Clinical Results with the Acoustic Puncture Assist Device, a New Acoustic Device to Identify the Epidural Space

Timo J. Lechner, MD*, Maarten G. van Wijk, MD*, Ad J. Maas, PhD†, Frank R. van Dorsten, MD*, Ronald A. Drost, MD*, Chris J. Langenberg, MD*, Leo J. Teunissen, MD*, Paul H. Cornelissen, MD*, and Jan van Niekerk, PhD*
Departments of *Anesthesiology and Pain Therapy and †Clinical Physics, Jeroen Bosch Ziekenhuis, ’s-Hertogenbosch, The Netherlands

Sixty patients scheduled for lumbar epidural anesthesia were included in a study in which we evaluated the efficacy of localizing the epidural space by means of an acoustic signal. A prototype of an acoustic puncture assist device, connected to the epidural needle by an extension tube, generated the pressure needed to perform the epidural puncture and translated this pressure into corresponding acoustic and visible signals. The device frees the anesthesiologist to handle the epidural needle with both hands and to detect the epidural space by means of these signals. In all 60 patients (100%), the epidural space was successfully located by using the acoustic signal. In all cases, this was confirmed by the pressure measurement, which proved to be a reliable indicator for correct identification of the epidural space. We conclude that it is possible to locate the epidural space by means of the acoustic puncture assist device. The method proved to be reliable, safe, and simple in this study. The benefits of this new epidural puncture technique include better needle control, teaching, control of correct catheter placement, and documentation. The last can be an important adjunct to anesthesia practice.

There is continuing evidence in the literature of the numerous beneficial effects of epidural anesthesia (1–5). Unfortunately, the technique is not applied as often as is possible.

One explanation could be that the puncture procedure itself can be very difficult and may be accompanied by mild or even severe complications (6). Especially during residency, the epidural technique has a relatively frequent failure rate (7,8). The skills of trainees differ greatly, and there are no standard teaching methods to teach epidural anesthesia (8–10).

The techniques most used are “loss of resistance” and “hanging drop,” both described in the 1930s (11,12). Over the years, many ingenious devices have been designed to improve the success of the puncture procedure (13,14). However, none of them is widely used today.

Recently, we described the clinical results with a new acoustic device to identify the epidural space (15).

The only disadvantages we found were that two anesthesiologists were required to perform the epidural puncture and that setting up the experimental gear was cumbersome. In this study, we wish to show that a continuous acoustic signal can permit a single anesthesiologist to perform the puncture and identify the epidural space.

Methods

After approval by the hospital’s human research committee and written, informed consent from the patients, 60 consecutive patients, ASA physical status I–III, were included in this study. Patients were scheduled for elective surgery under lumbar epidural anesthesia or for treatment of herpes zoster or ischemic pain in the lower limbs. Patients scheduled for a laparotomy received additional general anesthesia. Patients with known coagulation disorders, hypersensitivity to amide local anesthetics, skin lesions at the puncture site, or neuromuscular disease were not studied. Demographic data (age, height, weight) and type of surgery were noted.

A schematic presentation of the experimental setup used in this study is shown in Figure 1. Except for the extension tubes, the syringe, and the infusion pump,
there were no changes in the setup compared with the one we used in our previous study (15).

The epidural puncture was performed by one of the eight staff anesthesiologists in our department. Each of them had previously performed more than 500 epidural procedures.

In accordance with standard hospital procedures, patients were connected to a monitoring device (AS3; Datex, Helsinki, Finland) to observe electrocardiogram, pulse oximetry, and noninvasive blood pressure. An 18-gauge IV cannula was inserted, and a preload of a colloid solution (15 mL/kg) was given. Under aseptic conditions and with the patient in the sitting position, local infiltration of the skin with lidocaine 2% was performed at the level of the chosen lumbar vertebral interspace. An 18-gauge epidural needle (Braun Perican; Melsungen A.G., Melsungen, Germany) was inserted 1–2 cm into the interspinous ligament via the midline approach. After the stylet was withdrawn, the needle was flushed with saline, and the experimental device was attached to the needle via a 120-cm length of polyvinyl chloride tubing. The infusion pump (rate set at 100 mL/h), the sound amplifier, and the instrumentation recorder of the experimental setup were then activated. Pressure changes in the system, generated by the infusion pump and depending on the resistance offered by the tissues at the tip of the needle, resulted in corresponding variations in acoustic and visual signals; i.e., increasing pressure gave rise to a higher tone and an upward deflection of the pressure curve and vice versa. The passage of the needle tip from tissues of high resistance (ligamentum flavum) to those of low resistance (epidural space) was thus made audible and visible.

Holding the epidural needle with both hands, the anesthesiologist moved the needle in a continuous forward direction toward the epidural space. The moment the anesthesiologist heard a distinct fall in tone pitch, the needle advancement was stopped, and the documented pressure was checked. If the decreased pressure confirmed the aural findings, the apparatus was disconnected from the needle, and a 20-gauge epidural catheter (Braun Perifix; Melsungen A.G.) was inserted 3 cm cephalad. If not, the epidural needle was advanced until the epidural space was identified by means of the combined use of the acoustic signal and confirmative pressure documentation. Then the epidural catheter was placed. After negative aspiration, a test dose of a local anesthetic was administered through the catheter, and 3 min later, the complete dose was given.

Thirty minutes later, the sensory level (pinprick) and motor block (Bromage scale) were tested and recorded. In the case of treatment of herpes zoster, a combination of 4 mL of bupivacaine 0.5% and 80 mg of methylprednisolone-acetate was given.

For each patient, the level of puncture, the efficiency of the device in localizing the epidural space (good, normal, insufficient, or worthless), the usefulness of the acoustic signal (indicative or misleading), the need for supplemental analgesics, the tactile perception of the ligamentum flavum, and any observed complications were recorded. The procedure was considered to be a clinical success when adequate pain relief was achieved or no supplemental analgesics were needed during surgery.

Results

Of the studied population, the mean age was 65 yr (sd, 13 yr), mean weight was 78 kg (sd, 11 kg), and mean height was 170 cm (sd, 7). Of the procedures, 38 (64%) were orthopedic, 15 (25%) were gynecologic, 2 (3%) were urologic, and 2 (3%) were vascular. One patient was treated for herpes zoster and two (5%) for ischemic pain in the lower limbs. According to the ASA classification, 17 patients (28%) were classified as ASA status I, 37 (62%) as II, and 6 (10%) as III.

Forty-seven patients received epidural anesthesia combined with sedation only. Ten also received general anesthesia (muscle relaxant combined with propofol infusion) because they were scheduled for a laparotomy. Two patients treated for ischemic pain in the lower limbs and one patient treated for herpes zoster did not receive any sedative.

Figure 1. Experimental setup for acoustically guided puncture of the epidural space. 1, Infusion pump (Graseby 3300; Graseby Medical Ltd, Herts, UK); 2a, polyethylene extension tube (200 cm long, 1.0-mm inner diameter; Vygon, Ecouen, France); 2b, polyvinyl chloride extension tube (120 cm long, 1.8-mm inner diameter, part of a pressure transducer set; Edwards Lifesciences, Irvine, CA); 3, three-way stopcock; 4, epidural needle; 5, pressure transducer; 6, pressure amplifier; 7, voltage-controlled oscillator; 8, loudspeaker; 9, instrumentation recorder.

© International Anesthesia Research Society. Unauthorized Use Prohibited.
In all 60 patients (100%), the anesthesiologist detected the epidural space by means of the acoustic device, and correct identification was confirmed by the pressure registration (Fig. 2). An epidural block with successful analgesia was achieved and ultimately verified correct placement of the epidural catheter. In one patient, the anesthesiologist had to perform a puncture at three different levels because of an arthrotic spine with multiple calcifications. Eventually the epidural space was located solely by acoustic guidance.

In one patient, two punctures were needed because of extreme scoliosis. In two patients, the epidural catheter was placed intravascularly. In one of these patients, a second puncture was needed because on the first attempt the epidural catheter was no longer in the epidural space after a 2-cm withdrawal. In 11 patients, the ligamentum flavum was never felt but was detected by the acoustic signal.

In five patients, there was an initial fall in tone pitch, although it was not the typical one we expected from our preliminary studies. In these cases, the pressure reading was not confirmative for correct identification of the epidural space (Fig. 3). The anesthesiologist continued the needle insertion until there was a typical fall in tone pitch, and identification of the epidural space was confirmed by the pressure reading.

The mean puncture site was L2-3 (range, L1 to L4), the mean level of sensory block was T7 (range, T2 to T12), and the mean Bromage score of motor block was 2 (range, 1–3). In all patients, the efficiency of the device was scored as “good,” and the value of the acoustic signal was classified as “indicative.” Except for intravascular placement of the catheter in two patients, no complications were recorded.

Discussion
This study supports our previous findings that an auditory signal is accurate in identifying the epidural space (15). It is well documented that the sense of hearing is better suited to detect small changes than the sense of touch (16–18). This fact was supported in this study by the 11 patients in whom the tone correctly indicated that the epidural space was reached but for whom the anesthesiologist did not feel the passage through the ligamentum flavum.

In five cases, there was a distinct drop in tonal pitch, indicating loss of resistance. However, this drop was not typical, nor was the pressure reading. We concluded that the epidural space had not yet been entered and proceeded successfully. If we had used the conventional loss-of-resistance technique, we might have stopped when the first loss of resistance was felt. After catheter insertion, this would have resulted in failed epidural analgesia. These findings suggest some added advantages in performing the epidural puncture with the acoustic puncture assist device (APAD). With it, one might better discriminate between real and “pseudo” loss of resistance. When a distinct drop in tone pitch and pressure (resting pressure, approximately 40 mm Hg) were detected while the pitch remained constant (indicating free flow of infused saline), the epidural space was identified (Fig. 2). However, when the tone pitch and pressure curve rose again,
indicating no free flow of infused saline, the epidural space had not been entered (Fig. 3). The explanation for this might be that the needle tip entered a hole or cyst in the interspinous ligament. Sharrock (19) documented recordings of false-positive loss of resistance. For the recording, he used a four-way stopcock connected via saline-filled tubing to a pressure transducer and interposed between a 2-mL glass syringe and the Tuohy needle. Pressures within the air-filled syringe were recorded while testing manually for loss of resistance. He showed that a sudden loss of resistance may be encountered although the epidural space is not yet reached. He based his findings on the anatomical studies of Rissanen (20), who describes degeneration of the interspinous ligament leading to cavity formation. These degenerative changes are frequent in the elderly and are usually in the lumbar vertebral region. Entering such a cyst with the epidural needle will lead to a sudden loss of resistance, and the temptation will be to assume that the epidural space has been reached.

In two patients, we had to withdraw the epidural catheter a few centimeters because of intravascular placement. When we connected the APAD to the catheter at this moment, with the pump still running, at first the pressure increased because of the small diameter (high resistance) of the catheter. In one of these two patients, because the pressure stabilized and no further increase occurred, indicating a free flow of saline, we decided that the catheter was still in the epidural space (Fig. 4). A successful epidural block confirmed this. In the other patient, the pressure increased, indicating incorrect catheter placement, and we performed a second puncture.

The apparatus used in our previous study required two anesthesiologists. In this study, we used an infusion pump to generate the pressure needed. With this new technique, a single anesthesiologist can identify the epidural space.

Eight experienced anesthesiologists participated in this study, of whom six performed an acoustically-guided epidural puncture for the first time. An advantage of this technique is the ability to handle the needle with both hands. This is true of the “hanging drop” technique, but that technique lacks reliability in the lumbar vertebral region. An audible guide during epidural placement and the ease with which experienced anesthesiologists used this equipment suggest that this technique may be useful for teaching purposes.

We realize that the experimental setup used in this study is not suitable for everyday practice. For that reason, we are developing a dedicated infusion device that incorporates both audible and visible monitors. This device can be loaded with a saline-filled reservoir with an integrated extension tube for connection to the epidural needle. The device can be used in two different ways: one can use only the auditory and pressure mode and perform the epidural puncture with the conventional loss-of-resistance technique, or one can use the infusion mode as well, to free both hands for manipulating the epidural needle.

Because the infusion pump was programmed at a constant infusion speed, pressure changes at the tip of the needle were solely caused by the changes in resistance offered by the tissue through which the needle was passing. This phenomenon made the pressure record a reliable indicator for a correct identification of the epidural space (Fig. 2).

From this study we conclude that a correct puncture procedure with the APAD should consist of the combined use of hearing, touch, and sight—hearing for positive identification of the epidural space, touch for needle control, and visual confirmation of the pressure tracing in case of doubt. The technique is reliable, safe, and simple. Potential advantages of the technique include greater stability in needle handling, teaching
residents, and confirmation of correct catheter placement. Inclusion of the pressure record with the anesthesia record can also provide documentation of catheter placement.

The authors would like to thank the postanesthetic care unit nurses for their assistance in performing the epidural procedures and D. Brashear for her assistance in preparing the manuscript.

References

1. Harrop-Griffiths W, Picard J. Continuous regional analgesia: can we afford not to use it [editorial]? Anaesthesia 2001;56: 299–301.