A Retrospective Effectiveness Study of Loss of Resistance to Air or Saline for Identification of the Epidural Space

Scott Segal, MD, MS*

Katherine W. Arendt, MD†

BACKGROUND: Randomized trials comparing air to saline for loss of resistance (LOR) for identification of the epidural space have suggested the superiority of saline. We hypothesized that, in actual clinical practice, anesthesiologists using their preferred technique would produce similar analgesic outcomes with either air or saline.

METHODS: The labor analgesia records for 929 parturients requesting neuraxial analgesia were reviewed with respect to technique (epidural or combined spinal-epidural; air or saline for LOR), analgesic outcomes (initial comfort, asymmetry of the block, need for physician top-up during patient-controlled epidural analgesia, and catheter replacement), and complications (paresthesia, IV or intrathecal catheter placement, and unintentional dural puncture).

RESULTS: Of 929 labor analgesics analyzed, 52.6% were performed with LOR to air and 47.4% to saline. Among anesthesiologists who performed at least 10 blocks, 82% used 1 medium at least 70% of the time. There were no differences between the air and saline groups in patient characteristics, analgesic technique, or block success. Among operators with a preference for 1 medium, use of the preferred technique was associated with fewer attempts (1.3 ± 0.7 vs 1.6 ± 0.8, $P = 0.001$), fewer paresthesias (8.7% vs 18.5%, odds ratio = 0.42, $P = 0.007$), and fewer unintentional dural punctures (1.0% vs 4.4%, odds ratio = 0.23, $P = 0.03$).

CONCLUSIONS: When used at the anesthesiologist's discretion, there is no significant difference in block success between air and saline for localization of the epidural space by LOR.

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The epidural space is usually located by the loss-of-resistance (LOR) technique, in which a change in compliance is detected by easier injection of air or saline associated with passage of the tip of the epidural needle from the ligamentum flavum into the epidural space. The technique was originally described in 1933 using a fluid-filled syringe.[1] Subsequently, air was often substituted, perhaps as a way to avoid the technical difficulty associated with increased friction between the plunger and barrel of the LOR syringe.[2] Anesthesiologists' preference for one medium or the other was largely dictated by experience during training[3] rather than by objective evidence of superiority of either. In 1987, however, a case report described incomplete analgesia in 2 pediatric patients in whom the epidural space had been located by LOR to air. Imaging of the spine showed air bubbles adjacent to the unblocked nerve roots.[4] Subsequently, several randomized clinical trials (RCTs) investigated the performance of the 2 techniques, and some suggested superiority of saline over air, particularly with respect to the incidence of incomplete analgesia.[5–11] In our experience, however, few anesthesiologists use the 2 media interchangeably as they would in a RCT. Because it is impossible to mask the anesthesiologist to the medium used for LOR, we hypothesized that RCTs might overestimate the difference between air and saline by forcing the operator to use a less-preferred technique in half of the subjects. Therefore, we undertook an effectiveness study of the impact of LOR media choice on analgesic outcomes in laboring patients.

METHODS

The IRB of Partners Healthcare approved this retrospective study. Anesthesia records for all patients requesting labor analgesia at Brigham and Women's Hospital during two 1-mo periods separated by 1 yr (August 2007 and July 2006) were reviewed. The months studied were selected because no first-year (CA-1) residents rotate on the obstetric anesthesia service in the months of July or August, and the separation of more than a year was used to minimize the chance that a given resident or fellow would be active in both study months.

From the *Department of Anesthesiology, Perioperative and Pain Medicine, Brigham and Women's Hospital, Boston, Massachusetts; and †Department of Anesthesiology, Mayo Clinic, Rochester, Minnesota.

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Address correspondence and reprint requests to Scott Segal, MD, Department of Anesthesiology, Perioperative and Pain Medicine, Brigham and Women's Hospital, 75 Francis St., Boston, MA 02115. Address e-mail to bssegal@zeus.bwh.harvard.edu.

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Data abstracted from the record included demographic information on the patient (age, height, weight, parity, and history indicating possibly difficult epidural placement), details of anesthetic technique (LOR medium, patient position, interspinous space, self-reported number of attempts, depth of LOR, use of conventional epidural or combined spinal-epidural [CSE] technique, and length of catheter inserted), operator identity and training level (attending, fellow, senior [CA-3], or junior [CA-1 or CA-2]), and analgesic outcomes.

The primary outcome variable was unsatisfactory block, which was a composite comprising 1 or more of the following: 1) absence of initial comfort after block initiation, 2) initial block asymmetry, 3) intravascular catheter, 4) intrathecal catheter, or 5) catheter replacement. Initial comfort was defined by the patient's indication of effective analgesia and a record that showed no additional medication within 60 min after block initiation. Initial block symmetry was assessed after the initiating dose of epidural or intrathecal medication by patient report of effective analgesia. If no documentation of dermatomal asymmetry was present, but the record indicated adequate analgesia, then the block was considered symmetric. Some records, but not all, confirmed symmetry by documenting decreased sensation to pinprick in a similar bilateral dermatomal distribution. An "asymmetric block" required 2 criteria: 1) ineffective analgesia after initiating the block, and 2) documented asymmetry defined as a difference in decreased sensation to pinprick of at least 3 dermatomes. Blocks that included additional physician-administered anesthetic or opioid boluses at any time before delivery to augment analgesia were recorded, but additional doses of medication given to facilitate operative vaginal or cesarean delivery were excluded. If the additional drug was given for asymmetry or incomplete analgesia that developed after an initially symmetric and effective epidural block, the case was not recorded as asymmetric. Blocks initiated using a CSE technique were recorded as asymmetric if they became asymmetric up to 120 min after intrathecal drug administration. Catheter replacement was at the discretion of the attending anesthesiologist supervising the resident or fellow and was recorded as an outcome regardless of the timing relative to initiation.

All blocks during the study period were initially managed by a standard protocol. Epidural analgesia was initiated using a 17-gauge Weiss needle; CSE analgesia was initiated using a 25-gauge Whitacre spinal needle inserted through a 17-gauge Weiss needle. Epidural blocks were initiated with 20 mL bupivacaine 1.25 mg/mL (0.125%) combined with fentanyl 2 μg/mL; the first 5 mL of this solution was considered a test dose. CSE blocks were initiated with intrathecal bupivacaine 2.5 mg and fentanyl 25 μg. Test-dose administration through the epidural catheter with 3 mL lidocaine 20 mg/mL (2%) with epinephrine 1:200,000 (5 μg/mL) was performed at the discretion of the anesthesiologist. All epidural catheters were single-orifice, wire-reinforced catheters (Arrow International, Reading, PA) and were connected to a patient-controlled analgesia pump set to deliver 0.125% bupivacaine with fentanyl 2 μg/mL at 6 mL/h, with a 6-mL demand dose and 15-min lockout period. Unintentional dural puncture was managed by protocol by insertion of an intrathecal catheter if possible. When this event occurred, other analgesic outcomes were not assessed. Intravenous and unintentional intrathecal placements of catheters were also recorded.

Choice of air or saline for LOR was calculated for each operator who performed 10 or more blocks during the study period. Preference for 1 LOR medium was defined as $\geq$70% use of either air or saline. Differences between air and saline LOR were assessed by Pearson χ^2, Fisher's exact test, analysis of variance, or Kruskal–Wallis tests (for number of attempts), as appropriate. Because CSE analgesia is associated with better block outcomes,[12] subgroup analysis was performed for patients receiving conventional epidural as well as for the entire cohort. The relationship between the CSE technique and LOR medium was assessed by linear regression. Effect of training level was assessed by multivariable logistic regression. Required sample size was estimated by assuming a baseline incidence of 13% of blocks that required replacement with LOR to air (previous retrospective series at our institution[13]). At the time of this prior study, block replacement was the preferred response for any unsatisfactory block, so we based our power calculation on the primary outcome variable of "unsatisfactory block." We estimated the sample size necessary to exclude a 50% decrease (to 6.5%) in unsatisfactory block with 80% power at $\alpha = 0.05$ to be 328 subjects per group. Residents rotated in 1-mo rotations. We collected data from 2 complete months separated by 1 yr to ensure both a greater number of blocks per individual provider and a larger sample of providers. This strategy allowed us to analyze preferences of individuals. Where exact P values are not reported, $P < 0.05$ was considered significant.

RESULTS

The records of 929 labor analgesics were analyzed. For the entire cohort, 52.6% were performed with LOR to air and 47.4% to saline. The distribution among months was significantly different, with 82.9% performed with air in 2006 and 28.7% in 2007 ($P < 0.001$).

The preference for LOR medium varied greatly across operators (Fig. 1). Thirty-four different anesthesiologists performed at least 10 blocks during the study period (of 53 who performed any blocks). Eighty-two percent of these operators used 1 medium at least 70% of the time. The frequency of use of air for

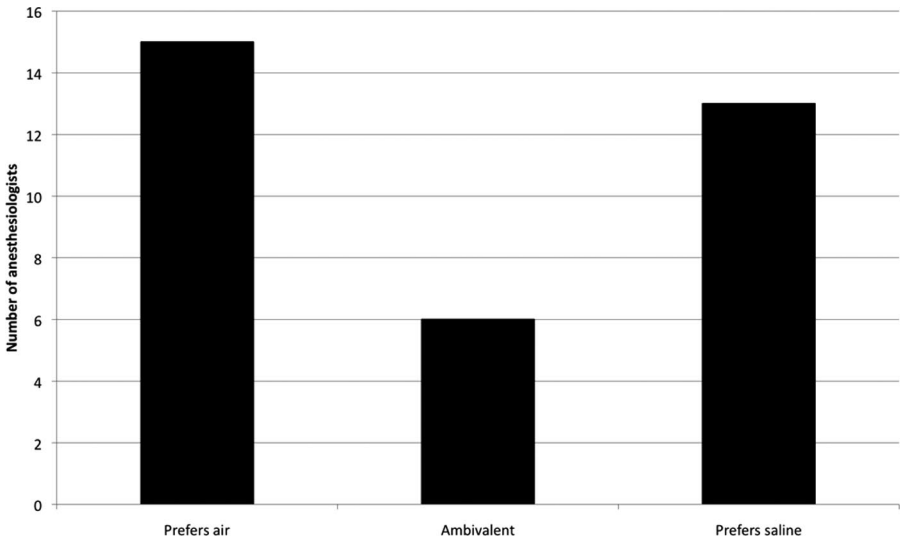

Figure 1. Preference of anesthesiologists for loss of resistance to air or saline for those performing at least 10 blocks during the study period. Prefers air = used air for ≥70% of placements; ambivalent = used either air or saline for <70% of placements; prefers saline = used saline for >70% of placements.

Table 1. Demographic Characteristics of the Study Subjects

Parameter	N^a	Air	Saline	P
Age (yr)	928	31 (6)	31 (6)	0.88
Height (cm)	925	164 (7)	164 (7)	0.88
Weight (kg)	922	80 (16)	79 (14)	0.20
BMI (kg/m^2)	921	30 (6)	29 (5)	0.14
Nulliparous (%)	911	52	51	0.69
Mode of delivery (%)	929			1.0
VD		77	77	
IVD		7	7	
CS		16	16	
Expected difficulty with placement[b] (%)	929	5	6	0.55
Interspace used (%)	899			0.23
L23		5	4	
L34		70	65	
L45		25	21	
Other		<1	0	
Position (%)	917			0.40
Sitting		95	97	
Lateral		5	3	
Block type (%)	924			<0.0001
Epidural		66	85	
CSE		34	15	
Loss of resistance depth (cm)	923	5.4 (1.1)	5.3 (1.0)	0.04
Catheter length at skin (cm)	921	10.2 (1.2)	10.2 (1.2)	0.39
Calculated catheter inserted (cm)	920	4.8 (0.6)	4.9 (0.6)	0.08

Values shown as mean (SD) or percent.

BMI = body mass index; VD = vaginal delivery; IVD = instrumented vaginal delivery; CS = cesarean delivery; CSE = combined spinal epidural.

[a] Total number of study subjects was 929. Values less than 929 indicate missing data.

[b] Expected difficulty was defined as a history of difficult epidural placement, previous back surgery, or diagnosis of scoliosis noted in the preoperative assessment.

LOR was positively correlated with frequency of use of the CSE technique ($R^2 = 0.36$, $P < 0.001$).

The demographics of the patients managed with LOR to air and saline are shown in Table 1. There were no differences between groups in any patient characteristic. Analgesic technique was similar with respect to interspace used and patient position. There was a small (mean 0.1 cm) but statistically significant difference in distance from the skin to LOR but not catheter distance at the skin or calculated length of catheter threaded into the epidural space between the 2 techniques. There was a significant difference in use of the CSE technique, with more frequent use in the air group. A test dose of lidocaine was given more frequently in the saline group. Use of a lidocaine-containing test dose was not associated with any adverse analgesic outcome, unintentional dural puncture, or number of attempts, but was associated with a greater risk of cesarean delivery (24% vs 15%, odds ratio [OR] [95% confidence interval] = 1.75 [1.1–2.8], $P = 0.02$).

Analgesic outcomes are shown in Tables 2–4. For the entire cohort, there were no differences in unsatisfactory block or in the incidences of initial comfort, paresthesia, asymmetry, physician-administered additional medication, catheter replacement, IV or intrathecal placement, or dural puncture between the groups (Table 2). There was a small increase in the number of self-reported attempts per epidural placement and number of blocks requiring more than 1 attempt in the air group. Subgroup analysis was performed for patients receiving conventional epidural (Table 3) or CSE (Table 4) techniques. For patients receiving conventional epidural analgesia, the results were similar to those of the entire cohort. Among patients receiving CSE analgesia, there were no differences in number of attempts between air and saline. However, significantly fewer patients were initially comfortable in the saline group, and significantly more patients required catheter replacement.

The observed rate of unsatisfactory block was lower than that used to estimate required sample size. *Post hoc* power analysis demonstrated that the data for the primary outcome of unsatisfactory block could exclude a difference of not >5.7% with 80% power at $\alpha = 0.05$.

Table 2. Outcomes for All Subjects

Variable	Air	Saline	*P*
Unsatisfactory block[a]	43/489 (9)	48/440 (11)	0.32
Number of attempts	1 (1–2)	1 (1–1)	0.002
More than 1 attempt	134/486 (28)	85/439 (19)	0.004
Initial comfort	461/489 (94)	403/439 (92)	0.15
Paresthesia	56/489 (11)	43/440 (10)	0.46
Asymmetric initial block[b]	19/489 (4)	21/439 (5)	0.52
Physician top-up	172/489 (35)	146/439 (33)	0.58
Catheter replaced	14/489 (3)	18/439 (4)	0.37
Intravenous catheter	0/489 (0)	1/440 (0)	0.47
Intrathecal catheter	8/489 (2)	5/440 (1)	0.59
Unintentional dural puncture	10/489 (2)	5/440 (1)	0.31
Lidocaine test dose	46/485 (9)	80/435 (18)	<0.0001

Values are *n*/*N* (%) or median (IQR).

IQR = interquartile range.

[a] Unsatisfactory block was defined as one or more of absence of initial comfort on block initiation, asymmetric block, intravenous or intrathecal catheter, or catheter replacement.

[b] Asymmetric initial block was defined as ineffective analgesia after initiating the block and documented asymmetry defined as a difference in decreased sensation to pinprick of at least 3 dermatomes.

Table 3. Outcomes for Subjects Receiving Conventional Epidural Blocks

Variable	Air (*N* = 323)	Saline (*N* = 371)	*P*
Unsatisfactory block[a]	41/323 (13)	40/371 (11)	0.48
Number of attempts	1 (1–2)	1 (1–1)	0.002
More than 1 attempt	93/321 (29)	72/370 (19)	0.004
Initial comfort	297/323 (92)	340/370 (92)	1.0
Paresthesia	46/323 (14)	37/371 (10)	0.10
Asymmetric initial block[b]	17/323 (5)	18/370 (5)	0.86
Physician top-up	127/323 (39)	127/370 (34)	0.18
Catheter replaced	14/323 (4)	15/370 (4)	0.85
Intravenous catheter	0/323 (0)	1/371 (0)	1.0
Intrathecal catheter	8/323 (2)	4/371 (1)	0.24
Unintentional dural puncture	10/323 (3)	4/371 (1)	0.10
Lidocaine test dose	45/320 (14)	77/367 (21)	0.02

Values are *n*/*N* (%) or median (IQR).

IQR = interquartile range.

[a] Unsatisfactory block was defined as one or more of absence of initial comfort on block initiation, asymmetric block, intravenous or intrathecal catheter, or catheter replacement.

[b] Asymmetric initial block was defined as ineffective analgesia after initiating the block and documented asymmetry defined as a difference in decreased sensation to pinprick of at least 3 dermatomes.

Training level of operators differed between the 2 media ($P = 0.01$), with attending physicians and fellows more frequently using saline and junior and senior residents more frequently using air (data not shown). Controlling for training level in logistic regression models did not alter the effect of LOR medium on any of the analgesic outcomes.

Among operators with a preference for 1 medium, defined as >70% of cases using either air or saline, use of the preferred technique was associated with fewer attempts (median [interquartile range], 1 [1–1] vs 1 [1–2], $P < 0.001$), fewer paresthesias (8.7% vs 18.5%, OR = 0.42, $P = 0.007$), and fewer unintentional dural punctures (1.0% vs 4.4%, OR = 0.23, $P = 0.03$).

DISCUSSION

Our data suggest that anesthesiologists generally have a strong preference for either air or saline for LOR, and in actual clinical use, analgesic outcomes are nearly identical with the 2 media. Conversely, when using the CSE technique, air is associated with fewer failures. Importantly, regardless of an operator's preference, when using the less-preferred medium, some outcomes seemed to be worsened.

Our study was retrospective and would therefore traditionally be considered to be weaker evidence than that from an RCT. We believe, however, that this is not the case for this particular clinical question. Because RCTs would require anesthesiologists to use a less-preferred technique 50% of the time, and because we have shown not only that few operators are ambivalent but also that the less-preferred technique may be less successful, such trials may exaggerate the difference between techniques. In this respect, RCTs may be interpreted as having internal consistency but limited external validity.

In addition, the RCTs comparing air with saline for LOR are not of high quality. Six trials have addressed the incidence of incomplete analgesia after LOR to saline versus air.[5,6,8–11] Various definitions of inadequate block were used, and the overall incidence reported varies between 2% and 36%. Two studies[5,11] found no difference between air and saline, and a third[10] found an identical number of dermatomes blocked and visual analog scale scores. This latter trial claimed a difference in "segmental block" favoring saline, but reanalysis of the report's data shows no difference between the treatments (Fisher's exact test, $P = 0.43$). Valentine et al.[6] randomized 50 parturients to LOR to air or saline and found 8 of 25 (32%) in the air group compared with 2 of 25 (8%) in the saline group had unblocked T12 or L1 dermatomes after the administration of 8 mL of 0.5% bupivacaine. All blocks were complete after an additional 4 mL of bupivacaine, highlighting the importance of high volume

Table 4. Outcomes in Subjects Receiving CSE Blocks

Variable	Air ($N = 166$)	Saline ($N = 69$)	P
Unsatisfactory block[a]	2/165 (1)	7/65 (11)	0.002
Number of attempts	1 (1–1.8)	1 (1–1)	0.38
More than 1 attempt (%)	41/165 (25)	13/69 (19)	0.40
Initial comfort (%)	164/169 (97)	63/69 (91)	0.009
Paresthesia (%)	10/166 (6)	6/69 (9)	0.57
Asymmetric initial block[b] (%)	2/166 (1)	3/69 (4)	0.15
Physician top-up (%)	45/166 (27)	19/69 (28)	1.0
Catheter replaced (%)	0/166 (0)	3/69 (4)	0.03
Intravenous catheter (%)	0/166 (0)	0/69 (0)	—
Intrathecal catheter (%)	0/166 (0)	1/69 (1)	0.29
Unintentional dural puncture (%)	0/166 (0)	1/69 (1)	0.29
Lidocaine test dose (%)	1/164 (1)	2/64 (3)	0.19

Values are *n/N* (%) or median (IQR).

CSE = combined spinal epidural; IQR = interquartile range.

[a] Unsatisfactory block was defined as one or more of absence of initial comfort on block initiation, asymmetric block, intravenous or intrathecal catheter, or catheter replacement.

[b] Asymmetric initial block was defined as ineffective analgesia after initiating the block and documented asymmetry defined as a difference in decreased sensation to pinprick of at least 3 dermatomes.

when initiating an epidural block. Most practitioners today would not use this low-volume, high-concentration methodology. Beilin et al.[8] randomized 160 women to air or saline for LOR. Fifteen minutes after administering 10 mL of 0.25% bupivacaine, women were asked during a contraction whether they desired more medication for pain. A high percentage of women in both groups answered affirmatively, again highlighting the disadvantage of low-volume initiation of the block. However, patients randomized to air asked more frequently (36% vs 19%, $P = 0.02$). Interestingly, median pain scores were not different at the time of inquiry, and 5 mL of additional bupivacaine improved virtually all the blocks to the patients' satisfaction. Finally, Evron et al.[9] randomized women to LOR to air or lidocaine followed by a 3-mL test dose of lidocaine 2% and then 10 mL of 0.2% ropivacaine and, not surprisingly, found that those in the lidocaine group had fewer incomplete blocks. Interestingly, a third group, randomized to LOR to air followed by lidocaine, had an even lower incidence of unblocked segments. Taken together, these 6 trials do not offer strong support for saline over air for LOR regarding incomplete analgesia.

Similarly, some reviews have suggested that saline is superior to air with respect to ease of insertion of the epidural catheter or incidence of paresthesia.[2] Neither Sarna et al.[5] nor Beilin et al.[8] could demonstrate any difference in either of these variables. Our data are in agreement with this finding. Evron et al.[9] reported greater difficulty passing epidural catheters in the group randomized to air. However, other investigators have shown that injection of saline after identification of the epidural space with air eases passage of the catheter.[14] A recent systematic review of RCTs evaluating strategies to avoid intravascular placement confirmed that fluid injection before catheter insertion was associated with a lower incidence of intravascular catheter placements.[15]

Some investigators have claimed that use of air is associated with a higher incidence of unintentional dural puncture. Evron et al.[9] found a difference across all treatment groups (air, air + lidocaine, and lidocaine) but no pairwise differences between any groups. Six other studies found no difference.[5–8,10,11] Aida et al.,[7] in a personal series of several thousand chronic pain patients allocated in alternating weeks to air or saline LOR, found no difference in dural puncture rates but an increased incidence of headache with air, which was attributed to pneumocephalus from intrathecal injection. Although our study was not powered to detect differences in dural puncture rates, we found no difference between LOR media in the entire cohort or the epidural subset.

Finally, case reports have also occasionally implicated LOR to air in the pathogenesis of venous air emboli, headache from pneumocephalus, nerve root compression, and subcutaneous emphysema.[2] Such events are evidently quite rare and may be related to large volumes of air injected upon localization of the epidural space. We do not advocate such practice when using LOR to air. Moreover, at least some of these complications have been reported after LOR to saline.[16]

We did find a small but statistically significant increase in the number of attempts required to locate the epidural space with LOR to air compared with saline. There are several possible explanations. First, the number of attempts is self-reported and at the discretion of the operator. Different anesthesiologists, perhaps influenced by training level, may interpret the meaning of "attempt" differently. Second, more senior residents, who are likely preferentially assigned to more complicated cases, tended to use air more frequently. Third, attendings and fellows, who tended to use saline more frequently, may require fewer attempts because of greater experience. In any case, the difference in number of attempts was small and probably of minimal clinical significance.

We also found some differences between air and saline for LOR with respect to the 2 study months and techniques used. Saline was used much more frequently in the second study month than in the first, as was a lidocaine test dose (data not shown). Administration of a lidocaine test dose was more common in the saline group, although lidocaine was not associated with differences in analgesic outcomes. We

speculate that both changes resulted from a change in packaging of the epidural tray between study months; the 2007 kit included the identical epidural needle and catheter as the 2006 version, but it included prepackaged saline and lidocaine. Thus, the significant increase in use of saline between 2006 and 2007 is likely because providers no longer needed to add it to their procedure tray. Also, the CSE technique was more frequently used in the air group. This might have introduced bias in favor of LOR to air, because the CSE technique is associated with some better analgesic outcomes.[12] However, subgroup analysis showed that the results among patients receiving the conventional epidural technique were similar to those in the overall cohort.

Although we do not advocate the use of air over saline in general, our data suggest that it may be superior when using the CSE technique. Failed blocks and need for catheter replacement were less frequent when air was used rather than saline. We speculate that saline returning from the spinal needle may be occasionally mistaken for cerebrospinal fluid when the epidural needle is not yet in the epidural space, resulting in a failed block.

In summary, this "real world" effectiveness study found no significant difference between air and saline when used at the anesthesiologist's discretion for localization of the epidural space by LOR. RCTs of the 2 media may overstate the difference between them by forcing the operator to use a less-preferred technique.

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