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Straight Advancement of Epidural Catheter

— Comparative Assessments by Method and Site of Epidural Needle Puncture and Angle of Puncture —

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The catheter straight advancement rate for introduction into the epidural space was investigated using a radiopaque catheter.
One hundred patients were divided into two groups and underwent thoracic or lumbar epidural punctures, with one of two different puncture methods: the median approach or paramedian approach.
Two different angles of epidural puncture needle insertion, 50-60° and 90° to skin surface plane, were used.
A catheter was inserted into the epidural space about 5 cm cephalad and the course of the inserted catheter was ascertained by radiography.
The results have shown that punctures performed at an insertion angle of 50-60° yielded higher catheter straight advancement rates than those performed at an angle of 90° in both thoracic and lumbar epidural punctures.

Key words : Epidural catheter, straight advancement, angle of puncture

INTRODUCTION

Factors affecting the rate of patients in whom straight advancement of an epidural catheter is achieved, hereafter referred to as the straight advancement rate, include the material of the catheters, epidural puncture method (i.e., median approach or paramedian approach), the puncture site (thoracic or lumbar), and the puncture angle.

Muneyuki *et al*. [7], Shima *et al*. [10] and Nishimoto *et al*. [8] have inferred that the angle of epidural puncture needle to the skin surface plane is a factor affecting the straight advancement rate. In the present study, we chose two different angles of epidural puncture needle insertion, 50-60° and 90° to skin surface plane, for thoracic and lumbar punctures.

A median approach and a paramedian approach were employed for the puncture method.

Epidural punctures were carried out at these angles and approaches, followed by introduction of a catheter into the epidural space to assess the straight advancement rate.

—Device (The Catheter Used in This Study)—

Flex Tip Plus™ (Arrow) catheters were used (Fig. 1).

This catheter is made of soft polyurethane and is radiopaque.

It is characterized by a stainless steel-coiled lumen, so is less flexible than catheters made of other hard materials (e.g., polyethylene, polyamide resins).

SUBJECTS AND METHODS

The subjects were one hundred patients whose clinical conditions required measures using epidural catheterization.

Each patient was given an explanation of the nature of the study and his/her informed consent was obtained prior to admission to

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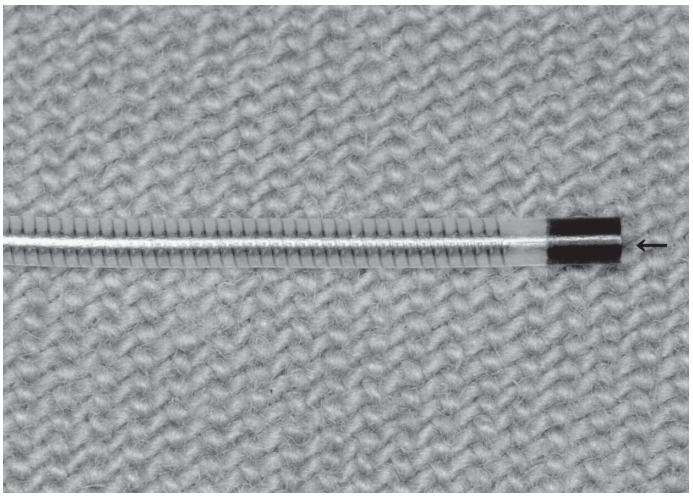

Fig. 1 Tip of a Flex Tip Plus epidural catheter
(A stainless steel coiling in the catheter lumen is noted. An arrow indicates the tip opening.)

	Procedure-1 (n=80)	Procedure-2 (n=20)
1) Method of Puncture	Thoracic (n=40) median (n=20) paramedian (n=20) Lumbar (n=40) median (n=20) paramedian (n=20)	Thoracic (n=10) paramedian (n=10) Lumbar (n=10) median (n=5) paramedian (n=5)
2) Site of Puncture	Thoracic (7-12) Lumbar (1-3)	Thoracic (7-12) Lumbar (1-3)
3) Angle of Puncture	Thoracic (50-60°) Lumbar (90°)	Thoracic (90°) Lumbar (50-60°)

Fig. 2 Trial procedures (Procedure 1 in the left panel and Procedure 2 in the right panel)

the study. The following two clinical trials were then carried out. The trial procedures used are illustrated in Fig. 2.

Procedure 1: This procedure was employed on 80 patients. Puncture was performed by assigning 40 of the patients to a thoracic puncture group, and 40 to a lumbar puncture group according to the puncture method. Each group was further divided into a median approach group consisting of 20 patients and a paramedian approach group also consisting of 20 patients. The puncture site under the paramedian approach was about 1.5 cm lateral to the spinous process at the level of the upper end of the spinous process. Upon paracentesis, an epidural needle was introduced cephalad-medially in a slanted position [2].

The puncture sites consisted of the Th7-Th12 thoracic vertebra and the L1-L3 lumbar vertebra. The puncture angle is defined here as the angle of the epidural needle to the skin surface plane. An acute puncture angle (50-60°) was used for thoracic puncture, while a right angle (90°) was used for lumbar puncture.

Procedure 2: This procedure was employed on 20 patients. Puncture was performed by assigning 10 of the patients to a thoracic puncture group, and 10 to a lumbar puncture group according to the puncture method. A paramedian approach was employed in

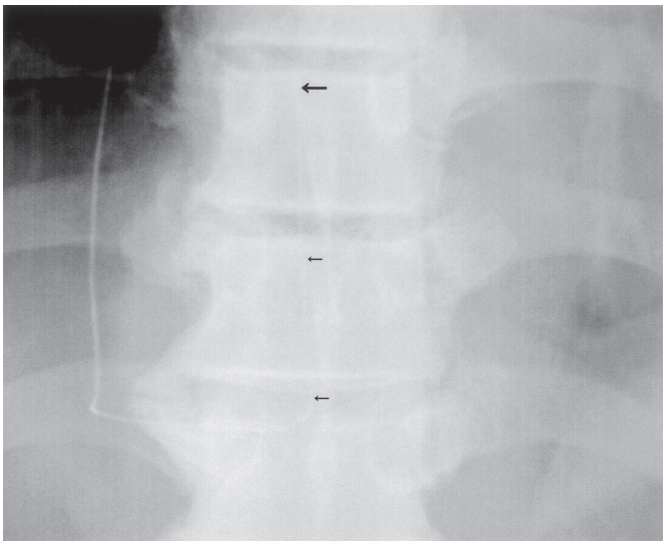

Fig. 3 Example of a straight advanced catheter (Th9/10, puncture angle: 50°)
The inserted catheter is advanced straight craniad in the epidural space as if it is coursing along the spinous process (two small arrows), and its tip is situated mostly medial to the pedicles of the right and left vertebral arches (a bigger arrow).

all patients of the thoracic puncture group, while a median approach was employed in 5 patients and a paramedian approach was employed in the remaining 5 patients of the lumbar puncture group. The reason for employing a paramedian approach for the puncture method in all patients of the thoracic puncture group is as described below. There is considerable bone overriding of thoracic vertebrae, so it is nearly impossible to accomplish an epidural puncture at an angle of 90° using the paramedian approach.

This thoracic puncture method was the Modified Laminar Approach (MLA) devised by Takino. The puncture site was about 1 cm lateral to the spinous process.

It has been reported that the inserted epidural needle, can thereby reach the epidural space via the shortest route [12].

In the case of the lumbar puncture group, the paramedian approach was performed using the same procedure as Procedure 1. The puncture site was also the same as in Procedure 1. However, the puncture angles differed from those used in Procedure 1.

A right angle (90°) was used for thoracic puncture, while an acute angle (50-60°) was used for lumbar puncture.

After confirming that the needle reached epidural space, an indwelling catheter was placed about 5 cm headward. Postoperatively, the course of the inserted catheter was ascertained by chest or abdominal X-ray film examination (single A-P projection).

Classification of Catheter Courses

Coursing of a catheter in place was classified into two groups: straight advanced and non-straight advanced. Figures 3 and 4 are radiograms taken after catheter insertion.

Figure 3 shows a typical radiographic feature of a straight advanced catheter.

The straight advanced group is defined as a group of patients in whom an inserted catheter is advanced craniad in the epidural space with its tip situated medial to the pedicles of the right and left vertebral arches.

Figure 4 shows a typical radiographic feature of a non-straight advanced catheter.

The non-straight advanced group is defined as a group of patients in whom an inserted catheter is in any other position than that of the straight advanced group.

Following are examples from the non-straight advanced group. In Fig. 4, the upper left radiogram shows a catheter coursing flexed, and the upper right radiogram depicts a catheter coursing gyratory. The lower

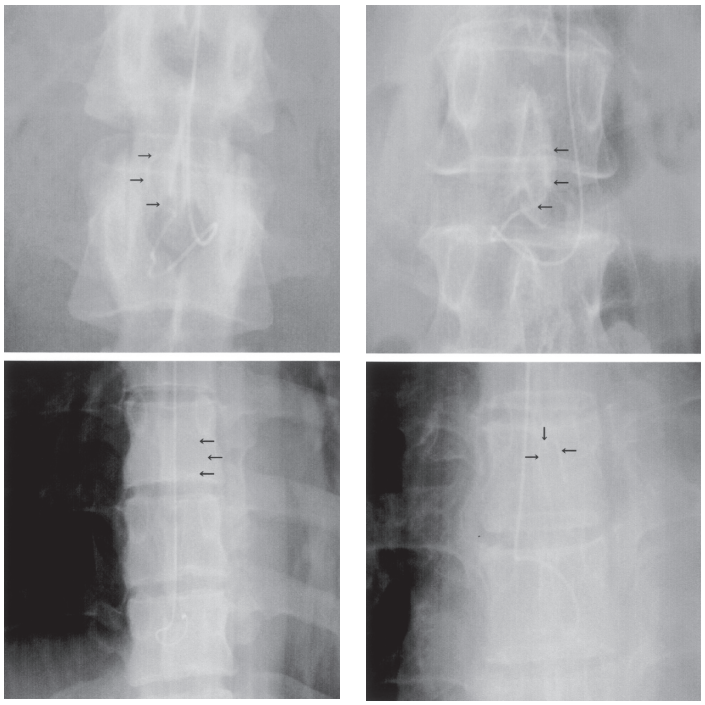

Fig. 4 Examples of non-straight advanced catheters
Upper left: Flexed (L1/2, puncture angle: 90°)
The catheter (←) is flexed.
Upper right: Gyrated (L2/3, puncture angle: 90°)
The catheter (←) is gyrated.
Lower left: Hooked (Th7/8, puncture angle: 50°)
The catheter (←) is hooked.
Lower right: U-turned (Th7/8, puncture angle: 50°)
The catheter (←) is U-turned.

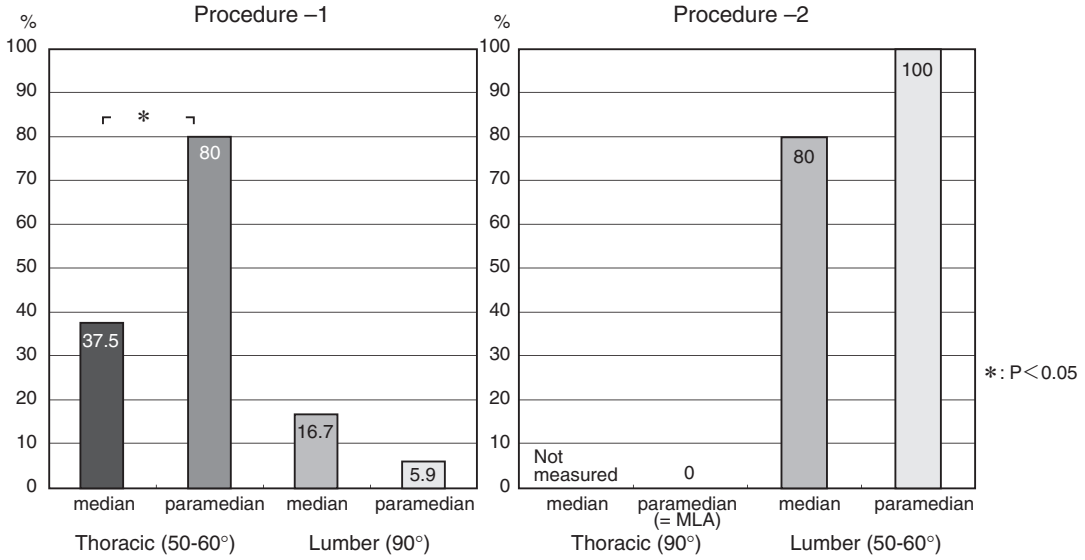

Fig. 5 Comparison of epidural catheter straight advancement rates by method and angle of epidural needle insertion in lumbar and thoracic punctures

left and right films in Fig. 4 show a catheter whose tip is hook-shaped despite being situated in the midst of epidural space and a catheter whose tip is U-turned, respectively.

Cases where the catheter tip was ill-defined on X-ray films were excluded from the study.

A comparison of straight advancement rates of epidural catheterization by epidural puncture method (median approach vs. paramedian approach), puncture site (thoracic vs. lumbar puncture), and puncture angle (50-60° vs. 90°) was made.

For statistical evaluation of data, Fisher's exact probability test ($P < 0.05$) was used.

RESULTS

The straight advancement rates of epidural catheters are shown in Fig. 5.

The results for Procedure 1 are shown on the left, while the results for Procedure 2 are shown on the right.

In Procedure 1, in the case of thoracic puncture using a median approach and paramedian approach at a puncture angle of 50-60°, the straight advancement rates of the epidural catheter were 37.5 % (6 out of 16 patients) and 80 % (12 out of 15 patients), respectively.

In the case of lumbar puncture using a median approach and paramedian approach at a puncture angle of 90°, the straight advancement rates of the epidural catheter were 16.7 % (3 out of 18 patients) and 5.9 % (1 out of 17 patients), respectively.

In Procedure 2, in the case of thoracic puncture using a paramedian approach (MLA) at a puncture angle of 90°, the straight advancement rate of the epidural catheter was 0 % (0 out of 7 patients).

In the case of lumbar puncture using a median approach and paramedian approach at a puncture angle of 50-60°, the straight advancement rates of the epidural catheter were 80 % (4 out of 5 patients) and 100 % (2 out of 2 patients), respectively.

In Procedure 1, in the case of carrying out thoracic puncture using a paramedian approach, the epidural catheter straight advancement rate was significantly higher as compared with a median approach. In the case of carrying out lumbar puncture at a puncture angle of 90°, there were no significant differences observed in the epidural catheter straight advancement rate between median and paramedian approach.

In Procedure 2, comparisons were made only in the lumbar puncture group. In the case of carrying out lumbar puncture at a puncture angle of 50-60°, there were no significant differences observed in the epidural catheter straight advancement rate between median and paramedian approach.

DISCUSSION

Drug infusion through epidural catheter occasionally fails to be effective. This is probably because the catheter tip misses the roots of the right and left vertebral arches, thus deviating from the intervertebral foramen. The anesthetic effects of the drug infusion can hardly be expected in such cases [1, 4 and 5].

For epidural anesthesia to be effective, it is considered essential to position the catheter tip medial to the roots of the right and left vertebral arches while maintaining straight advancement of the catheter in the epidural space.

We used Flex Tip Plus™ catheters in assessing the straight advancement rate in this study because the Flex Tip Plus™ (Arrow) catheter is radiopaque and its coursing is easily viewed on radiograms.

However, a problem with this method is that the catheter tip may be ill-defined.

In the present study, the catheter tip appeared ill-defined on X-ray films in approximately 20 % of the cases. The fineness of the catheter coil and bone shadow overriding of the vertebral body are thought to account for this trend [9].

In the present study, the epidural catheter straight advancement rate was 61.3 % when thoracic puncture was carried out at a puncture angle of 50-60° without considering the puncture method. This rate was close to the rate reported by Nishiyama *et al.* [9].

As their study assessed the thoracic puncture procedure alone, however, we investigated both the lumbar puncture technique and the thoracic puncture procedure.

Results for Procedure 1

In the case of thoracic puncture, the puncture angle of the epidural needle relative to the skin surface plane is typically an acute angle due to the presence of overriding of spinous process of thoracic vertebra.

The use of an acute angle facilitates inser-

tion of the catheter into the thoracic epidural space, and the straight advancement rate of the catheter is thought to increase.

In this study, the straight advancement rate of thoracic epidural catheter was significantly higher for a paramedian approach than a median approach.

This was because the catheter tip became hook-shaped or U-turned in 6 cases when the catheter was advanced 5 cm in the epidural space with the median approach.

Sato *et al*. [11] assessed the straight advancement rates of polyethylene thoracic epidural catheters. The catheter straight advancement rate was 100 % when using a median approach and 90 % when using a paramedian approach.

When using a catheter made of a hard material, high straight advancement rates are demonstrated by the catheter in the thoracic epidural space regardless of the puncture method employed. In the case of catheters made of a soft material, however, differences were found to occur in the straight advancement rates in the epidural cavity between median and paramedian approach employed.

On the other hand, in the case of lumbar puncture, the puncture angle of the epidural needle relative to the skin surface plane is nearly perpendicular.

For this, the catheter is inserted into the epidural space in perpendicularly.

The catheter tends to be prone to flexion or rotation, and this is thought to lead to a decrease in the straight advancement rate.

Nishimoto *et al*. [8] assessed the straight advancement rate of comparatively hard lumbar epidural catheters.

In the case of puncturing at a puncture angle of 90° to the skin surface plane, the straight advancement rate fell to 32 %. They drew the following conclusions regarding possible reasons for this.

In the case of a puncture angle of 90° relative to the skin surface plane, it becomes easier for the catheter to proceed in the left, right and anterior directions, namely towards the left and right intervertebral foramen, in the epidural space.

However, their rates are higher than the rates achieved in the present investigation.

In the case of harder catheters, the force of advancing a catheter with fingers in a lumen is liable to travel to the tip [7]. However, that force is less likely to be transferred in the case of catheters made of soft materials like polyurethane, thereby contributing to a lower straight advancement rate, whichever approach is employed.

Results for Procedure 2

In the case of lumbar puncture at a puncture angle of 50-60°, the straight advancement rate of epidural catheter was higher as compared with a puncture angle of 90° of lumbar puncture. Possible reasons for this include the use of an acute angle for the puncture angle as well as the anatomical characteristics of the epidural space in the lumbar region.

The epidural space is in contact with vertebra on the anterior side, and in contact with the vertebral canal on the posterior side. However, the vertebral canal in the lumbar region is in the shape of an inverted triangle [3]. Consequently, the shape of the epidural space in the lumber region tends to be more convex towards the posterior side than towards the anterior side. Nishimoto *et al*. [8] also stated the following with regard to this. Namely, as a result of employing an acute angle for the lumbar epidural puncture, after having been inserted into the epidural space, the catheter proceeds along the convex surface of the epidural space, thereby facilitating its straight advancement.

In the present study, there were no significant differences observed in the straight advancement rates of lumbar epidural catheter, whichever approach was employed.

This is thought to be because, differing from the thoracic epidural space, there were few cases in which the catheter hooked or became turned around in the lumbar epidural space when a median approach was employed. One possible factor behind this is believed to involve the width of the epidural space. The epidural space in the lumbar region is wider than that in the thoracic region. Consequently, the mobility of the catheter is enhanced, thereby contributing to greater ease of straight advancement even in the case of employing a median approach.

In the case of MLA, the straight advancement rate of the catheter in the epidural space was 0 %. The primary factor behind this result is considered to be perpendicular to the skin surface plane employed for the puncture angle.

On the basis of these results, the present study have revealed that straight advancement of a catheter in the epidural space depends on the puncture angle, whichever puncture site (thoracic or lumbar) is employed.

Furthermore, due to the small number of patients used in Procedure 2, a more detailed study is scheduled to be conducted in the future using a larger number of subjects.

In conclusion, the present study has demonstrated that the epidural catheter straight advancement rate is increased by inserting an epidural needle at an acute angle to the skin surface plane in conducting thoracic or lumbar punctures using a catheter of softer material such as polyurethane.

It is considered preferable to introduce and advance a catheter less than 5 cm in performing a thoracic puncture using the median approach.

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