Spread of Epidural Analgesia Following a Constant Pressure Injection

– An Investigation of Relationships between Locus of Injection, Epidural Pressure and Spread of Analgesia –

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(1) The spread of epidural analgesia following injection of 15 ml of 2% mepivacaine was 17.3 ± 0.6, 14.3 ± 0.4, and 13.3 ± 0.7 spinal segments in cervical, thoracic, and lumbar epidural analgesia, respectively. The patient's age showed significant correlation with the spread of epidural analgesia in cervical ($r=0.5776$, $p<0.001$), thoracic ($r=0.3758$, $p<0.01$), and lumbar area ($r=0.8195$, $p<0.001$). The spread of cervical epidural analgesia was more caudad than cephalad ($p<0.05$), but in lumbar epidural analgesia it was more cephalad than caudad ($p<0.05$). There was no difference between the cephalad and caudad spread in thoracic epidural analgesia.

(2) The epidural pressure immediately after injection of 15 ml of 2% mepivacaine into the lumbar epidural space at a constant pressure (80 mmHg) correlated to the patient's age ($r=-0.5714$, $p<0.001$) and the spread of analgesia ($r=-0.3904$, $p<0.05$). The lower epidural pressure associated with higher age, the wider spread of analgesia. There was no significant correlation between the residual pressure at 60 seconds and the age or the spread of analgesia. (Key words: epidural pressure, spread of epidural analgesia, drip infusion technique)

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The spread of local anesthetic solution in the epidural space is affected by many factors that include technical, pharmacologic, anatomical, and physical factors. Injections of local anesthetic solution into the cervical, thoracic, and lumbar epidural space may have different spread of analgesia because of anatomical characteristics of epidural space. The investigation of the spread of epidural analgesia at different parts of the spine carried out under the technical and pharmacologic standardization has received little attention.

On the other hand, the spread of local anesthetic solution in the epidural space may be influenced by the instantaneous change in the epidural pressure at the site of injection, which was reported by Usubiaga et al.[1] They demonstrated a significant correlation between

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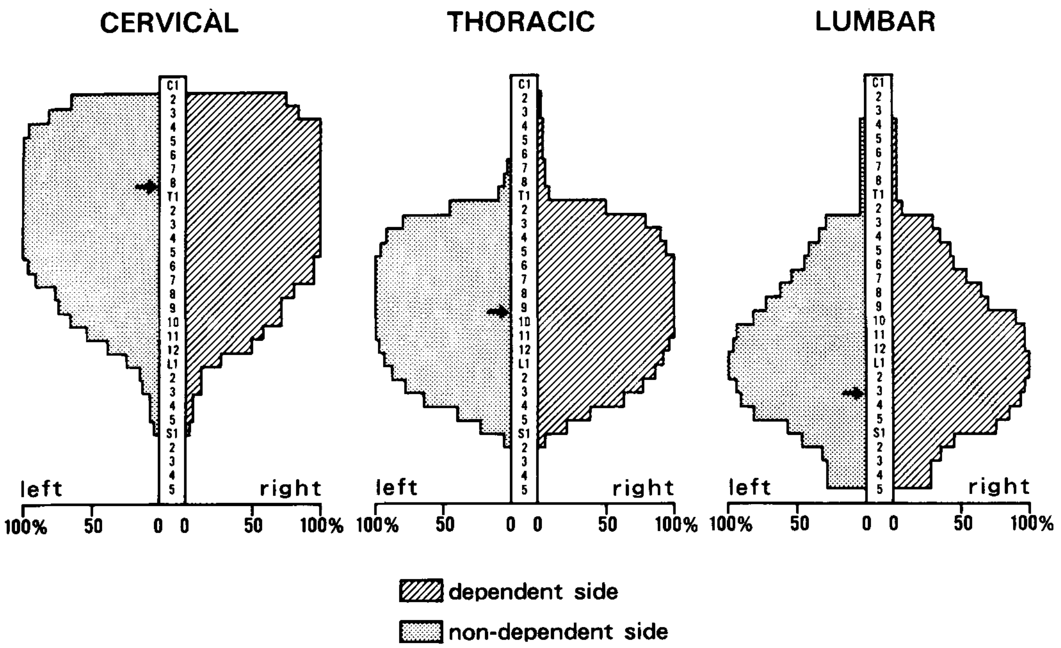

Fig. 1. Distribution of epidural analgesia 15 minutes after injection of 15 ml of 2% mepivacaine into the cervical, thoracic,and lumbar epidural space. Arrow indicates the level of the spine into which local anesthetic solution was injected.

the residual pressure 2 minutes after the injection of local anesthetic solution and the age as well as the level of analgesia, and assumed that, in general, a higher level of anesthesia was associated with greater residual pressures. However, Husemeyer and White[2] recently reported no correlation between the residual pressure 2 minutes after the injection of local anesthetic solution and the spread of analgesia.

The present study was designed to investigate the relationships between the epidural pressure during a constant pressure injection of local anesthetic solution into epidural space and the spread of analgesia, as well as to reveal the differences of the spread of analgesia at the site of injection in different parts of the spine.

Materials and Methods

One hundred and twenty-four patients who required epidural anesthesia for elective surgery were studied. None had a history of neurologic diseases or bleeding diathesis. The mean age of the patients was 47 years (range 14–84), mean height 159 cm (range 141–181), and mean weight 55 kg (range 35–80). Premedication consisted of atropine (0.5 mg) and hydroxyzine (25–50 mg) in most of the patients intramuscularly. The patient was placed in the right lateral position on a horizontal operating table. A 17-gauge Tuohy needle with the bevel directed cephalad was introduced via mid-line approach, and the epidural space was identified using the dripping method of Matsuda[3]. Epidural punctures were performed at C7–T1, T1–T2, T8–T9, T9–T10, L2–L3, and L3–L4 interspace in 30, 4, 18, 33, 10, and 29 cases, respectively. After the entry of the needle point into the epidural space, the hub of the needle was connected through a three way tap to an electromanometer (YHP-78342A) calibrated in mmHg and recording system. Before injection of local anesthetic solution the epidural pressure was allowed to equilibrated with the atmosphere across the Tuohy needle. Therefore all injection began with the same zero reference point (atmospheric pressure) in the epidural space at the site of injection. In all cases, 15 ml of 2% mepivacaine without epinephrine was injected into the epidural space at a constant pressure (80 mmHg) using a drip infusion set. The

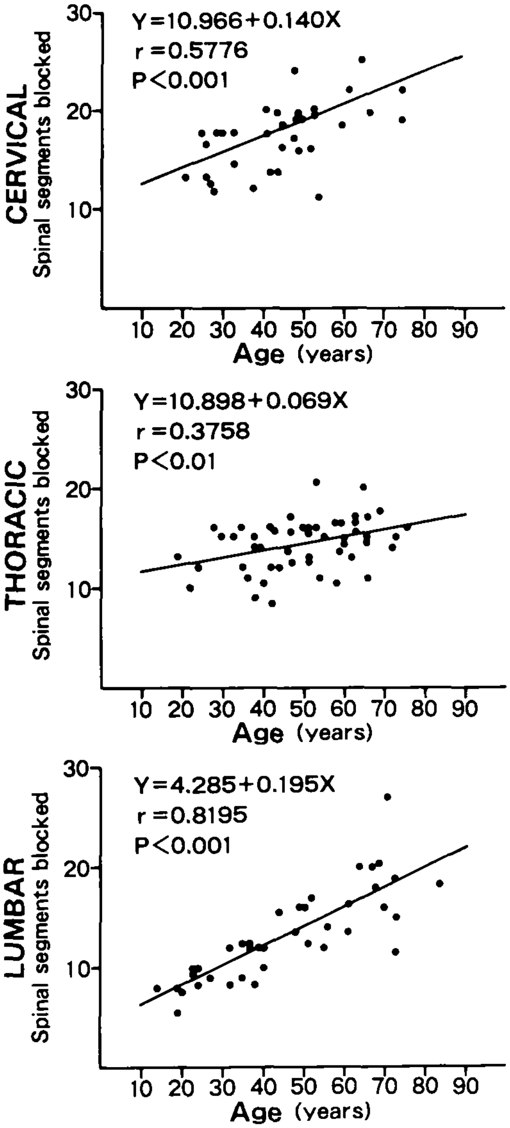

Fig. 2. Relationship between patient's age and spread of analgesia 15 minutes after injection of 15 ml of 2% mepivacaine into the cervical, thoracic, and lumbar epidural space

pressure curve was continuously recorded during each epidural injection and the residual pressure was recorded for 60 seconds. An epidural catheter was inserted to 5 cm beyound the point of the Tuohy needle, and the patient was turned to the supine position. From the recordings obtained, the infusion pressure (P_I), the dripping pressure (P_D), the epidural pressure immediately after completion of injection (P_{EO}), and the residual pressures at 10 seconds intervals ($P_{E10}-P_{E60}$) were calculated. Fifteen minutes after the injection of local anesthetic solution, the distribution of analgesia to pin-prick according to the dermatome map[4] was recorded on the left and right sides. The spread of analgesia was expressed by the average of the numbers of analgesic segments on each side.

Values given were mean ± SEM, and the linear regression lines in figures (fig. 2, 4–7) were calculated with least-square method. Statistical analysis were performed using Student's t test, and differences were considered to be significant when $p<0.05$.

Results

The cephalad and caudad spread of analgesia at the site of injection varied considerably in different part so the spine (fig. 1). The spread of cervical epidural analgesia for cephalad and caudad was 6.6 ± 0.8 and 10.6 ± 3.0 spinal segments, respectively ($p<0.05$). The spread of thoracic epidural analgesia for cephalad and caudad was 7.1 ± 1.8 and 7.2 ± 1.7 spinal segments, respectively. The spread of lumbar epidural analgesia for cephalad and caudad was 9.2 ± 3.5 and 4.1 ± 2.2 spinal segments, respectively ($p<0.05$).

Fig. 2 showed significant correlation between the age and the spread of epidural analgesia in cervical ($r=0.5776$, $p<0.001$), thoracic ($r=0.3758$, $p<0.01$), and lumbar area ($r=0.8195$, $p<0.001$). The segmental dose requirement : the number of ml of 2% mepivacaine needed to block one spinal segment in patients over 60 years of age was significantly ($p<0.05$) different from that in patients under 40 years of age in all three parts of the spine (table 1).

The changes of the epidural pressure in cervical, thoracic, and lumbar area following the drip infusion of 15 ml of 2% mepivacaine were illustrated in fig. 3. The infusion pressure was presetted at 80.3 ± 0.2 mmHg. The mean values of dripping pressure were 75.1 ± 0.7, 72.2 ± 0.7, and 73.3 ± 0.8 mmHg in cervical, thoracic, and lumbar epidural injection, respectively. Injection rates were 0.87 ± 0.08, 0.97 ± 0.06, and 1.01 ± 0.06 ml/sec in cervical, thoracic, and lumbar epidural injection, respectively. Average values of P_{E0} and P_{E60} were 39.0 ± 1.8

and 9.8 ± 1.0 mmHg in cervical area, 37.0 ± 1.5 and 10.2 ± 0.8 mmHg in thoracic area, and, 33.9 ± 1.7 and 11.4 ± 0.8 mmHg in lumbar area, respectively.

Epidural pressure (P_{E0}) showed significant correlation with the age in thoracic area (r= -0.4480, $p<0.01$) and lumbar area (r=-0.5714, $p<0.001$; fig. 4). This inverse correlation bet ween the epidural pressure and the age was also observed in P_{E10} of thoracic area, P_{E10} and P_{E20} of lumbar area.

Table 1. Segmental dose requirements (ml)

	~ 39	40 ~ 59	60 ~ (years)
Cervical	1.04±0.03	0.88±0.03*	0.72±0.01**
Thoracic	1.17±0.03	1.10±0.03	0.99±0.02*
Lumbar	1.62±0.06	1.11±0.03*	0.87±0.03**

Values are means ± SEM.

*$p<0.05$ values are significantly different from those of under 40 years of age.

**$p<0.05$ values are significantly different from those of 40 ~ 59 years of age.

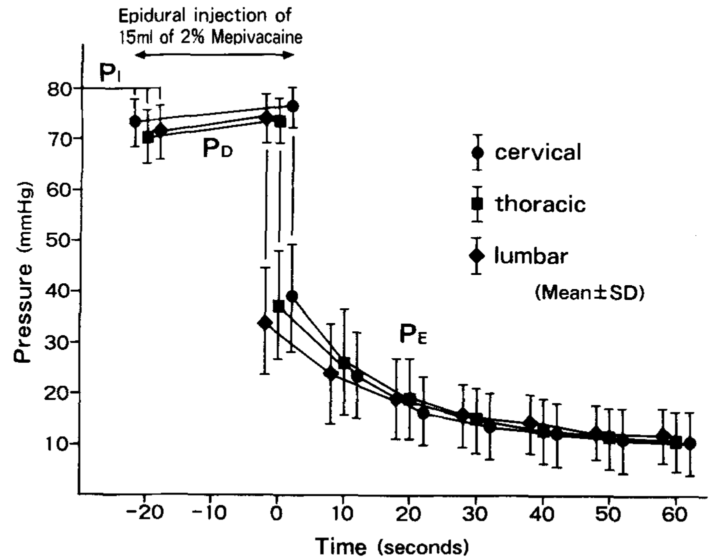

Fig. 3. The change of epidural pressure during and after injection of 15 ml of 2% mepivacaine into cervical, thoracic, and lumbar epidural space
P_I: infusion pressure
P_D: dripping pressure
P_{E0}: epidural pressure immediately after completion of injection
P_{E10-60}: residual pressures at 10 seconds intervals

The spread of lumbar epidural analgesia showed significant correlation with P_{E0} (r= -0.3904, $p<0.05$: fig. 5).

There was no significant correlation between P_{E60} and the age, nor was there a significant correlation between P_{E60} and the spread of analgesia in any parts of the spine (fig. 6, 7).

Discussion

A number of factors may influence the spread of local anesthetic solutions in the epidural space. The longitudinal spread of local anesthetic solution in the epidural space at different parts of the spine in any one individual is influenced by anatomical factors which include capacity of epidural space, cephalad and caudad boundaries of epidural space, size and patency of intervertebral and sacral foramina. The spread of

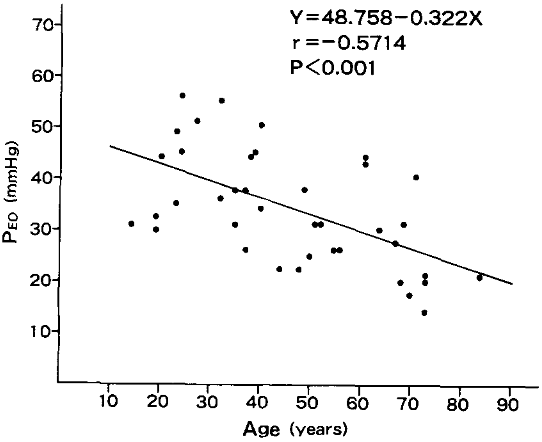

Fig. 4. Relationship between patient's age and lumbar epidural pressure immediately after completion of injection (P_{E0})

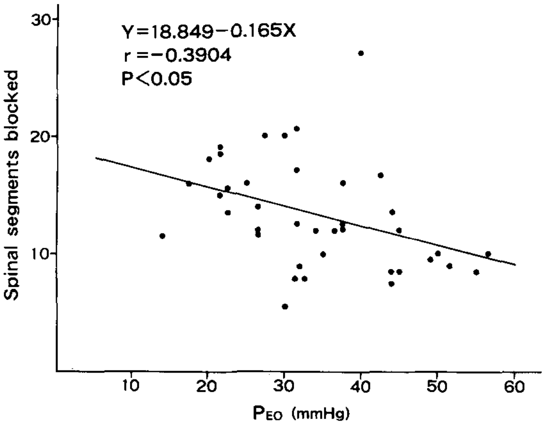

Fig. 5. Relationship between lumbar epidural pressure immediately after completion of injection (P_{E0}) and spinal segments blocked

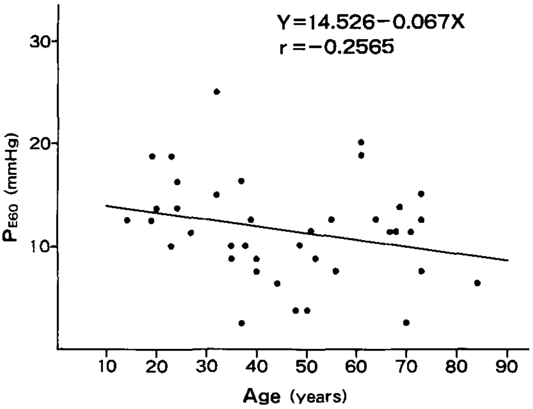

Fig. 6. Relationship between patient's age and residual pressure at 60 seconds (P_{E60}) in lumbar epidural anesthesia

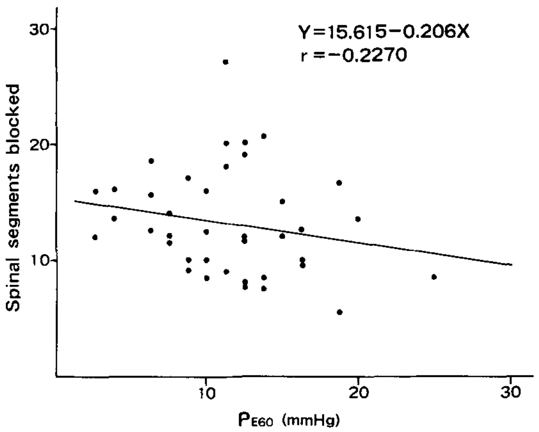

Fig. 7. Relationship between residual pressure at 60 seconds (P_{E60}) and spinal segments blocked in lumbar epidural anesthesia

local anesthetic solution in the locus of epidural space injected at the same part of the spine in different individuals may be influenced by physical characteristics which include age, pregnancy, pneumoperitoneum, arteriosclerosis, epidural fat, venous and lymphatic plexuses. In our study even though technical and pharmacologic factors were standardized, there was still a wide individual variation in the spread of analgesia, due, no doubt, to intrinsic anatomical and physical factors which play such an important role in determining the epidural spread of local anesthetic solution.

The spread of cervical epidural analgesia was more caudad than cephalad, but in lumbar epidural analgesia it was more cephalad than caudad. Whereas, there was no significant difference between the cephalad and caudad spread in thoracic epidural analgesia. The epidural space is closed, and the spread of solution injected into the cervical epidural space because of anatomical boundatry – foramen has a tendency to spread rather easily caudad because of anatomical boundatry, foramen magnum where the periosteal and spinal layers of dura fuse together. On the other hand, if a local anesthetic solution is injected into the lumbar epidural space, the spread of solution may be limited caudadly, and has a tendency to spread rather cephaladly[5].

Our results showed linear correlation of age on the spread of epidural analgesia not only in lumbar area but thoracic and cervical areas. The segmental dose requirement in patients over 60 years of age was smaller value than that in under 40 years of age in all three parts of the spine. This is at variance with the results of Bromage[6], who reported large reductions in dose requirements with advancing age. Park et al.[7] showed that lumbar epidural analgesia was significantly higher in patients older than 40 to 60 years of age, than in younger patients. But, they could not find a linear correlation between the age and the spread of lumbar epidural analgesia. Nishimura et al.[8] reported that the age plays only a minor role in determining the level of lumbar epidural analgesia. They assumed that the wider spread of lumbar epidural analgesia was usually achieved in seniles because of the spread of analgesia to cauda equina blocked by the diffusion of local anesthetic solution from the epidural to subarachnoid space at the lower lumbar area. In our lumbar cases, the spread of analgesia to the end of the sacrum was achieved in 2 and 9 cases, in patients under 60 years of age and over 60 years of age, respectively. A volume of local anesthetic solution blocked more spinal segments with advancing age. We also observed significant correlation between the age and the spread of analgesia in both cervical and thoracic epidural analgesia without the spread of analgesia to the end of the sacrum. Our results indicate the significant correlation between the age and the spread of epidural analgesia at any part of the spine. This has been well suggested in a study of Shanta[9], which demonstrated that, with age, the dura becomes more permeable to local anesthetic solution owing to a progressive increase in size and number of arachnoid villi, providing a large area through which local anesthetic solution can diffuse into the subarachnoid space.

The anesthetic solution injected into the epidural space initially fills the epidural space where the pressure is negative, and as additional volume is injected, positive pressure builds up in the epidural space and spreads cephaladly, caudadly, and laterally in the epidural space. Therefore, instantanous change of the epidural pressure following injection of loca anesthetic solution is determined by the quality and quantity of injected solutions, capacity of the epidural space, and epidural compliance. Usubiaga et al.[1] measured the rise and fall of epidural pressure following manual injection of 10 ml of 2% lidocaine at a constant rate (0.67 ml/sec) into the lumbar epidural space, and reported inaccuracies from artifacts in comparison pressure/volume curve with the spread of analgesia. To resolve this problem more accurately, they studied the residual pressure 2 minutes after the injection of local anesthetic age as well as the level of analgesia 10 minutes after injection. Husemeyer et al.[2] investigated the injection pressure and residual pressure continuously measured during the injection of 10 ml of 1.5% lidocaine into the lumbar epidural space using a compressed carbon dioxide hydraulic syring pump at constant rates between 0.143 and 0.333 ml/sec. They found no correlation between the spinal analgesic segments at 20 minutes and the residual pressure at 2 minutes. This study, injection of 15 ml of 2% of mepivacaine into the lumbar epidural space at a constant pressure, showed that the residual pressure at 60 seconds did not correlate on the age or the spread of analgesia. We found a significant correlation between the epidural pressure immediately after completion of injection (P_{E0}) and the age as well as the spread of analgesia. The lower epidural pressure associated with higher age, the wider spread of analgesia. The relationship of pressure (P), compliance (C), and volume (V) is expressed as follows; $P = V/C$. Therefore, the greater change in epidural pressure following the injection of a constant volume of solution indicates the lower epidural compliance. Contrary, the smaller instantanous change of epidural pressure following the injection of a constant volume of solution is observed in patients who have the higher epidural compliance. Bromage[10] speculated the reduction of epidural compliance with increasing age, based upon the study of residual pressure repoted by Usubiaga[1]. Our finding disagrees with that of Bromage. The difference in results of two studies could be due to the fact that in Usubiaga's study the level of analgesia 10 minutes after 10 ml of 2% lidocaine at a constant rate of manual injection (0.67 ml/sec) through Tuohy needle turning of the bevel to dependent part, whereas, we recorded the spinal analgesic segments 15 minutes after 15 ml of 2% mepivacaine at a constant pressure injection (80 mmHg) through Tuohy needle turning of the bevel to cephalad.

We believe that the contents of epidural space may vary with aging between individuals and play an important role in determining the epidural spread of local anesthetic solution. The epidural space of young subjects is filled up tightly with rigid fat[11], and has low compliance and high resistance, providing interfered spread of local anesthetic solution in the epidural space. Whereas, the wider spread of epidural analgesia might be achieved in seniles who have higher compliance and lower resistance probably caused by degeneration of epidural fat with age.

We assume that the epidural pressure immediately after injection of loca anesthetic solution is more important than the residual pressure in determining the relationship between the epidural pressure and the spread of epidural analgesia.

We recorded continuously the change of the epidural pressure during and after the injection of local anesthetic solution using the drip infusion technique. The residual pressure could not show any significant correlation with the age or the spread of analgesia. We found a significant correlation between the epidural pressure immediately after completion of injection and the age as well as the spread of analgesa. The lower epidural pressure associated with higher age, the wider spread of analgesia.

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