

obvious why condensation into the liquid phase should take place under the circumstances described here. If, as is almost invariably the case, the vaporizer operates at a temperature below ambient, one would expect a saturated vapor to become less saturated as it emerged into the (relatively) warm exterior tubing and circuit. Supersaturation and condensation would not be expected. That something more is involved than a simple phase change is indicated by the failure to condense on glass or silicone. Of the commonly used plastics, PVC is probably the most soluble with halothane, due in a great part to the presence of a very soluble plasticizer.<sup>5</sup> It is probable that what is being observed is an actual dissolution of the halothane in the PVC, and vice versa. This would indicate that PVC is not an appropriate material to use in a circuit through which volatile anesthetics will be administered. If an alternative to conductive rubber is desired, polyethylene (which does not contain a similar plasticizer) or gum rubber might be suitable.<sup>5</sup> Silicone could also be used, but its extreme flexibility makes it prone to kinks.

The consequences of contaminating an anesthesia system with volatile drugs have been reported.<sup>1-3</sup> In the situation we describe here, use of published formulas<sup>6</sup> to calculate a "dose" of anesthetic for a closed system allows the construction of a "worst case" in these circumstances. If 10 ml of liquid halothane were in the tubing, and a standard adult circle system was used with very low flows (approaching a closed

system), and no other inhalational drug was being used, *exhaled* concentrations in excess of 5 per cent should be produced for the first minute of use. Other problems range from the physical trauma of blowing liquid halothane down an endotracheal tube with an oxygen "flush" (especially if a low-volume pediatric system is being used) to the psychic effects of "pre-oxygenating" an awake patient with high inhaled concentrations of halothane. This report illustrates one more way in which such incidents may occur, and emphasizes the importance of a meticulous approach to the handling of equipment, including the preanesthesia equipment check.

The authors thank Dr. Ronald Dueck for performing the gas chromatography, and Drs. Douglas Magde and John Wheeler for their very helpful comments.

#### REFERENCES

1. Munson WM: Cardiac arrest: Hazard of tipping a vaporizer. *ANESTHESIOLOGY* 26:235, 1965
2. Kopriva IJ, Lowenstein E: An anesthetic accident: Cardiovascular collapse from liquid halothane delivery. *ANESTHESIOLOGY* 30:246-247, 1969
3. Mark LC, Marx GF, Erlanger H, et al: Improper filling of kettle-type vaporizers. *NY State J Med* 65:1151-1152, 1965
4. Lowe HJ, Titel JH, Hagler KJ: Absorption of anesthetics by conductive rubber in breathing circuits. *ANESTHESIOLOGY* 34: 283-289, 1971
5. Halocarbon Industries, Hackensack, N. J.: personal communication
6. Gorsky BH, Hall RL, Redford JE: A compromise for closed system anesthesia. *Anesth Analg (Cleve)* 57:18-24, 1978

Anesthesiology  
52:513-516, 1980

## Ultrasonic Localization of the Lumbar Epidural Space

RANDALL C. CORK, M.D., PH.D.,\* JOSEPH J. KRYC, M.D.,† ROBERT W. VAUGHAN, M.D.‡

Ultrasound imaging applications in anesthesiology have been limited. Barash *et al.*<sup>1</sup> and Rathod *et al.*<sup>2</sup> used ultrasound to assess effects of volatile anesthetics on cardiovascular hemodynamics. Other medical specialties employ ultrasound for real-time imaging to guide needle placement for aspiration of renal cysts,<sup>3</sup> amniocentesis,<sup>4</sup> and pericardiocentesis,<sup>5</sup> and to measure the diameter of the spinal canal.<sup>6</sup>

An extension of ultrasound scanning in anesthesiology may be identification of the epidural space for correct needle positioning. The purpose of this communication is to demonstrate the use of ultrasound for landmark identification for lumbar epidural anesthesia.

#### METHODS AND MATERIALS

This study was approved by the Arizona Health Sciences Center Human Subjects Committee. All patients gave informed consent. Thirty-six patients, 22 male and 14 female, scheduled for procedures involving epidural needle puncture were studied. Real-time scanning was performed with an Air-Shields® Sono Scan™ Ultrasonic Scanner (Model SSD-202).

\* Chief Resident.

† Resident.

‡ Associate Professor.

Received from the Department of Anesthesiology, University of Arizona, Health Sciences Center, Tucson, Arizona 85724. Accepted for publication December 17, 1979. Presented at the annual meeting of the American Society of Anesthesiologists, October 1979.

Address reprint requests to Dr. Cork.

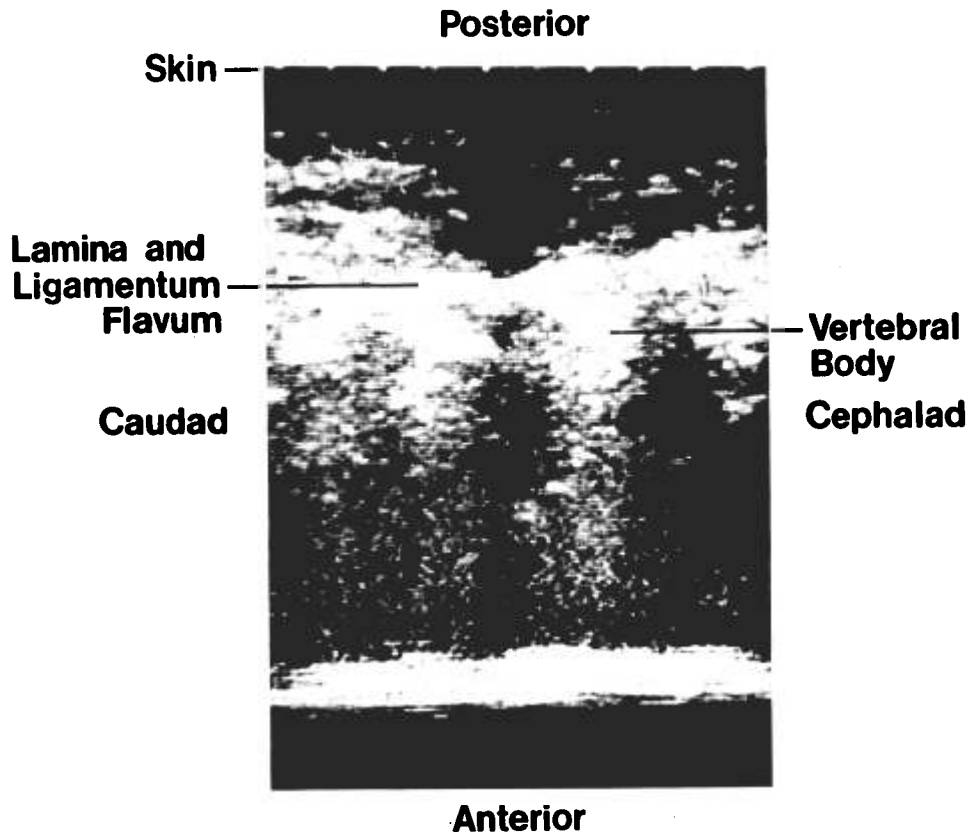


FIG. 1. Sagittal midline long-axis section of the lumbar area as seen with ultrasound. The transducer is placed on the patient's back (posterior) and directed toward the vertebral bodies. The first interface discerned is the patient's skin. The ligamentum flavum and lamina produce the next discernible echo. The distance from the skin to this echo increases from the cephalad side of the image to the caudad side. Vertebral bodies are indicated by strong segmental reflections deep to the ligamentum flavum.

This machine was selected because of portability, electronic calipers for accurate distance measurement, and ability to record videotapes of real-time examinations for later analysis. Sagittal and transverse plane scans were performed from T12-L1 through L4-L5 interspaces. Distance measurements were made from skin to ligamentum flavum. A needle was then inserted into the lumbar epidural space using the loss-of-resistance technique. Local anesthetic, blood or steroid was then injected into the space. Prior to removal of the epidural needle, skin surface markers were placed on it. After removal, distance from marker to needle tip was measured. Results of the scan study were not available at the time of the performance of the lumbar puncture in order to avoid biasing the technique and subsequent needle measurement.

Linear regression was used to evaluate the correlation between the ultrasound measured distance and the distance measured with a ruler on the epidural needle. Also, using linear regression analysis, age, height, weight, body mass index (BMI), and body surface area (BSA) were correlated with distance to the epidural space. Body mass index (BMI) is calculated as weight in kilograms divided by the square of the height in meters<sup>7</sup>:

$$\text{BMI} = \frac{\text{wt}}{\text{ht}^2}$$

Body surface area (BSA) in m<sup>2</sup> is calculated as<sup>8</sup>:

$$\text{BSA} = \frac{\text{wt}^{0.425} \times \text{ht}^{0.725} \times 71.84}{10,000}$$

Both BMI and BSA are measures of obesity.

Sex and age differences in observations were compared using the Student *t* test for non-paired data.

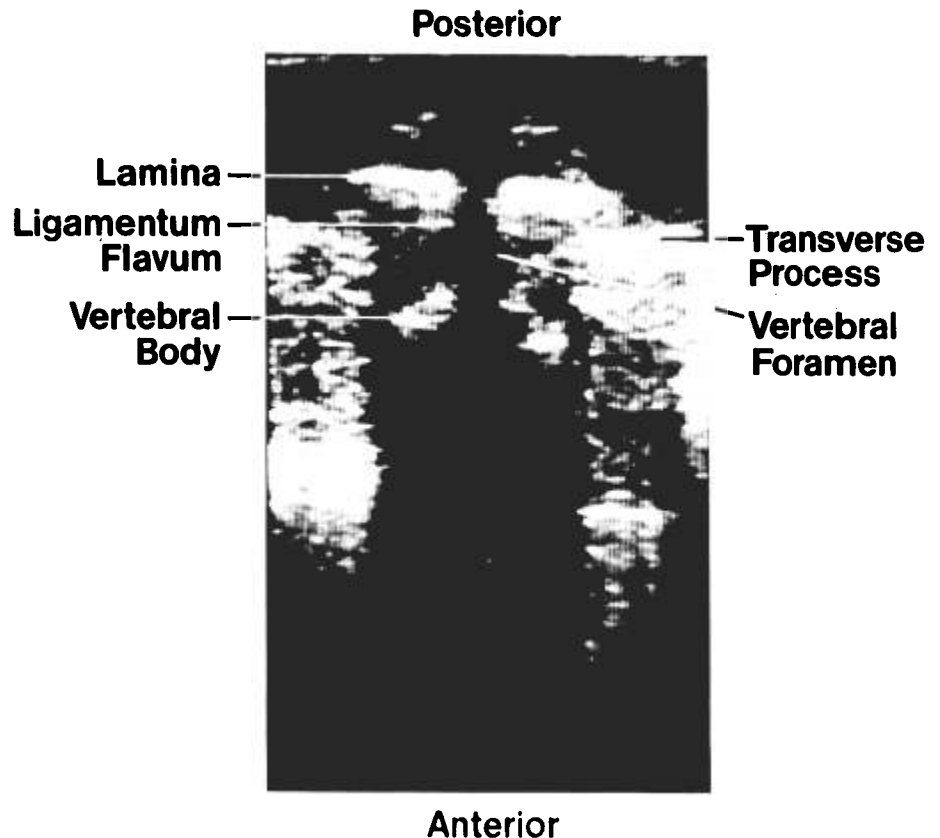
## RESULTS

Interspaces most often selected were L2-L3 (n = 19) and L3-L4 (n = 14). The remaining three punctures were performed at T12-L1, L1-L2, and L4-L5. Mean age of the study population was 43 ± 4 years, mean height 168 ± 2 cm, and mean weight 71 ± 2 kg. Mean BMI was 25.3 ± 0.7 and mean BSA was 1.80 ± 0.03 m<sup>2</sup>.

Anatomic landmarks for epidural anesthesia are identified in the ultrasonic scans pictured in figures 1 and 2. Figure 1 shows a sagittal section demonstrating segmental organization of the vertebral bodies. With caudal progression, the distance from the skin to the epidural space increases. Figure 2 shows a transverse section of an interspace, with bony landmarks and ligamentum flavum identified.

Thirty-two of the 36 attempted epidural needle placements were successful, as indicated by satisfactory analgesia, successful blood patch, or successful

FIG. 2. Transverse section of a lumbar interspace as seen by ultrasound. The transducer is rotated 90 degrees from its position in figure 1 and directed at that interspace. The first reflections are lamina; then, deep to the lamina, distinct echoes that represent the ligamentum flavum can be seen. Transverse bodies produce strong ultrasound reflections bilaterally. The deepest reflections in the scan image are from the vertebral body. Between the vertebral body and the ligamentum flavum is the vertebral foramen, which causes no significant ultrasound reflection.



steroid administration. Ultrasound measurements of distance to the epidural space for the four unsuccessful procedures were 0.4 cm to 1.5 cm more than the measured needle depths. In 29 of the 32 successful epidural needle placements, clear ultrasound reflections of the ligamentum flavum were obtained. In the other three successful placements, there was a "double shadow" in the area of the ligamentum flavum, rendering the examination useless for predictive purposes.

For the 29 successful epidural needle placements with adequate ultrasound examinations, there was a high correlation ( $r = 0.98$ ,  $P < 0.001$ , fig. 3) between predicted distance (ultrasound) and measured needle distance. Average distances to the epidural space were  $4.45 \pm 0.10$  cm by ultrasound scan and  $4.50 \pm 0.10$  cm by needle measurement.

Other significant correlations of needle distance to the epidural space ( $P < 0.05$ ) were with age ( $r = 0.39$ ), weight ( $r = 0.38$ ), and BMI ( $r = 0.33$ ). Small  $r$  values with  $P < 0.05$  indicate significant but weak correlations between distance to the epidural space and age, weight, and BMI. Patient height and body surface area did not significantly correlate with distance to the epidural space. The mean distance to the epidural space for those patients more than 50 years old ( $n = 10$ ) was  $4.8 \pm 0.2$  cm, while that for those less than 50 years old ( $n = 19$ ) was  $4.3 \pm 0.1$  cm ( $P < 0.05$ ). There

was no significant difference ( $P > 0.35$ ) in distances to the epidural space related to sex.

#### DISCUSSION

The present study demonstrates the potential usefulness of ultrasound for lumbar epidural anesthesia.

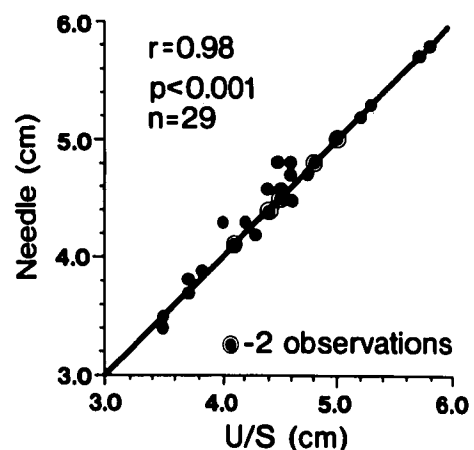


FIG. 3. Distance to the epidural space measured by ultrasound as correlated with measured needle distance in 29 successful epidural needle punctures. The ultrasound axis represents the depth of the epidural space in centimeters as measured by ultrasound. The needle axis represents the distance to the epidural space as measured on the puncture needle. A circle around a point represents two observations with the same ultrasound and needle distances.

Excellent correlation was found between ultrasound predicted distance and measured needle distance to the epidural space. The mean needle distance measured in this study (4.5 cm) is greater than the mean (4.2 cm) of needle measurements obtained in 3,199 cases by Gutierrez<sup>9</sup> ( $P < 0.05$ ). After each epidural puncture, measurement of the distance to the epidural space was made. Although he did not report an average distance, mean calculated distance from his reported data was 4.2 cm. The difference between the mean distances in the two studies may be due to either population difference or sampling error.

Advance knowledge of distance to the epidural space might have been very helpful in our four unsuccessful procedures. The ultrasound examination in each of these cases measured a greater ultrasound distance to the epidural space than that measured on the needle. This finding suggests insufficient advancement of the needle as the cause of the failure of the technique.

The "double shadow" in the three inadequate ultrasound examinations may have been due to thickness of the ligamentum flavum, causing reflection of ultrasound from both the epidural surface and the surface closer to the transducer. Other possibilities are beam-width error and reverberations of ultrasound. An investigation into this problem is currently proceeding.

Since most regional anesthesia is performed in areas of the body that are ultrasonically accessible and associated with soft tissue or skeletal landmarks that are ultrasonically detectable, this new imaging modality could have an expanded role in anesthetic practice. Certain advantages commend its use. The technique is noninvasive and has no harmful effect at the energy levels and time frames utilized. Obtaining a distance measurement in advance may avoid re-probing and subarachnoid puncture, resulting in

less patient discomfort and greater safety. Ultrasonic examination of relevant anatomic landmarks may also be used for training residents in regional anesthesia. Some disadvantages also exist. The equipment is sophisticated, and scan performance and interpretation can be difficult at times. Although the use of ultrasound scanning in anesthesiology may not yet be clinically feasible, further developments in image-processing and transducer design may have significant impact on regional anesthetic techniques in the near future.

The authors thank Ms. Susie Anderson, Ultrasonic Technician, and the Department of Obstetrics-Gynecology at the University of Arizona Health Sciences Center for the use of both their time and their ultrasonic equipment, and Drs. Hugh Allen and Burnell Brown, Jr., for many helpful editorial suggestions.

#### REFERENCES

1. Barash PG, Glanz S, Katz JD, et al: Ventricular function in children during halothane anesthesia. *ANESTHESIOLOGY* 49:79-85, 1978
2. Rathod R, Jacobs HK, Kramer NE, et al: Echocardiographic assessment of ventricular performance following induction with two anesthetics. *ANESTHESIOLOGY* 49:86-90, 1978
3. Goldberg BB, Pollack HM: Ultrasonically guided renal cyst aspiration. *J Urol* 109:5-7, 1973
4. Crandon AJ, Peel KR: Amniocentesis with and without ultrasound guidance. *Br J Obstet Gynecol* 86:1-3, 1979
5. Pederson JF: Percutaneous puncture guided by ultrasonic multitransducer scanning. *J Clin Ultrasound* 5:175-177, 1977
6. Porter RW, Wicks M, Ottewell D: Measurement of the spinal canal by diagnostic ultrasound. *J Bone Joint Surg (Br)* 60B(4):481-484, 1978
7. Keys A, Fianza F, Karvonen MJ, et al: Indices of relative weight and obesity. *J Chronic Dis* 25:329-343, 1972
8. DuBois D, Dubois E: A formula to estimate the approximate surface area if height and weight be known. *Arch Intern Med* 17:863-871, 1916
9. Gutierrez A: Anesthesia extradural. *Rev Cir Buenos Aires* 18:349-389, 1939

Anesthesiology  
52:516-518, 1980

## Intravenously Administered Lidocaine Prevents Intracranial Hypertension during Endotracheal Suctioning

MARTHA F. DONEGAN, M.D.,\* AND ROBERT F. BEDFORD, M.D.†

One of the primary goals of intensive care for comatose patients with head trauma is normalization

of intracranial pressure (ICP). Some necessary procedures, such as endotracheal tube suctioning, however, can result in marked increases in intracranial pressure despite the presence of paralysis and hypocarbia.<sup>1</sup> Intravenously administered lidocaine, 1.5 mg/kg, is effective in depressing the cough response of awake unmedicated subjects,<sup>2</sup> and is also effective in blocking the increases in ICP that often occur when the tracheas of anesthetized patients with space-occupying lesions are intubated.<sup>3</sup> This study was undertaken to

\* Resident Fellow.

† Assistant Professor.

Received from the Department of Anesthesiology, University of Virginia Medical Center, Charlottesville, Virginia 22908. Accepted for publication December 25, 1979. Presented at the Scientific Session of the annual meeting of the American Society of Anesthesiologists, October 1979.

Address reprint requests to Dr. Bedford.