Roentgenographic Analysis of the Positions of Catheters in the Epidural Space

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The optimum site for insertion of the needle into the epidural space for epidural anesthesia is controversial because understanding of the behavior of the catheter in the space is incomplete. This paper reports the results of roentgenographic analysis of the positions of catheters inserted into the epidural spaces of 151 patients. About 50 per cent of the catheters inserted by a conventional technique curled up or doubled back on themselves. Significant differences between the lumbar and thoracic regions were observed, in both length of catheter directly inserted and distance of the catheter tip from the puncture site. In the lumbar region, the probability that the catheter tip was situated three segments beyond the intervertebral space of insertion was only about 0.5 per cent; in the thoracic region it was about 50 per cent. (Key words: Epidural anesthesia; Epidural catheter.)

IN EPIDURAL ANESTHESIA it is desirable to place the catheter tip opposite a predetermined segment, so that the zone of blockade can be restricted to a minimum. To do this, the catheter should be inserted at the nearest possible spinal level. Few reports describing the condition and site of the catheter in the epidural space are available. Bromage[1] reported that the catheter tends to be deflected by blood vessels and nerve roots that lie in its path, curling up or doubling back after passing only a short distance in the direction in which it started. Moore[2] stated that the tubing might curl when inserted for more than two inches beyond the bevel of the needle.

The purpose of this study was to determine how far the catheter tip is threaded into the lumbar or thoracic epidural space and to clarify some factors that affect the state of the catheter in the epidural space. Our aim was to reduce apparent failures caused by incomplete understanding and a lack of quantitative information about these points, and to increase the accuracy of the technique of epidural anesthesia.

Methods

A hundred and fifty-one patients scheduled for abdominal surgery were studied, without regard to age, weight or height. Most of the patients were adults in good physical condition between the ages of 20 and 60 years (mean ages 36 ± 1.1 SE years in the lumbar group; 49 ± 2.0 years in the thoracic group). The study was confined to investigation of the behavior of the catheter in the epidural space.

At all levels of the spinal column epidural puncture was done with the patient in the lateral flexed position. A modified Tuohy needle with a Huber point was introduced, using the loss-of-resistance test; once the tip reached the epidural space, the needle was rotated until the bevel pointed cephalad. In most instances a median approach was used. However, in the thoracic region, where there was more obliquity of the spines than in the lumbar region, a paramedian approach was used when the median approach proved unsuccessful. The catheter was inserted until resistance to insertion was felt. No stylet was employed. The catheter was threaded into the epidural space until its further advance was impeded, but when an impediment was felt excessive force was not applied. A catheter adaptor was then attached and aspiration with a dry syringe carried out to determine whether the catheter was located in the subarachnoid or the peridural space. The point of entry of the catheter was marked and the catheter and marker were securely fixed in place with adhesive tape. The patient was then placed

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supine. The procedures were executed by two physicians experienced in epidural block.

The 100 patients who had lumbar cannulation were divided into three groups: Group 1, 40 patients; Group 2, 44 patients; Group 3, 16 patients. In Group 1 and Group 2, the lumbar epidural space was entered with soft polyethylene catheters (ID 0.50 mm; OD 0.91 mm). In Group 3, hard polyvinyl catheters (ID 0.50 mm; OD 0.91 mm) were used. In Group 1 and Group 3, the lumbar epidural space was entered using the technique mentioned above. In Group 2, with insertion of the catheter, an injection of saline solution was made with a 15-ml syringe. The rate of injection was kept as constant as possible at about 1 ml/sec. In the group in which the catheters were inserted in the thoracic region, polyethylene catheters were used in all patients (51 cases) and the catheters were inserted without saline-solution pressure, as in Group 1 and Group 3.

An x-ray film was placed beneath the patient, with the catheter site centered on the film. After injection of 0.2 ml of ethyl iodophenylundecylate (Myodil) through the catheter anterior–posterior and, in some cases, lateral roentgenographs were taken, preoperatively or at the end of operation with the patient still on the operating table. The interspinous level at which the space had been entered was indicated by the marker, and the length of catheter threaded within the epidural space was measured in cm on the roentgenogram. The error between the length measured on the roentgenogram and the actual length, measured after the catheter was withdrawn, was within 10 per cent when the length of catheter threaded into the space was less than 5 cm, and within 5 per cent when threaded further than 5 cm.

The spinal segments between the puncture site and the catheter tip were counted from the intervertebral space of entry and expressed as the segment number.

Statistical significances of differences between data from the various groups were tested with the Chi-square test or Student's *t* test.[3] In addition, the rejection limits of the segment number were calculated by the following formula: $X_o = \bar{x} \pm st\sqrt{(n+1)/n}$, where $\bar{x}$ is the mean segment number, n is the number of cases, *s* is the standard deviation of the samples, and the value of "*t*" corresponds to each percentage level of n − 1 degrees of freedom.

Results (Table 1)

The behaviors of the sections of catheter threaded in the epidural spaces in Group 1, Group 2 and the thoracic group were traced from the roentgenograms, superimposing them on each other, as shown in figures 1 (A, B, C, D) and 2 (A, B, C, D). The catheters inserted were straight in 26 patients (65 per cent) and kinked or curled in the remaining 14 (35 per cent) in Group 1. In Group 2, the catheters were straight in 11 patients (25 per cent) and curled in 33 (75 per cent). In Group 3, they were straight in seven patients (44 per cent) and curled in nine (56 per cent), and in the thoracic group, the catheters were straight in 35 patients (69 per cent) and curled in 16 (31 per cent). There was a highly significant difference between Group 1 and Group 2 ($P < 0.001$); however, there were no significant differences between Group 1 and Group 3 or between Group 1 and the thoracic group.

The mean lengths of catheters threaded into the epidural spaces were: 5.9 ± 0.47 (SE) cm in Group 1; 9.2 ± 0.63 cm in Group 2; 7.7 ± 0.71 cm in Group 3; 10.2 ± 0.60 cm in the thoracic group. There were significant differences between the lengths inserted in Group 1 and Group 2 ($P < 0.01$); Group 1 and Group 3 ($P < 0.05$); and Group 1 and the thoracic group ($P < 0.001$).

The mean lengths of catheter threaded into the epidural space without curling were: Group 1, 4.5 ± 0.49 (SE) cm; Group 2, Group 3, and the thoracic group, 5.5 ± 0.89, 6.5 ± 1.04, and 10.0 ± 0.81 cm, respectively. There were no significant differences between Group 1 and Group 2 or between Group 1 and Group 3, but a highly significant difference between Group 1 and the thoracic group ($P < 0.001$) was noted.

The mean numbers of segments which lay between the interspace at entry and the catheter tip were expressed numerically as segment numbers. In Group 1, the level of the catheter tip was found to be 1.04 ± 0.12 (SE) seg-

TABLE 1. Characteristics of Catheters Inserted into the Epidural Space*

	Lumbar Puncture			Thoracic Puncture
	Group 1 (40 Patients). Soft Polyethylene Catheters; No Saline Solution	Group 2 (44 Patients). Soft Polyethylene Catheters; Injection of Saline Solution	Group 3 (16 Patients). Hard Polyvinyl Catheters; No Saline Solution	Group 4 (51 Patients). Soft Polyethylene Catheters; No Saline Solution
Insertions in which catheters remained straight†				
Number	26	11§	7	35
Per cent	65	25	44	69
Length of catheter inserted (cm)‡				
Mean	5.9	9.2§	7.7¶	10.2§
± SE	0.47	0.63	0.71	0.60
Length of catheter inserted straight (without curling) (cm)‡				
Mean	4.5	5.5	6.5	10.0§
± SE	0.49	0.89	1.04	0.81
Number of segments between interspace at entry and catheter tip‡				
Mean	1.04	0.98	1.32	3.21§
± SE	0.12	0.11	0.16	0.31
Rejection limit (upper side tail)				
2.5 per cent level	$X_0 = 2.53$			$X_0 = 7.57$
0.5 per cent level	$X_0 = 3.07$			$X_0 = 9.03$

* Groups 2, 3 and 4 were compared with Group 1 for statistical analyses.
† Subjected to the Chi-square test.
‡ Subjected to Student's t test.
§ $P < 0.01$.
¶ $P < 0.05$.

ments higher than the site of puncture. In Group 2, it was 0.98 ± 0.11, in Group 3, 1.32 ± 0.16, and in the thoracic group, 3.21 ± 0.31 segments above the punctured intervertebral space. There was no significant difference between segment numbers in Group 1 and Group 2, or in Group 1 and Group 3, but there was a highly significant difference between Group 1 and the thoracic group ($P < 0.001$).

The values of the 2.5 per cent and 0.5 per cent levels of rejection limits in segment numbers in Group 1 and the thoracic group indicate that in the lumbar region the probability that catheter tip was inserted beyond 2.53 segments above the puncture site was about 2.5 per cent or less; beyond 3.07 segments, only about 0.5 per cent or less, in all cases. In the thoracic region the probability of insertion beyond 7.57 segments above the puncture site was about 2.5 per cent or less; that for insertion beyond 9.03 segments was about 0.5 per cent or less.

Discussion

Bromage[1] contends that for epidural anesthesia the puncture should never be made above the second lumbar interspace, and Ansbro[4] compromises by introducing the needle in the lumbar region and advancing the catheter to an extent such that the point reaches the center of the anesthetic zone. Lund[5] agrees with the latter. On the other hand, Moore[2] believes insertion should correspond as closely as possible to the center of the zone of anesthesia.

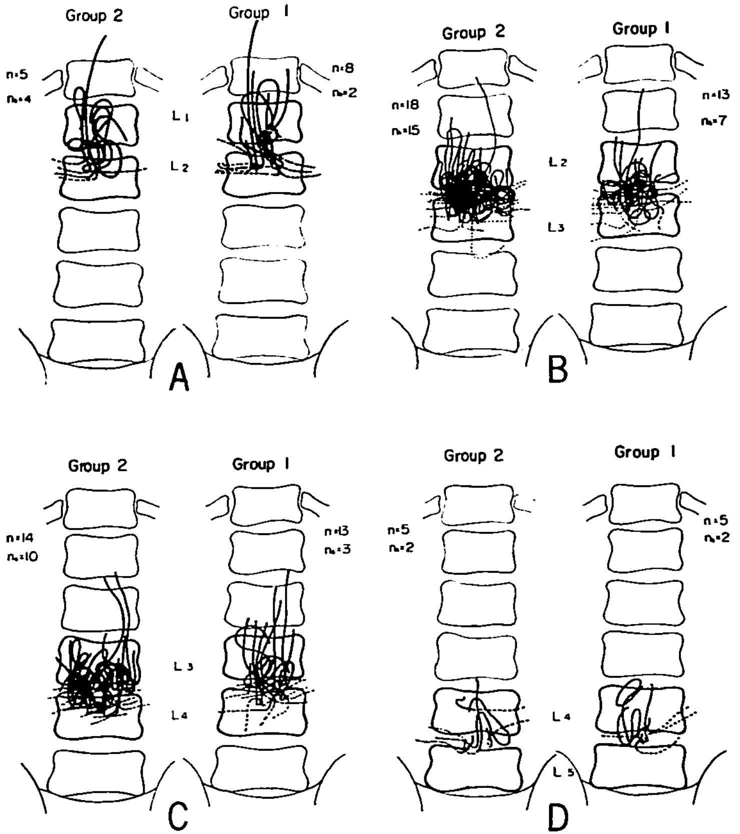

FIG. 1. X-rays of polyethylene tubing in the epidural space in the lumbar region. Anteroposterior projection. Tracings of the roentgenograms of the vertebral columns with inserted catheters were superimposed on each other. In Group 1, the epidural space was cannulated in the conventional way. In Group 2, saline solution was injected during insertion of the cathters. One patient in whom insertion was at the interspace between T_{12} and L_1 in Group 1 and two patients in whom insertion was at L_5–S_1 in Group 2 were omitted from these figures. n = number of cases; n_k = number of cases in which catheters inserted were curled. Catheters were inserted at the interspace between L_1 and L_2 (A), L_2 and L_3 (B), L_3 and L_4 (C), and L_4 and L_5 (D).

The findings presented in table 1 show that the catheter curled or doubled back on itself in many cases, even when only 5 to 10 cm of the catheter were inserted into the epidural space, a result compatible with the findings reported by Sánchez.[6] It is also interesting

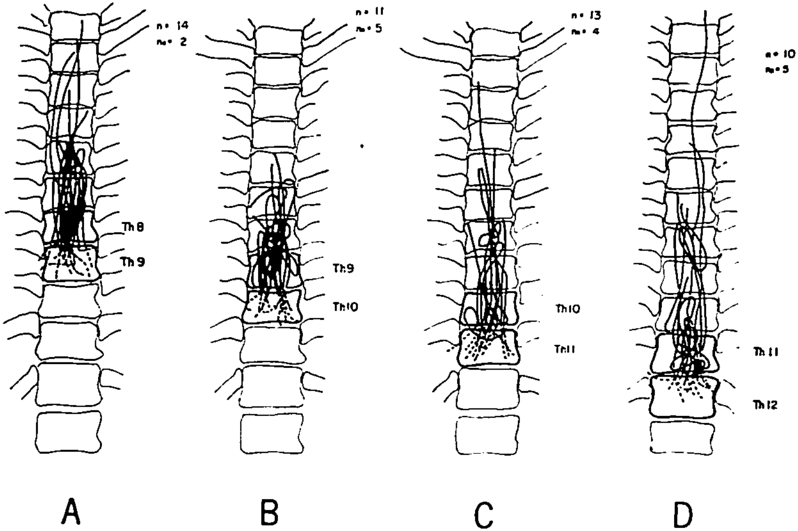

FIG. 2. X-rays of polyethylene tubing in the epidural space in the thoracic region. n = total number of cases; n_k = number of cases in which catheters inserted were curled. Catheters were inserted at the interspace between T_8 and T_9 (A), T_9 and T_{10} (B), T_{10} and T_{11} (C), and T_{11} and T_{12} (D). Three patients (insertions at T_7–T_8) were omitted from these figures.

that no difference with regard to the quality of catheter was observed (table 1, Group 1 *vs.* Group 3).

The opinion that the catheter may be passed more easily into the epidural space when saline solution is injected into the epidural space through the catheter during insertion has been commonly accepted. It is reasoned that the solution should distend the epidural space and displace the intervening venous structures; however, the tendency for the catheter to kink (Group 2) and the absence of a significant difference between the mean values of segment numbers in Group 1 and Group 2 do not confirm this opinion. The longer mean insertion length of the catheters in Group 2 compared with Group 1 may be one reason for the difference in incidence of kinking. The modification of resistance by insertion of the catheters with saline injection may have been responsible for the difference between the mean lengths of catheters inserted in Group 1 and Group 2. The highly significant difference between the mean lengths of catheters inserted into the epidural space in the thoracic group and Group 1 is noteworthy, considering that there was no significant difference between the incidence of kinking in Group 1 and the thoracic group.

In addition, in the thoracic region the catheter is easily inserted for a far longer distance without kinking than in the lumbar region.

Other striking features appeared in the determination of the positions of catheter tips as indicated by segment number deviation from the puncture site. No significant differences between segment numbers in the lumbar region were observed. Considering all the data, we conclude that the tip of the catheter remains at the same level even if the catheter curls and further insertion is made.

The data clearly demonstrate differences between the lumbar and thoracic groups. Frumin[7] reported that passage via the caudal canal for distances exceeding 5 cm without curling required a catheter–stylet unit. This concept is supported by our findings in the lumbar region, but the same conclusion does not hold for the thoracic region. As shown in table 1, when an attempt was made to pass a catheter in a cephalad direction, about 99.5 per cent failed to pass beyond three segments in the lumbar region, but the catheter went beyond nine segments in the thoracic region. This is a favorable outcome, because puncture in the midthoracic region is difficult, owing to the obliquity and overlap of the vertebral spines and laminae. Although the reason for the differences between the two groups is not clear, it may be partially the result of the angle of insertion of the needle. In the lumbar region, a catheter thrust through the Huber-point needle impinges on the dura or other structures at a right angle, with little chance of passing further in a cephalad direction. In contrast, the fact that in the thoracic region the catheter is thrust through the needle parallel to the epidural canal may be a logical explanation for these differences.

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Drugs

DIGITALIS The chronotropic effect of digitalis on denervated *in-situ* mammalian hearts was studied. When both the vagi and sympathetic nerves were cut, digitalis had no effect upon sinus rate. When either nerve was intact, digitalis caused some sinus slowing. This suggests that cardiac glycosides do not have a direct negative chronotropic effect and that the sinus slowing caused by cardiac glycosides may be mediated by alteration of the neural control of the heart. *(Ten Eick, R. E., and others: Chronotropic Effect of Cardiac Glycosides in Cats, Dogs, and Rabbits, Circ. Res. 25: 365 (Oct.) 1969.)*

DRUG-INDUCED HEPATIC INJURY A 37-year-old hypertensive man evidenced signs of hepatic injury while receiving *l*-alpha-methyldopa (Aldomet). Bilirubin, alkaline phosphatase and SGOT values were increased and biopsy of the liver showed diffuse cellular injury and necrosis. Liver-function tests returned to normal following discontinuance of the drug but hepatic injury recurred three weeks after resumption of Aldomet. The hepatic disease following Aldomet may closely resemble that seen with viral hepatitis. Although the course is usually benign and reversible, massive hepatic necrosis has been reported. The hepatic injury associated with Aldomet usually begins during the first three months of therapy and resembles the pattern seen with hypersensitivity reactions in that: the incidence is low but variable; the latent period is variable; dosage level is irrelevant; it may be associated with eosinophilia or a positive direct Coombs test. SGOT should be checked periodically in patients receiving Aldomet. *(Elkington, S. G., and others: Hepatic Injury Caused by L-Alpha-Methyldopa, Circulation 40: 589 (Oct.) 1969.)*