A Systematic Review of Randomized Controlled Trials That Evaluate Strategies to Avoid Epidural Vein Cannulation During Obstetric Epidural Catheter Placement

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BACKGROUND: In this systematic review, we evaluated the evidence for seven strategies which have been proposed to minimize the incidence of epidural vein cannulation during lumbar epidural catheter placement in pregnant women.

METHODS: Multiple databases were searched to identify prospective, randomized, controlled trials between December 1966 and October 2007 that evaluated methods to avoid epidural vein cannulation after lumbar epidural catheter placement in pregnant women. Published trials were evaluated using a quality assessment tool, and results were combined to evaluate efficacy to prevent epidural vein cannulation.

RESULTS: Of 90 trials screened, 30 trials were included (n = 12,738 subjects). Five strategies reduce the risk of epidural vein cannulation: the lateral as opposed to sitting position (six trials, mean (SD) quality score = 35% [11%], odds ratio (OR) 0.53 [95% confidence interval (CI) 0.32–0.86]), fluid administered through the epidural needle before catheter insertion (8 trials, quality score 48% [18%], OR 0.49 [95% CI 0.25–0.97]), single rather than multiorifice catheter (5 trials, quality score 30% [6%], OR 0.64 [95% CI 0.45–0.91]), a wire-embedded polyurethane compared with polyamide epidural catheter (1 trial, 31%, plus 4 unscored abstracts, OR 0.14 [95% CI 0.06–0.30]) and catheter insertion depth ≤6 cm (2 trials, 47% [11%], OR 0.27 [95% CI 0.10–0.74]). The paramedian as opposed to midline needle approach and smaller epidural needle or catheter gauges do not reduce the risk of epidural vein cannulation.

CONCLUSION: The risk of intravascular placement of a lumbar epidural catheter in pregnancy may be reduced with the lateral patient position, fluid predistension, a single orifice catheter, a wire-embedded polyurethane epidural catheter and limiting the depth of catheter insertion to 6 cm or less. In general, low manuscript quality weakens the strength of these conclusions.

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Unintended epidural vein injury complicates as many as 9% of lumbar epidural catheter placements, with higher rates reported in pregnant patients compared with nonpregnant patients.[1–7] If unrecognized, the consequences of intravascular local anesthetic administration can be life-threatening, including seizures, cardiovascular toxicity and cardiovascular collapse.[8,9] Even when recognized during initiation of anesthesia or before the onset of significant sequelae, an intravascular catheter can still hinder patient care. Manipulation or replacement of the catheter can lead to analgesic delays and additional risks. Withdrawing the epidural catheter 1 or 2 cm may be helpful in some cases,[1] but may increase the risk of subsequent analgesic failure.[10,11] Replacing the catheter may result in repeated intravascular cannulations. Norris et al.[2] reported a 5.5% rate of intravascular catheters among primary catheter placements. Of the 48 women who received at least one replacement attempt after an intravascular catheter, five were diagnosed with a second intravascular insertion, and one was diagnosed with a third intravascular insertion.[2] Strategies to avoid epidural vein cannulation during the initial epidural catheter placement may facilitate both efficient and safe epidural anesthesia and analgesia.

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This systematic review evaluates the evidence for seven strategies in pregnant women that have been proposed to minimize epidural vein cannulation during lumbar epidural catheter placement: 1) positioning the patient in the lateral as opposed to sitting posture; 2) using the paramedian as opposed to the midline approach to the epidural space; 3) using a smaller epidural needle or catheter compared with larger; 4) injecting fluid through the epidural needle before inserting the catheter compared with inserting the catheter without fluid injection; 5) using a single versus multiorifice catheter; 6) using a wire embedded polyurethane catheter versus alternative designs; and 7) limiting the depth of catheter insertion.

METHODS

Literature Review

In 2007, Medline, Excerpta Medical Data (EMBASE), the Cochrane Central Register of Controlled Trials, and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) database were searched to identify randomized controlled trials (RCTs) published in any language between 1968 and 2007 that tested elements of lumbar epidural catheter insertion. A preliminary Medline search used free-text terms for the procedure of interest (epidural analgesia or anesthesia) and the outcome of interest (epidural vein or intravascular). The final search strategy combined medical subject headings assigned to relevant trials, and excluded headings found only in nonrelevant trials (Web Supplement available at http://www.anesthesia-analgesia.org). This search strategy was applied to Cochrane Central Register of Controlled Trials and the CINAHL database, and adapted to search EMBASE. Reference lists for all relevant papers were reviewed, and trials were entered into the Institute for Scientific Information Web of Knowledge to identify citing articles.

Relevant publications were reviewed independently by two reviewers using a standard abstraction form to verify inclusion and exclusion criteria, and to ascertain study methodology and results. Disagreements were resolved by discussion. An effort was made to contact the corresponding author for each publication to clarify any specific techniques of epidural catheter insertion not reported in the published paper.

Trial Quality

To evaluate study quality, a modified version of the Chalmers weighted quality assessment tool[12–14] was used to evaluate seven domains associated with the study protocol and six domains related to data analysis. Three modifications were introduced. First, the study was deemed appropriately controlled and given a full score (3 of 3) if all aspects of management between the control and study groups were identical except the stated intervention. Second, the requirement for patient blinding was considered not applicable for all studies that evaluated patient position. Third, the domain for testing compliance was omitted. For each study, three authors completed a standardized form of the quality evaluation checklist. Disagreements were resolved by discussion.

Operational Definition of Intravascular Cannulation

There is no ideal test for intravascular cannulation.[15] Each study was reported with the testing method used and the number of intravascular catheters diagnosed. For those manuscripts in which the number of intravascular epidural catheters was not precisely defined, the authors were contacted for clarification.

In some protocols, intravascular catheters were replaced using the technique originally assigned during random allocation, and the second placement was included in the statistical analysis as an independent placement attempt. For this systematic review, only the results from the primary placement attempts were included in the analysis.

Two studies comparing single and multiorifice catheters reported intravascular cannulation as a series of nonexclusive outcomes.[16,17] To calculate a minimum difference, the numerators chosen for meta-analysis represented the maximum possible number of intravascular cannulations with a single orifice catheter (lower value) and the minimum possible number of intravascular cannulations with a multiorifice catheter (higher value).

Only one published trial compared a wire-embedded polyurethane epidural catheter with a control catheter. However, four large unpublished RCTs were identified. A *post hoc* analysis included both this published RCT and the unpublished RCTs presented at North American anesthesiology meetings between 1992 and 2007. For all relevant abstracts, details about catheter insertion and epidural vein cannulation were abstracted, but quality scores were not assigned.

Data Analysis

For strategies with at least two comparable RCTs, individual study results were combined using the random effects model on an intent-to-treat basis in Stata 9.0 (College Station, TX). Odds ratio (OR) and 95% confidence intervals (CI) were calculated for dichotomous data by using the methods of DerSimonian and Laird.[18] A statistical difference between groups was considered to occur if the pooled 95% CI for the OR did not include 1. The χ^2 test was used to evaluate heterogeneity, with a P value below 0.10 considered statistically significant.[19] In cases in which significant heterogeneity was detected among a group of studies, potential explanatory variables were tested using metaregression.

RESULTS

Thirty RCTs of strategies proposed to decrease the risk of epidural vein cannulation were included (Fig. 1). Included studies were published in English between 1984 and 2007. The overall incidence of intravascular

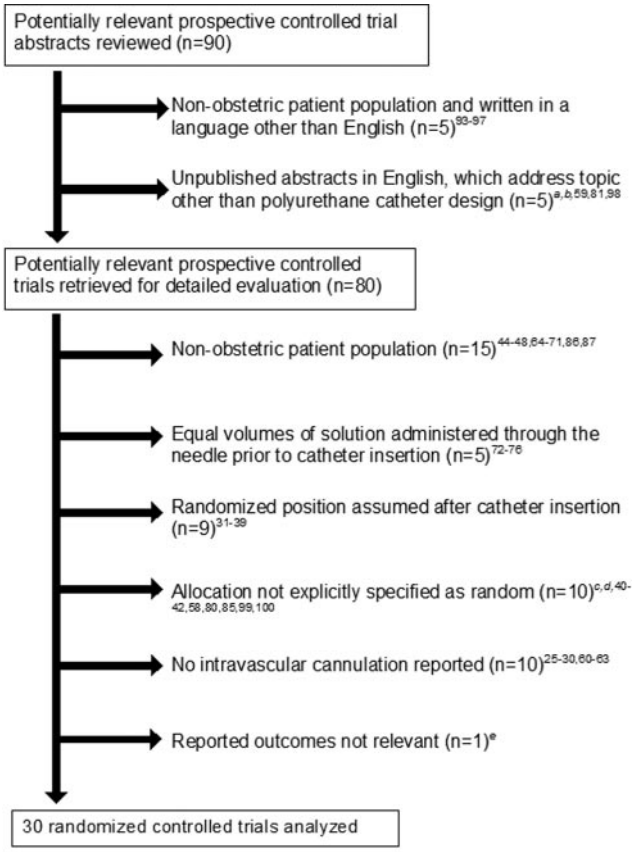

Figure 1. Flow diagram to illustrate excluded trials. [a]Ahn NN, Ung DA, DeFay S, Cannelli G, Rudy TE, McKenzie R. Blood vessel puncture with epidural catheters. Anesthesiology 1989;51:A916. [b]Herbstman C, Newman L. Evaluation of single versus multiple orifice epidural catheters in laboring women. Anesthesiology 1997;87:A908. [c]Mandell G, Ramanthan S. Single orifice soft-tipped catheters vs multi orifice firm-tipped catheters for epidural analgesia. Anesthesiology 1999;91:A1104. [d]Hayashi RD, Cross JS, Jones BR. Efficacy and complications of two types of epidural catheters for obstetric anesthesia. Anesthesiology 2001;94:A26. [e]Cohen S, Lin A, Pantuck CB, Pantuck E, Cioce L. Arrow versus B Braun epidural catheter for epidural block in obstetric patients. Anesthesiology, 2004;101:A1199.

catheter placement was 6.2% (795 of 12,738; 95% CI 5.8%–6.7%). An additional 10 trials evaluated 1 of the 7 interventions, but did not report any intravascular catheter placements in either group. Assuming there were no intravascular cannulations in these studies, the overall incidence of intravascular catheter placement was 5.9% (795 of 13,406; 95% CI 5.5%–6.3%).

Patient Position

Six studies compared the sitting with the lateral horizontal patient position and reported at least one intravascular cannulation in 1403 pregnant women (Table 1 [expanded Table available as a Web Supplement at http://www.anesthesia-analgesia.org]).[10,20–24] Eighteen trials were excluded because they did not report any cases of intravascular catheter placement,[25–30] because the randomized position was assumed after epidural insertion,[31–39] or because allocation was not specified as random.[40–42] Two included trials also evaluated the lateral head-down position.[20,21] Two trials evaluated the combined spinal-epidural technique for cesarean delivery in 150 parturients[22,23] and all others evaluated an epidural technique for labor analgesia. In three trials, intravascular catheter placement was the primary outcome.[10,20,21]

Among included trials, the mean SD quality score was 35% (11%). Based on these trials, the placement of the epidural catheter with the patient in the lateral position compared with the sitting position reduces the epidural vein cannulation rate (OR 0.53, 95% CI 0.32–0.86) (Fig. 2) from 11.9% (81 of 683) to 6.7% (48 of 720). The χ^2 test for heterogeneity was not significant ($P = 0.31$). The corresponding rates of intravascular catheter placement decrease to 9.5% (81 of 849) and 5.1% (48 of 934), respectively, if the 6 trials without any cases of intravascular catheter placement[25–30] are included.

Anatomic Approach

One study compared the midline and paramedian approach to the lumbar epidural space in 165 pregnant women (Table 1).[43] The paramedian approach resulted in no significant difference in the rate of intravascular catheterization ($P = 0.90$). Six studies evaluating anatomic approach were excluded because they were conducted in nonpregnant adults[44–48] or were published solely in abstract form.*

Needle and Catheter Gauge

One study evaluated the effect of epidural needle and catheter gauge on the incidence of epidural vein cannulation (Table 1)[49] by comparing the 16- and 18-gauge Portex Minipack epidural systems (Hythe, United Kingdom) in which the 16-gauge Tuohy needle carries a 19-gauge nylon epidural catheter, and the 18-gauge Tuohy needle carries a 20-gauge nylon epidural catheter.† The 16-gauge system was no more likely to result in blood return after Tuohy insertion ($P = 0.25$) or after catheter insertion ($P = 0.75$).

Fluid Injection Before Catheter Insertion

Eight trials compared two different volumes of fluid injection through the epidural needle before catheter insertion in 1427 pregnant women (Table 1).[50–57] Of these, two evaluated a loss-of-resistance to air technique versus loss-of-resistance to either saline or local anesthetic for identification of the epidural space.[50,56] An additional five trials used a standard method for loss-of-resistance, but then evaluated the injection of additional fluid through the epidural needle before threading the epidural catheter.[51,52,54,55,57] The final study evaluated both

*Landa S, Pai K, Winikoff S. The insertion angle of the epidural needle affects the success of the blockade. Anesthesiology 2003;98:A113.

†Information received from Lisa Smith, International Custom Kitting Advisor, Smiths Medical International, e-mail dated September 19, 2007.

Table 1. Studies of Strategies to Reduce Epidural Vein Cannulation

Author, year	Population and primary outcome	Test for IV placement	Results: Group A	Results: Group B	Results: Group C	Quality score (%)
Sitting versus lateral patient position (n = 1403 plus 450 lateral head-down)						
Bahar, 2001[20]	Labor epidural analgesia; blood in epidural catheter	Passive flow or aspiration of blood, or neurologic symptoms with lidocaine 60 mg	Sitting 10.7% (32 of 300)	Lateral 6.0% (18 of 300)	Lateral head-down 2.0% (6 of 300)	25
Bahar, 2004[21]	Labor epidural analgesia; blood in epidural catheter	Passive flow of blood or neurologic symptoms with lidocaine 60 mg	Sitting 13.3% (20 of 150)	Lateral 7.3% (11 of 150)	Lateral head-down 2% (3 of 150)	31
Coppejans, 2006[22]	CSE analgesia for cesarean delivery; difference in lowest SBP before delivery	Blood in the epidural catheter	Sitting 0% (0 of 30)	Lateral 3.3% (1 of 30)		54
Harney, 2005[10]	Labor epidural analgesia; epidural vein cannulation	Passive flow of blood	Sitting 15.7% (16 of 102)	Lateral 3.7% (4 of 107)		34
Russell, 2002[23]	CSE analgesia for cesarean delivery; spinal block height	Aspiration of blood	Sitting 0% (0 of 30)	Lateral 6.7% (2 of 30)	Oxford[a] position 10.0% (3 of 30)	42
Stone, 1990[24]	Labor epidural analgesia; ease of insertion, complication rates, patient discomfort	Not reported	Sitting 18.3% (13 of 71)	Lateral 12.3% (9 of 73)		25
Midline versus paramedian approach (n = 165)						
Griffin, 1984[43]	Labor epidural analgesia; ease of insertion, complications	"Penetration of a vessel by the catheter"; test dose of bupivacaine 10 mg	Midline 8.1% (7 of 86)	Paramedian 7.6% (6 of 79)		19
Needle and catheter gauge (n = 685)						
McNeill, 1988[49]	Labor epidural analgesia; complication rates, ease of use, patient discomfort	Needle: bleeding following needle insertion; catheter: blood aspirated, or blood in the catheter but unable to aspirate	Needle: 16-gauge Tuohy 3.6% (12 of 334) Catheter: 19-gauge[b] 15.9% (53 of 334)	18-gauge Tuohy 2.0% (7 of 351) 20-gauge[b] 14.8% (52 of 351)		23
Fluid injection through the epidural needle prior to catheter insertion (n = 1427)						
Beilin, 2000[50]	Labor epidural analgesia; unacceptable analgesia	Aspiration of blood or neurologic symptoms with bupivacaine 7.5 mg	0 mL[c] 5.0% (4 of 80)	2 mL[c] 7.5% (6 of 80)		53
Crochetière, 1989[51]	Epidural anesthesia for cesarean delivery; quality of analgesia, incidence of complications, maternal and fetal local anesthetic concentrations	Aspiration of blood; pharmacologic test dose (lidocaine 60 mg and epinephrine 15 μg) administered through the needle in the 0 mL group and through the catheter in the 20 mL group	0 mL[c] 13.6% (3 of 22)	23 mL[c] 17.4% (4 of 23)		28
Evron, 2004[53]	Labor epidural analgesia; inability to insert epidural catheter	Aspiration of frank blood, or neurologic symptoms with lidocaine 60 mg	Air only (0 mL)[c] 17.2% (31 of 180)[d]	Lidocaine only (3 mL)[c] 5.9% (11 of 185)[d]	Air plus lidocaine (3 mL)[c] 7.7% (14 of 182)[d]	44
Evron, 2007[52]	Labor epidural analgesia; intravascular epidural catheter insertion	Passive flow or aspiration of frank blood, or neurologic symptoms with lidocaine 45 mg	2 mL[c] 15.8% (16 of 101)	5 mL[c] 2.0% (2 of 102)		79
Gadalla, 2003[54]	Labor CSE analgesia; intravascular epidural catheter insertion	Passive flow or aspiration of frank blood, or increased heart rate with epinephrine 15 μg, or precordial doppler to detect 1.5 mL air	0 mL[c] 20.0% (10 of 50)	10 mL[c] 2.0% (1 of 50)		43
Rolbin, 1990[55]	Labor epidural analgesia; incidence of paresthesia	Passive flow or aspiration of blood, or neurologic symptoms with lidocaine 45 mg followed by bupivacaine 15 mg	0 mL[e] 10.4% (8 of 77)	3 mL[e] 9.8% (12 of 123)		24

(*Continued*)

Table 1. Continued

Author, year	Population and primary outcome	Test for IV placement	Results: Group A	Results: Group B	Results: Group C	Quality score (%)
Sarna, 1990[56]	Epidural analgesia/ anesthesia for all deliveries; incidence of paresthesia	Not reported	0 mL[e] 9.4% (3 of 32)	10 mL[e] 5.7% (2 of 35)		50
Siddik-Sayyid, 2006[57]	Labor epidural analgesia; total number of dermatomes blocked	Passive flow or aspiration of blood, or increased heart rate with epinephrine 15 μg coadministered with lidocaine 60 mg	2 mL[e] 3.8% (2 of 53)	10 mL[e] 1.9% (1 of 52)		68
Single versus multiorifice catheters (n = 2227)						
Collier, 1994[77]	Epidural analgesia/ anesthesia for all deliveries; proportion of unsatisfactory analgesia or anesthesia	Presence of a column of blood in the catheter, or aspiration of blood before or after test dose, or untoward effects in response to a test dose consisting of bupivacaine 15 mg (for labor) or lidocaine 80 mg with epinephrine 20 μg (for cesarean)	Multiorifice 7.7% (4 of 52)	Single orifice 4.0% (2 of 50)		28
D'Angelo, 1997[78]	Labor epidural analgesia; insertion-related complication rates	Aspiration of frank blood, or neurologic symptoms after lidocaine 40 + 100 mg	Multiorifice 6.5% (16 of 245)	Single orifice 7.0% (17 of 242)		35
Dickson, 1997[16]	Labor epidural analgesia; efficacy and incidence of complications	Aspiration of blood or blood-tinged fluid; "toxic" symptoms with lidocaine 80 mg	Blood in the catheter: Multiorifice 12.0% (21 of 175)[d]	Single orifice 4.3% (8 of 187)[d]		23
			"Toxic" symptoms on test dose: Multiorifice 1.7% (3 of 175)[d]	Single orifice 1.6% (3 of 187)[d]		
			Intravascular catheter (blood in catheter or "toxic" symptoms): Multiorifice 12.6%–13.1% (22–23/175)[d,e]	Single orifice 4.8–5.3% (9–10/187)[d,e]		
Michael, 1989[79]	Labor epidural analgesia; incidence of complications, quality of sensory block	Blood in the catheter, or symptoms of intravenous bupivacaine 10 mg, or increased heart rate with epinephrine 10 μg palpated by a blinded observer	Multiorifice 10.5% (42 of 401)	Single orifice 5.7% (23 of 401)		37
Morrison, 1990[17]	Epidural analgesia/ anesthesia for all deliveries; incidence of adverse events	Passive flow of frank blood; aspiration of frank blood before and after test dose; "toxic" symptoms with lidocaine 80 mg	Blood in catheter: Multiorifice 11.4% (26 of 229)	Single orifice 3.3% (8 of 245)		28
			Aspiration of blood before test dose: Multiorifice 7.4% (17 of 229)	Single orifice 4.1% (10 of 245)		
			Test dose: 0%	0%		
			Aspiration of blood after test dose: Multiorifice 2.2% (5 of 229)	Single orifice 2.4% (6 of 245)		
Wire-embedded polyurethane catheter versus polyamide catheters (n = 5903)						
Banwell, 1998[82]	Labor epidural analgesia; incidence of venous cannulation, paresthesia	Aspiration of blood or neurologic symptoms with lidocaine 60 mg[d]	Portex 11.3% (11 of 97)	Arrow 0% (0 of 103)		31
Cohen, 2006[83]	Labor epidurals; multiple outcomes	Passive return or aspiration of blood, increase in heart rate[d] with epinephrine 10 μg, neurologic symptoms[d] with ropivacaine 5 mg	B Braun 1.8% (20 of 1095)	Arrow 0.5% (6 of 1095)		Abstract, quality not evaluated

(*Continued*)

Table 1. Continued

Author, year	Population and primary outcome	Test for IV placement	Results: Group A	Results: Group B	Results: Group C		Quality score (%)
Juneja, 1996*	Labor epidural analgesia; incidence of venous cannulation	Aspiration of blood	B Braun 4.7% (52 of 1110)	Arrow 0.5% (6 of 1122)	Kendall 5.6% (63 of 1122)		Abstract, quality not evaluated
Sarna, 1996†	Labor epidural analgesia; multiple outcomes	Independent observer noted presence of blood in catheter; increased heart rate with 15 μg epinephrine	Portex 7.1% (2 of 28)	Arrow 0% (0 of 26)			Abstract, quality not evaluated
Sakr, 2005[84]	CSE anesthesia for elective cesarean delivery; multiple outcomes	Aspiration of blood; increased heart rate with 15 μg epinephrine	Arrow 0% (0 of 52)	B Braun 18.9% (10 of 53)			Abstract, quality not evaluated
Polyurethane versus polyamide catheters (n = 150)							
Rolbin, 1987[88]	Labor epidurals; evaluation of 2 types of catheters	Spontaneous return or aspiration of blood	Portex 12.0% (9 of 75)	Vas-Cath 6.7% (5 of 75)			19
Epidural catheter insertion depth (n = 963)							
Beilin, 1995[89]	Labor epidural analgesia; optimal length defined as the highest rate of successful analgesia and lowest complication rate	Aspiration of blood or neurologic symptoms with bupivacaine 7.5 mg	7 cm 21.2% (7 of 33)	5 cm 3.1% (1 of 32)	3 cm 2.9% (1 of 35)		48
Cartagena, 2005[90]	Labor epidural analgesia; intravascular placements	Aspiration of blood or neurologic symptoms with lidocaine 45 mg or increased heart rate with epinephrine 15 μg	Inserted 5 cm 7.5% (3 of 40)	Inserted 10 cm and retracted to 5 cm 10.3% (4 of 39)			45
D'Angelo, 1996[11]	Labor epidural analgesia; catheter related complications	Aspiration of blood or neurologic symptoms with lidocaine 40 mg followed by 100 mg	8 cm 14.2% (27 of 190)	6 cm 5.6% (11 of 196)	4 cm 6.6% (13 of 198)	2 cm 5.0% (10 of 200)	40

IV = intravascular; CSE = combined spinal epidural; SBP = systolic blood pressure.

[a] The Oxford position is a modification of the left lateral decubitus position in which a 3-L inflatable bag is placed under the shoulder, and three pillows support the head, producing an upward slope in the mid-thoracic region.[23] Outcomes for this group were pooled with those of the lateral position for the purpose of meta-analysis.

[b] Information received from Lisa Smith, International Custom Kitting Advisor, Smiths Medical International, e-mail dated September 19, 2007.

[c] Includes the total volume of either saline or local anesthetic solution injected through the epidural needle prior to inserting the epidural catheter. Volume excludes any air injected during loss of resistance procedure used to identify the epidural space.

[d] Information received by e-mail from the authors.

*Juneja MM, Kargas G, Miller D, Perry E, Botick Z, Rigor B. Incidence of epidural vein cannulation in parturients with three different epidural catheters. Reg Anesth 1996;21:4.

†Sarna MC, Soni AK, Oriol NE. Comparison of flexometallic and nylon catheters for epidural labor analgesia in parturients using midline and paramedian approach. Anesthesiology 1996;9660.

[e] Based on personal communication with the authors, among single orifice catheters, there were 8 cases of blood in the catheter and 3 cases of toxic symptoms. Among multiorifice catheters, there were 21 cases of blood in the catheter and 3 cases of toxic symptoms. For both the multiorifice and single orifice groups, there was some combination in which at least one woman, but not all three, had both conditions.

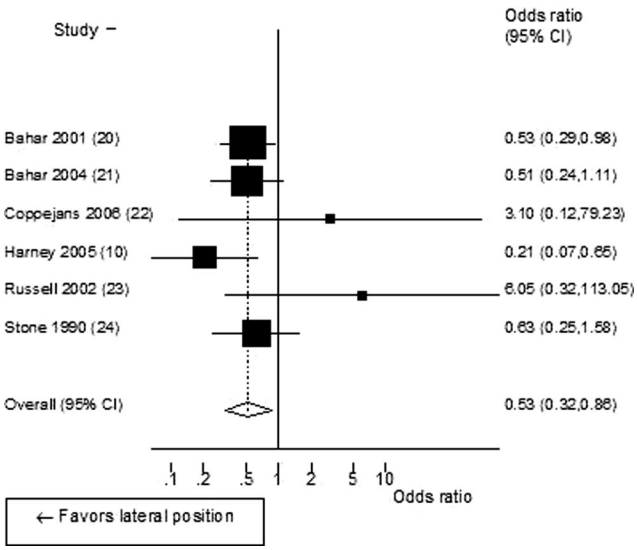

Figure 2. Pooled results of the effect of patient position on rate of intravascular cannulation.

the effect of loss-of-resistance media and predistension of the epidural space with fluid.[53] In four trials, intravascular catheter placement was the primary outcome.[40,52,54,58]

Twenty-two trials compared loss-of-resistance media or predistension, but were excluded because allocation was not specified as random,[40,42,58] the trial was reported solely in abstract form,‡[59] no cases of intravascular catheter placement were reported,[60–63] only nonobstetric patients were included,[64–71] or because equal volumes of solution were administered through the epidural needle before catheter insertion.[72–76]

Predistension of the epidural space with fluid reduces the risk of epidural vein cannulation (OR 0.49, 95% CI 0.25–0.97) (Fig. 3). The rate of intravascular cannulation with no predistention was 12.9% (77 of 595); the rate with predistension was 6.4% (53 of 832).

‡Ahn NN, Ung DA, DeFay S, Cannelli G, Rudy TE, McKenzie R. Blood vessel puncture with epidural catheters. Anesthesiology 1989;71:A916.

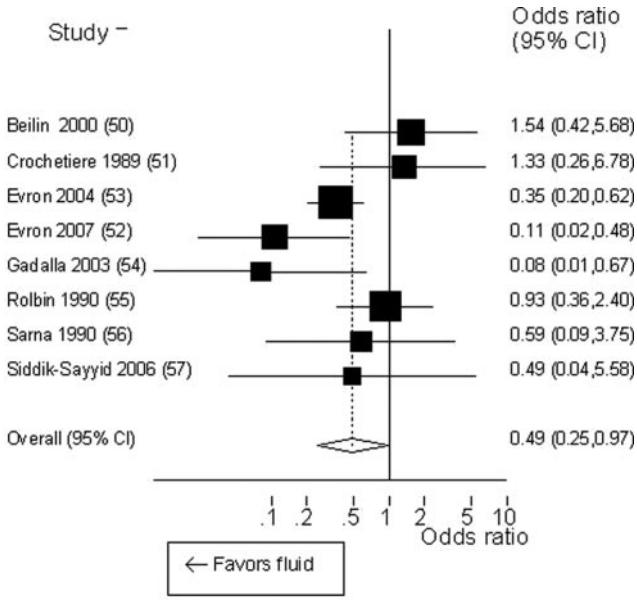

Figure 3. Pooled results of the effect of fluid injection through the epidural needle before catheter insertion on rates of intravascular cannulation.

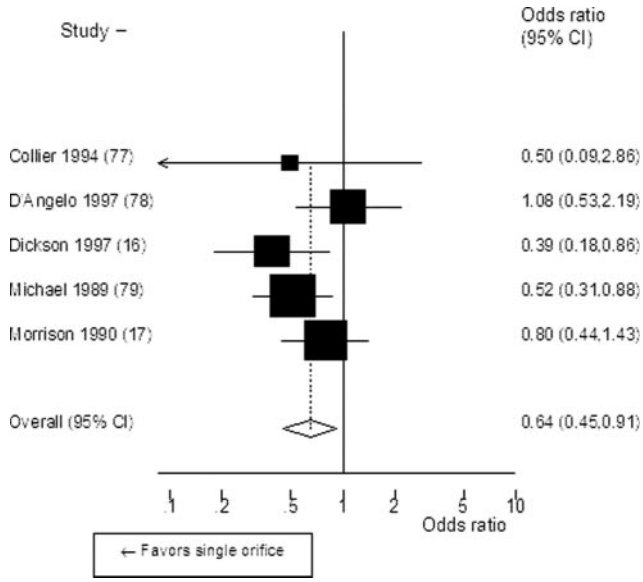

Figure 4. Pooled results of the effect of single versus multiorifice catheters on rates of intravascular cannulation. In two studies by Dickson and Morrison,[16,17] the number of intravascular cannulations was reported as a series of nonexclusive outcomes. In order to test for a minimum possible difference, the numerators entered into the meta-analysis include the maximum possible number of single-orifice intravascular catheters reported by each study respectively (10 of 187; 24 of 259) and the minimum number of multiorifice catheters reported by each study respectively (22 of 175; 26 of 229).

If trials without any cases of intravascular catheter placement[60–63] are included, the corresponding rates decrease to 10.8% (77 of 715) and 5.6% (53 of 952). The mean quality score of included trials was 48% (18%). The χ^2 test for heterogeneity was significant ($P = 0.04$) [19] with a τ^2 estimate for between-study variance of 0.43. Based on metaregression, there was a relationship between study outcome and year of publication ($P = 0.008$), with more recent trials more likely to show favorable results for fluid predistension. There was no relationship between risk of intravascular cannulation and either the quality score or the volume of solution administered through the epidural needle.

Multiorifice Catheters

Five trials compared multiorifice catheters with single-orifice epidural catheters in 2227 obstetric patients (Table 1).[16,17,77–79] In two protocols, the multiorifice catheters were inserted more deeply than the single-orifice catheters in order to ensure that the proximal orifice remained within the epidural space.[16,79] In two trials,[16,17] the outcomes are reported as a series of nonexclusive outcomes, thus the meta-analysis represents a minimum difference. In all five trials, the incidence of intravascular catheter placement was reported as one of a list of catheter-related effects, rather than as the primary outcome of the study. Three trials comparing multiorifice and single-orifice catheters were excluded, including one observational study[80] and two trials available only as abstracts.§[81]

Overall, single-orifice catheters reduced the detected epidural vein cannulation rate when compared with multiorifice catheters (OR 0.64, 95% CI 0.45–0.91) (Fig. 4) from at least 10.0% (110 of 1102 multiorifice) to at most 6.8% (76 of 1125 single-orifice). The mean quality score was 30% (6%). The χ^2 test for heterogeneity was not significant ($P = 0.31$).

Wire-Embedded Polyurethane Catheter Design

One published RCT[82] including 200 parturients, and 4 unpublished RCTs‖¶[83,84] including 5703 parturients, compared a 19-gauge single-orifice wire-embedded polyurethane epidural catheter with a nylon (polyamide) control catheter (Table 1). Eight trials were excluded because they were observational or not specifically reported as randomized,#**††‡‡[85] evaluated catheters in a nonobstetric patient population,[86,87] or did not distinguish between intravascular cannulation at the

§Herbstman C, Newman L. Evaluation of single versus multiple orifice epidural catheters in laboring women. Anesthesiology 1997;87:A908.

‖Juneja MM, Kargas G, Miller D, Perry E, Botick Z, Rigor B. Incidence of epidural vein cannulation in parturients with three different epidural catheters. Reg Anesth 1996;21:4.

¶Sarna MC, Soni AK, Oriol NE. Comparison of flexometallic and nylon catheters for epidural labor analgesia in parturients using midline and paramedian approach. Anesthesiology 1996; 9660.

#Hayashi RD, Cross JS, Jones BR. Efficacy and complications of two types of epidural catheters for obstetric anesthesia. Anesthesiology 2001;94:A26.

**Mandell G, Ramanathan S. Single orifice soft-tipped catheters vs. multi orifice firm-tipped catheters for epidural analgesia. Anesthesiology 1999;91:A1104.

††Ramanathan S, Makishima S. Single orifice soft-tip catheters vs. multi-orifice firm-tip catheters for epidural labor analgesia. Anesth Analg 1999;88:S264.

‡‡Spriggs LE, Vasdev GM, Leicht CH. Clinical evaluation of wire impregnated epidural catheter with standard epidural catheter for labor analgesia. Reg Anesth 1995;20:154.

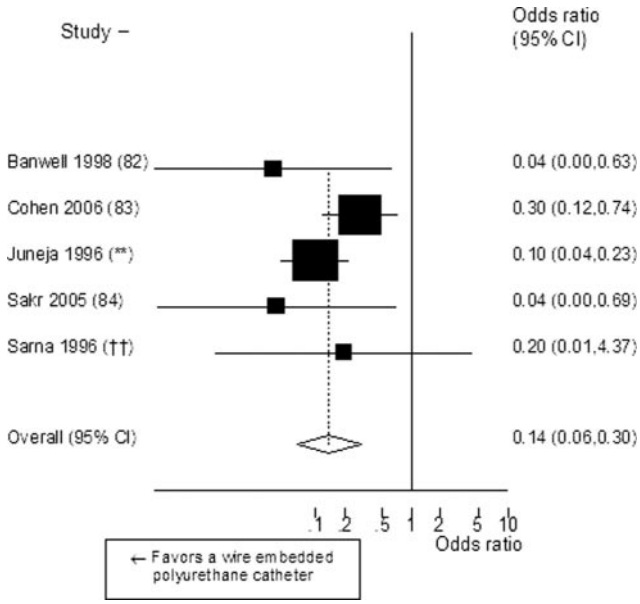

Figure 5. Pooled results of the effect of the wire-embedded polyurethane catheters compared with standard polyamide catheters on rates of intravascular cannulation, published and unpublished randomized controlled trials.

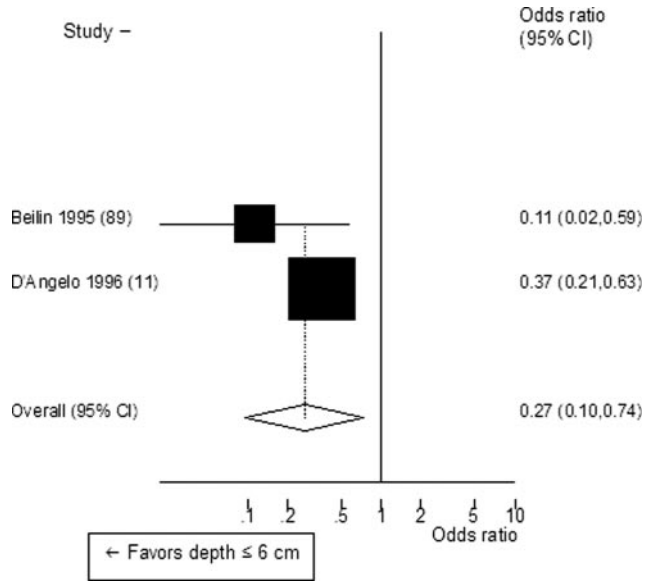

Figure 6. Pooled results of the effect of catheter insertion depth of 6 cm or less compared with more than 6 cm on rate of intravascular cannulation.

time of insertion as opposed to catheter migration during infusion.§§

Based on one published RCT, a single-orifice wire-embedded polyurethane catheter does decrease the incidence of intravascular cannulation (0%, 0 of 103) compared with a multiorifice polyamide catheter (11.3%, 11 of 97), $P < 0.001$. Pooled analysis of the published[82] and unpublished RCTs‖¶[83,84] in pregnant women demonstrates a decreased intravascular catheter rate for the wire-embedded polyurethane design compared with conventional nylon catheters (0.5% [12 of 2398] vs 4.5% [158 of 3505]; OR 0.14 [95% CI 0.06–0.30]) (Fig. 5). The χ^2 test for heterogeneity was not significant ($P = 0.26$).

An additional published RCT by Rolbin and Hew[88] demonstrated a trend towards decreased rate of intravascular cannulation with a 19-gauge multiorifice polyurethane catheter with a radio opaque strip but no wire coil, compared with a standard nylon catheter ($P = 0.26$) (Table 1).

Epidural Catheter Insertion Depth

Three trials addressed the impact of catheter insertion depth on intravascular placement (Table 1).[11,89,90] Two trials compared a series of insertion depths for single-orifice[11] and multiorifice[89] catheters in 884 parturients. Based on pooled results from these two studies, insertion depths of 6 cm or less reduce the intravascular cannulation rate compared with insertion depths of 7 cm or more from 15.2% to 5.4% (OR 0.27, 95% CI 0.10–0.74) (Fig. 6). The mean quality score for these 2 trials was 47% (SD = 11%).

§§Cohen S, Lin A, Pantuck CB, Pantuck E, Cioce L. Arrow versus B Braun epidural catheter for epidural block in obstetric patients. Anesthesiology 2004;101:A1199.

The third protocol, by Cartagena and Gaiser[90] tested if catheter insertion to a depth of 10 cm followed by catheter retraction to a final depth of 5 cm increased the risk of epidural vein cannulation when compared with insertion strictly to 5 cm. In this randomized study of 79 laboring women, the authors noted no difference in the rate of intravascular catheter placement ($P = 1.0$).

DISCUSSION

Of the seven strategies evaluated in this systematic review to avoid epidural vein cannulation during lumbar epidural catheter placement, a reduction in vein cannulation was achieved by positioning the patient in the lateral as opposed to the sitting posture, injecting fluid through the epidural needle before catheter insertion, using a single versus multiorifice catheter, using a wire-embedded polyurethane versus nylon catheter, and limiting the depth of catheter insertion to 6 cm or less. Insufficient evidence is available to support the use of the paramedian versus midline approach or smaller epidural needle or catheter sizes.

These conclusions are limited by two considerations. First, study quality averaged 38% among the 30 published RCTs identified in this systematic review, based on the quality assessment tool. A score of 80% is considered to be reasonably good using this assessment technique.[12] Only 10 of 30 studies reported a truly random method of group allocation, and only 2 ensured that group assignments remained concealed as much as possible. Two studies attempted to blind the observer measuring intravascular cannulation.[57,79] None reported that investigators refrained from interim analysis. Therefore, the strength of the conclusions based on these trials is limited.

Second, the definition of intravascular cannulation varied widely among studies. The testing method used will influence the observed rate of intravascular catheter placement.[15] For the purpose of this systematic review, the testing method used for each protocol and the number of intravascular catheters diagnosed are reported. Given the various definitions among studies, it is not possible to determine which intervention is most effective.

The lateral position seems to reduce the rate of epidural vein cannulation[10,20–24,40] in pregnant women, and the lateral head-down position may reduce the rate further.[20,21] Epidural venous engorgement related to pregnancy[91,92] may be more significant in the sitting position compared with the lateral position, although this comparison has not been directly observed. Based on magnetic resonance imaging, the degree of anterior epidural venous engorgement is reduced in the lateral, compared with the supine position in the third trimester of pregnancy.[92]

Neither needle approach nor needle or catheter gauge have been found to affect the risk of epidural vein cannulation based on published RCTs.[43,49] One unpublished RCT found a reduced risk of vein cannulation with a steeper angle of needle insertion by the midline approach.[47] Epidural catheters as small as 23-gauge are currently available, but there are no published data about the relative risk of intravascular cannulation for catheters smaller than 20-gauge.

Injection of saline or local anesthetic solution through the epidural needle reduces the risk of intravascular placement of the epidural catheter. Nevertheless, there may be disadvantages to distending the epidural space with fluid. When saline is chosen as the medium for predistension, subsequent anesthetic quality may be altered if a fixed local anesthetic dose is administered.[66,67] If local anesthetic is chosen as the medium for predistension, inadvertent intrathecal or intravascular injection through the epidural needle could result in a high spinal or systemic toxicity.

Compared with single-orifice open-tip catheters, multiorifice catheters increase the rate of observed intravascular placement. Multiorifice catheters may produce more epidural vein trauma. Alternatively, more holes may increase sensitivity for detecting blood.[77] One prospective RCT presented as an abstract comparing single and multiorifice wire-embedded polyurethane catheters demonstrated no difference in the rate of intravascular cannulation.[81]

Based on the published literature and unpublished abstracts presented in North America, a wire-embedded polyurethane catheter reduces the rate of recognized intravascular cannulations compared with a standard nylon catheter.[82] Because a single published RCT with limited methodologic quality found a large effect size,[82] *post hoc* analysis of unpublished abstract data was completed to confirm or refute the effect. The unpublished literature uniformly supports the wire-embedded polyurethane design. The effect size is so large that other techniques for reducing the risk of intravascular cannulation may be irrelevant if a wire-embedded polyurethane catheter is used. This conclusion must be tempered by two points. First, it is not possible to assign quality scores to studies published only as abstracts. Second, in four of five trials, the control catheter was clear with multiple ports, a design that may increase the likelihood of recognizing intravascular catheter placement. Several manufacturers produce wire-embedded polyurethane catheter designs, however, all published and unpublished trials compared the FlexTip Plus™ catheter (Arrow International, Reading, PA) with a control catheter.

Based on two trials that examined epidural catheter insertion depth,[11,89] a final depth ≥7 cm increases the risk of epidural vein cannulation. Initial insertion of excess catheter followed by retraction to the desired depth does not seem to increase the risk of intravascular cannulation,[90] although the sample size was insufficient to exclude Type II error. Initial insertion beyond 6 cm is not recommended for polyurethane catheters to avoid knot formation in the epidural space.

In conclusion, this systematic review supports a reduction in vein cannulation during epidural catheter placement in pregnant women with patient positioning in the lateral position, predistension of the epidural space with fluid before threading the catheter, using a single rather than multiorifice catheter, using the wired embedded polyurethane rather than nylon catheter, and limiting the depth of catheter insertion to 6 cm or less. Insufficient evidence is available to support the use of the paramedian versus midline approach or smaller needle or epidural catheter sizes. Limitations in trial quality markedly weaken these conclusions. Future higher quality studies should test the interaction between patient position, predistension, and alternative catheter designs to avoid epidural vein cannulation during lumbar epidural catheter placement for obstetric patients.

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