Subdural Injection

What's the Gold Standard?

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Administering 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 end points. A catheter is passed, which cannot be steered but can be controlled only by the single parameter of how far it is advanced. The distribution of the injected solution is likewise not under direct control except by also a 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 anatomical 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 using 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. Because 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, Hoftman and Ferrante[3] 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 because, 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 subdural injections their test will identify), but not specificity (the likelihood that there is no subdural injection if the test is negative) or positive predictive value (the likelihood that a subdural injection was performed if the test is positive) of their new criteria, because only cases with the positive gold standard are considered. But we suspect that there are also limitations in the case reports that form the primary data for their study: first, because of the nature of how these events are gathered and, second, because of 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 anatomical features of the spinal canal.[4,5] Even with normally functioning epidural anesthesia, there are highly diverse patterns of solution spread within the epidural space.[6] 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 toward 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 Hoftman and Ferrante.[3] The dura is excessively thin to be resolved by imaging, even by computed tomography in

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Accepted for publication July 17, 2008.
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ISSN: 1098-7339
DOI: 10.1097/AAP.0b013e31819268a0

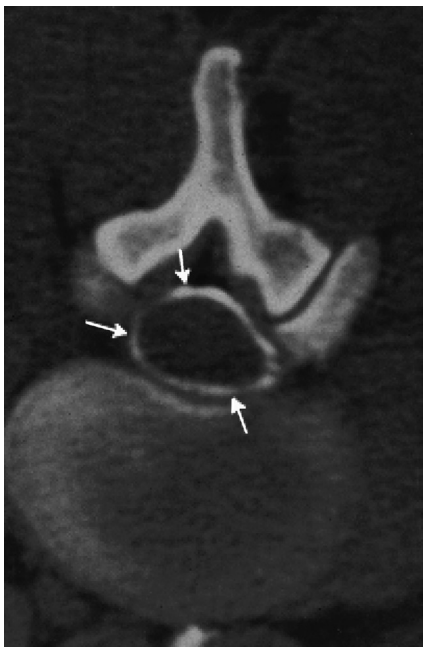

FIGURE 1. Computed tomographic image of the lumbar spinal vertebral canal, showing contrast (arrows) injected through a normally functioning epidural catheter, placed in a 47-year-old woman for epidural analgesia during brachytherapy for cervical cancer. The image after 4-mL injection demonstrates layering of the contrast and no passage through the foramina. Injection of an additional 10 mL showed passage through the foramina in continuity with the layered solution.

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. Although these criteria are widely accepted, there are no studies that have validated them, for instance, using autopsy subjects and surgical confirmation of the injection plane. Problematically, 1 report describing intentional subdural injections shows that subdural solution tends to preferentially accumulate along the nerve root sleeve in the intervertebral foramina.[7] 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 (Fig. 1). 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 cerebrospinal fluid 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 the solution to spread outside the dura that would be indistinguishable from the spread inside the dura. Because there are so many epidural injections, if even a few percent performed this way, there would be many of these events compared with the probably very few true subdurals.

A random sample of recent reports that claim to show subdural injections includes images that are compatible with epidural[8] or even typical for epidural,[9] as well as strongly suggestive of subdural.[10] 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.

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