▼ Review Articles

Assessing the Superiority of Saline Versus Air for Use in the Epidural Loss of Resistance Technique: A Literature Review

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Epidural anesthesia is widely utilized as a means of acute and chronic pain control and as an adjunct to general anesthesia.[1] Epidural catheters are most commonly placed percutaneously, using a loss of resistance (LOR) technique. Originally described in 1933 by Dogliotti[2] using fluid as a medium, this technique is based on the different densities of tissues as one passes a needle through the thick ligamentum flavum into the epidural space. Subsequently, the technique has been modified so that both fluid and gas have developed as acceptable media for determining LOR. The 2 most commonly used media are air and saline.[3] The physician's choice of medium has been historically based on his/her training and experience, as a paucity of evidence-based literature supported the superiority of saline versus air. In 1997, Saberski et al.[4] published a review of the complications associated with the use of LOR to air. His list of complications included pneumocephalus, nerve root compression, subcutaneous emphysema, venous air embolism, a greater incidence of incomplete analgesia, and a higher incidence of paresthesias.[4] Several clinical studies have since been published, which supplement the discussion over the superiority of LOR to saline or air. The purpose of this report is to review the literature and evaluate the data supporting the advantages and shortcomings of the 2 media in an attempt to determine whether one is superior.

We searched the National Library of Medicine's PubMed database (www.ncbi.nlm.nih.gov), which catalogues literature for the years 1966 through 2002, and the Partners HealthCare System's intranet Medline database (http://is.partners.org/handbook/TextJournal/ovid), which catalogues literature for the years 1963 through 2002. Key words entered into the databases' search engines were "epidural anesthesia" and "loss of resistance." Inclusion criteria were English language, human subjects, and percutaneous epidural techniques. Fifty-nine references were found in the initial search. Of these 59, 38 were excluded based on review of their titles and abstracts. The remaining 21 were found and reviewed in full. Related references listed in the initial search articles that did not appear in the primary literature search were found and reviewed. In total, our search produced 42 relevant peer-reviewed articles.

The results of our literature search are organized under the major complications and adverse results associated with accessing the epidural space.

Incomplete Analgesia

In 1987, Dalens et al.[5] reported 2 cases of incomplete analgesia when a LOR to air technique was used. In both of these cases, radiographic studies confirmed air in the spinal canal at the levels of the unblocked dermatomes.[5] A similar case was reported in 1989 by Boezaart et al.[6] In 1991, Valentine et al.[7] published the first randomized, double-blinded study comparing analgesia obtained when using air versus saline for determination of LOR. He used 4 mL of either air or saline to locate the epidural spaces of 50 parturients and found that the use of air led to a greater number of unblocked dermatomes ($P < .01$).[7] In 2000, Beilin et al.[8] performed a single-blinded, randomized study of 156 parturients, placing epidural catheters using 4 mL either air or saline. At 15 minutes, a larger percentage of patients in the air group had incomplete analgesia relative to those in the saline group ($P = .022$).[8]

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Incomplete analgesia has also been demonstrated when large amounts of saline are used for determination of LOR. A prospective, randomized, double-blinded study performed by Okutomi and Hoka[9] in 1998 assigned 70 patients undergoing upper abdominal surgery to have their epidural spaces located using a LOR to either 1, 5, or 10 mL saline. The patients whose epidural spaces were located using 10 mL saline reported a fewer number of dermatomes with hypesthesia to pinprick relative to the group who received 1 mL saline (22 dermatomes *v* 16 dermatomes, $P < .004$).[9]

Venous Air Emboli

In 1982, Naulty et al.[10] attempted to determine the incidence of venous air embolism (VAE) when air is used to confirm entry into the epidural space. He studied 17 American Society of Anesthesiologists (ASA) I parturients who were having epidural catheters placed for acute pain control. The patients were monitored using transthoracic echocardiography (TTE). Entry into the epidural space was determined using the "hanging-drop" technique and confirmed by injection of 5 mL air into the space. In 7 patients, VAE was detected shortly after the injection of 5 mL air into the epidural space. In an eighth patient, a VAE was detected during the hanging-drop test. None of the 8 patients experienced clinically significant changes in their hemodynamic profile.[10] Although none of the patients in Naulty's original study suffered hemodynamic compromise secondary to their VAE, 2 case reports since that time demonstrate this phenomenon. In 1993 Schwartz et al.[11] reported a case of clinically significant VAE in a pediatric patient who previously had a normal TTE. Hemodynamic instability occurred within 10 seconds of a rapid injection of 3 mL air into the patient's epidural space during a LOR technique.[11] Guinard and Borboen[12] in 1993 reported a similar case of VAE after 2.5 mL air was used for determination of LOR. The incidence of unintentional puncture of an epidural blood vessel in the pediatric population has been estimated between 0% and 10.6 %.[13-15] In adults, the incidence ranges from 0.67% to 8%.[1,8]

Pneumocephalus/Headache

Two types of headaches have been described in patients who have had their dura mater unintentionally punctured during attempted epidural catheter placement. The first is caused by the development of a pneumocephalus. This headache is commonly reported either immediately after dural puncture or when the patient changes from the lateral to the upright position. The headache is severe, partially relieved with the supine position, improves with 100% oxygen therapy,[16] and is of shorter duration than the "classic" postdural puncture headache (PDPH). While the incidence has not been reported in the literature, numerous case reports detail this phenomenon. Abram and Cherwenka[17] described 2 cases of patients undergoing epidural steroid injection using LOR to 3 mL air. Neither patient had cerebrospinal fluid (CSF) return with aspiration. Upon sitting upright from the lateral position, both patients complained of severe, generalized headaches, one associated with nausea and vomiting. Upright, lateral radiographs revealed small amounts of air in the basilar cisterns. Complete resolution of symptoms for both patients occurred within 2 hours.[17] Ahlering and Brodsky[18] reported a similar case of pneumocephalus after accidental dural puncture using a combined air and saline LOR technique. In 1990, Katz et al.[19] described the case of a 25-year-old parturient undergoing epidural anesthesia for cesarean delivery. Multiple attempts were made to identify the epidural space, using an estimated 20 mL air. Subsequently, the patient's catheter was dosed with 16 cc of 0.5% bupivacaine. She became apneic, requiring endotracheal intubation, mechanical ventilation, and vasopressor support as treatment for a "high spinal." Even after spontaneous respiration and movement resumed, the patient continued to be "drowsy and stuporous." The patient's continued altered mental status was attributed to the large (approximately 25 mL) air-filled cavity in the parietofrontal cerebral cortex, as seen on computed tomography (CT) scan. The following day, the patient's neurologic status returned to baseline, and a repeat CT scan was negative for residual air.[19] Katz et al.[20] described the case of a 77-year-old female whose epidural space was located using 3 mL air. She immediately complained of a bifrontal and bitemporal headache. Aspiration was negative and a further 6 mL air was injected to confirm LOR. Eight milliliters of 0.125% bupivacaine was then administered, resulting in a "high spinal" with the need for assisted ventilation and hemodynamic support. Plain skull radiographs revealed subdural air in the apex of the tentorium.[20] Sherer et al.[21] described a similar case in a 36-year-old parturient who had an epidural catheter placed using LOR to air. The cases presented by Katz and Sherer suggest that the acute onset of headache in a patient whose epidural space is being located using LOR to air may be an indication that, despite negative aspirate, the needle is in the subdural space, and the patient is at risk for

developing a high-spinal block. Ash et al.[22] recognized this phenomenon when treating a 29-year-old parturient who developed a severe bifrontal headache with occipital radiation after 5 cc air was injected during the LOR technique. No further attempt at epidural access was made, and no medications were injected. There was no change in consciousness and no focal neurologic deficits. CT scan revealed air in the lateral ventricles and basilar cisterns. The patient's symptoms resolved on the first postoperative day.[22] In 1993, Gonzalez et al.[23] reported the case of a 45-year-old female whose epidural space was located using LOR to air. CSF was noted to return into the syringe upon advancement of the needle. The patient developed a severe frontotemporal headache. X-ray of the cranium confirmed pneumocephalus. The patient's symptoms resolved within 4 hours.[23]

The second type of headache seen after penetration of the dura mater during attempted epidural catheter placement is the classic PDPH. Symptoms usually start 24 to 48 hours after the procedure and almost always have a postural component. The patient may also experience nausea, photophobia, and visual changes. The pathophysiology of this headache is thought to be a combination of cerebral vasodilation and development of traction on pain-sensitive structures in the brain secondary to loss of CSF.[24] In 1998, Aida et al.[25] performed a prospective, randomized, double-blinded study including 1,812 patients who had their epidural space located using a glass syringe filled with 4 to 5 mL air versus 1,918 patients for whom the space was located using a glass-filled syringe with 4 to 5 mL of 0.9% saline from which all air had been removed. The study found no difference in the incidence of dural perforation between the 2 groups (2.6% in the air group *v* 2.7% in the saline group). However, 66.7% (n = 32) of the patients in the air group who had evidence of meningeal perforation versus 9.8% (n = 5) of the patients in the saline group reported PDPH ($P < .01\%$). Aida's statistical analysis did not distinguish between headache caused by pneumocephalus and the more classic PDPH. However, air was seen on the CT scans of 30 of the 32 patients in the LOR to air group who developed headache. No air was seen on CT scans of the patients who had the procedures performed using LOR to saline.[25] The results of Aida's data is different than that of Stride and Cooper,[26] whose retrospective review of more than 34,000 epidural catheter placements revealed a significantly lower incidence of dural puncture when saline was used (0.6% *v* 1.0%, $P < .01$).

Catheter Insertion

The effect of the medium used during one's LOR technique on the safety of epidural catheter insertion was first studied in 1990 by Sarna et al.[27] They performed a randomized, double-blinded study of 67 parturients undergoing epidural anesthesia. The incidence of paresthesias upon threading the epidural catheter was compared in patients whose epidural spaces were located using 10 mL of either air or saline. There was no significant difference in the incidence of paresthesias, nor was there any difference in the number of intravascular catheters.[27] Beilin's study also found no significant difference in the incidence of paresthesias or intravascular catheters when either air or saline was used.[8] A decrease in the incidence of paresthesias has only been demonstrated with the use of a paramedian technique[28,29] or with the use of soft polyurethane catheters.[30] While the incidence of intravascular catheters was found by Verniquet[31] to be lower if 10 cc 0.5% plain bupivacaine was injected into the epidural space prior to threading of the catheter ($P = .05$), this technique may hinder the patient's ability to alert the clinician of paresthesias.

Nerve Root Compression

Several case reports of neurologic sequelae secondary to nerve root compression after the epidural space was accessed using LOR to air have been reported in the literature. Recently a similar case was reported when LOR to saline was used. In 1989, Hirsch et al.[32] reported the case of a 40-year-old patient who developed weakness and paresthesias in bilateral upper and lower extremities after having a lumbar epidural catheter placed using LOR to air. CT scan revealed epidural air compressing the thecal sac in the cervical, thoracic, and lumbar regions. The patient's catheter was discontinued, and she had full resolution of her symptoms.[32] In 1991 Miquel et al.[33] reported the case of a 64-year-old male who had an epidural catheter placed using LOR to approximately 10 mL air. Upon injection of morphine through the catheter, the patient complained of sharp left chest, shoulder, and arm pain. Slowing the rate of injection did not lessen the pain. CT scan demonstrated air in the epidural space, causing impingement of the nerve root.[33] In 1993, Nay et al.[34] reported a case of a 52-year-old female whose epidural space was located after multiple attempts, using approximately 40 mL air. Eight hours after the procedure, the patient complained of motor deficits involving the left leg. CT scan revealed a large amount of air in the epidural space, displacing the cauda equina. She was treated with intravenous (IV) steroids overnight and, by the fol-

lowing morning, her symptoms resolved. Follow-up CT showed substantial resorption of the epidural air.[34] Two similar cases of neurologic deficits after the placement of epidural catheters using LOR to 6 and 2 mL air, respectively, were reported by Overdiek et al.[35] in 2001.

In 1998, Gracia et al.[36] reported the case of a patient who had an uncomplicated placement of an epidural catheter using LOR to saline. After a total of 13 mL of a mixture of local anesthetic and opioids were delivered through the catheter, the patient developed sharp pain in his upper abdomen and lower extremities. Magnetic resonance imaging revealed 5 mL of air compressing the patient's thecal sac at L3/4. Gracia proposed that the air had entered the epidural space with the initial puncture and that after the patient was turned supine and the catheter dosed, the air lodged in the left anterolateral area of the epidural space, causing the nerve root compression.[36]

Subcutaneous Emphysema

The development of subcutaneous emphysema has been listed as a complication of LOR to air.[4] The proposed mechanism for the development of subcutaneous emphysema is that the air travels from the epidural space through the intervertebral foramen and spreads into the deep fascial planes of the back and neck. This phenomenon may be exacerbated by the use of nitrous oxide during general anesthesia.[37] In 1978, Laman et al.[38] reported the case of a 25-year-old female requesting epidural analgesia for labor and delivery. Location of her epidural space required multiple LOR attempts, using approximately 35 mL air. Six hours postpartum, the patient complained of an unusual sensation in her neck, which upon physical examination and radiographic confirmation, was found to be subcutaneous emphysema. The patient did not experience respiratory difficulty, and the air resorbed over the subsequent 48 hours.[38] A series of case reports by Carter,[39] in 1984, discussed the formation of subcutaneous emphysema in 3 obstetric patients who had epidural catheters placed using LOR to air. None of the patients suffered any adverse sequelae associated with the development of subcutaneous emphysema.[39] In 1991, Viel et al.[40] reported a case of subcutaneous emphysema after placement of a thoracic epidural catheter using LOR to air in a patient with acute pancreatitis. The subcutaneous emphysema did not harm the patient, but its appearance on CT scan resembled an anaerobic soft-tissue infection, leading to extensive medical workup.[40]

Discussion

The types of studies produced by our literature search included randomized, blinded, controlled trials (RBCTs); retrospective analyses; observational studies; surveys; and case reports. The strongest data come from the RBCTs performed by Valentine, Beilin, Aida, Okutomi, and Sarna. Both Valentine and Beilin demonstrated an increased incidence of incomplete analgesia when using LOR to air. Okutomi demonstrated the importance of minimizing the amount of saline used in the LOR technique, as dilution of local anesthetic can occur when larger amounts of saline are injected into the epidural space. These studies point to LOR using limited amounts of saline as producing the most dense and complete analgesia.

Aida determined that the incidence of PDPH is significantly greater using LOR to air, despite no difference in the incidence of dural puncture. The results of Aida's study differed from those found in the large, retrospective study performed by Stride and Cooper, who demonstrated a statistically greater incidence of dural puncture when LOR to air was used.

Neither Sarna nor Beilin as able to demonstrate a significant difference in the incidence of paresthesias or intravascular catheters using air versus saline. Naulty et al. demonstrated a 41% incidence of VAE when air was injected into the epidural space.

Finally, 22 reported complications, including incomplete analgesia, VAE, pneumocephalus, nerve root compression, and subcutaneous emphysema have been reported with the use of LOR to air. This can be compared with the 1 case of pneumocephalus using a combination of air and saline and the 1 case of nerve root compression with the use of saline alone.

Dogliotti is credited with describing the use of the LOR technique to locate the epidural space. Dogliotti described this technique using a fluid-filled glass syringe, as the lack of compressibility of fluid provides a well-defined LOR, and glass syringes were all that were available for use. Over the years, many modifications of Dogliotti's original description have occurred. One of the major changes has been the use of gas as a medium for determining LOR. It has been theorized that the utilization of gas in the LOR technique began because of the problem of the "sticky syringe." This phenomenon is seen when saline wets a glass syringe, causing adherence of the piston to the glass. In such a case, even once the epidural space is entered, no fluid is injected, leading to a false negative LOR. The end result is accidental dural puncture. Use of air in the syringe avoided the problem of adherence. The use

of saline in a plastic syringe, however, has the advantage of both preventing adherence and avoiding the complications associated with the use of air.

It does appear that physicians are realizing the validity of the arguments against using a LOR to air technique. A recent survey of 404 obstetrical anesthesiologists performed in 1998 revealed that 239 (59.1%) initially learned epidural placement using LOR to air versus 135 (33.4%) who trained using LOR to saline. Of that same group, 37.1% currently use air, while 52.7% use saline. Reasons listed by those who changed to a LOR to saline included a clearer "endpoint" using saline relative to air, a decreased incidence of dural puncture, and fewer "patchy" blocks with saline than with air. In contrast, 4.2% of anesthesiologists switched from saline to air. Reasons included difficulty discriminating between saline and CSF and a more "sensitive" endpoint using air. Twenty-eight percent of respondents stated that they only taught a LOR to air technique, while 57.2% teach only LOR to saline.[3] Reviewing Howell's data, one can see that LOR to saline is regaining dominance, as increasing numbers of practicing anesthesiologists, including teachers of future clinicians, are using LOR to saline. The argument has been made that encouraging clinicians who have used a LOR to air for many years to change to a LOR to saline may lead to an increased number of complications for the individual practitioner during the period of adjustment. There are no data on this subject. However, the argument that use of saline in the LOR technique makes it difficult to determine whether one has had an accidental dural puncture is perhaps overstated, as simple bedside testing allows for differentiation of the 2 types of fluids.[41]

In conclusion, the literature supports not only analgesic superiority, but also decreased morbidity when using saline as the medium for determining LOR.

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