural filling patterns in postsurgery syndrome. (**a**) PA view of caudal epidural with injection of contrast with contrast limiting its spread to below L5 with typical Christmas tree pattern with filling of multiple nerve roots. (**b**) Caudal epidural filling patterns in a patient with fusion in PA view showing good epidural pattern up to L4. (**c**) Lateral view showing a double-line pattern of the epidural filling pattern with both ventral and dorsal epidural filling patterns. (**d**) Lateral view showing extensive filling pattern into the epidural space with ventral and dorsal filling observed. (**e**) Epidural filling pattern in a patient with lumbar fusion up to L5 with nerve root filling for the sacral roots. (**f**) Lateral view illustrating ventral and dorsal filling pattern with a double line filling into the epidural space

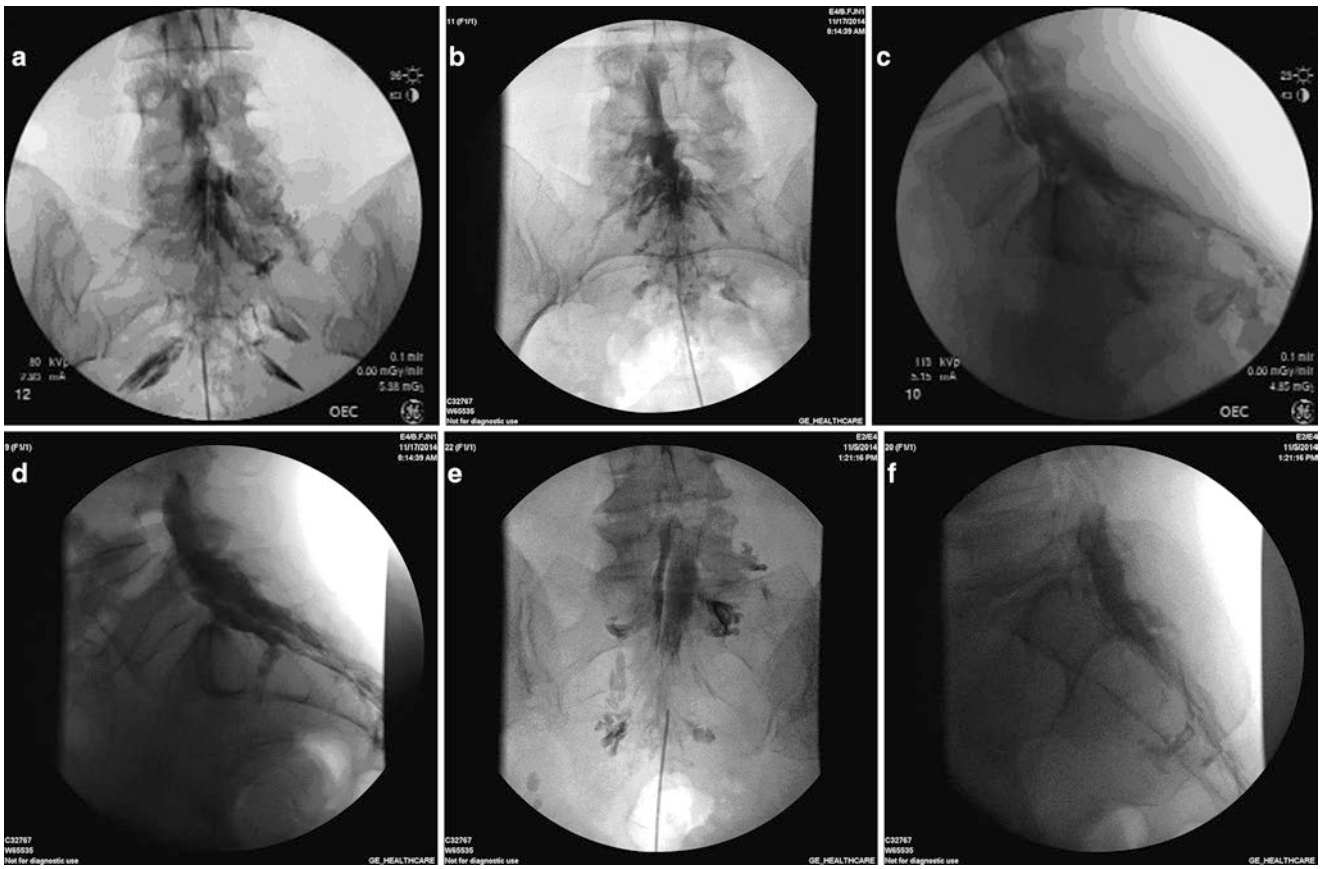

Fig. 11.40 (**a**–**f**) Multiple epidural filling patterns on PA and lateral views in patients without surgery. (**a**) PA view of caudal epidural with injection of contrast showing filling pattern for multiple nerve roots, along with air bubbles with typical Christmas tree appearance. (**b**) Caudal epidural injection showing bilateral filling up to L5 with unilateral filling above that level. (**c**) Lateral view of caudal epidural injection showing dorsal and ventral epidural filling pattern. (**d**) Lateral view showing predominantly dorsal filling up to L4, whereas ventral filling was noted up to L5 vertebral segment. (**e**) Caudal epidural injection with filling noted predominantly on the right side with some filling noted on the left side with nerve root filling on the right side at L5 and S1 and on the left side only below S1. (**f**) Lateral view illustrating epidural filling both ventral and dorsal, predominantly dorsal at L5 segmental level

Table 11.2 Side effects and complications of caudal, interlaminar, and transforaminal epidural injections

Pain
Pain at the site of the needle insertion
Exacerbation of existing pain
Pain in the low back and leg(s)
Infection
Soft tissue injection/abscess
Systemic infection
Epidural abscess
Meningitis
Encephalitis
Osteomyelitis/discitis
Bleeding
Bleeding
Soft tissue hematoma
Epidural hematoma
Spinal cord hematoma
Nerve root sheath hematoma

Table 11.2 (continued)

Trauma
Soft tissue
Nerve root
Spinal cord
Inadvertent injection
Dural puncture
Subdural injection
Intrathecal injection
Intravascular injection
Intra-arterial injection
Cardiac
Hypotension
Bradycardia
Neurologic
Nerve injury
Paresthesias
Paralysis
Paraplegia

(continued)

Table 11.2 (continued)

Pneumocephalus
Spinal cord compression
Cauda equina syndrome
Arachnoiditis
Increased intrathecal pressure
Seizures
Increased sciatic pain
Headaches
Ophthalmologic
Retinal hemorrhage
Chorioretinopathy
Increased intraocular pressure
Miscellaneous
Anaphylaxis
Dysphonia
Hiccups
Cerebrospinal fluid – cutaneous fistula
Adverse effects of contrast media
Local anesthetic
Epidural steroids

  - American Society of Interventional Pain Physicians (ASIPP) guidelines [1], American Society of Regional Anesthesia (ASRA) and Pain Medicine guidelines [96], International Spine Intervention Society (ISIS) guidelines [97], and other guidelines consider aspirin and NSAIDs as safe [1, 88, 89, 95–101].
    - However, a combination of these drugs, or when taken with other therapeutic antiplatelet drugs, may increase the risk of bleeding.
  - The risk of multiple complications related to discontinuing antiplatelet therapy has been well described [88]. Safety must be taken into consideration in reference to a thromboembolic event.
  - In certain cases, the risks of stopping anticoagulation may outweigh the risks of bleeding from epidural injections, specifically with caudal approach. In these cases, it may be advisable to allow patients to continue anticoagulation and also give special consideration with assessment of risk/benefit ratio and patient condition.
- Prior to lumbar epidural injections, patients on warfarin therapy must have their prothrombin time (PT) checked and documented to be at acceptable levels.
  - In stopping anticoagulant therapy, one should take into consideration the risk/benefit ratio of the procedure.
  - In addition, the interventional pain physician may also consult with the physician in charge of anticoagulant therapy.
  - It is prudent to advise the patient to contact the physician in charge of anticoagulant therapy and let him/her make the decision as to the appropriateness of discontinuing anticoagulant therapy.
  - The ASIPP guidelines [1] provide guidance that an international normalized ratio (INR) of two may be acceptable for caudal epidural and 1.4–1.9 for lumbar interlaminar and transforaminal based on risk/benefit ratio and individual consideration.
- Other antithrombotics including dabigatran (Pradaxa®) may be stopped for 1–5 days, and anti-Xa agents such as rivaroxaban (Xarelto®), edoxanban (Savaysa), and apixaban (Eliquis®) should be stopped for 24 h [1, 88, 100, 101].
- It has been recommended that multiple antiplatelet agents, including phosphodiesterase inhibitors, be continued prior to lumbar epidural procedures.
  - Platelet aggregation inhibitors including clopidogrel (Plavix®), prasugrel (Effient®), or ticlopidine (Ticlid®) may be continued or may be stopped for 7 days for clopidogrel and prasugrel and ticagrelor (Brilinta®) for 5 days, whereas ticlopidine for 14 days.
- Aspirin and NSAIDs alone are considered safe [1, 88].
  - The combination of multiple drugs with aspirin and NSAIDs or other antiplatelet therapies with clopidogrel or ticlopidine is considered to increase the risk of spinal hematoma.
  - The potential risk of anticoagulant discontinuation should be considered by the physician in charge of antiplatelet therapy.

Key Points

1. There are multiple causes described for chronic low back and lower extremity pain that include disc herniation, discogenic pain, post-lumbar laminectomy syndrome, and spinal stenosis.
2. Lumbar epidural injections are administered with three approaches, namely, caudal, interlaminar, and transforaminal. All three approaches are associated with certain benefits and risks.
3. The philosophy of epidural steroid injections is based on the premise that the corticosteroid delivered into the epidural space attains higher local concentrations over an inflamed nerve root.
4. Lumbar epidural injections are indicated in patients with chronic low back and lower extremity pain who have failed to respond to conservative modalities of treatments.
5. The evidence of efficacy of epidural injections with three approaches is Levels I–II in managing disc herniation based on multiple relevant high-quality randomized trials and Level II based on at least one high-quality relevant randomized controlled trial in managing pain of central spinal stenosis, lumbar postsurgery syndrome,

and lumbar discogenic pain without facet joint pain, disc herniation, or sacroiliac joint pain.

6. The emerging evidence shows lack of significant difference between local anesthetic alone and with steroids, specifically in spinal stenosis, discogenic pain, and post-surgery syndrome, with somewhat superior results with steroids in disc herniation.
7. The complications related to needle placement include infection, hematoma formation, abscess formation, subdural injection, intracranial air injection, nerve damage, intravascular injection, vascular injury, spinal cord ischemia, paralysis, and cerebral vascular or pulmonary embolus.
8. The major theoretical complications of corticosteroid administration include suppression of pituitary adrenal axis, Cushing's syndrome, osteoporosis, avascular necrosis of the bone, steroid myopathy, epidural lipomatosis, weight gain, fluid retention, and hyperglycemia.
9. Multiple precautions must be exercised with application of risk reduction strategies in performing transforaminal epidural injections.
10. Anticoagulant therapy must be carefully balanced considering the high risk of thromboembolic phenomenon associated with bleeding complications. Caudal epidural injections may be performed at a higher INR, whereas interlaminar and transforaminal epidural injections must be performed with additional caution.

Acknowledgments This book chapter is modified and updated from previous book chapters, "Lumbar Interlaminar Epidural Steroid Injections" by Kenneth Botwin, MD, and "Lumbar Transforaminal Epidural Injections" by Laxmaiah Manchikanti, MD; David M. Schultz, MD; and Gabor B. Racz, MD, in *Interventional Techniques in Chronic Spinal Pain* published by ASIPP Publishing. Permission has been obtained from ASIPP Publishing.

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