J Anesth (2009) 23:494–499
DOI 10.1007/s00540-009-0818-4

Journal of
Anesthesia

Insertion length and resistance during advancing of epidural catheter

Pankaj Kundra, Senthil Kumar Viswanath, Dharam S. Meena, and Ashok Badhe

Department of Anaesthesiology and Critical Care, Jawaharlal Institute of Postgraduate Medical Education and Research (J.I.P.M.E.R), Pondicherry, India

Abstract
Purpose. The migration of an epidural catheter into the intravascular and subarachnoid spaces sometimes occurs. This study was designed to investigate where the resistance was felt during the advancing of the catheter into the epidural space and whether the length of catheter advanced in the epidural space affected the incidence of catheter migration.
Methods. One hundred and twenty women, American Society of Anesthesiologists (ASA) 1 or 2, scheduled to undergo lower abdominal surgeries with epidural anesthesia were randomly assigned to two groups according to the length of the epidural catheter advanced; 4 cm ($n = 60$) or 8 cm ($n = 60$). The length where resistance to advancing the catheter was perceived was recorded in all patients, and the incidence of aspiration of blood or cerebrospinal fluid (CSF) was obtained. Further, the catheters removed 48 h after surgery were scrutinized for their bending sites.
Results. Resistance was felt in 83 (69.2%) patients and the mean length in the epidural space at which resistance was found was 2.5 ± 1.2 cm. Blood was aspirated in 9 (7.5%) patients when resistance to advancing the catheter was overcome, but CSF was aspirated in no patient. A distal bend was observed 2.4 ± 1.3 cm from the tip of the catheter, and the sites of bending were correlated with the length where resistance was encountered. An additional proximal bend was observed in 35 (58%) patients in the 8-cm group, and in 2 patients (3%) in the 4-cm group ($P < 0.001$), probably due to coiling of the catheter.
Conclusion. At approximately 2.5 cm in the epidural space, advancing an epidural catheter causes resistance. Further advancing past this point may cause migration of the catheter into the vessels, or the coiling of the catheter.

Key words Regional anesthesia · Epidural · Complications · Intravascular

Address correspondence to: P. Kundra, DII/21, J.I.P.M.E.R Campus, Pondicherry 605006, India
Received: January 6, 2009 / Accepted: July 8, 2009

Introduction

The improper spread of the local anesthetic due to variations in the epidural anatomy [1–3] and suboptimal positioning of the catheter within the epidural space [4,5] are reasons suggested for failure in epidural anesthesia. An optimal length, varying from 2 to 4 cm, has been suggested for epidural catheter insertion, but this length is associated with the risk of catheter dislodgement during fixation to the skin and patient positioning [6–9]. As a result, anesthetists tend to push in an extra length to avoid dislodgement, especially in obese patients [9]. Insertion lengths of 7 and 8 cm were reported to have a higher incidence (8%–8.3%) of intravascular placement than shorter lengths [7, 8], while in another study, the incidence of intravascular location remained the same with a 3-cm insertion length [6].

We speculate that intravascular or subarachnoid placement is likely to occur during the initial process of catheter insertion [10] when the force applied on the outside catheter is sufficient enough to be transmitted to its tip for penetrating the vessel wall. Once the tip confronts an obstruction, it tends to coil beyond that length [11]. Obstruction encountered by the tip is perceived as resistance to insertion by the operator. As a result of the force applied to overcome the resistance, bends are produced in the catheter that can be seen on its removal. A correlation between what is felt and what is observed can assist in gauging the behavior of a catheter when it is inserted at different lengths inside the epidural space. Investigators have used radiological methods to study the behavior of a catheter inside the epidural space, but it is not feasible to use such methods to determine the point of intravascular placement [12]. This study was designed to investigate where the resistance was felt during the advancing of a catheter into the epidural space and whether the length of catheter advanced in the epidural space affected the incidence of catheter migration.

Patients, materials, and methods

This study was conducted at Jawaharlal Institute of Postgraduate Medical Education and Research, Pondicherry, India, between July 2006 and July 2008, after approval was given by the Institutional Research and Ethics Committee. One hundred and twenty women, American Society of Anesthesiologists (ASA) 1 and 2, scheduled to undergo elective lower abdominal gynecological surgeries were recruited for the study after obtaining informed consent for the study and anesthesia/surgery. Patients with a history of myocardial infarction or cerebrovascular insufficiency, height less than 140 cm, bleeding disorders, and evidence of local infection around the lumbar region, and those on anticoagulant therapy were excluded from the study.

The 120 patients were randomly assigned to two groups, according to the length of epidural catheter to be inserted inside the epidural space; assignment was done by a sealed envelope technique by a person not involved in the study. The allocation sequence was generated by computer in blocks of 10. The groups were based on the length of epidural catheter left inside the epidural space: a length of 4 cm (4-cm group; $n = 60$) and a length of 8 cm (8-cm group; $n = 60$).

All patients were premedicated with diazepam 10 mg (tablet) the night before and in the morning of the surgery. In the operating theater, baseline ECG, heart rate (HR), mean arterial pressure (MAP), and percutaneous oxygen saturation ($S_{P_{O_2}}$) were recorded. Lactated Ringer's solution (1000 ml), prewarmed to 37°C, was infused over 30 min.

Epidural puncture was performed in the left lateral position with the needle bevel oriented cephalad and perpendicular to the skin, under complete aseptic precautions [13]. The epidural space was identified through the midline approach with an 18-gauge Tuohy needle, using a BD Perisafe Epidural Anesthesia Kit (Becton Dickinson Medical Devices, Suzhou, P. R. China) in the L2–L3 intervertebral space by a loss-of-resistance technique using air and confirmed by negative aspiration of blood and cerebrospinal fluid (CSF).

A multiorifice epidural catheter was inserted according to the designated length for the group through the cranially directed tip of the epidural needle. Anesthesiologists experienced in epidural catheter insertion were asked to note whether any resistance to insertion was felt. The resistance was ranked with a four-point score (1, no resistance and smooth insertion; 2, mild initial resistance and subsequent insertion; 3, continuous resistance to insertion requiring force to overcome; 4, resistance not overcome by force requiring needle repositioning). The length at which the resistance was encountered in threading the epidural catheter beyond the hub of the Tuohy needle was noted. A second attempt, made by reinserting the needle in the same space, was carried out in patients with a resistance score of 4; if this was unsuccessful the epidural block was abandoned.

As soon as the resistance was overcome, a gentle aspiration was done at that length to rule out intravascular or subarachnoid placement, and the remaining length of the catheter was then threaded in. If blood or CSF was aspirated, the catheter was removed and reinserted in the same space. If there was no aspirate, a 3-ml test dose of 1.5% lidocaine with 15 μg adrenaline was administered through the catheter. The presence of clinical signs of an intravascular injection were sought for the following 2–3 min by asking the patient whether she felt dizzy, had tinnitus, or had a metallic taste in her mouth. If there were no signs of an intravascular injection, the catheter was then secured firmly on the back using an adhesive plaster. Five minutes after the test dose, if there were also no clinical signs of a subarachnoid injection, as evidenced by the patient's ability to move her legs and the absence of hypotension, an additional 13 ml of 2% lidocaine with 5 $\mu g \cdot ml^{-1}$ of adrenaline was injected through the catheter in patients in both groups. The patient was turned supine and, with the pin-prick method, the maximum height of sensory level achieved at 20 min was noted. Unilateral block, unblocked sacral segments, low level or a patchy block, or the patient complaining of pain despite adequate height of sensory level were regarded as "unsatisfactory block" before surgery. Patients with unsatisfactory block were administered general anesthesia.

In all patients, epidural morphine (4 mg) was given on demand, or when the visual analogue score (VAS) was more than 5 out of a possible value of 10 cm, to provide postoperative analgesia. The epidural catheter was removed after 48 h and subjected to close scrutiny after removal. The retrieved length and kinks or bends, if any, were further assessed. The most distal point at which the catheter was bent (primary bend) was noted. The primary bend was ranked on a three-point score (1, no bend in the catheter; 2, mild noticeable bend; 3, definitive bend). The catheter was further examined for evidence of any secondary bend between the primary bend and the point where it had been secured to the skin (Fig. 1).

The data were collected and analyzed using SPSS (SPSS, Chicago, IL, USA) statistical software, version 15. The sample size was estimated according to the data collected for all the epidural anesthesias performed during a period of 1 year at our institution; the data revealed a 20% incidence of improper epidural catheter placement with a difference of 15% between the groups at an alpha error of 0.05 at a power of 0.8. Improper epidural catheter placement consisted of unsatisfactory block (unilateral, patchy effect, or patient complaining

of pain despite adequate sensory level height), appearance of blood or CSF on aspiration, and catheters getting stuck. The parametric and nonparametric data of the two groups were compared and analyzed using two tailed Student's *t*-test and the Mann-Whitney *U*-test, respectively. The χ^2 test was used for analysis of nominal data. Linear regression analysis was performed for correlating the length at which resistance was encountered during insertion of the epidural catheter and the primary bend seen on its removal. $P < 0.05$ was considered significant

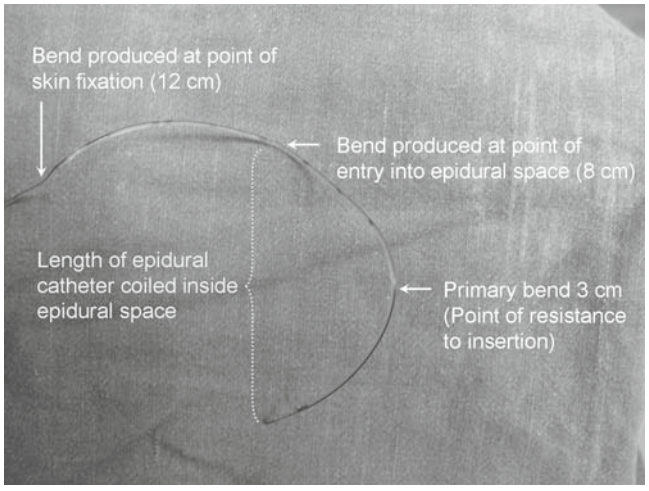

Fig. 1. Bends that were imposed on the epidural catheter during insertion, revealed after removal

Results

The physical characteristics of the two groups were comparable (Table 1). Successful insertion of the epidural catheter was accomplished in 87% of the patients. Epidural anesthesia had to be abandoned in 4 patients in whom blood appeared on aspiration during the second attempt and in 12 patients who had an unsatisfactory block.

Resistance to insertion of the epidural catheter was felt in 83 out of the 120 patients (69.2%). However, the incidence of resistance to insertion and the mean length at which it was felt were similar in the two groups (Table 2). In 8 patients (6.6%), with a resistance score of 4 (Table 2), the needle had to be reintroduced in the same space to achieve catheter insertion.

Blood could be aspirated in 9 of the 120 patients (7.5%) as soon as the resistance was overcome; however, the incidence of bloody tap was similar in the two groups (6.7% and 8.3% in the 4-cm and 8-cm groups, respectively; Table 3). In these 9 patients, frank blood was seen on aspiration before the insertion length designated for the group could be achieved. The catheter was removed and reinserted in the same space. In 4 of these patients (2 in each group) bloody tap occurred again during the second attempt, and the epidural anesthesia had to be abandoned. The overall incidence of unsatisfactory blockade was 10%, but the incidence was similar in the two groups (6.7% versus 13.3% in the 4-cm and 8-cm groups, respectively). Supplementary

Table 1. Physical characteristics of patients who had an epidural catheter inserted 4 cm and 8 cm into the epidural space

Physical characteristics	4-cm Group ($n = 60$)	8-cm Group ($n = 60$)
Age (years)	46.4 ± 11	48.3 ± 21. 3
Weight (kg)	52.2 ± 5.7	50.9 ± 5.1
Height (cm)	154.7 ± 4.7	153.1 ± 3.9

Values are expressed as means ± SD

Table 2. Resistance encountered during catheter insertion and the imposed bends observed on the catheter after removal in the 4-cm group and 8-cm group

Resistance during catheter insertion	4-cm Group ($n = 60$)	8-cm Group ($n = 60$)
Resistance encountered (*n*)	39/60 (65%)	44/60 (73%)
Mean length at which resistance was encountered (cm)	2.2 ± 0.65	2.8 ± 1.21
Resistance score		
Score 1, no resistance and smooth insertion	21 (35%)	16 (26.7%)
Score 2, mild initial resistance on subsequent smooth insertion	24 (40%)	20 (33.3%)
Score 3, continuous resistance to insertion requiring force to overcome	12 (20%)	19 (31.6%)
Score 4, resistance not overcome by force requiring needle repositioning	3 (5%)	5 (8.3%)
Bends imposed on the catheter		
Primary bend	46 (77%)	56 (93%)
Primary and secondary bend	2 (3%)	35 (58%)*

* $P < 0.001$; odds ratio, 35.67
Values are means ± SD or numbers (percentages)

Table 3. Frequency of insertion complications and unsatisfactory analgesia

Insertion complications	4-cm Group (n = 60)	8-cm Group (n = 60)	Overall (n = 120)
Bloody tap	4 (6.7%)	5 (8.3%)	9 (7.5%)
Length of catheter in epidural space at which bloody tap seen (cm)	2.5 (2–3)	2.5 (2–3)	2.5 (2–3)
Paresthesia	18 (30%)	18 (30%)	36 (30%)
Subarachnoid placement	0	0	0
Unsatisfactory analgesia	4 (6.7%)	8 (13.3%)	12 (10%)

Values are medians (ranges) or numbers (percentages)

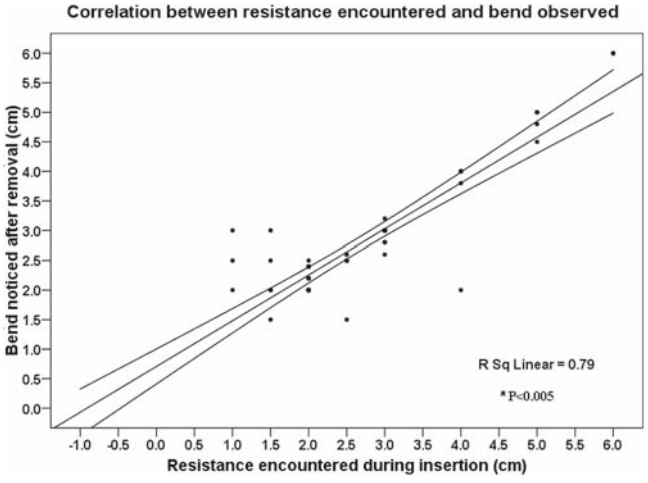

Fig. 2. Scatter plot showing linear correlation between the length of the catheter at which a primary bend was noted after removal and the length at which resistance was felt during insertion (n = 83 pairs). Regression prediction lines at 95% confidence intervals ($R^2 = 0.79$, $P < 0.005$)

general anesthesia was administered in all the patients who had an unsatisfactory block. Both these complications (blood aspiration and unsatisfactory block) were observed among the patients who had resistance to the insertion of the catheter. Thirty-six patients (30%) felt paresthesia during catheter insertion; no patient had subarachnoid location of an epidural catheter.

On removal of the epidural catheters, a bend in the catheter was noted in 56 patients in the 8-cm group (93%) and in 46 patients (77%) in the 4-cm group. However, a significantly greater number of catheters with 8-cm insertion (58%) had a secondary bend in addition to the primary bend, compared to the number with a secondary bend in catheters with 4-cm insertion (3%; $P < 0.001$; odds ratio, 35.67; Table 2). The length at which resistance was felt during insertion was correlated with the length at which the primary bend was noted after removal of the epidural catheter ($P < 0.005$; Fig. 2).

Discussion

We demonstrated that resistance to insertion of an epidural catheter was perceived at about 2.5 cm in the epidural space. Blood was aspirated immediately after the resistance was overcome and within 3 cm of advancing the catheter into the epidural space. Advancing the catheter any further may cause intravascular migration of an epidural catheter.

Blood was aspirated immediately after the resistance was overcome in 9 patients in the present study (7.5%; this occurred in 6.7% of the 4-cm group and in 8.3% of the 8-cm group) and it occurred within 3 cm of catheter advancement into the epidural space. A bloody tap can result from intravascular catheter placement or from blood oozing out of damaged veins. However, we aspirated frank blood in all these patients.

Cesur et al. [6] reported an 8.2% incidence of intravascular placement with 3-cm catheter insertion in normal healthy adult patients, while Beilin et al. [8] reported an 8.3% incidence of intravascular location in healthy parturients, with the highest frequency occurring in the 7-cm group, as compared to a 7.5% incidence of intravascular placement in our study. Beilin et al. [8] had performed aspiration to rule out intravascular placement after the entire 7 cm had been advanced into the epidural space. It is possible that intravascular placement had occurred earlier and it was only by chance that these patients were part of the 7-cm group. The catheter tip is likely to penetrate the vessel wall when the force of insertion generated by the operator is transmitted to it; that is, until it confronts obstruction; subsequently the force is transmitted to the part of the catheter emerging out of the tip. In our study, resistance was felt at a mean length of 2.5 ± 1.2 cm; thus, it seems that the tip is likely to penetrate the vessel wall at a shorter length of insertion. The use of softer catheters may help to decrease the incidence of bloody tap and the incidence of catheters getting stuck. Nevertheless it is wise to keep in mind the occasional hazardous dual-compartmental misplacement of multiorifice catheters, in which a distal opening can lie intravascular or within

the subarachnoid space, while the proximal orifice simultaneously retains normal access to the epidural space. Administration of a test dose and a 5-min interval before performing the epidural injection should help to identify such catheter misplacement [14].

In our study, on removal of the epidural catheter, a distal (primary) bend was noted at a mean length of 2.4 ± 1.3 cm; this was similar to that reported by Lim et al. [11]. These investigators demonstrated, with the help of fluoroscopy, that single-orifice epidural catheters could be threaded into the lumbar space without coiling up to a median length of 2.8 cm, ranging from 1 to 8 cm. The coiling length was similar irrespective of the cephalad (1–5.5 cm) or caudal direction (1.5–8 cm) of the needle. Bends were noted on the removed catheters, suggesting that after being advanced a short distance into the epidural space, the catheters became coiled within the epidural space [12,15,16]. A catheter bends when the tip confronts the dura mater, blood vessels, connective tissue, and neural structures that may hinder its advancement [4]. The force applied on the outside of the catheter catheter to thread it through the needle is transmitted to its tip until it confronts the structures in the epidural space (Fig. 3A). Any further force that is applied to overcome the obstruction gets applied to the part of the catheter emerging from the needle tip and not to the catheter tip. This results in the bending of the catheter in the epidural space (primary bend), which is seen as the most distal bend on the catheter (Fig. 3B). Our observations in the present study suggest that another bend proximal to the primary bend (secondary bend) can be imposed if the catheter is inserted beyond 3–4 cm into the epidural space, as the catheter forms an S-shaped loop within the epidural space (Fig. 3C). In our study, the rate of occurrence of a secondary bend was shown to be 17.5 times higher in the 8-cm group than in the 4-cm group, indicating that once the catheter is threaded beyond the resistance (primary bend), it does not advance into the epidural space, but coils into an S-shaped loop. In 37 patients, resistance to insertion was not appreciated, while a primary bend in the catheter was present in 102 patients. This discrepancy suggests that, despite the satisfactory technical performance of epidural catheterization, at times the catheter is still likely to bend and coil within the epidural space even when the resistance is not felt, as the catheters possess packing memory. Epidural catheters are coiled and dispensed for use and therefore tend to coil when threaded into the epidural space.

The optimal length of an epidural catheter to be threaded into the epidural space is controversial [7–10]. It is suggested to thread in a length of at least 4 cm inside the epidural space to prevent inadequate block that might occur due to the movement of the catheter out of the epidural space during traction applied by fixation to the skin [8]. Conversely, if a greater length of the catheter is threaded in, there is uncertainty regarding the position of the catheter and the possibility of extrusion of the catheter through the intervertebral foramen [16–18]; probably this is the reason why a higher incidence of unsatisfactory analgesia was seen with 8-cm insertion in our study (13.3% in the 8-cm group and 6.7% in the 4-cm group). Radiological evidence reported by Bridenbaugh et al. [15] also suggested that only 12% of all epidural catheters directed in a cephalad direction actually threaded to the "hoped for" anatomic levels, while 21% of the catheters had a terminal loop, 48% coiled at the insertion site, and 5% went in a caudal direction or migrated out through an intervertebral foramen. However, these investigators did not correlate the failure rate or the sensory level of epidural analgesia to the attained catheter position.

We conclude that resistance to the insertion of an epidural catheter is encountered after advancing the catheter approximately 2.5 cm in the epidural space. Further advancement may cause intravascular placement or coiling.

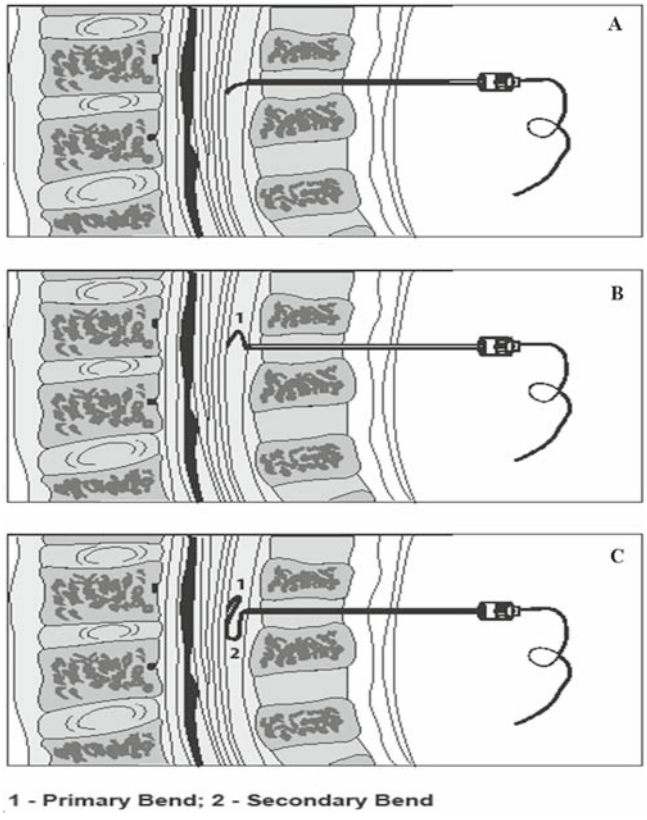

Fig. 3A–C. Estimated behavior of an epidural catheter. *1*, Primary bend; *2*, secondary bend

References

1. Savolaine ER, Pandya JB, Greenbalt SH, Conover SR. Anatomy of the human epidural space: new insights using CT-epidurography. Anesthesiology. 1988;68:217–20.
2. Blomberg GR, Olsson SS. The lumbar epidural space in patients examined with epiduroscopy. Anesth Analg. 1989;68:157–60.
3. Gallart L, Blanco D, Samso E, Vidal F. Clinical and radiological evidence of the epidural plica mediana dorsalis. Anesth Analg. 1990;71:698–701.
4. Motamed C, Farhat F, Remerand F, Laplanche A. An analysis of postoperative epidural analgesia failure by computed tomography-epidurography. Anesth Analg. 2006;103:1026–32.
5. Usubiaga JE, Dos Reis A, Usubiaga LE, Epidural misplacement of catheters and mechanism of unilateral blockade. Anesthesiology. 1970;32:158–61.
6. Cesur M, Alici HA, Erdem AF, Silbir F, Yuksek MS. Administration of the local anesthetic through the epidural needle before catheter insertion improves the quality of anesthesia and reduces catheter related complications. Anesth Analg. 2005;101:1501–5.
7. D'Angelo R, Berkebile B, Gerancher JC. Prospective examination of epidural catheter insertion. Anesthesiology. 1996;84: 1524–5.
8. Beilin Y, Bernstein HH, Zucker-Pinchoff B. The optimal distance a multiorifice epidural catheter should be threaded into the epidural space. Anesth Analg. 1995;81:301–4.
9. Hamilton CL, Riley ET, Cohen SE. Changes in the position of epidural catheters associated with patient movement. Anesthesiology. 1997;86:778–84.
10. Cartagena R, Gaiser RR. Advancing an epidural catheter 10 cm and then retracting it 5 cm is no more effective than advancing it 5 cm. J Clin Anesth. 2005;17:528–30
11. Lim YJ, Bahk JH, Ahn WS, Lee SC. Coiling of lumbar epidural catheters. Acta Anaesthesiol Scand. 2002;46:603–6.
12. Sanchez R, Acuna L, Rocha F. An analysis of the radiological visualization of the catheters placed in the epidural space. Br J Anaesth. 1967;39:485–9.
13. Richardson MG, Wissler RN. The effect of needle bevel orientation during epidural catheter insertion in laboring parturients. Anesth Analg. 1999;88:352–6.
14. Beck H, Brassow F, Doehn M. Epidural catheters of the multiorifice type: dangers and complications. Acta Anaesthesiol Scand. 1986;30:549–55.
15. Bridenbaugh LD, Moore DC, Bagdi P, Bridenbaugh PO. The position of plastic tubing in continuous-block techniques. An X-ray study of 552 patients. Anesthesiology. 1967;29:1047–9.
16. Quinn Hogan. Epidural catheter tip position and distribution of injectate evaluated by computed tomography. Anesthesiology. 1999;90:964–70.
17. Kumar CM, Dennison B, Lawier PGP. Excessive dose requirements of local anesthetic for epidural analgesia. How far should an epidural catheter be inserted? Anaesthesia. 1985;40:1100–2
18. Asato F, Goto F. Radiographic findings of unilateral epidural block. Anesth Analg. 1996;83:519–22.