A Prospective Comparative Study of Two Indirect Methods for Confirming the Localization of an Epidural Catheter for Postoperative Analgesia

Etienne de Medicis, MD, MSc, FRCPC, Jean-Pierre Tetrault, MD, MSc, FRCPC, Rene Martin, MD, FRCPC, Remi Robichaud, MD, and Lucie Laroche, BSc

Departement d'Anesthesiologie Centre Hospitalier Universitaire de Sherbrooke, Sherbrooke, Quebec, Canada

We prospectively evaluated, in randomized order, 2 indirect methods of confirming the localization of an epidural catheter for postoperative analgesia in 218 surgical patients: epidural stimulation test (EST) and epidural pressure waveform analysis (EPWA). The epidural space was localized by using a loss of resistance technique. All catheters were inserted 5 cm into the epidural space and primed with 5 mL of 0.9% normal saline. There were no differences between the methods: the positive predictive value and specificity were high (100% in both groups), but the sensitivity was moderate (80% for EST and 81% for EPWA) and the negative predictive value was low (16% for EST and 17% for EPWA). Combining both methods yielded better sensitivity (97%) and negative predictive value (57%) ($P < 0.001$). The sensitivity of EST was increased to 87% ($P < 0.05$) if sensory response was included as well as motor response for stimulation less than 10 mA. We suggest the inclusion of sensory response in the appropriate dermatome at a current <10 mA as a criterion for adequate epidural catheter localization for EST testing. EPWA sensitivity was significantly better with older patients: 94% for patients older than 80 yr compared with 63% for patients younger than 40, 73% for patients 40 to 60, and 85% for patients aged 60 to 80 yr ($P = 0.03$). We conclude that the two tests are comparable for confirming catheter placement.

(Anesth Analg 2005;101:1830–3)

Continuous epidural analgesia is effective for postoperative pain control (1). To be successful, the catheter must be located in the appropriate epidural space. In a university teaching hospital, epidural block failure may occur between 4.2% and 6.3% of the time (2,3). In the operating room (OR), the "gold standard" of proper epidural catheter positioning is the clinical response. However, establishing a segmental block with local anesthetics may take time (4), and it may be difficult to test the segmental response to pinprick in sedated or uncooperative patients after epidural catheter placement.

The confirmation of the appropriate localization of epidural catheters by epidural nerve stimulation (5) and epidural pressure waveform (6) has been described. These tests are attractive because they can be performed within 2 min in an OR without the use of extensive or cumbersome equipment. We prospectively compared both methods in the surgical population.

Methods

After IRB approval, all adult patients scheduled for nonurgent surgery who consented to epidural postoperative analgesia, were approached for the study. Inclusion criteria were as follows: 1) age > 18 yr old; 2) ability to consent; 3) absence of contraindications to epidural catheter placement (coagulopathy, infections either systemic or at the localization of the planned epidural site).

After the patient entered the OR, before surgery, the epidural catheter was placed by the staff anesthesiologist in charge of the case or this anesthesiologist's resident. Sedation, the site of epidural catheterization and the epidural space approach (median or paramedian) were left to the discretion of the attending anesthesiologist. The epidural space was localized by using a loss of resistance technique. All catheters used were the Arrow Flex Tip Plus® with the Arrow Johans

Presented, in part, at the Annual Meeting of the ASA October 2004, Las Vegas, Nevada.

Accepted for publication June 28, 2005.

Address correspondence and reprint requests to Etienne de Medicis, MD, MSc, Departement d'Anesthesiologie Centre Hospitalier Universitaire de Sherbrooke 3001, 12 E. Avenue Nord Sherbrooke, Quebec, Canada J1H 5N4. Address e-mail to estria1@globetrotter.net.

DOI: 10.1213/01.ANE.0000184130.73634.BE

0003-2999/05

electrocardiogram (ECG) Adapter®. After the catheter was inserted 5 cm into the epidural space, 5 mL of 0.9% saline was injected in the catheter and both the epidural nerve stimulation (EST) and epidural pressure waveform analysis (EPWA) were performed randomly according to a previously determined random order. After the 2 tests were computed, 3 mL of 2% lidocaine + epinephrine 1/200,000 was injected as a test dose. If the test dose was negative, an additional 2 mL of the solution was injected for thoracic epidural and 5 mL for lumbar epidural. Five minutes later, sensation for pinprick in the dermatome of the epidural insertion level was tested for confirmation of the correct placement of the epidural catheter. If the attending anesthesiologist, unblinded to results of the tests, felt confident about the epidural catheter placement, the case would start and the patient would be evaluated the next day by our acute pain team to confirm appropriate postoperative analgesia. If the attending anesthesiologist believed that the catheter was not in the epidural space, then either the epidural catheter was replaced or an alternative analgesic technique was initiated, at which point the placement of the epidural would be considered negative (not in the epidural space) and the study would be finished. These patients were included in the final analysis.

The EST was performed as previously described (7). After epidural catheter priming, the cathode was connected to the metal hub of the adapter, and the anode was connected to the patient's skin. The stimulator was set at a frequency of 1 Hz with a pulse width of 0.2 ms. The current output was increased until a segmental motor response was visualized in a dermatome congruent with the epidural insertion level. A segmental unilateral motor response <1 mA or a segmental response (unilateral or bilateral) 1–10 mA was considered positive for adequate epidural space catheterization. Current of up to 15 mA was used to evaluate the response.

The EPWA was performed by connecting a transducer apparatus to the epidural catheter, leveled to the insertion site of the catheter. The test was considered positive for epidural catheter placement in the epidural space when positive pressure waveform deflections, suggestive of arterial pulsation transmitted by the cerebrospinal fluid pushing the dura mater, were seen on the monitor screen in synchrony with cardiac contractions (either by ECG or pulse oximetry). No minimal value was set for the positive waveform deflections.

The primary data were the results of EST and EPWA compared with the clinical response of the patient to the epidural catheter. Block randomization was done by an independent person using a random number table. Assuming that the EST would have a sensitivity of 90%, 214 patients were required to show that both tests are equivalent within 10% of each other with an α coefficient of 0.05 and a β coefficient of 0.20. An interim analysis after 107 patients, supervised by an independent statistician, led to an adjustment of the total number of patients to 218. Additional secondary data considered were the patient's sex, age, body mass index, level of epidural site (thoracic versus lumbar), and approach used (median versus paramedian). Each method was analyzed for secondary data by χ^2 or Fisher's exact probability test. Paresthesia or other complaints were also noted if they occurred as part of any test. Sensitivity, specificity, and positive and negative predictive values (PPV and NPV) were calculated for each technique.

Results

Two-hundred-twenty-one patients agreed to participate in the study. Three were excluded: 1 had a severe vagal reaction during the attempted epidural catheter insertion; in the other 2 patients, the epidural space could not be identified (0.91%). There was no intravascular placement of the epidural catheter according to the test dose. There were 93 women and 125 men, ranging in age from 22-yr-old to 91-yr-old, with body mass index ranging from 16 to 55 kg/m^2. Forty patients underwent lumbar epidural placement and 170 patients underwent thoracic epidural catheter placement. In the majority of patients (196 patients), a median approach to the epidural space was used. The paramedian approach was used in the remaining 22 patients. There were 8 patients (3.67%) who had an epidural catheter placement outside the epidural space according to EST, EPWA, and clinical response to pinprick, despite an apparent adequate loss of resistance technique and uneventful epidural catheter insertion. The epidural technique was repeated with success in 6 of these patients and the other 2 had another mode of postoperative analgesia used. There was no case of inadequate epidural postoperative analgesia, except for one patient who had a postoperative catheter dislodgement (his initial 3 tests were positive and he was considered positive for the analysis).

There were no significant differences detected between the 2 techniques (Table 1). There were no false positive tests; hence the PPV was 100%. There were a significant number of false negatives in both methods, hence the NPV were $<20\%$. Both methods had sensitivities of around 80%.

Sixteen patients (7.35%) with segmental motor response at a current more than 10 mA noted sensory response at a current <10 mA in the appropriate dermatome before the apparition of the motor response. Including those patients as positive and adding them to the patients who met the usual EST criteria improved the sensitivity to 87% ($P < 0.05$); the NPV

Table 1. Results of the EST and EPWA Compared with Clinical Response

Technique	Sensitivity	Specificity	PPV	NPV
EST	80% (167/210)	100% (8/8)	100% (167/167)	16% (8/51)
EPWA	81% (170/210)	100% (8/8)	100% (170/170)	17% (8/48)

EST = epidural stimulation test; EPWA = epidural pressure waveform analysis; PPV = positive predictive value; NPV = negative predictive value. There was no difference between groups.

remained low, at 23% (modified EST [MEST]). Combining both methods (i.e., a positive result in either EST or EPWA) gave a 97% sensitivity and a 57% NPV (EST + EPWA) ($P < 0.001$) (Table 2).

Comparing both methods for level of epidural (thoracic versus lumbar), approached used (median versus paramedian), sex, age and body mass index yielded no significant result except for the EPWA versus age. The sensitivity increased from 63% for patients aged 20–39 to 73% for patients 40–59, to 85% patients aged 60–79, and to 94% for patients older than 79 yr ($P = 0.03$).

Discussion

The present study confirms with a β error of 20% that the two tests, EST and EPWA, are equivalent for confirming adequate epidural space catheter insertion. For the EST, Tsui et al. (5,8) published two studies: in a pilot study of 40 patients, the EST, when compared with a standard test dose, showed a sensitivity of 100%; for predicting the clinical effect of epidural morphine, the sensitivity was 96.1%. In an obstetric population of 39 patients, the sensitivity of the test was 100% compared with incremental local anesthetic bolus.

We reported a sensitivity of 80% in this prospective cohort of 218 patients using Tsui et al.'s (9) motor response to electrical stimulation criteria. We injected 5 mL of 0.9% NaCl, contrary to only 0.2–1.0 mL, as was used in Tsui et al.'s studies. This could have had an effect of current dispersion and decreased the sensitivity of the test (9).

We used standard neurostimulators (Digistim 3PLUS or III) that were different in different ORs. We do not know if Tsui et al. used the same neurostimulator for every patient in each study.

The sensitivity of the EST was improved to 87% using the modified criteria: the same motor response as the previously published sensory response in the appropriate dermatome with a current output <10 mA if the motor response was seen at a current more than 10 mA.

The EPWA technique has not been evaluated in a prospective study. It has been published in a single retrospective study (the result of analgesia already known) comparing EPWA and computed tomography (CT) scan contrast cathetergram (6). It showed a perfect correlation between EPWA and the cathetergram: 5 patients had a functioning epidural catheter with positive EPWA and confirmation of the localization of the catheter in the epidural space on the CT scan study, 13 patients with failed epidural analgesia had negative EPWA and localization of their catheter outside the epidural space, with contrast in the paraspinous muscles on the CT scan study. The test relies on the catheter conducting the pressure wave generated by the pulsating dura mater. We used the same amount of 0.9% saline as in the first report. More studies are needed to define the optimal amount of fluid to be injected.

Sensitivity of EPWA increases with age. This may be a result of the reduction of the epidural space and closure of the intervertebral foramina occurring with older age causing a decreased compliance of the epidural space and a better pulse wave transmission (10).

Using both methods increases sensitivity significantly to 97%. However, 71 (32%) of the pairs tested did not match. Calculating Cohen's Kappa (an index of inter-rater reliability for categorical/qualitative variables), we found a value of 0.07, showing a very poor correlation between tests (generally, Kappa > 0.70 is considered satisfactory). We do not have an explanation concerning the lack of concordance between tests.

Both techniques had very poor NPV, approximately 16%. This is in the context of the loss of resistance technique for localizing the epidural space. Our success rate was 96.2% with this technique, on par with previously published studies (2,3). Using both methods, the NPV increased to 57% (8/14). All false negatives were found by the 5 minute lidocaine test dose test.

A major limitation of this study is that it was not blinded. The organization of our OR made the availability of three assessors plus the attending anesthesiologist impossible to respect blinding. Tsui et al.'s studies were not blinded. Their criteria are objective. We always looked for the minimum current for motor stimulation. Different body habitus and level of epidural insertion (abdominal versus thoracic dermatome) may influence the results of EST, as the motor response may not be as visible from one patient to another. We did not find any correlation between EST and level of epidural insertion or body mass

Table 2. Results of the Modified Tests (MEST and EST + EPWA) Compared with Clinical Response

Technique	Sensitivity	Specificity	PPV	NPV
MEST*	87% (183/210)	100% (8/8)	100% (183/183)	23% (8/35)
EST + EPWA†	97% (204/210)	100% (8/8)	100% (204/204)	57% (8/14)

MEST = modified epidural stimulation test: sensory or motor dermatomal response to current < 10 mA; EST + EPWA = epidural stimulation test and epidural pressure wave form analysis; PPV = positive predictive value; NPV = negative predictive value.

* $P < 0.05$ compared to epidural stimulation test's sensitivity; † $P < 0.001$ compared to epidural stimulation test's and epidural wave form analysis' sensitivity.

index. For EPWA, there is no published minimum waveform deflection value, so there may be some subjectivity in the assessment (present or not). Obviously, the scale of the monitoring screen can have an impact on the visualization of the waves, as most of the epidural pressures are measured around 20–30 mm Hg. Depending on the patient, determination of sensory blockade may be unclear. Also, because we do not have an area where blocks and epidurals can be performed ahead of time, we needed a practical and rapid protocol to avoid unduly delaying procedures. This is why we chose a 5-minute interval between the lidocaine test dose injection and pinprick testing. A 20-minute time interval may have been more appropriate.

This study was designed to compare the ability of EST and EPWA to predict adequate epidural space catheterization. Adequate epidural postoperative analgesia is not only dependent on adequate catheter location but also on the epidural drug regimen used (11).

In summary, we prospectively compared EST and EPWA in 218 surgical patients. There were no false positive results, but the tests were comparable, with sensitivities of around 80%. The sensitivity of EST could be increased to 87% by including sensory stimulation with a current output <10 mA in patients with negative EST. We suggest the inclusion of sensory stimulation in the appropriate dermatome at current <10 mA as a criterion for adequate epidural catheter localization for EST testing. Combining both tests increased the sensitivity to 97%. The sensitivity of EPWA increases with the age of the patient.

We thank Theophile Niyon Senga, PhD, for his interim analysis.

References

1. Dolin SJ, Cashman JN, Bland JM. Effectiveness of acute pain management: I. Evidence from published data. Br J Anaesth 2002;89:409–23.
2. de Leon-Casasola OA, Parker B, Lema MJ, et al. Postoperative epidural bupivacaine-morphine therapy: experience with 4,227 surgical cancer patients. Anesthesiology 1994;81:368–75.
3. Tanaka K, Watanabe R, Harada T, Dan K. Extensive application of Epidural anesthesia and analgesia in a university hospital: incidence of complications related to technique. Reg Anesth 1993;18:34–8.
4. Holman SJ, Bosco RR, Kao TC, et al. What constitutes an effective but safe initial dose of lidocaine to test a thoracic epidural catheter? Anesth Anal 2001;93:748–54.
5. Tsui BCH, Gupta S, Finucane B. Confirmation of epidural catheter placement using nerve stimulation. Can J Anaesth 1998;45:640–5.
6. Ghia JN, Akora SK, Catillo M, Mukherji SK. Confirmation of location of epidural catheters by epidural pressure waveform and computed tomography cathetergram. Reg Anesth Med 2001;26:337–41.
7. Tsui BCH, Finucane B. Epidural stimulator catheter. Tech Reg Anesth Pain Man 2002;6:150–5.
8. Tsui BCH, Gupta S, Finucane B. Determination of epidural catheter location using nerve stimulation in obstetric patients. Reg Anesth Pain Med 1999;24:17–23.
9. Tsui BCH, Wagner A, Finucane B. Electrophysiologic effects of injectates on peripheral nerve stimulation. Reg Anesth Pain Med 2004;29:189–93.
10. Usubiaga JE, Wikinski JA, Usubuaga LE. Epidural pressure and its relation to spread of anesthetic solutions in epidural space. Anesth Analg 1967;46:440–6.
11. de Leon-Casasola OA. When it comes to outcome, we need to define what a perioperative epidural technique is. Anesth Analg 2003;96:315–8.