Published in final edited form as:

Reg Anesth Pain Med. 2009 ; 34(1): 10–11. doi:10.1097/AAP.0b013e31819268a0.

Subdural Injection: What's the Gold Standard?

Quinn H. Hogan, M.D.^{a,*} and Leighton Mark, M.D.^b

^aProfessor, Department of Anesthesiology, Medical college of Wisconsin, Milwaukee, Wisconsin

^bProfessor, Department of Radiology, Medical college of Wisconsin, Milwaukee, Wisconsin

Epidural anesthesia is an act of faith. We insert the epidural needle, typically without radiological guidance, to a depth that is determined by inferred rather than directly witnessed endpoints. A catheter is passed that cannot be steered but can only be controlled by the single parameter of how far it is advanced. The distribution of the injected solution is likewise not under direct control except by the single parameter of how much is injected. In addition to these considerations, the contents of the epidural space are highly heterogeneous,^{1,2} so it is understandable that the anesthetic effect is variable. Possibilities include excessive or inadequate anesthetic spread, brief anesthetic duration, excessive hemodynamic changes, and variable motor block. When the actual events in a particular case fall outside the range of expected possibilities, a good clinician will ponder the pathophysiological options.

One anatomic explanation for aberrant responses to intended epidural anesthesia is delivery of the solution mistakenly into the subdural space. Unlike the stiff tissue present in fixed specimens, the natural arachnoid membrane is an insubstantial and elastic film that radiologists are taught to puncture cleanly by employing a twisting motion of the needle. This yielding consistency accounts for events in which the dura is cleanly penetrated but the arachnoid is not. Although it is unknown how often needle tips or catheters end up in this space, it is highly likely that some do. When witnessed during fluoroscopy for myelography, solution injected into this plane spreads in a laminar fashion, typically with a greater longitudinal extent than would occur in the epidural space with a similar volume. Since the layered solution is also closely applied to the subarachnoid space, it can be expected that clinical events may differ substantially from those in a customary epidural anesthetic.

In this issue, Hoffman and Ferrante [insert citation here] seek to make the determination of this anatomical diagnosis more reliable by examining the clinical features that are associated with the finding of a confirmed subdural injection, using radiological imaging as the gold standard for comparison. This is a commendable exercise since, as these authors point out, the earliest possible recognition of this event is important so that additional injection may be avoided. Excess injection into the subdural space risks rupture of the arachnoid membrane, thereby dumping a large dose of anesthetic into the subarachnoid space with unintended excessive anesthesia.

The authors acknowledge that their study can establish the sensitivity (what fraction of the actual subdurals their test will identify), but not specificity (the likelihood there is no subdural if the test is negative) or positive predictive value (the likelihood that a subdural exists if the test is positive) of their new criteria, because only cases with the positive gold standard are considered. But we suspect there are also limitations in the case reports that

*Corresponding author. Address: Department of Anesthesiology, Medical College of Wisconsin, Room M4280, 8701 Watertown Plank Rd. Milwaukee, WI, USA, 53226; Tel.: 414 456-5727; fax 414 456-6507. E-mail address: qhogan@mcw.edu .

form the primary data for their study, due first to the nature of how these events are gathered, and due secondly to the limitations of radiological confirmation.

Suspicion of an anatomically incorrect injection arises only if our clinical expectations are not met. However, subjects show great natural variability in fundamental anatomic features of the spinal canal.^{3,4} Even with normally functioning epidural anesthesia, there are highly diverse patterns of solution spread within the epidural space.⁵ Thus there is no reason to assume that all epidural injections will perform alike, and outliers are expected on the basis of natural variability. Thus, the population of subjects with unexpected extent, duration, intensity, or hemodynamics can be expected to contain both subdural injections as well as epidural outliers. Unfortunately, there are no data on how often subjects with clinically aberrant anesthetics show a customary epidural pattern of contrast distribution, but it is reasonable to assume that disinterest in reporting negative findings will result in a bias towards reporting only cases in which the image is also unexpected, namely subdural.

The anesthetic literature probably overestimates the ability of radiological techniques to identify subdural injection, and this is a second limitation in the case report data used by Hoffman and Ferrante. The dura is excessively thin to be resolved by imaging, even by CT in most cases, and the location of the arachnoid membrane can only be guessed by inference based on its effect on contrast distribution. Therefore, the most common criteria for identifying a subdural injection are secondary, including a smooth layering of contrast against the inside of the dural sac and lack of solution passage into the intervertebral foramina. While these criteria are widely accepted, there are no studies validating them, for instance using autopsy subjects and surgical confirmation of the injection plane. Problematically, one report describing intentional subdural injections shows that subdural solution tends to preferentially accumulate along the nerve root sleeve in the intervertebral foramina.⁶ Furthermore, there is no *a priori* reason to believe that epidural injections may not themselves produce a layering appearance and fail to pass through the foramina. Although this is not the most common pattern, it may occasionally do so (Figure). Solution injected into the epidural space has little motive to leave the low pressure environment of the spinal canal, where inherent compliance is dictated by the ready displacement of CSF at low pressures as solution is injected. Also, because the outer surface of the dura is not adherent to surrounding tissues, there is an available plane for solution to spread along the outside of the dura that would be indistinguishable from spread against the inside of the dura. Since there are so many epidural injections, if even a few percent performed this way, there would be many of these events compared to the probably very few true subdurals.

A random sample of recent reports of that claimed to show subdural injections includes images that are compatible with epidural⁷ or even typical for epidural,⁸ as well as strongly suggestive of subdural.⁹ In the absence of radiological resolution adequate to see the membranes and without more complete data on what images may be produced by confirmed subdural and epidural injections, imaging is a problematic gold standard for subdural injection. At this point, the lack of prospective data collection and a definite gold standard leave the clinical identification of subdural injection necessarily uncertain.

References

1. Hogan QH. Lumbar epidural anatomy. A new look by cryomicrotome section. *Anesthesiology* 1991;75:767–775. [PubMed: 1952201]
2. Hogan Q. Distribution of solution in the epidural space: examination by cryomicrotome section. *Reg Anesth Pain Med* 2002;27:150–156. [PubMed: 11915061]
3. Hogan QH. Epidural anatomy examined by cryomicrotome section. Influence of age, vertebral level, and disease. *Reg Anesth* 1996;21:395–406. [PubMed: 8895998]

4. Hogan QH, Prost R, Kulier A, Taylor ML, Liu S, Mark L. Magnetic resonance imaging of cerebrospinal fluid volume and the influence of body habitus and abdominal pressure. *Anesthesiology* 1996;84:1341–1349. [PubMed: 8669675]
5. Hogan Q. Epidural catheter tip position and distribution of injectate evaluated by computed tomography. *Anesthesiology* 1999;90:964–970. [PubMed: 10201664]
6. Mehta M, Maher R. Injection into the extra-arachnoid subdural space. *Anaesthesia* 1977;32:760–766. [PubMed: 579075]
7. Forrester DJ, Mukherji SK, Mayer DC, Spielman FJ. Dilute infusion for labor, obscure subdural catheter, and life-threatening block at cesarean delivery. *Anesth Analg* 1999;89:1267–1268. [PubMed: 10553848]
8. Lena P, Martin R. Subdural placement of an epidural catheter detected by nerve stimulation. *Can J Anaesth* 2005;52:618–621. [PubMed: 15983148]
9. Garutti I, Hervias M, Barrio JM, Fortea F, De La, Torre J. Subdural spread of local anesthetic agent following thoracic paravertebral block and cannulation. *Anesthesiology* 2003;98:1005–1007. [PubMed: 12657864]

Figure 1.

Computerized tomographic (CT) image of the lumbar spinal vertebral canal, showing contrast (arrows) injected through a normally functioning epidural catheter, placed in a 47yo woman for epidural analgesia during brachytherapy of cervical cancer. The image after 4ml injection demonstrates layering of the contrast and no passage through the foramina. Injection of an additional 10ml showed passage through the foramina in continuity with the layered solution.