Epidural Pressure and Its Relation to Spread of Epidural Analgesia

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The relationships between the epidural pressures following the injection of local anesthetic solution and the spread of epidural analgesia were investigated. In 46 patients, 15 ml of 2% mepivacaine was injected into the lumbar epidural space at a constant rate (1 ml/sec) using an electropowered syringe pump. Injection pressures and residual pressures were recorded and the spread of analgesia to pinprick was assessed. The changes of the epidural pressures during and following the injection of a volume of local anesthetic solution in old subjects were significantly smaller than those in young subjects ($P<0.05$). The spread of analgesia closely correlated with the epidural pressures during and following the injection of local anesthetic solution. The most close correlation was found between the epidural pressure immediately after the completion of injection and the spread of analgesia ($r=-0.5659$, $P<0.001$). In conclusion, the lower the terminal injection pressure and the residual pressures associated with higher age, the wider the spread of epidural analgesia. (Key words: epidural pressusre, epidural compliance, spread of epidural analgesia)

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The instantaneous change of the epidural pressure at the site of injection and its relation to the spread of analgesia has received little attention. Usubiaga, Wikinski, and Usubiaga[1] investigated the epidural pressures following the manual injection of 10 ml of 2% lidocaine into the lumbar epidural space. They reported a significant correlation between the residual pressure at 2 min and the level of analgesia, and assumed that, in general, a higher level of analgesia was associated with the greater residual pressure. However, Husemeyer and White[2] recently investigated the injection pressures and residual pressures during the injection of 10 ml of 1.5% lidocaine into the lumbar epidural space using a compressed carbon dioxide hydraulic syringe pump, and found no correlation between the spread of analgesia and the residual pressure at 2 min. We previously investigated the epidural pressures during and following a constant pressure (80 mmHg) injection of 15 ml of 2% mepivacaine using an intravenous apparatus. The residual pressure at 60 seconds could not show any significant correlation with the age or the spread of analgesia. We demonstrated a significant correlation between the epidural pressure immediately after the completion of injection and the age or the spread of analgesia, and assumed that the lower the epidural pressure associated with higher age, the wider the spread of analgesia[3]. The present study was designed to investigate the relationships between the spread of epidural analgesia and

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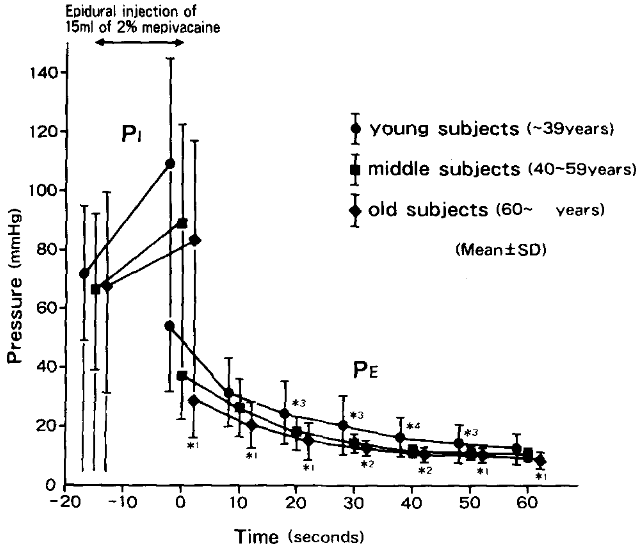

Fig. 1. Changes of epidural pressure following injection 15 ml of 2% mepivacaine at a constant rate (1 ml/sec).
Values in old subjects are significantly different from those in young subjects ($*^1$; $P<0.05$, $*^2$; $P<0.01$).
Values in middle subjects are significantly different from those in young subjects ($*^3$; $P<0.05$, $*^4$; $P<0.01$).
PI: injection pressures
PE: epidural pressures after the completion of injection

the epidural pressures during and following the injection of 15 ml of 2% mepivacaine at a constant rate using an electropowered syringe pump.

Methods

Forty-six patients who required lumbar epidural anesthesia for elective surgery were studied. Informed consent was obtained from each patient. None had a history of neurologic disease or bleeding diathesis. The mean age of the patients was 38 years old (range 17–70), mean height 164 cm (range 150–182), and mean weight 59 kg (range 37–80). Atropine (0.5 mg) and hydroxyzine (25–50 mg) were given in most of the patients intramuscularly 30 minutes prior to arrival in the operating room. 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 through the second or third lumbar intervertebral space. The epidural space was identified by the dripping method, that is, an intravenous apparatus for children, maintaining the force of gravity (80 mmHg), was attached to the needle and successful puncture was indicated by the appearance of dripping flow in the drip bulb as the needle was advanced. After the entry of the needle point into epidural space, the hub of the needle was connected through a three-way tap to electromanometer (Yokokawa Hewlett Packard 78342A) and recording system calibrated in mmHg. 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 same zero reference point (atmospheric pressure) in the epidural space at the site of injection. When no drip back of cerebrospinal fluid or blood was noted, epidural injection of 15 ml of 2% mepivacaine was delivered at a constant rate (1 ml/sec) using an electropowered syringe pump (Kimura Medical). Pressure curve was recorded during each epidural injection, and the residual pressure was recorded over 60 seconds thereafter. An epidural catheter was inserted to 5 cm beyond the bevel point of the Tuohy needle, and the patient was turned to the supine position. From the recordings obtained, the initial and terminal injection pressures (PI), the epidural pressure immediately after the completion of injection (PE0), and the residual pressures every 10 seconds (PE10–PE60) were calculated. Fifteen minutes after

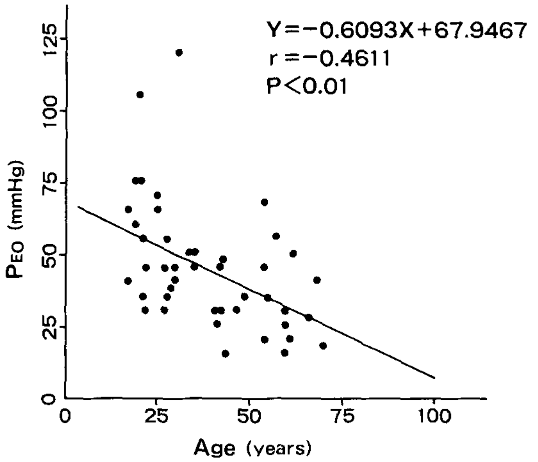

Fig. 2. Relationship between the age and the epidural pressure immediately after the completion of injection (P_{E0}).

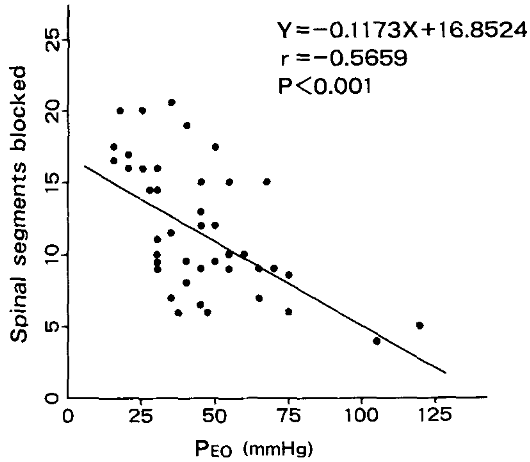

Fig. 3. Relationship between the epidural pressure immediately after the completion of injection (P_{E0}) and the spread of analgesia.

Table 1. Correlation coefficients between the epidural pressures and the age or the spread of analgesia

	P_I initial	P_I terminal	P_{E0}	P_{E10}	P_{E20}	P_{E30}	P_{E40}	P_{E50}	P_{E60}
age	-0.1017	-0.3183*[1]	-0.4611*[2]	-0.3068*[1]	-0.3849*[2]	-0.3719*[1]	-0.4802*[3]	-0.3300*[1]	-0.2599
spread of analgesia	-0.2914*[1]	-0.4619*[2]	-0.5659*[3]	-0.4289*[2]	-0.3915*[2]	-0.3204*[1]	-0.4893*[2]	-0.3779*[2]	-0.3737*[1]

*[1] $P<0.05$, *[2] $P<0.01$, *[3] $P<0.001$

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 side. The spread of analgesia was expressed by the average of the numbers of analgesic segments on each side.

Results are expressed as means±SD, and linear regression lines in fig. 2 and 3 were calculated with least-square method. Statistical evaluation was performed using Student's t-test, and differences were considered to be significant when $P<0.05$.

Results

The changes of the epidural pressure during and following the injection of 15 ml of 2% mepivacaine at a constant rate (1 ml/sec) were illustrated in figure 1. The averages of initial and terminal injection pressures (P_I) were 69.3±25.2 and 98.3±36.4 mmHg, respectively. The epidural pressures after the completion of injection (P_E) decreased from 44.6±21.4 mmHg (P_{E0}) to 10.9±4.1 mmHg (P_{E60}). The epidural pressures (P_{E0}–P_{E60}) in old subjects (60∼years old) were lower than those in young subjects (∼39 years old). The correllation coefficients between the age and the epidural pressures, and those between the spread of analgesia and the epidural pressures were showed in table 1. The epidural pressures (terminal P_I and P_{E0}–P_{E50}) showed a significant correlation with the age. The epidural pressures (initial and terminal P_I and P_{E0}–P_{E60}) also closely correlated with the sprad of analgesia. The most close correlation was found between P_{E0} and the spread of analgesia. The lower epidural pressure associated with higher age resulted in the wider spread of analgesia (fig. 2,3).

Discussion

Results of our study suggest that the

instantaneous changes of epidural pressure during and following the injection of local anesthetic solution may elementally affect the physical spread of injected solutions in the epidural space. The anesthetic solution injected into the epidural space initially fills the epidural space where the pressure is negative, and additional volume builds up positive pressure in the epidural space, and spreads cephaladly, caudadly, and laterally in the epidural space. Therefore, the epidural spread of local anesthetic solution may be influenced by the instantaneous changes of the epidural pressure, which are determined by the volume and concentration of injected solutions, the speed of injection, the capacity of the epidural space, and the epidural compliance as a most important factor. Widely accepted examination about the epidural pressure and its relation to the spread of analgesia was reported by Usubiaga, Wikinski, and Usuibiaga[1]. They measured the rise and fall of epidural pressure following the 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 a study which aimed to compare epidural pressure/volume curves with the spread of analgesia. To resolve this problem more accurately, they studied the residual pressure 2 min after injection, and showed that, in general, the wider the spread of analgesia, the higher the residual positive pressure in the epidural space. Same authors assumed that the residual pressure falls rapidly in young subjects, because the intervertebral foramina in young subjects are open and the injected solution can spread paravertebrally, whereas the residual pressure falls more gradually in old subjects, because the intervertebral foramina in old subjects are less patent[5] and the injected solution can easily remain within the epidural space. However, Husemeyer and White[2] recently investigated the injection and residual pressures during and following the injection of 10 ml of 1.5% lidocaine into the lumbar epidural space using a compressed carbon dioxide hydraulic syringe pump at constant rates between 0.143 and 0.333 ml/sec, and found no correlation between the extent of analgesia at 20 min and the residual pressure at 2 min. Unfortunately, they did not study about the epidural pressure immediately after the injection of local anesthetic solution. We previously investigated the relationships between the epidural pressures and the spread of analgesia during and following the injection of 15 ml of 2% mepivacaine at a constant pressure (80 mmHg) using an intravenous apparatus[3], and found an inverse correlation between the epidural pressure immediately after the completion of injection and the age or the spread of analgesia. We assumed that the lower the epidural pressure immediately after the completion of injection (P_{E0}) associated with higher age, the wider the spread of analgesia. Data of this study about a constant rate injection of 15 ml of 2% mepivacaine using an electropowered syringe pump also showed a significant correlation between the epidural pressures not only P_{E0} but also terminal P_I and P_{E10}–P_{E50} and the age or the spread of analgesia. The most close correlation was found between P_{E0} and the spread of analgesia. It is confirmed that, the smaller change of the epidural pressure during and following the injection associated with higher age, the wider the spread of analgesia. The relationship of pressure (P), and compliance (C), and volume (V) is expressed as follows; $P=V/C$. Therefore, the greater change of the epidural pressure following the injection of a constant volume of solution indicates the lower epidural compliance, and vice versa. Bromage[5] speculated that the epidural compliance decreases with advancing age, based upon the study of residual pressure reported by Usubiaga et al[1]. Our findings disagreed with those of Bromage. The difference in results of the two studies could be due to the fact that in Usubiaga's study the level of analgesia 10 min after the manual injection of 10 ml of 2% lidocaine over a 15-second period through Tuohy needle with the bevel turned towards the dependent part was investigated, whereas, in our study the spinal analgesic segments 15 min after mechanical injection of 15 ml of 2% mepivacaine at a constant rate (1 ml/sec) through Tuohy needle with the bevel turned towards cephalad was investigated. We believe that the contents of epidural space which may vary with aging play an important role in determining the initial epidural spread of local anesthetic solution injected into the epidural space. The spread of local anesthetic solution in the epidural space in young subjects is interfered, because the epidural space in young subjects is filled up tightly with rigid fat[6] and has the low compliance and the high resistance. On the other hand, the wider spread of epidural analgesia is achieved in seniles who have the high compliance and the low resistance probably caused by degeneration of epidural fat with advancing age. Matsuda[7] found the epidural resistance to decline in a linear manner with aging.

We recorded the changes of the epidural pressure during and following the injection of 15 ml of 2% mepivacaine at a constant rate (1 ml/sec) using an electropowered syringe pump. The terminal injection pressure and residual pressures showed a significant correlation with the age or the spread of analgesia.

The lower the terminal injection pressure and the residual pressures associated with higher age, the wider the spread of epidural analgesia.

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