

Correlation between the Distribution of Contrast Medium and the Extent of Blockade during Epidural Anesthesia

Masataka Yokoyama, M.D., Motohiko Hanazaki, M.D.,† Hiromi Fujii, M.D.,† Satoshi Mizobuchi, M.D.,‡ Hideki Nakatsuka, M.D.,‡ Toru Takahashi, M.D.,‡ Masaki Matsumi, M.D.,‡ Mamoru Takeuchi, M.D.,‡ Kiyoshi Morita, M.D.§*

Background: **If the epidural spread of contrast medium can be well correlated with the spread of local anesthetics, epidurography can predict the dermatomal distribution of the anesthetic block. The authors evaluated the relation between radiographic and analgesic spread.**

Methods: **An epidural catheter was inserted in 90 patients, and predicted catheter tip position was recorded. The analgesic area was determined by pinprick after a 5-ml injection of 1.5% lidocaine, and epidurography was performed after a 5-ml injection of 240 mg I/ml iotrolan. Patients were assigned to three groups according to catheter tip position (group C: C–T4; group T: T5–T10; group L: T11–L), and patterns of spread were compared. In 16 of 90 subjects, radiographic and analgesic spread was further investigated after an additional 5-ml injection of iotrolan and lidocaine.**

Results: **The total radiographic spread correlated well with analgesic spread (right side: $Y = 0.84 X + 0.16$, $r = 0.92$, $P < 0.01$; left side: $Y = 0.78 X + 0.45$, $r = 0.91$, $P < 0.01$). The mean radiographic spread in the cephalad and caudal directions from the catheter tip also correlated well with mean analgesic spread ($r = 0.97$, $P < 0.01$, each direction). The mean distance between the predicted catheter tip and radiographically determined positions was 1.0 ± 0.8 segments: the value in group T was significantly larger than that in groups C ($P < 0.05$) and L ($P < 0.01$). Although the correlation of radiographic spread with age was statistically significantly ($r = 0.39$, $P < 0.01$), great individual variation in spreading pattern was seen. In 16 subjects, mean radiographic spread correlated well with analgesic spread after 5- and 10-ml injections of iotrolan and lidocaine.**

Conclusions: **Epidurography is useful to indicate epidural catheter position and can help to predict the exact dermatomal distribution of analgesic block.**

CONTINUOUS epidural anesthesia and analgesia are popular and accepted methods of anesthesia in many clinical applications. However, we often experience instances of inadequate analgesia in the cephalad and caudal directions, of unilateral analgesia, and of analgesia completely deviating from the target segments. Also, an excessively wide analgesic area can result in unnecessary sensory and motor block in some patients. Such problems are often difficult to manage. The prediction of local anesthetic spread in the epidural space is important in deciding the proper injection dose of local anesthetics. Although many factors affecting the spread of local anesthetics in the epidural space (analgesic spread)[1–7] and the mean dose of local anesthetics required to block one segment have been reported,[1–3] the area anesthetized after epidural block varies significantly from patient to patient. It is therefore difficult to predict the exact dose of anesthetic required.[8]

Epidurography has been used for diagnosis of spinal disease, confirmation of the epidural space and position of the epidural catheter, and observation of the pattern of spread.[8–12] If the epidural spread of contrast medium (radiographic spread) correlates well with the analgesic spread, epidurography can predict the dermatomal distribution of the anesthetic block. Previously, few trials have been performed to clarify the correlation between radiographic spread and analgesic spread in the epidural space.[13,14] Unfortunately, these trials showed no relation between radiographic spread and sensory blockade except when large volumes of contrast medium and local anesthetic were used. We thought that the results of these trials might be due to insufficient radiographic resolution and sensory checks because the epidurograms were taken with a portable bedside x-ray apparatus, a low-contrast concentration was used, and sensory checks were performed on patients immediately after surgery or on patients with cancer pain.[13,14]

We reevaluated the relation between radiographic spread and analgesic area by local anesthetics. Epidurography was performed under fluoroscopy after 5 ml iotrolan, 240 mg I/ml, was administered, and sensory block was checked by pinprick after administration of 5 ml lidocaine, 1.5%, in patients before surgery or radiographic intervention. We also investigated the relation between dose of contrast medium and epidural spread and whether the site of epidural injection targeting different segments of the spinal cord affects the pattern of spread of contrast medium.

Materials and Methods

Institutional and ethics committee approval (Okayama City, Japan) was obtained for this study, and all participants gave their informed consent. The study comprised 90 patients who underwent continuous epidural block for surgery or radiologic intervention. Patients with abnormalities of the spine or metastases limiting the spread of contrast medium were excluded. Patients were not premedicated and were not sedated during the study.

* Associate Professor, † Staff Anesthesiologist, ‡ Assistant Professor, § Professor and Chairman.

Received from the Department of Anesthesiology and Resuscitology, Okayama University Medical School, Okayama City, Japan. Submitted for publication October 7, 2003. Accepted for publication February 3, 2004. Support was provided solely from institutional and/or departmental sources.

Address reprint requests to Dr. Yokoyama: Department of Anesthesiology and Resuscitology, Okayama University Medical School, 2-5-1 Shikata-cho, Okayama City, Okayama 700-8558, Japan. Address electronic mail to: masayoko@cc.okayama-u.ac.jp.

With the patient in the left lateral position, the epidural space was identified *via* paramedian approach by loss of resistance to saline. A 19-gauge closed-end epidural catheter with three side holes was advanced 3–4 cm in the cephalad direction into the epidural space. Catheter tip position predicted by the anesthesiologist was recorded. On the day of the procedure, the analgesic areas of the right- and left-side dermatomes were determined by pinprick 20 min after 5-ml injection of 1.5% lidocaine. A time interval between epidural catheter placement and analgesic testing by lidocaine was more than 5 h. On the following day, the position of the catheter tip and the spread of contrast medium were determined by fluoroscopy after 5-ml injection of 240 mg I/ml iotrolan through the epidural catheter. The position of the catheter tip was identified by a lateral view of fluoroscopy during the initial 1- to 1.5-ml injection of contrast medium, and an x-ray was taken; then, the residual volume of contrast medium was injected. Anterior–posterior and lateral epidurograms were taken within 3 min of injecting the contrast medium. In 16 of 90 subjects, an additional 5 ml iotrolan, 240 mg I/ml, was injected immediately after the first set of epidurograms, and a second set of epidurograms were taken. Thirty minutes after the second set of epidurograms, epidural block was performed using 10 ml lidocaine, 1.5%, and analgesic spread was determined by pinprick. It is assumed that local anesthetic acts the level of the intervertebral foramina, although other sites and mechanisms are involved.[14] The extent of contrast spread was determined by calculating numbers of the intervertebral foramina completely covered by contrast medium. The same radiologist compared images from before and after injection and performed the interpretations of the epidurograms. The assessment of loss of pinprick sensation was unknown to the radiologist. The spread of contrast medium to the right and left of midline was recorded. Segments were counted upward from the fifth sacral segment, and the coccygeal segments were excluded because they occupy such a small part of the spinal cord. Therefore, the spread to all segments up to and including the second thoracic was counted as 21 segments (5 sacral, 5 lumbar, and 11 thoracic).[1] Mean analgesic area and mean spread of contrast medium were calculated as follows: mean analgesic area = 1/2 (right-side analgesic dermatomes + left-side analgesic dermatomes) and mean spread of contrast medium = 1/2 (right-side segments covered + left-side segments covered). Patients were assigned to three groups according to catheter tip position (group C: C–T4; group T: T5–T10; group L: T11–L), and the spreading patterns were compared.

Statistical Analysis

Values are given as mean ± SD. Statistical analysis was performed by analysis of variance followed by Fisher exact test, and coefficient of correlation was calculated by the Pearson method. Differences were considered statistically significant at $P < 0.05$.

Results

Patient age, height, and weight were 57 ± 15 yr (range, 21–83 yr), 157 ± 10 cm (143–183 cm), and 57 ± 11 kg (31–91 kg), respectively, and there were no significant differences in these values between groups. The mean distance between the catheter tip position predicted by the anesthesiologist and that indicated on the epidurogram was 1.0 ± 0.8 segments; this value was significantly larger in group T (1.3 ± 0.9 segments, n = 34) than in group C (0.8 ± 0.8 segments, n = 20, $P < 0.05$) and group L (0.7 ± 0.7 segments, n = 36, $P < 0.01$). Radiographic spread to the right side in the epidural space was 9.4 ± 3.9 segments, and radiographic spread to the left side was 9.3 ± 3.9 segments. Analgesic spread to the right side was 7.6 ± 3.6 dermatomes, and analgesic spread to the left side was 7.6 ± 3.3 dermatomes. Radiographic spread correlated well with analgesic spread (right side: $Y = 0.81 X + 0.16$, $r = 0.92$, $P < 0.01$; left side: $Y = 0.78 X + 0.45$, $r = 0.91$, $P < 0.01$; figs. 1A and B). The mean difference between the spread of contrast medium to the right and left sides was 1.6 ± 2.2 segments, and these values were similar between groups (group C: 2.2 ± 0.6 segments; group T: 1.4 ± 0.4 segments; group L: 1.4 ± 0.3 segments). The difference between radiographic spread to the right and left sides was more than 5 segments in 11 patients.

The mean radiographic spread in the cephalad and caudal directions from the catheter tip correlated well with mean analgesic spread (cephalad: $r = 0.97$, $P < 0.01$; caudal: $r = 0.97$, $P < 0.01$; figs. 1C and D and fig. 2). Although the mean radiographic spread in group C tended to be wider than that in the other two groups, there were no significant differences in mean radiographic spread between groups (group C: 10.5 ± 3.4 segments; group T: 9.4 ± 3.5 segments; group L: 8.6 ± 3.8 segments; $P = 0.07$ *vs.* group C; fig. 2). The man radiographic spread from the catheter tip in the caudal direction was significantly wider than that in the cephalad direction in group C (cephalad: 4.1 ± 1.6; caudal: 6.4 ± 3.4; $P < 0.05$), whereas radiographic spread was significantly wider in the cephalad than caudal direction in groups T (cephalad: 6.4 ± 3.2; caudal: 3.1 ± 1.9; $P < 0.01$) and L (cephalad: 6.5 ± 3.9; caudal: 2.1 ± 1.5; $P < 0.01$; fig. 2). The contrast spread was not related to the patient's weight. Although the mean radiographic spread was in positive correlation with the patient's age ($r = 0.39$, $P < 0.01$) and was in inverse correlation with the patient's height ($r = -0.25$, $P < 0.05$) statistically significantly, there was great individual variation in the pattern of spread (fig. 3).

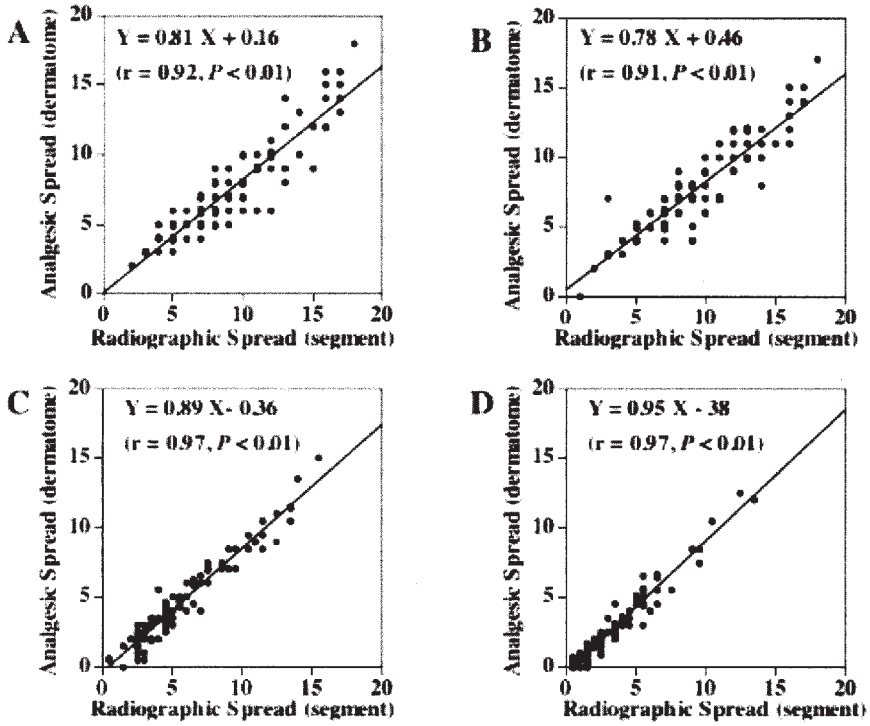

Fig. 1. Correlation of the radiographic and analgesic spread in 90 patients. (*A*) Correlation of right-sided spread of contrast medium with analgesic area. (*B*) Correlation of left-sided spread of contrast medium with analgesic area. (*C*) Correlation of mean cephalad spread of contrast medium from the catheter tip with analgesic area. (*D*) Correlation of mean caudal spread of contrast medium from the catheter tip with analgesic area.

In 16 subjects receiving additional doses of iotrolan and lidocaine, the mean radiographic spread was 6.7 ± 2.1 segments and the mean analgesic spread was 5.6 ± 1.3 dermatomes after the 5-ml injections. The mean radiographic spread was 9.4 ± 2.7 segments and the mean analgesic spread was 8.3 ± 2.4 dermatomes after the10-ml injections (fig. 4). Although the mean radiographic spread and analgesic spread correlated well after both injection doses ($r = 0.94$, $P < 0.01$; fig. 4), radiographic spread was noted even more to the

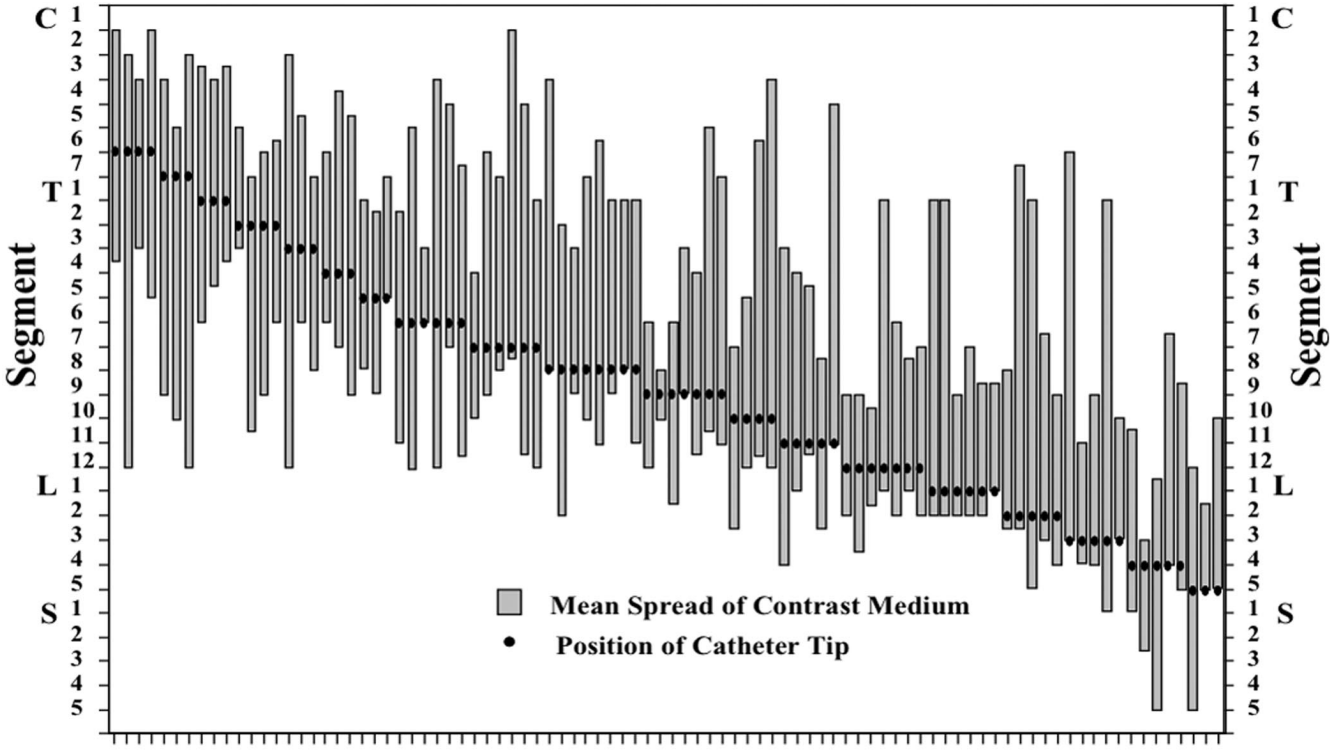

Fig. 2. Mean radiographic spread after injection of 5 ml iotrolan, 240 mg I/ml, in 90 patients. C = cervical segment; L = lumbar segment; S = sacral segment; T = thoracic segment.

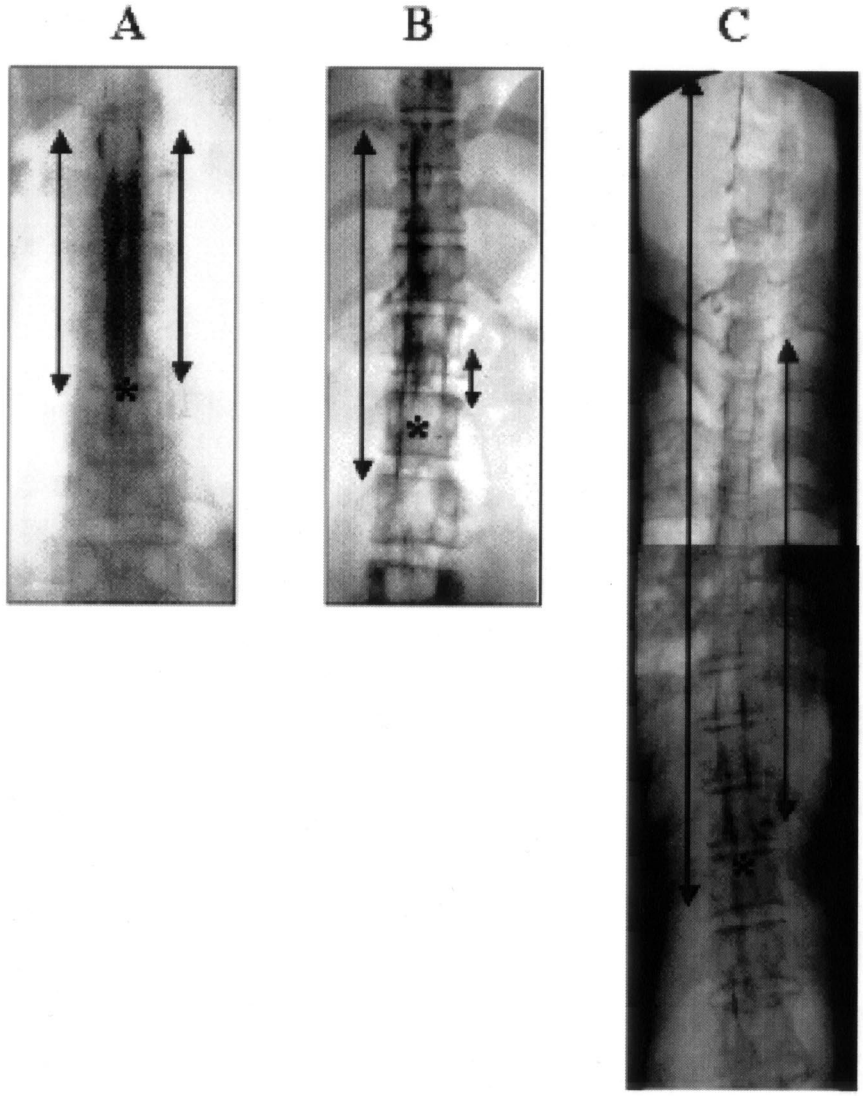

Fig. 3. Patterns of spread. (*A*) Right- and left-sided spread of contrast medium are almost even. (*B*) Right-sided spread of contrast medium is unilaterally predominant. (*C*) Contrast medium spreads extremely widely to the right side. The length of the *arrow* represents right- or left-sided spread of contrast medium. The *asterisk* represents the position of the catheter tip.

right and left of midline after the 10-ml injection, and the epidurogram after the injection of 10 ml iotrolan was more clearly opacified than that after the 5-ml injection (fig. 5).

Discussion

Our results showed that the spread of 5 ml iotrolan, 240 mg I/ml, correlated well with the analgesic area after epidural injection of 5 ml lidocaine, 1.5%, although the analgesic area and radiographic spread did not match completely. Epidurography with 5 ml iotrolan, 240 mg I/ml, is useful to indicate the position of the epidural catheter and can help to predict the dermatomal distribution of the block.

A number of variables determine how far neural blockade will spread after injection of local anesthetics into the epidural space.[1–7] Some variables are intrinsic to the patient and some are extrinsic, depending on variations in technique and the drugs given. In the current study, although the correlation between radiographic spread and age was statistically significant and the region at which epidural block was administered tended to affect radiographic spread, as reported previously,[1] there was great individual variation as to the area and pattern of spread. It is impossible to predict cephalad and caudal spread of anesthetic, whether it will spread unilaterally, and the general pattern of spread. Burn *et al.*[8] reported that it is impossible to predict accurately the level attained after epidural injection of contrast medium. The unpredictable pattern of spread is likely due to anatomical variation of the epidural space. Recent reports have indicated that the structure of the epidural space is more complex and variable than ever thought,[4] and this intrinsic factor makes the spread of solution in the epidural space unpredictable. Regardless of the area or pattern of spread of contrast medium, the area of radiographic and analgesic spread correlated well in the current study.

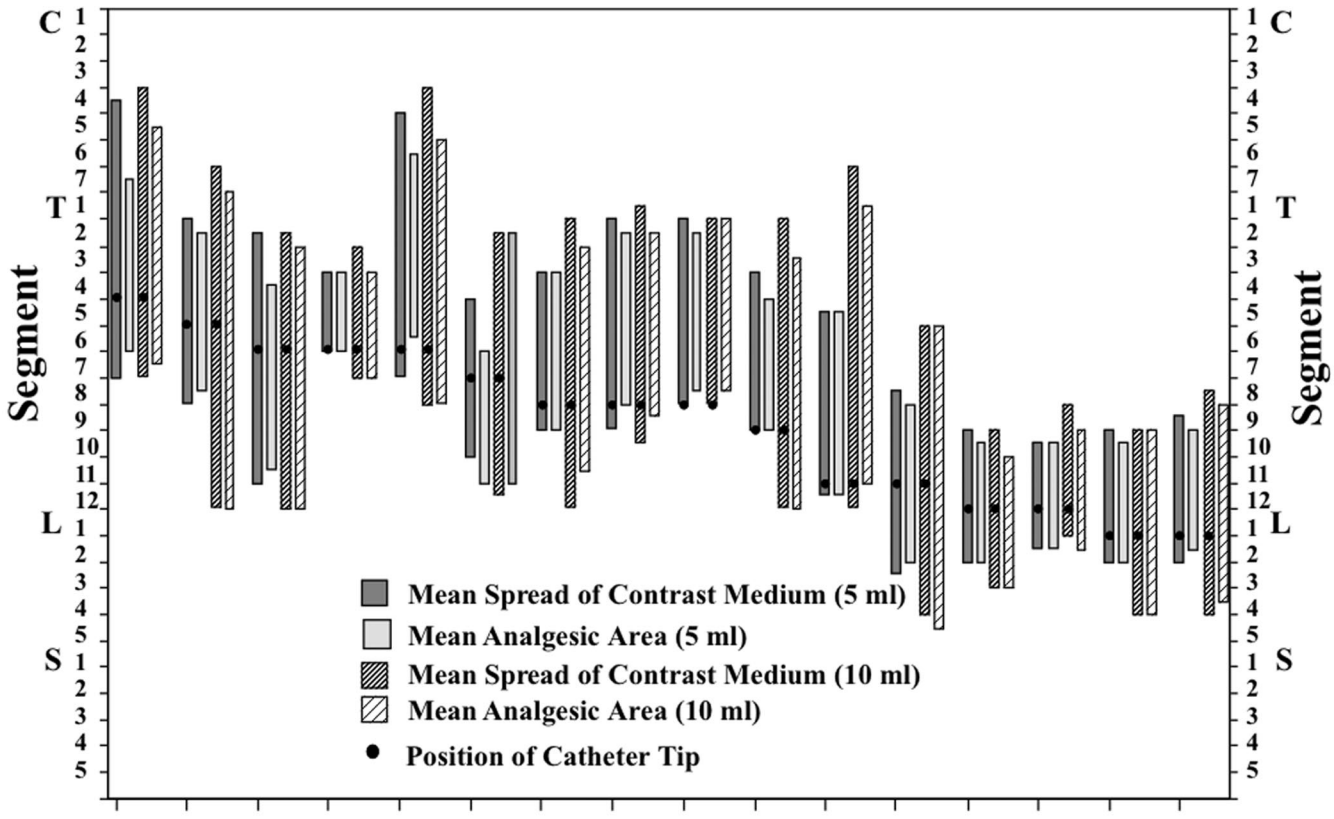

Fig. 4. Mean radiographic spread after the injection of 5 or 10 ml iotrolan, 240 mg I/ml, and mean analgesic spread after injection of 5 or 10 ml lidocaine, 1.5%, in 16 patients. C = cervical segment; L = lumbar segment; S = sacral segment; T = thoracic segment.

The analgesic spread could be calculated with the equations presented in this study.

Few studies have been performed to clarify the correlation between the spread of local anesthetic and a radiographic contrast medium in the epidural space.[13,14] Slappendel *et al.*[13] used 3 ml iohexol, 300 mg I/ml, or 8 ml iohexol, 180 mg I/ml, and identical volumes of 2% lidocaine. The spread of the contrast medium showed no relation to the injected volume or the sensory spread after the 3-ml injections, and no contrast medium could

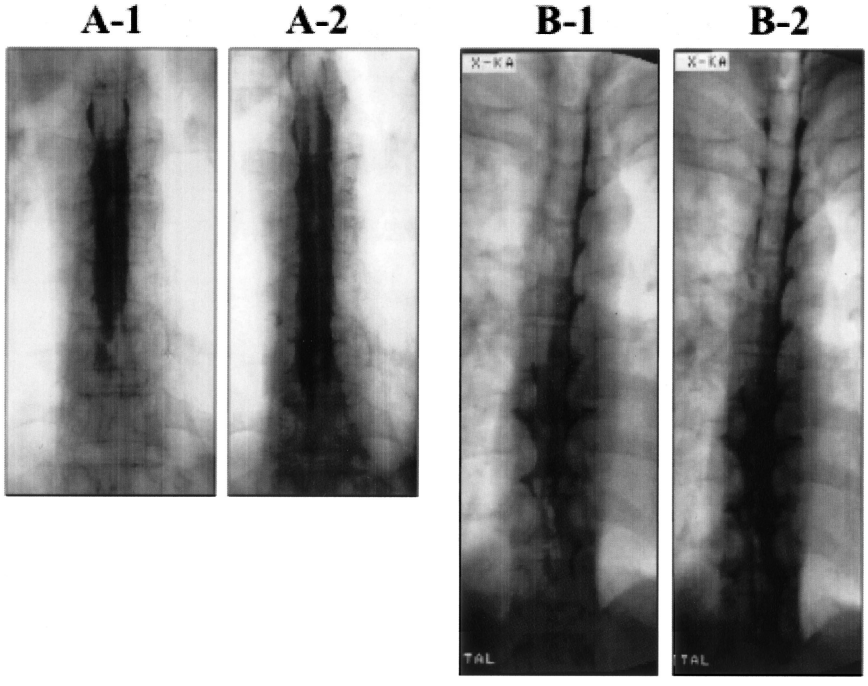

Fig. 5. Spread of contrast medium after the injection of 5 ml (*A-1, B-1*) and 10 ml (*A-2, B-2*) iotrolan, 240 mg I/ml. Epidurograms of *A-1* and *A-2* were taken from the same patient, and epidurograms of *B-1* and *B-2* were both taken from another patient.

be seen in many cases after injection of 8 ml iohexol, 180 mg I/ml. They concluded that it seems more reliable to choose a more concentrated radiopaque dye. Sjøgren *et al.*[14] used 8 or 16 ml iohexol, 180 ml I/ml, and an identical volume of 0.5% bupivacaine. They found a statistically significant correlation between the extension of epidural block and the spread of contrast medium only in the patients who received larger volumes. These results indicate that 3 ml is too small an injection and 180 mg I/ml iohexol is too low a concentration to obtain an adequate epidurogram. In the current study, the epidurography was performed by fluoroscopy because the catheter tip position can be easily identified during the injection of a small dose of contrast medium. Furthermore, spread area and pattern are observed directly, which can make it easy to take a well-contrasted epidurogram by x-ray.

Our result showed that total radiographic spread was 7 ± 2 segments when 5 ml contrast medium was injected and 9 ± 3 segments when 10 ml was injected. Our and other investigators' results indicate that the spread of the solution in the epidural space in the cephalad or caudal direction is not linearly volume dependent.[15–17] The order of spread of a solution in the epidural space seems to be longitudinal, lateral, and circumferential because the posterior midline fatty tissue structures in the epidural space act as a spread barrier to circumferential spread.[7] A large-volume injection can clearly show the circumferential spread of contrast; our results showed that the epidurogram with 10 ml contrast medium was more clearly opacified than that with 5 ml. However, 5 ml iotrolan, 240 mg I/ml, was adequate to observe the pattern of spread and predict analgesic area in most cases. Du Pen *et al.*[12] recommended that an initial dose of 5 ml iohexol, 180 mg I/ml, followed by an additional 5 ml should be used to observe the pattern of spread in the epidural space. They did not compare radiographic spread with analgesic spread, however. If a clear epidurogram cannot be obtained with 5 ml contrast medium, an additional 5-ml injection may help to clarify the pattern of spread. The additional injection is especially useful in patients showing a predominantly unilateral pattern of spread. Nevertheless, an extremely large volume, such 16 ml iotrolan, 240 mg I/ml, which is of significantly higher viscosity than that of local anesthetics, may cause a transient pressure of the spinal cord. Therefore, we should avoid injecting an extremely large volume of contrast medium in the epidural space, although the viscosity of the contrast medium has little influence on its epidural spread.[18] We used 1.5% lidocaine for sensory checks because it is often used during surgery in our institution, and this concentration is adequate to confirm sensory block quickly and reliably by pinprick.

It is well known that solution injected into the epidural space spreads more widely at the upper thoracic segments than that at the lumbar segments.[3,5,6] Although our results showed this tendency, there was no significant difference between the three groups ($P = 0.07$, group C *vs.* group L). At the cervical and upper thoracic segments, the pattern of solution spread was significantly wider in the caudal direction than in the cephalad direction, and at the lower thoracic and lumbar segments, the pattern of spread was significantly wider in the cephalad than caudal direction, as indicated in other previous reports.[5,6] In the middle of the thoracic region, however, the contrast medium spread cephalad approximately twice as far as it spread caudally, although equal spread of analgesia in both the cephalad and caudal directions has been reported at the middle thoracic segments.[3] The reason for this discrepancy is not clear, and further study is necessary.

The position of the epidural catheter is as important as the pattern of spread. The mean distance between the catheter tip position predicted by the anesthesiologist and that indicated by epidurogram was 1.0 segment, and this gap is not of serious concern. However, nine patients showed a 3-segment gap, indicating that confirmation of catheter position by epidurogram is necessary in some patients. The following factors are likely to cause this gap: curling or buckling of the catheter inferiorly in the epidural space, epidural puncture from a deviated intervertebral space by paramedian approach, and misidentification of the spinal segment. The gap value in group T was significantly larger than that in the other two groups. The anesthesiologists might be likely to inaccurately puncture the middle thoracic segment because the puncture point is far from the anatomical landmark of the C7 or L4 spinous process, and epidural puncture was often difficult at the thoracic segment because of its anatomical character, which could deflect the epidural needle to a deviated target segment.

In conclusion, epidurography is a simple, relatively inexpensive, and accurate method to confirm catheter placement and to help to determine anesthetic infusion volume. The benefits to the patient must be weighed against the radiation exposure received.

References

1. Bromage PR: Spread of analgesic solutions in the epidural space and their site of action: A statistical study. Br J Anaesth 1962; 34:161–78

2. Bromage PR: Ageing and epidural dose requirements: segmental spread and predictability of epidural analgesia in youth and extreme age. Br J Anaesth 1969; 41:1016–22

3. Bromage PR: Mechanism of action of epidural analgesia. Br J Anaesth 1975; 47:199–211

4. Savolaine ER, Pandya JB, Greenblatt SH, Conover SR: Anatomy of the human lumbar epidural space: New insights using CT-epidurography. ANESTHESIOLOGY 1988; 68:217–20

5. Park WY: Factors influencing distribution of local anesthetics in epidural space. Reg Anesth 1988; 13:49–57

6. Grundy EM, Rao LN, Winnie AP: Epidural anesthesia and the lateral position. Anesth Analg 1978; 57:95–7

7. Asato F, Goto F: Radiographic findings of unilateral epidural block. Anesth Analg 1996; 83:519–22

8. Burn JM, Guyer PB, Langdon L: The spread of solutions injected into the epidural space: A study using epidurograms in patients with the lumbosciatic syndrome. Br J Anaesth 1973; 45:338–45

9. Muneyuki M, Shirai K, Inamoto A: Roentgenographic analysis of the position of catheters in the epidural space. ANESTHESIOLOGY 1970; 33:19–24

10. Mehta M, Salmon N: Extradural block: Confirmation of the injection site by x-ray monitoring. Anaesthesia 1985; 40:1009–12

11. Mourisse J, Gielen MJ, Hasenbos MA, Heystraten FM: Migration of thoracic catheters: Three methods for evaluation of catheter position in the thoracic epidural space. Anaesthesia 1989; 44:574–7

12. Du Pen SL, Williams AR, Feldman RK: Epidurograms in the management of patients with long-term epidural catheters. Reg Anesth 1996; 21:61–7

13. Slappendel R, Gielen MJ, Hasenbos MA, Heystraten FM: Spread of radiopaque dye in the thoracic epidural space. Anaesthesia 1988; 43:939–42

14. Sjøgren P, Gefke K, Banning AM, Parslov M, Olsen LB: Lumbar epidurography and epidural analgesia in cancer patients. Pain 1989; 36:305–9

15. Grundy EM, Ramamurthy S, Patel KP, Winnie AP: Extradural analgesia revisited: A statistical study. Br J Anaesth 1978; 50:805–9

16. Park WY, Hagins FM, Rivat EL, Macnamara TE: Age and epidural dose response in adult men. ANESTHESIOLOGY 1982; 56:318–20

17. Sharrock NE: Epidural anesthetic dose responses in patients 20 to 80 years old. ANESTHESIOLOGY 1978; 49:425–28

18. Kim YC, Lim YJ, Lee SC: Spreading pattern of epidurally administered contrast medium in rabbits. Acta Anaesthesiol Scand 1998; 42:1092–5