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The Air Test as a Clinically Useful Indicator of Intravenously Placed Epidural Catheters

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The authors performed a clinical trial in 313 patients in labor to determine the safety and efficacy of an air test for unintentional intravenous placement of epidural catheters. Following routine aspiration for blood and cerebrospinal fluid, 1 ml of air was injected through each epidural catheter while heart tones were continually monitored with a Doppler ultrasound probe placed over the maternal precordium. In 281 patients, Doppler heart tones did not change following air injection (negative air test). All but eight of these patients developed an adequate level of analgesia following anesthetic administration, and no patients with negative air tests developed signs or symptoms of local anesthetic toxicity (false-negative rate, 0%; 95% confidence limits, 0.0–1.1%). Doppler heart tone changes followed air injection in 22 cases (positive air test). In 16 of these, intravenous catheter position was subsequently shown by aspiration of blood from the catheter or by the use of test doses consisting of local anesthetics with or without epinephrine. In six cases, adequate levels of analgesia developed despite a positive air test (false-positive rate, 2%; 95% confidence limit, 0.7–4.3%). None of the 303 patients receiving the air test developed any complications attributable to the injection of air (95% confidence limits, 0.0–1.0%). The authors conclude that air, with precordial Doppler detection, is a safe and effective test for identifying intravenously located epidural catheters. (Key words: Anesthesia, obstetric. Anesthetic techniques: epidural, continuous. Monitoring equipment: Doppler ultrasound. Test doses, epidural.)

WE PREVIOUSLY have demonstrated that a Doppler ultrasound probe positioned over the right ventricle can reliably detect intravenously injected air microbubbles in actively laboring patients.[1] This led to the concept of an air test for confirming the position of intravenously located epidural catheters. We performed the current study to determine whether a precordial Doppler probe, placed without confirmation over the lower maternal sternum, could reliably detect intravenous epidural catheter placement during labor.

Methods

Between April and October 1989, 313 actively laboring patients who received lumbar epidural anesthesia (supervised by one of the authors) participated in this institutionally approved study. As summarized in figure 1, we first used the air loss-of-resistance technique to insert a single orifice, 20-G epidural catheter *via* the L2–3 or L3–4 interspace of each patient.[2] Then, in accordance with routine clinical practice, we attempted to aspirate blood or cerebrospinal fluid (CSF) from each catheter using a 3-ml syringe; we removed the catheters without further testing if blood or CSF was obtained during this first aspiration. Three milliliters of 0.25% bupivacaine served as a further test for unintentional subarachnoid catheter placement. If this test was negative (*i.e.*, no evidence of spinal blockade after 3 min),[3] we placed the Doppler probe of a Hewlett Packard HP8040A fetal heart rate monitor over the lower half of the maternal sternum. We initially placed the probe in the midline and adjusted its position slightly (maximum of 1–2 cm from the midline) until maternal heart tones were heard most clearly. With patients either sitting or supine (left uterine displacement), we injected 1 ml of air through the epidural catheter and listened for maternal heart tone changes during the next 15 s. If a patient's uterus contracted during heart tone observation, we ignored the results and repeated the test following the uterine contraction. If no heart tone changes were heard, we began epidural analgesia by injecting 9 ml of 0.25% bupivacaine in divided doses.

When Doppler heart tone changes occurred following injection of air *via* the epidural catheter (*i.e.*, positive air test), we made a second attempt to aspirate blood from the catheter. We removed those catheters from which blood was obtained during this second aspiration. If the second aspiration proved negative, we attempted to confirm intravenous epidural catheter location using one of the following, previously recommended test regimens (as chosen by the attending anesthesiologist): 5 ml of 2% lidocaine[4] (n = 8), 5 ml of 0.25% bupivacaine[5] (n = 3), or 3 ml of 1.5% lidocaine with epinephrine 1:200,000[6] (n = 2). Maternal tachycardia (following epinephrine) or evidence of local anesthetic toxicity confirmed intravenous epidural catheter location; these catheters were removed. If analgesia developed normally following local anesthetic administration, we assumed that the air test had been false-positive and continued to use the epidural catheters for maternal analgesia. Conversely, if patients developed no evidence of epidural blockade after 10 min, we withdrew the catheter 1 cm, aspirated for blood (third aspiration),

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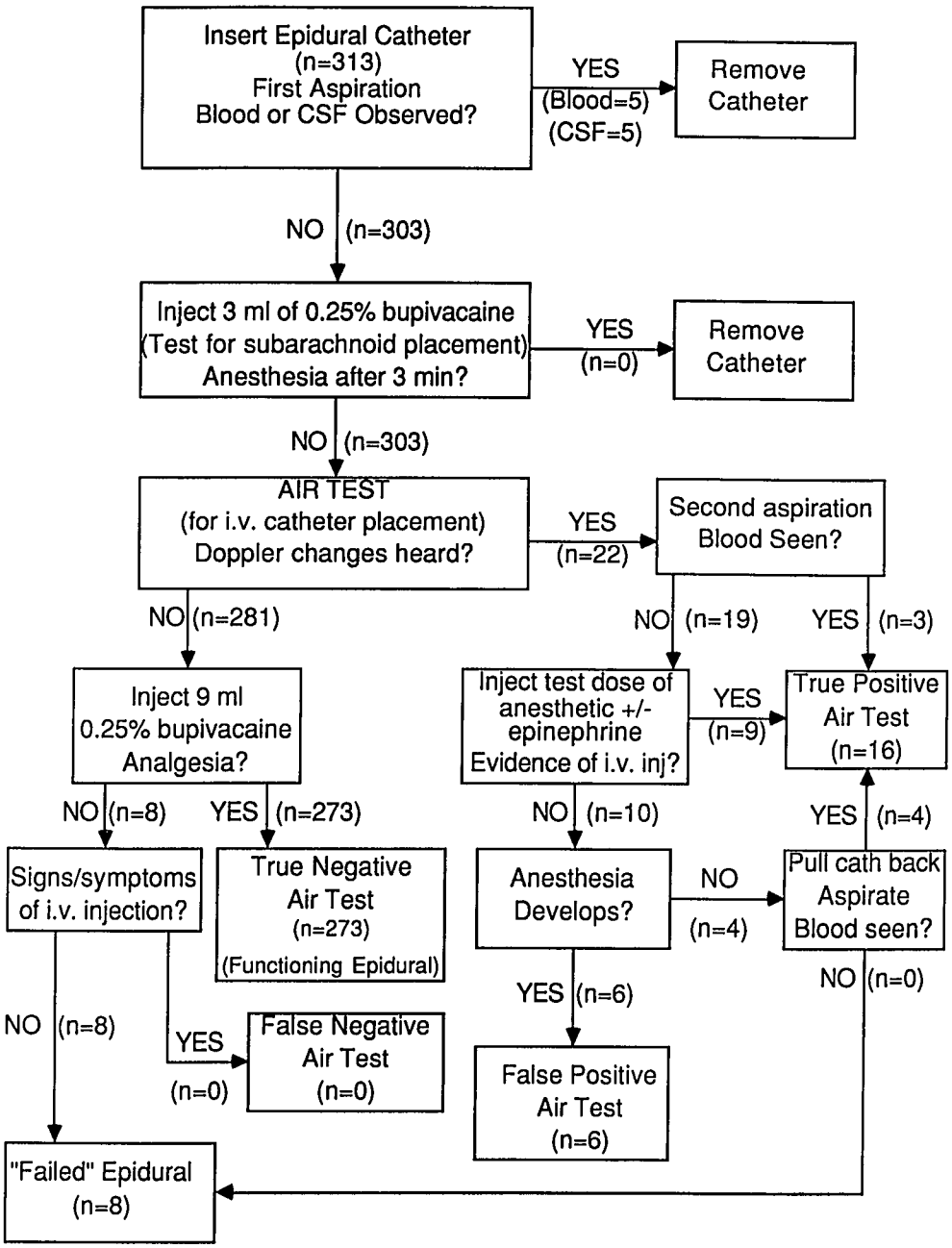

FIG. 1. Flow chart of the study sequence used for determining the sensitivity and specificity of the air test for unintentional intravenous placement of epidural catheters. Detailed descriptions of the procedures we used are given in the text. Two patients with "false-positive" air tests demonstrated signs of toxicity after administration of local anesthetics (see discussion).

removed the catheter, and inserted a new catheter at another interspace.

For each epidural catheter insertion, we recorded the following: presence of blood or CSF during any aspiration; evidence of subarachnoid injection following local anesthetic test dose; development of Doppler heart tone changes following injection of air *via* the epidural catheter; outcome of alternative tests (epinephrine or local anesthetic) for iv catheter location; and presence or absence of segmental epidural blockade following a therapeutic dose of 0.25% bupivacaine. We applied chi-square and Fisher's exact tests for categorical variables, with $P < 0.05$ indicating significance; confidence limits were based on a binomial probability distribution.

Results

A total of 313 patients received epidural catheters during this study. The first aspiration (immediately after catheter insertion) revealed CSF in five cases and blood in an additional five cases; there was no indication to perform an air test before removing these catheters. Of the 303 patients who received an air test, none developed any

new symptoms (*e.g.*, chest pain, dyspnea) or signs (*e.g.*, focal neurologic changes) attributable to the test (95% confidence limits, 0.0–1.0%).[7]

As shown in table 1, the air test was negative in 281 of these patients, of whom 273 developed segmental analgesia following injection of bupivacaine through the epidural catheter. In the remaining eight cases, analgesia never developed. However, blood could never be aspirated from these catheters, and the patients never developed evidence of toxicity despite having received at least 12 ml of 0.25% bupivacaine within 4 min, suggesting that these catheters were located in the paraspinal tissues. (This failure rate is consistent with the fact that many of the epidural catheters were inserted by relatively inexperienced first-year anesthesia residents.[8]) Thus, there were no proven "false-negative" air test results in our series (95% confidence limits, 0.0–1.1%). In contrast, three of eight patients receiving 100 mg of plain lidocaine and one of three patients receiving 12.5 mg of plain bupivacaine through epidural catheters likely to be located intravenously (based on prior positive air test *and* subsequent aspiration of blood) failed to develop subjective symptoms of anesthetic toxicity. The two patients who received 45 mg of lidocaine with 15 μg of epinephrine *via* such catheters developed marked tachycardia (fig. 1).

There were 22 positive air tests. In 16 of these cases, intravenous catheter location was subsequently confirmed by aspiration of blood or by signs and symptoms of intravenous local anesthetic or epinephrine injection; none of these patients subsequently developed any evidence of epidural analgesia. The remaining six patients obtained satisfactory epidural analgesia despite their positive air tests. This corresponds to a false-positive rate of 2% (95% confidence limits, 0.7–4.3%). Interestingly, two of these patients developed tinnitus when local anesthetics were administered, suggesting that these catheters were "partially intravascular" (*vide infra*).

Discussion

The present data demonstrate the efficacy and clinical utility of an air test for unintentional intravenous epidural catheter placement. Although the absolute safety of any therapeutic intervention can never be proven, the fact that none of our patients developed any complication from the air test demonstrates that the complication rate is less than 1% ($P < 0.05$).[7] Furthermore, the test was easily adapted to our busy clinical practice. Anesthesia residents and labor floor nurses readily learned to place the Doppler probe properly, and we found that it was not necessary to confirm Doppler probe placement or to place the patient in an atypical position (*i.e.*, *right* uterine displacement) before performing the test. The sensitivity of the air test is apparent: we were never able to document intravenous catheter location in cases where the air test was negative.

TABLE 1. Results of Air Test After Epidural Catheter Placement

Clinical Outcome	Air Test Result	
	Negative	Positive
Epidural anesthesia demonstrated	273	6*
No epidural level but no evidence of iv placement	8	0
Intravenous catheter placement confirmed	0	16**
Total	281	22

* Two of these patients developed tinnitus after subsequent doses of local anesthetics.

** $P < 0.01$ compared wth negative air test group.

Although this study was not designed to compare air with other tests, our results suggest that aspiration and local anesthetic test doses may be unreliable for detecting unintentional intravenous placement of epidural catheters. A total of 21 catheters appeared to be located in an epidural vein; only five of these were detected by the routine first aspiration. The fact that blood could be aspirated from three additional catheters following the air test dose suggests that the our initial inability to aspirate blood resulted from occlusion of the catheter tip, either by the wall of a vein or by a small clot, and that repeated or prolonged aspiration may not greatly improve the sensitivity of the aspiration test.

Test doses consisting of local anesthetics with or without epinephrine detected only nine of the 13 intravenously located epidural catheters through which they were injected. In the remaining four cases, probable intravenous catheter location was established by aspiration of blood during catheter withdrawal. Of course, aspiration during catheter withdrawal was performed solely on the basis of a positive air test result; if we had not been forewarned by the air test, it is conceivable that these four patients might have received repeated doses of local anesthetic through their intravenously located epidural catheters.

In the current study, the air test had an apparent sensitivity of 100%; it was positive whenever iv catheter location could be documented by *any* means. In contrast, the sensitivity of test doses consisting of local anesthetics with or without 15 μg of epinephrine in laboring women is between 50 and 80%.[9,10] Their insensitivity may be related to the unreliability of subjective signs of local anesthetic toxicity during labor[10] or to the insensitivity of maternal heart rate to catecholamines during the third trimester.[11]

Six patients developed adequate segmental epidural analgesia despite positive air tests, corresponding to a specificity of 98%. This contrasts with the 50–88% specificity previously reported for heart rate changes following epinephrine test doses in laboring women.[9,12,13] (Although a more specific peak-to-peak heart rate criterion for epinephrine test doses has been proposed, it has never been

prospectively validated and takes several minutes to perform.[9]) Since we used single orifice catheters, our false-positive results cannot be explained by the presence of one orifice in an epidural vein with the remaining orifices in the epidural space. We hypothesize that although the tips of our epidural catheters were located in the epidural space, nearby veins may have been punctured or lacerated during catheter insertion.[14] These holes may have allowed air to enter the vascular system following its injection into the epidural space. This is consistent with our observation that two patients with false-positive air tests (so designated because segmental analgesia developed following anesthetic administration) developed tinnitus following administration of local anesthetics. Therefore, in the presence of a positive air test, administration of local anesthetic *via* the suspected catheter may be contraindicated; our current practice is to immediately remove any such catheters and move to another interspace.

A significant, although probably unavoidable, flaw of the present study results from the absence of a gold standard for establishing that an epidural catheter is *not* located intravenously. The fact that anesthesia develops following injection of a local anesthetic is suggestive; however, in some cases such catheters may be partially intravascular (*vide supra*). Eight patients with negative air tests never developed analgesia despite repeated injections of "therapeutic doses" of local anesthetics. Two observations suggest, but by no means prove, that these catheters were not located intravenously. First, none of the patients developed signs or symptoms of local anesthetic toxicity following the injection of 30 mg of bupivacaine. Second, in none of these cases were we able to aspirate blood from the catheters as they were slowly removed from the patients' backs.

The fact that none of the 303 patients who received an air test developed any complications suggests, but does not prove, the safety of this technique. However, other lines of reasoning also imply that there is essentially no risk to injecting 1 ml of air into an epidural vein. For example, many patients receive similar volumes of intravenous air when drugs are injected into "y" sites of iv tubing or when iv solutions are changed. Also, significant volumes of air may be inadvertently injected into epidural veins when the air loss-of-resistance test is used to identify the epidural space.[14] Nonetheless, there are no case reports or series describing complications associated with venous or paradoxical air embolism in these patients.

In conclusion, 1 ml of air with precordial Doppler detection appears to be a safe, reliable test for intravenously located epidural catheters in laboring women. In fact, other tests have failed to detect catheter malposition in some cases where catheters were subsequently shown to be located intravenously. There did not appear to be any false-negatives (*i.e.*, intravenously located catheters not detected by the air test) or associated complications. The authors believe that the use of an air test may help to reduce the likelihood of unrecognized injections of local anesthetics into epidural veins. These results, however, should be confirmed by independent investigation in another institution before there is widespread introduction of this regimen into clinical practice.

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