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Air: An Effective Indicator of Intravenously Located Epidural Catheters

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The authors conducted a two-part study to evaluate the efficacy of 1 ml of air as a "test dose" for detection of intravenously located epidural catheters. In part 1, a Doppler fetal heart rate monitoring probe was placed over the precordium of 33 laboring patients in whom functioning epidural catheters were in place. Each patient received, more than 90 s apart, in random order: 10 ml of agitated saline (containing less than 0.5 ml of air microbubbles) *via* a peripheral vein; 2 ml of air *via* the epidural catheter; and a sham injection (*i.e.*, nothing injected). In all 33 cases, a blinded observer identified Doppler changes 10–30 s following the injection of air (microbubbles) *via* peripheral vein. Doppler changes were never heard following epidural air injection ($P < 0.001$ compared with iv air microbubble injection) or the sham injection ($P < 0.001$ compared with iv air microbubble injection). In part 2, the authors listened for Doppler heart tone changes while injecting 1 ml of air *via* catheters that were accidentally inserted in the epidural veins of five other patients. Unequivocal Doppler changes compatible with intracardiac air always occurred within 3 s, and no signs or symptoms of air embolism developed. The results suggest that 1 ml of air may be a suitable indicator of iv epidural catheter location. (Key words: Anesthesia: obstetric. Anesthetic techniques: epidural, obstetric. Test doses: epidural.)

DETECTION OF INTRAVASCULAR placement of epidural catheters is an important yet difficult task in laboring women.[1] Recognized intravascular placement or migration of an epidural catheter may occur in 3–5% of epidural anesthetics.[2,3] Three methods are presently recommended to avoid massive intravascular injection of local anesthetic: careful aspiration of the catheter for blood[4]; injection of a "test dose" containing epinephrine 15 μg while observing maternal heart rate[5–7]; and administration of small doses of local anesthetic while observing the patient for signs of toxicity.[4] However, aspiration, epinephrine 15 μg, and fractionated anesthetic may fail to detect 33, 50, and 23% of intravascular epidural catheters, respectively.[3,8] Other chemical intravascular markers have been proposed[9–12]; however, each of these is limited in its applicability. Some produce substantial tachycardia in the mother[9,10] while others require accurate reporting of subtle subjective changes by unanesthetized laboring women.[11,12]

Small volumes of intracardiac air are readily detected by precordial Doppler monitors.[13] We hypothesized that iv epidural catheter placement should be readily detectable by injecting a small volume of air through the epidural catheter while listening over the maternal precordium for changes in Doppler heart tones. We performed the present study to confirm this hypothesis. Specifically, our goals were: 1) to determine whether precordial Doppler monitoring can detect small volumes of air (in the form of agitated saline) injected *via* peripheral vein during labor; 2) to determine if injection of air *via* properly positioned epidural catheters caused (false-positive) changes in Doppler heart sounds; and 3) to determine if 1 ml of air injected *via* epidural vein caused changes in Doppler heart tones similar to those observed following injection of air (in agitated saline) *via* peripheral vein.

Methods

PART ONE

Thirty-three healthy parturients who were between 37 and 42 weeks gestation and carrying single fetuses consented to participate in this study, which was approved by our Institutional Review Board. All patients were in active labor (between 4 and 10 cm cervical dilation), had received at least 500 ml of balanced salt solution intravenously, and had a functioning, single-orifice epidural catheter (bilateral segmental analgesia of three to seven dermatomes following 10–12 ml of bupivicaine 0.25%). In no case could blood be aspirated from the catheters, and no patients had symptoms of local anesthetic toxicity following injection of bupivicaine. Patients were supine with 15 degrees of right uterine displacement; pilot studies showed that this position allowed Doppler heart sounds to be detected more reliably in pregnant patients. One investigator (BLL) performed all of the injections while a research fellow, unaware of the sequence of the injections, recorded whether Doppler sound changes occurred within 60 s of each injection.

For Doppler monitoring, we placed the ultrasound probe of a Hewlett Packard® HP–8040A fetal heart rate monitor just to the right of the lower maternal sternum.

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To verify proper Doppler probe placement, we injected 10 ml of agitated saline (containing less than 0.5 ml of air in the form of microbubbles) *via* peripheral vein. In only three cases was it necessary to reposition the Doppler probe before beginning the randomized injection sequence.

Each patient then received in a random sequence: 10 ml of agitated saline (containing air microbubbles) *via* peripheral vein; 2 ml of air *via* the epidural catheter; and a sham injection (*i.e.*, nothing injected). We waited until Doppler heart tones had returned to normal before giving the next injection; if there was no change in heart tones, we waited at least 90 s. At the end of the test sequence, we reconfirmed proper placement of the Doppler probe by documenting heart tone changes following administration of air microbubbles *via* peripheral vein. In some cases, uterine contractions caused nonspecific changes in Doppler heart tones; therefore, if a patient had a uterine contraction within 60 s of a test injection, the results for that injection were not recorded, and the injection was repeated after the contraction ended.

Fisher's exact test compared the incidence of changes in Doppler heart tones following injection of air (microbubbles) *via* peripheral iv and the incidence of changes in Doppler heart tones following injection of air into the epidural space. $P < 0.05$ indicated significance.

Part Two

Five patients in whom the tip of the epidural catheter was located intravenously consented to participate in this phase of our IRB approved study. Intravenous catheter location was confirmed by aspiration of blood in four cases and by subjective symptoms of toxicity following anesthetic injection in the fifth case. As before, the Doppler fetal heart rate probe was placed to the right of the maternal precordium. Three patients were sitting, one was supine, and one was supine with left uterine displacement. We injected 1 ml of air through the epidural catheter while trained (anesthesiologists) and untrained (labor floor nurses and obstetricians) observers listened for changes in Doppler heart tones. We then removed the epidural catheters and, in three cases, reinserted them at another interspace. We then injected 2 ml of air through the second functional epidural catheter while listening for Doppler sound changes.

Results

Part One

The blinded observer correctly identified changes in Doppler heart tones 10–30 s following the injection of air microbubbles (*i.e.*, agitated saline) *via* peripheral vein in all 33 subjects. Conversely, changes in Doppler heart tones were never observed following injection of air through the functioning epidural catheters ($P < 0.001$), or following the sham injection ($P < 0.001$). Thus, in this study, the Doppler probe detected intravenously administered air (microbubbles) 100% of the time (95% confidence limits 89–100%) while Doppler changes never occurred following epidural injection of air (95% confidence limits 0–11%).

Part Two

Following each injection of air through intravenously located epidural catheters, Doppler heart sound changes compatible with intracardiac air occurred within 3 s. Although no sham injections were used in this part of the study, the Doppler changes were unequivocal and much more distinct than those following injection of air in agitated saline *via* peripheral vein. They were clearly identified by the anesthesiologists, obstetricians, and nurses caring for the patients; the sounds were described as being "like a tornado" and "like a freight train." There were no clinically significant (*i.e.*, > 10%) changes in maternal pulse, maternal blood pressure, or fetal heart rate following the injection of 1 ml of air into an epidural vein. No patient reported symptoms following the air injection. In the three cases in which an epidural catheter was reinserted at another interspace, injection of 2 ml of air through the functioning catheter did not affect maternal Doppler heart tones.

Discussion

Unintentional iv placement has been reported to occur in 3–5% of epidural anesthetics.[2,3] If unrecognized, subsequent iv injection of local anesthetics can cause seizures, cardiac arrhythmias, and death.[4,5] In addition to careful aspiration of epidural catheters before injecting the local anesthetic, a "test dose" is often administered through the catheter in an attempt to detect iv placement. Ideally, such a test dose would be safe, reliable in detecting iv catheter placement, and have a low incidence of false-positive results (requiring unnecessary removal of properly positioned catheters).

Presently, the only drugs approved for use as a marker for iv placement of epidural catheters are local anesthetics with epinephrine 1:200,000 (*e.g.*, Sensorcaine® Test Dose, ASTRA; Xylocaine® Test Dose, ASTRA). Unfortunately, epinephrine 15 μg iv is neither as safe nor as effective in laboring patients as it is in nonpregnant patients. Epinephrine significantly decreases uterine blood flow in animals; in pregnant women, epinephrine 15 μg iv may be associated with heart rate patterns indicative of fetal distress lasting 10–12 min.[8,14,15] The decreased efficacy of epinephrine in laboring patients is related to two factors. First, the variability of maternal heart rate in laboring

patients may mask the changes induced by epinephrine.[7,8,16] Furthermore, pregnant patients have a decreased sensitivity to the chronotropic effects of beta-adrenergic agonists.[17]

Local anesthetics have also been proposed as markers for inadvertent iv injection *via* epidural catheters. However, their efficacy relies upon subjective reports of symptoms by patients, which are potentially unreliable in the labor and delivery environment. It is not surprising, therefore, that a significant number of patients who received "rather large" iv injections of local anesthetics reported no symptoms of toxicity.[3]

Part 1 of the present study demonstrates that small volumes of air (<0.5 ml dissolved in agitated saline), injected intravenously, are readily detected by precordial Doppler monitoring in laboring patients. In fact, we detected an air "test dose" administered *via* peripheral iv in each of 33 blinded trials. Conversely, in a previous study,[8] only five of ten patients who received epinephrine 15 μg iv developed heart rate changes that met prospectively determined criteria based on the work of Moore and Batra.[18] Thus, when administered *via* peripheral iv, air (<0.5 ml as microbubbles in saline) can be detected significantly more readily than epinephrine 15 μg ($P < 0.002$).

Part 1 of our study also addressed the possibility that injection of air into the epidural space might cause changes in Doppler heart tones.[19] We found that when 2 ml (*i.e.*, twice the proposed "test dose") of air were injected through catheters known to be in the epidural space (*vide supra*), blinded observers never heard changes in Doppler heart sounds. This rate of false-positives (0 of 33) is significantly lower than that which we observed using heart rate changes following epinephrine as an indicator of iv injection (two of ten, $P < 0.05$).[8]

In previous controlled studies of "test doses" for detection of iv catheter placement, the proposed "test dose" has been injected *via* peripheral vein.[5,7–9,11,12] It has been implicitly assumed that the effect of the "test dose" administered *via* peripheral vein is the same as if the "test dose" were injected through an intravenously located epidural catheter. We made an analogous although not identical assumption in part 1 of the present study: *i.e.*, that peripheral iv injection of 0.5 ml of air microbubbles in agitated saline affects Doppler heart tones in a similar manner to 1 ml of air injected directly into an epidural vein. In part 2, however, we went one step further: we demonstrated that when administered *via* an intravenously located epidural catheter, 1 ml of air can produce unmistakable changes in Doppler heart tones. This suggests that air injected into an epidural vein can be sensed by a precordial Doppler monitor in a manner similar to air from other veins, provided Doppler probe placement is adequately confirmed and rechecked after changes in patient position. (In our laboring patients, Doppler heart tones were best heard during right uterine displacement.)

By their nature, epidural "test doses" are sometimes administered intravenously or intrathecally. Therefore, proposed test agents must be safe when injected into these spaces. Intravenous air produces no adverse effects in dogs until almost 0.5 ml/kg is injected.[13] This would correspond to 35 ml of air in a 70 kg patient, which is more than an order of magnitude larger than the 1 ml dose we propose. One might be concerned about the risk of paradoxical air embolization in patients with probe-patent foramina ovale. However, several lines of reasoning suggest that the risk is not significant in adult patients receiving small volumes of air (1 ml or less). For example, many patients receive similar volumes of 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 administered through epidural veins when an air-loss-of-resistance test is used to identify the epidural space.[19] Specifically, if the "loss of resistance" occurs when the tip of the needle is in an epidural vein, several ml of air may be rapidly injected into the vein, even before the needle can be observed or aspirated for evidence of a "bloody tap." Therefore, many patients may be receiving several ml of air *via* epidural veins each day, yet there are no case reports or series describing complications associated with venous or paradoxical air emboli in patients whose epidural spaces are identified by an air-loss-of-resistance test.

Intrathecal injection of small volumes of air is known to be safe. Pneumoencephalography with much larger volumes of air (20–30 ml) was a common diagnostic procedure before the advent of computed tomography.[20]

In conclusion, small volumes of air may prove to be a suitable indicator of inadvertent iv placement of epidural catheters in laboring patients. When injected into a peripheral vein, less than 0.5 ml of air (as microbubbles in agitated saline) reliably caused changes in precordial Doppler heart tones. Conversely, injection of a larger volume (2 ml) of air into the epidural space *via* a properly positioned epidural catheter never caused changes in Doppler heart tones. Injection of 1 ml of air into epidural veins produced changes that were even more pronounced than those following injection of air microbubbles *via* peripheral vein. The use of a 1 ml air test dose with precordial Doppler monitoring may help to reduce the risk of local anesthetic toxicity during epidural anesthesia.

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References

1. Chestnut DH, Weiner CP, Herrig JE: The effect of intravenously administered 2-chloroprocaine upon uterine artery blood flow

velocity in gravid guinea pigs. ANESTHESIOLOGY 70:305–308, 1989
2. Dawkins CJM: Analysis of the complications of extradural and caudal block. Anaesthesia 24:554–563, 1969
3. Kenepp NB, Gutsche BB: Inadvertent intravascular injections during lumbar epidural anesthesia (letter). ANESTHESIOLOGY 54:172–173, 1981
4. Marx GF: Cardiotoxicity of local anesthetics—The plot thickens (editorial). ANESTHESIOLOGY 60:3–5, 1984
5. Albright GA: Epinephrine should be used with the therapeutic dose of bupivicaine in obstetrics (letter). ANESTHESIOLOGY 61: 217–218, 1984
6. Shnider SM, Levinson G: Obstetric anesthesia, Anesthesia. Edited by Miller RD. New York, Churchill Livingstone, 1986, pp 1681–1728
7. Cartwright PD, McCarroll SM, Antzaka C: Maternal heart rate changes with a plain epidural test dose. ANESTHESIOLOGY 65: 226–228, 1986
8. Leighton BL, Norris MC, Sosis M, Epstein R, Chayen B, Larijani GE: Limitations of epinephrine as a marker of intravascular injection in laboring women. ANESTHESIOLOGY 66:688–691, 1987
9. Leighton BL, DeSimone CA, Norris MC, Chayen B: Isoproterenol is an effective marker of intravenous injection in laboring women. ANESTHESIOLOGY 70:206–209, 1989
10. van Zundert A, Vaes L, Soetens M, de Vel M, van der Aa P, van der Donck A, Meeuwis H, de Wolf A: Every dose given in epidural analgesia for vaginal delivery can be a test dose. ANESTHESIOLOGY 67:436–440, 1987
11. Grice SC, Eisenach JC, Dewan DM, Mandell G: Evaluation of 2-chloroprocaine as an effective intravenous test dose for epidural anesthesia (abstract). ANESTHESIOLOGY 67:A627, 1987
12. Roetman KJ, Eisenach JC: Evaluation of lidocaine as an intravenous test dose for epidural anesthesia (abstract). ANESTHESIOLOGY 69:A669, 1988
13. English JB, Westenskow D, Hodges MR, Stanley TH: Comparison of venous air embolism monitoring in supine dogs. ANESTHESIOLOGY 48:425–429, 1978
14. Hood DD, Dewan DM, James FM: Maternal and fetal effects of epinephrine in gravid ewes. ANESTHESIOLOGY 64:610–613, 1986
15. Chestnut DH, Weiner CP, Herrig JE, Wang J: Effect of intravenous epinephrine upon uterine blood flow velocity in the pregnant guinea pig. ANESTHESIOLOGY 65:633–636, 1986
16. Chestnut DH, Owen CL, Brown CK, Vandewalker GE, Weiner CP: Does labor affect the variability of maternal heart rate during induction of epidural anesthesia? ANESTHESIOLOGY 68:622–625, 1988
17. DeSimone CA, Leighton BL, Norris MC, Chayen B, Menduke H: The chronotropic effect of isoproterenol is reduced in term pregnant women. ANESTHESIOLOGY 69:626–628, 1988
18. Moore DC, Batra MS: The components of an effective test dose prior to epidural block. ANESTHESIOLOGY 55:693–696, 1981
19. Naulty JS, Ostheimer GW, Datta S, Knapp R, Weiss JB: Incidence of venous air embolism during epidural catheter insertion. ANESTHESIOLOGY 57:410–412, 1982
20. Campkin TV, Turner JM: Blood pressure and cerebrospinal fluid pressure studies during lumbar air encephalography. Br J Anaesth 44:849–853, 1972