

Epidural Catheter Tip Position and Distribution of Injectate Evaluated by Computed Tomography

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Background: The distribution of solutions injected into the epidural space has not been determined. The author therefore examined the site of catheter tips and the spread of contrast material in the epidural space using computed tomographic (CT) imaging in patients receiving successful epidural analgesia.

Methods: Lumbar epidural catheters were placed in 20 female patients by a midline technique. Anesthetic effect was determined by motor and sensory examinations during analgesic infusion. CT images were obtained for identification of the catheter tip and after radiographic contrast injection of 4 ml and then an additional 10 ml.

Results: Catheter tips were most often found lateral to the dura in the intervertebral foramen. In these subjects with normally functioning epidural analgesia, there was remarkable interindividual variability in patterns of spread, including various amounts of anterior passage, layering along the dura, and compression of the dura creating a posterior fold. Accumulation becomes more symmetric with increasing injectate volume. Spread through the intervertebral foramina was seen in all subjects. Air and fat in the region of the catheter interfered with solution spread in three subjects, but only over a limited area. Asymmetry in anesthetic effect was attributable to catheter position. No substantial barriers to solution spread were observed.

Conclusions: A variety of catheter tip positions and patterns of solution spread underlie normal epidural anesthesia. Non-uniform distribution of injectate is common and is compatible

with uniform anesthesia. Posterior midline structures play a minimal role in impeding distribution of injectate. A far lateral catheter position is a more common cause of asymmetric block than anatomic barriers to solution spread. (Key words: Anatomy; anesthetic techniques; epidural space; imaging.)

A MAJOR factor that limits the usefulness of epidural drug administration is uneven drug effect. Asymmetry of local anesthetic epidural blockade is common, and entirely unilateral block occurs in up to 21% of patients.¹⁻³ Proposed causes of uneven distribution of injected solution include placement of the tip of epidural catheters at sites other than the posterior midline,^{4,5} air bubbles,⁶ and epidural fibrous barriers.^{7,8} Other reports link abnormal extent of anesthesia to solution spread in the subdural space between the dura and arachnoid membranes.^{9,10}

A causal relationship between asymmetric anesthesia and the putative causes mentioned previously have been claimed by imaging in selected cases.^{2,4,8,11,12} However, a pattern can only be identified as abnormal and therefore a possible cause of inadequate anesthesia if the images that accompany normal epidural anesthesia are known. Catheter tip positions have been examined during successful epidural anesthesia^{13,14} but are limited by using plane radiography. Solution distribution has been examined by epidurography¹⁵⁻¹⁷ but often by using diagnostic techniques different from methods used for clinical anesthesia.^{18,19}

To determine catheter positions and the patterns of circumferential distribution of solution injected during routine epidural anesthesia, I examined unselected patients with lumbar epidural catheters placed for clinical use. Computed tomographic (CT) imaging was used because it is the optimal *in vivo* means for revealing topographic relationships and identifying the margins of solution spread in the axial plane.²⁰⁻²²

Methods

After institutional human research committee approval, 20 women presenting for brachytherapy of cervical cancer were enrolled in the study. None of the patients had a

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history of back surgery or disease, and there was no evidence of metastatic disease in the spinal canal. An epidural catheter was placed for surgical anesthesia and postoperative analgesia. With the patient sitting, a Tuohy needle was inserted into the epidural space using loss of resistance to air injection (≤ 3 ml) to confirm entry. In 17 patients, an 18-gauge radiopaque polyamide catheter (Perifix, Burrion, Bethlehem, PA) was advanced 3 cm into the epidural space. This catheter has lateral sideports 14 mm, 10 mm, and 6 mm from the closed tip. In three patients, a 19-gauge, soft-tip, spring-wound epidural catheter (Racz model, Medic Inc., Gloversville, NY) was used, which has a 4-mm-long open area starting 2.5 mm back from the closed tip. The intended vertebral level of insertion (identified by palpation of iliac crests) was noted. Various members of the anesthesia department, including resident trainees under the supervision of faculty, performed the catheter placement.

For the surgical procedure, epidural anesthesia was used alone unless laparoscopy was also performed, in which case general anesthesia was also used. Postoperatively, continuous epidural infusion of bupivacaine, 0.125%, with fentanyl, 3 μ g/ml, was initiated. The infusion rate and bupivacaine concentration were adjusted to produce suitable analgesia throughout the course of brachytherapy. The patient was examined twice daily, and the dermatomal level of analgesia was determined by pin scratch. Ability to flex ankles, knees, and hips was documented.

Computed tomographic imaging was performed within 4 h of surgery. This time was chosen to coincide with the needs of the radiation therapists who use CT imaging of the brachytherapy device to guide exact placement of radiation sources within the rods to create the optimal geometry of radiation distribution. For the purposes of this study, the lumbar vertebral column was imaged as well, using a 9800 Hi-light Advantage System (GE Medical Systems, Milwaukee, WI) with mA = 140–230, kV = 120, scan time = 2 s, and slice thickness = 3–5 mm. An in-plane spatial resolution of 0.29–0.39 mm was achieved by using a 15- to 20-cm field-of-view and a 512×512 imaging matrix. One woman was allergic to iodinated contrast material, and none was injected in her case, but a spring wound catheter was used, which could be seen on CT. In the 19 other patients, a series of images at 5-mm intervals was obtained after injection of 0.4 ml nonionic radiographic contrast material (iopamidol 41%, Isovue-M 200, Bracco Diagnostics, Princeton, NJ) to aid in the identification of the catheter. Extra images at 3-mm intervals were obtained as necessary to

identify the tip of the catheter. In 15 women, 4 ml of solution (1 ml contrast material diluted with 3 ml saline) was then injected, and a series of images was obtained. All 19 non-allergic patients received a final additional 10 ml of this contrast solution after which further CT images were obtained. Injection rate was about 0.5 ml/s, and no more than 5 min elapsed between injections of contrast-containing solutions.

The CT images were evaluated later with blinding suitable to conceal the extent of anesthetic effect. The level of the end of the contrast column inside the catheter (henceforth referred to as the *catheter tip*) and presence and location of injected solution and air were determined. Passage of solution anterior or posterolateral to the dura and out the intervertebral foramina at each level was graded as just evident, clearly present, or abundant. Also tabulated was any dural indentation (concavity in the outline of the dura), tethering of the dura causing deformity after injection, subdural accumulation (contrast material loculated within a clearly outlined dura), and solution entry between the posterior fat and the canal walls. Accumulation of injectate without spread into adjacent areas was sought as presumptive evidence of impediment to solution distribution from tissue barriers or air bubbles.

Results are reported as mean \pm SEM.

Results

The average age of the patients was 55 ± 3 yr. Height was 161 ± 1 cm, weight 64 ± 5 kg, and body mass index was 24 ± 2 kg/m (range, 13–42). In all women, epidural analgesia provided adequate pain relief and minimal need for systemic opioids.

Air was identified in the spinal canal of all 20 patients, as well as in the paraspinal tissues of 14, in the psoas muscles in 15, and in retroperitoneal tissues anterior or lateral to the psoas muscle in 5. The catheter was placed in the intended interspace in 8 of 20 women and at a higher space in 11. In only one patient was the catheter seen to pass through the posterior epidural fat. In the other 19 the fat was pushed aside. The catheter tip was identified in 19 of the 20 women (fig. 1). The tips of eight catheters were found in or near the posterior epidural space; nine catheters (including all three spring-wound catheters) were in the intervertebral foramina, and two catheters that entered the epidural space had tips in the paravertebral tissues lateral to the intervertebral foramina. (Additional details and images document-

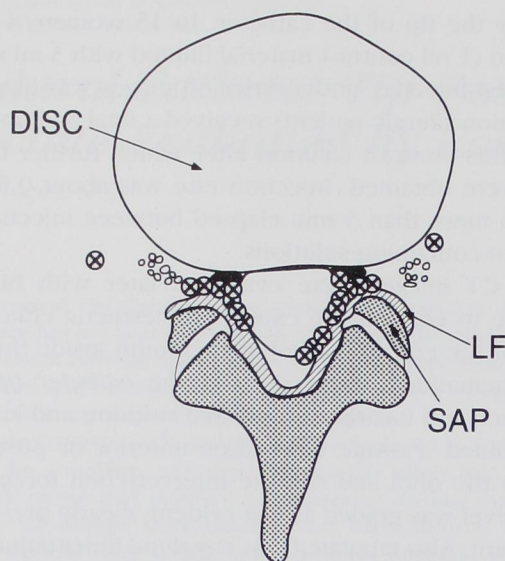


Fig. 1. Locations of 19 catheter tips (circled x) placed by a midline approach. The position of six catheter tips that did not lie at the longitudinal level of the intervertebral foramen and disc shown in the drawing are indicated in their correct position in the axial plane. In this and other images, anterior is at the top of the image, and anatomic left is at the right of the image. LF = ligamentum flavum; SAP = superior articular process.

ing findings reported here are available on the ANESTHESIOLOGY web site at <http://www.anesthesiology.org/tocs/v90n4-TOC.cfm>.)

There was no single pattern of spread but rather marked differences between patients in sites of accumulation and amount of exit out the intervertebral foramina. For example, although most showed spread anterior to the dura (figs. 2C, 3B, 4), in 2 of 19 there was none. Distribution became more uniform with additional injection. Posterior and lateral spread was seen in most subjects (all after large volume injection). Indentation of the dura (fig. 2C) was evident in 11 patients, and tethering of the posterior dura producing a dural fold (fig. 2C) was found in 13; 6 showed a smooth contour to the posterior dura (fig. 3). In most women, posterior fat was outlined at least on one side by contrast material entering between the fat and the canal wall (fig. 2).

Contrast material exited through an intervertebral foramen all but 2 patients after 4-ml injection but in all 20 after an additional 10-ml injection. Even after the larger volume injection, there was noticeable asymmetry of foraminal passage in 11 of 19 women. In eight patients with catheter tips in the foramen, solution passed out the contralateral foramen in six. Solution passed into the epidural space and out the contralateral foramen (fig. 3) in both women with

paravertebral catheters. Catheter tip position predicted solution distribution (symmetric for midline catheter, to the side of the catheter otherwise) in half of the patients. On exiting the foramina, solution traveled predominantly anterior and lateral into the psoas muscle. In nine women, there was also spread of contrast material posteriorly after exiting the intervertebral foramen.

There was evidence in three patients of impediment to the distribution of 4 ml of injected solution. In one woman, the catheter passed through the posterior epidural fat, and circumferential solution distribution was arrested by a combination of air bubbles and posterior epidural fat. This persisted after the 10-ml injection, but adjacent areas were not affected. In a second patient, an air bubble in combination with posterior fat and the catheter arrested spread of infused injectate, although incompletely and only after the 4-ml injection. In a third woman, solution spread was impeded in the area of an air bubble at the tip of the catheter in the intervertebral foramen, which also did not persist after injection of 10 ml of solution. In all patients, obstruction was not evident at adjacent levels.

There was an appearance at one or more levels of uniform layering of solution along the surface of the dura without any foraminal spread in 9 of 15 patients after the 4-ml injection and in 5 of 19 after the 10-ml injection. Subdural accumulation was clearly present in one woman with a foraminal catheter tip in whom contrast material formed a bleb-like opacification within the posterior dura evident at the initial CT after infusion of contrast material (fig. 4). Substantial solution was also seen in the epidural space of this patient, and further bolus injection of contrast material did not produce enlargement or intensification of contrast agent within the bleb. Leakage of solution from the spinal canal through the ligamentum flavum along the catheter was seen in two women. In one patient, solution tracked anteriorly between the psoas muscle and the vertebral body to the area of the paravertebral sympathetic chain.

A maximum difference in sensory block of four segments was noted in two patients, and five segments were noted in one. These women had foraminal catheter tips on the side of greatest block. All other patients, including the six with foraminal catheters had left and right block levels that differed by two or fewer segments. One woman with the catheter tip in the paravertebral space had a totally symmetric block, whereas the other had symmetric sensory levels but developed inability to lift the leg on the side of the catheter.

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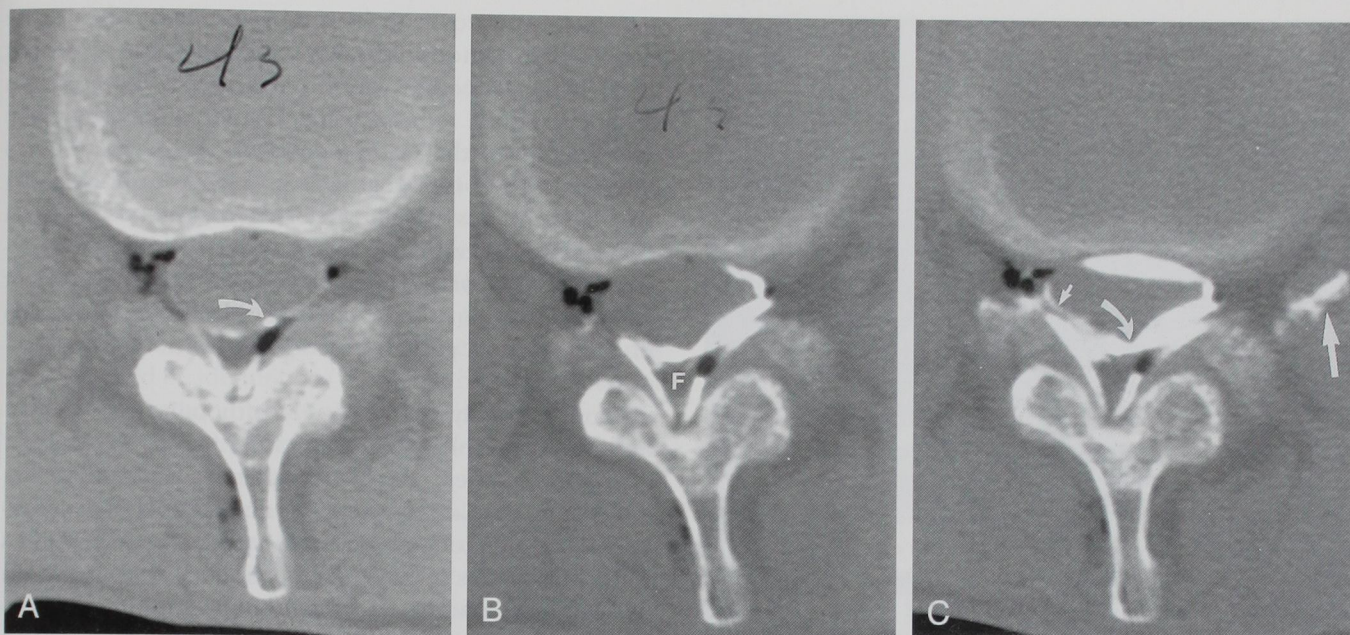


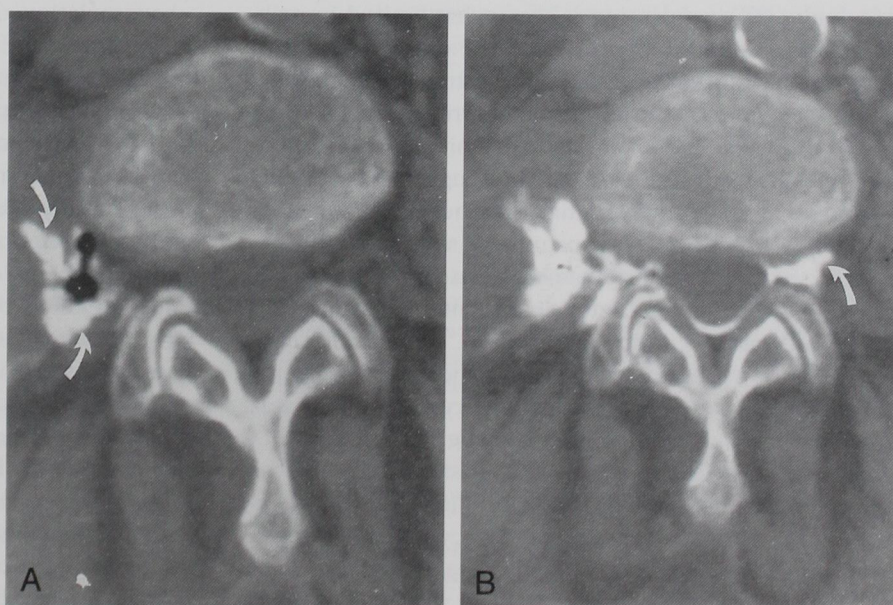
Fig. 2. (A) Computed tomographic image after 0.4 ml of contrast material is injected in a 55-yr-old woman with an epidural catheter tip in the posterior epidural space (arrow). Multiple air bubbles (black areas) are evident in the spinal canal and along the spinous process. (B) After an additional 4 ml is injected, contrast material outlines the posterior epidural fat (F) and passes predominantly to the left of the dura (to the right in the image). (C) After an additional 10 ml is injected, contrast material passes out both foramina, especially the left (large straight arrow) and also accumulates anterior to the dura. Air bubbles produce no impediment. Tethering of the posterior dura produces a fold (curved arrow). An epidural tissue membrane directs a layer of contrast material (small arrow) along the outer aspect of the dural sac, distinct from the larger posterior collection.

Discussion

This study used CT imaging of a group of unselected patients to provide detailed normative data on the position of lumbar epidural catheters and on the distribution of solution injected through them. The central findings

are the anterior and lateral position of most catheter tips, great variability of solution distribution, more uniform spread with larger volume injection, and a general but imperfect dependence of anesthetic effect on catheter position.

Fig. 3. (A) Computed tomographic image after 4 ml of contrast material is injected into a 71-yr-old woman. Contrast material accumulates locally in the psoas muscle (arrows). The far lateral tip is at the air bubble but not seen in these views. (B) After an additional 10 ml is injected, contrast material spreads around the dural sac, outlining it without compression. Contrast material emerges through the contralateral intervertebral foramen (arrow). Solution stays anterior to the posterior epidural fat (dark triangular area) and does not pass anterior to the dura.



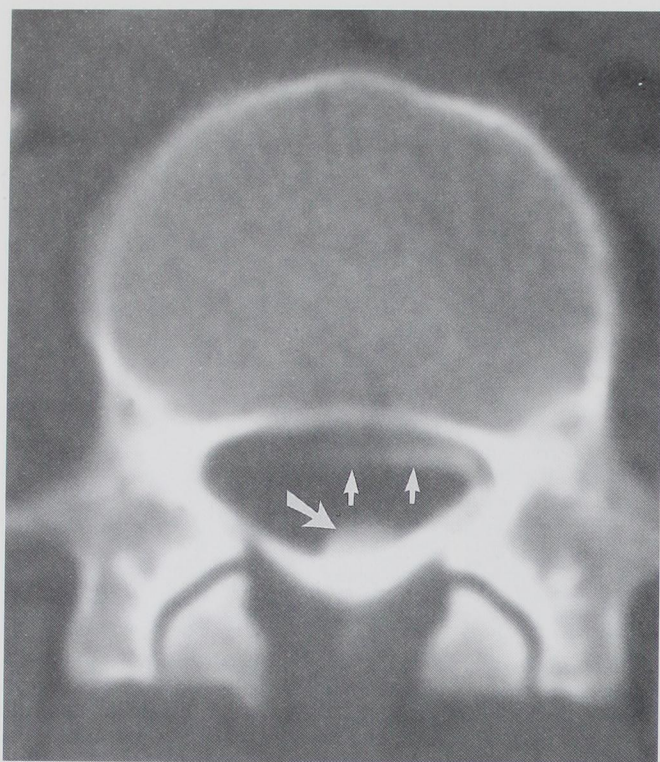


Fig. 4. Computed tomographic image of a 31-yr-old woman with a catheter tip against the left pedicle (not seen in this view). There is substantial posterior epidural injectate accumulation between the dura and ligamentum flavum, and some spread anterior to the dura (small arrows). A locus of contrast material within the dura (large arrow) represents a subdural collection.

There are several limitations to the methods used in this study. CT examination is somewhat limited in resolution. One catheter tip could not be located, and it is possible that pharmacologically relevant amounts of solution were missed at the limits of spread. Longitudinal distribution was not examined to limit radiation exposure and disruption of care. At the longitudinal margins of spread, the circumferential distribution of solution may differ from the areas examined, so correlation between injectate distribution and extent of block was not examined. Different catheter designs might produce different patterns of solution distribution.²³ Finally, for consideration of patient care and safety, the bolus injections did not contain anesthetic, so symmetry of blockade was only examined during infusion of drug.

Catheter tips are rarely in the posterior midline as portrayed in illustrations. Using a midline insertion technique, the catheter approaches the cylindrical dura at approximately a right angle to the long axis of the dural sac. It is not surprising that catheters rarely ascend the

posterior aspect of this cylinder because inserting needle directs them anteriorly, whereupon they are deflected laterally by the convex posterior dura into the area of a foramen. Other reports using plain radiography have also concluded that catheters rarely ascend rostrally as intended.^{12,14,24} It is possible that catheter tip locations are different, resulting from using techniques with an angle less perpendicular to the dura, such as with thoracic insertion or paramedian techniques. The level of catheter insertion was accurately selected by clinicians in only 40% of patients, consistent with previous reports.^{15,24,25}

Solution usually spreads freely, although not necessarily uniformly, through the epidural space. Patterns of distribution differ greatly between patients, including uniform coating of the dural sac or preferential accumulation in the anterior or posterolateral areas, as well as variable amounts of passage out the foramina. Injection of additional solution improved the uniformity of distribution. This finding is consistent with those of others who found that asymmetric blocks may be improved with additional bolus injection.^{1,3} Solution injected into the foramina or even more laterally preferentially spreads back into the epidural space, probably a result of displacement of cerebrospinal fluid, which limits pressure increase in the spinal canal, allowing fluid accumulation. Some authors have claimed that lateral spread from the epidural space out through the foramina is limited,²⁶ especially in the aged population.²⁷ The contrasting findings of this study may be a result of the greater resolution of CT examination.

Accumulation of contrast material between the anterior dura and the posterior longitudinal ligament is variable. The dura may adhere to the posterior longitudinal ligament, but a tight connection is limited to the level of the L4–L5 disc and is present in only 20% of patients,²⁸ possibly explaining the variability in my findings. In the present study, contrast material is excluded from the epidural space anterior to the posterior longitudinal ligament, probably constrained by the membrane that extends laterally from it.²⁹

The majority of patients exhibited indentation of the dura by posterolateral solution and tethering of the posterior dura into a fold. This plica dorsalis medianalis³⁰ is only present after compression of the dura and has been proposed as an impediment to solution spread in the epidural space. However, in this study, there was no evidence that distortion of the dura acted as a barrier, and tethering was only evident in the presence of abundant injectate accumulation. The significant compres-

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sion of the dural sac observed in this study supports a role for cerebrospinal displacement in the extension of spinal anesthesia on epidural injection during combined techniques.

Consistent with previous anatomic examination,³¹ no fibrous barriers were found in the posterior epidural space. Epiduroscopy has identified posterior midline tissue,³² seen in the present study as normal epidural fat. Although present in all patients, this fat produced only an occasional and limited impediment to solution distribution. In three women in whom interference to fluid spread could be identified, a combination of air, epidural fat, and the catheter produced a mechanical barrier. The blockage was overcome by additional injection in two patients and affected only a narrow region in all patients such that normal anesthesia resulted. It is disputed whether air in the epidural space may be a cause of incomplete anesthetic spread.^{6,33} However, air is of doubtful clinical significance because the present study shows that extensive air is typically present in those with normal epidural catheter function.

The three patients in this study with greater than two-segment difference in level of block during anesthetic infusion had catheter tips located on the side of greatest anesthesia. However, no barriers were evident in these women, and circumferential spread in response to bolus injection was evident in all three. It is likely that solution simply spreads further longitudinally on the side of the catheter. Position of the catheter tip cannot be the only influence on the area blocked because catheters placed in foramina or more laterally resulted in uniform block, as noted by others.¹⁷

Conventionally, a subdural pattern of spread is considered confirmed if injectate layers smoothly against the dura without passage into or through the intervertebral foramina.^{9,10} This has not been formally studied, however, and there are no data proving that this pattern reliably represents injection into the subdural space. The present study indicates that sites where contrast material is thinly layered (on the outside of the dura) are common in normal epidural injections, especially with small volumes as has been noted after thoracic epidural injections.²² Slips of epidural tissue (fig. 2C) may guide solution along the exterior of the dura and, in doing so, encourage longitudinal spread. Reports of patients in whom unexpected extent of epidural anesthesia is accompanied by thin layering of injectate on imaging may simply represent extensive spread in the epidural space. A subarachnoid bleb of contrast material on axial imaging is a clear manifestation of subdural injection.

Anterior spread of anesthetic along the lateral aspect of the vertebral body to the sympathetic chain, as was seen in one patient, might occasionally contribute to sympathetic blockade during epidural anesthesia. Because solutions can presumably pass along the same route in a reverse direction, this channel could result in somatic nerve damage during neurolytic injection at the lumbar sympathetic chain. Passage of solution posteriorly from the foramen along the posterior primary ramus of the segmental spinal nerve has not previously been noted, but it is evidently a common route of spread. As well as contributing to anesthesia of posterior elements, this is a path for solution to enter the posterior paravertebral musculature, possibly causing local anesthetic myotoxicity³⁴ or spasm and pain when chloroprocaine is used.³⁵ Leak of injected solution along the course of the catheter is occasionally evident and may limit anesthetic effect in some patients by loss of injectate from the epidural space.

In conclusion, positions of catheter tips and distribution of solution injected into the epidural space show extraordinary variability between patients. Factors that dictate the exact pattern of spread are not obvious on detailed examination by CT. Solution injected into the complex topography of the epidural space travels in patterns probably determined by the subtle pressures that force the various opposing surfaces together. Fortunately for clinical purposes, the epidural space is a forgiving system, and markedly different sites of catheter tips and spread of injected solution are compatible with adequate anesthetic effect. Although this study cannot disprove the existence of anatomic barriers to solution distribution across the midline, they must be rare, and technical factors like catheter position more commonly contribute to asymmetrical blockade.

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