Age and Epidural Dose Response in Adult Men

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Unlike Bromage's findings of a strong inverse linear relationship between age and epidural dose requirement,[1,2] results of our previous study using 20 ml of 1.5 per cent lidocaine with epinephrine (1:200,000) showed only a minimum effect of age on epidural anesthesia level. Because of this difference, the present study was designed to evaluate further the effect of age on the level of anesthesia from different epidural anesthetic doses and to construct epidural dose-response curves in different age groups.

METHODS

Two hundred seventy adult men who required epidural anesthesia for elective surgery were investigated using two different epidural anesthetic doses. One hundred seventy patients received 15 ml and 100 patients, 10 ml of 1.5 per cent lidocaine with freshly added epinephrine (1:200,000). An additional 231 patients from our previous study[3] were included for analysis because they received 20 ml of the same anesthetic solutions. The mean age of the patients was 54 years (range 21–95) and the mean height 176 cm (range 157–208). Informed consent was obtained from each patient prior to the procedure. Premedication consisted of diazepam (5–10 mg) and morphine sulfate (5–10 mg), or a combination of both administered intramuscularly approximately one hour before surgery.

After an intravenous catheter was inserted and a blood pressure cuff and EKG electrodes applied, the patient was placed in the lateral position on a horizontal operating table. A #17 Tuohy needle was introduced through the third or second lumbar intervertebral space, and the epidural space was identified using "loss of re-sistance" technique. With the bevel of the needle pointing cephalad, 2 ml of 1.5 per cent lidocaine with epinephrine (1:200,000) was injected. After one minute, if there was no evidence of an inadvertent subarachnoid or intravenous injection of the drug, the remaining anesthetic solution was injected at the approximate rate of 0.7 ml per second. An epidural catheter was inserted if indicated and the patient was then turned to a supine position.

Ten, twenty, thirty, and sixty minutes after injection of the anesthetic, the level of sensory blockade was determined by pinprick using a segmental dermatome chart.[4] The arithmetic mean of the number of spinal segments anesthetized on each side was determined. The amount of local anesthetic per spinal segment per unit of patient's height (ml/D/M) was calculated using the following formula: Amount of local anesthetic injected (ml) divided by number of spinal segments anesthetized times height (m). The time for regression of anesthesia to T12 was noted also. Analysis of variance and linear regression were used for the statistical analysis.

RESULTS

Data from this study and our previous study using 20 ml[3] of the same anesthetic solutions are summarized in table 1. Epidural anesthetic spread was complete in about 30 minutes. Complete sacral anesthesia was obtained in all patients in about 20 to 30 minutes. There was a wide individual variation in epidural anesthesia level in all age and dosage groups. In both the 10 ml and 15 ml groups, upper levels of anesthesia increased significantly by approximately three dermatomes when age increased from 20–39 to 40–59 years. However, thereafter, the level of anesthesia remained essentially unchanged with further advancing age in both dosage groups (table 1).

The number of segments anesthetized by 15 ml of 1.5 per cent lidocaine with epinephrine (1:200,000) was 2.4 (2.1–2.5) spinal segments greater than those with 10 ml of the same anesthetic solution and these increases were statistically significant ($P < 0.01$) in all age groups. When the number of segments anesthetized from 15 ml was compared further with data from 20 ml in our previous study, there was an increase of only one (0.5–1.7) spinal segment with 20 ml and this increase was statistically significant in the younger age groups but insignificant in patients older than 60 years of age (table 1).

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TABLE 1. Epidural Dose Responses in Different Age Groups

Age Groups (Years)	Amount of Anesthetic (ml)	Number of Patients	Height (cm)	Number of Spinal Segments Anesthetized	ml/D/M*
20–39	10	21	177.1 ± 1.4	12.7 ± 0.3	0.45 ± 0.01
	15	29	181.6 ± 1.2	14.6 ± 0.4	0.57 ± 0.01
	20	57	178.9 ± 1.5	16.3 ± 0.5	0.69 ± 0.02
40–59	10	43	175.7 ± 1.1	15.3† ± 0.4	0.37† ± 0.01
	15	76	175.5 ± 0.9	17.5† ± 0.2	0.48† ± 0.01
	20	100	175.9 ± 1.2	18.8† ± 0.3	0.61† ± 0.02
60–79	10	29	174.1 ± 1.4	15.8 ± 0.5	0.36 ± 0.01
	15	56	175.7 ± 1.1	18.3 ± 0.3	0.47 ± 0.01
	20	69	175.2 ± 1.3	18.7 ± 0.3	0.61 ± 0.01
80+	10	7	171.3 ± 3.0	16.3 ± 0.5	0.36 ± 0.01
	15	9	169.3 ± 2.3	18.8 ± 0.5	0.47 ± 0.01
	20	5	170.7 ± 2.4	19.5 ± 0.8	0.60 ± 0.02

Values are means ± SEM. All values were compared with those of same dosage groups in preceding age groups (i.e., values of 10 ml in 40–59 age group were compared with those of 10 ml in 20–39 age group and values of 10 ml in 60–79 age group with those of 10 ml in 40–59 age group, etc).

* ml/D/M: Amount (ml) of 1.5 per cent lidocaine with epinephrine

(1:200,000) required to anesthetize one spinal segment per each meter of patient's height.

† P < 0.001 denotes that values of 40–59 age group are signifficantly different from those of 20–39 age groups when values of same dosage are compared.

Calculated epidural segmental dose requirements (ESDR) changed significantly (r = 0.76, P < 0.001) with amount of local anesthetic injected in all age groups. The greater the total dosage injected into the epidural space, the greater the ESDR per height (ml/D/M). Times for sensory recovery to T12 were 111, 147, and 164 min after the epidural injections of 10 ml, 15 ml, and 20 ml, respectively, and these differences were statistically significant (P < 0.01).

Eleven out of 100 patients who received 10 ml anesthetic solution, four out of 170 patients who received 15 ml, and three out of 231 patients who received 20 ml and who had adequate anesthesia to the S5 as tested by pinpricks complained of slight burning pain on skin incision at the lumbosacral area, requiring either an additional dose of local anesthetic through the epidural catheter or general anesthesia.

DISCUSSION

Following epidural administration of local anesthetic through the second or third lumbar intervertebral space, a volume of anesthetic sufficient to spread cephalad to a level of T12 would also spread caudad to S1–2 assuming reasonably even spread in both cephalad and caudad directions.[5] At this level the dural sac ends and the rest of sacral nerves, i.e., S3,4,5 which enter the epidural space, can be blocked by anesthetic that diffuses through the dural root sleeves.[1] Furthermore, diffusion of local anesthetic from the epidural to the subarachnoid space at the lower lumbar area can block the cauda equina.[6] These might be the reasons why all of the patients studied

including those who received only 10 ml of 1.5 per cent lidocaine with epinephrine (1:200,000) had caudad spread of anesthesia to the end of the sacrum (S5).

The capacity of the epidural space in different spinal segments varies considerably. The epidural space is largest in the sacral area and narrowest in the area of the cervical spine with the thoraco-lumbar spaces intermediate in size.[5,7] Leakage of anesthetic solution from the epidural space also varied greatly with location. Greater leakage occurs from the sacral epidural space than from any other epidural space.[8] Considering these anatomical variations in epidural capacity and the extent of leakage, we believe that any generalization of epidural segmental dose requirement is misleading. These anatomical differences could also explain in part our finding that no patient in our studies had an anesthetic level above T1 even with the highest dose, i.e., 20 ml. High resistance caused by the narrow epidural space in the cervical area could have interfered with anesthetic spread above this level, forcing anesthetic solution to leak out through less resistant openings, i.e., sacral foramina and thoraco-lumbar intervertebral foramina. However, with very large volumes (greater than 20 ml) levels higher than T1 obviously can occur.

Bromage assumed that epidural dose-anesthesia relationship is directly linear and therefore, doubling the epidural dose would double the number of spinal segments blocked.[1] Our results, however, disagree with those of Bromage. With an epidural dose range of 10 to 20 ml, the level of anesthesia achieved had no direct linear relationship with epidural dose in any age group tested. Epidural injection of 10 ml of 1.5 per cent lidocaine with

epinephrine (1:200,000) blocked 15 spinal segments while 20 ml of the same anesthetic solution blocked 18 segments. Thus, doubling epidural dose blocked only three rather than 15 additional spinal segments. Grundy *et al.* found results similar to ours in that doubling the volume of 0.75 per cent bupivacaine from 10 ml to 20 ml produced a 3–4 segment higher level of anesthesia.[9]

When a local anesthetic solution is injected into the epidural space, it not only fills the epidural space adjacent to the epidural needle but it also leaks out through the intervertebral foramina.[1,8] While the volume of local anesthetic required to fill each segmental epidural space is relatively constant and limited, the volume that leaks out through the intervertebral foramina is unlimited and variable.[8] This variability depends on the patency of individual intervertebral foramen,[10] the distance of the foramen from site of injection, and the total volume of local anesthetic injected. The volume that leaks out through a given intervertebral foramen is inversely related to the distance of the foramen from the needle, while it is positively related to the total volume of local anesthetic injected. Thus, increasing the volume of anesthetic solution will result in greater anesthetic leakage and consequently greater ESDR calculated. This anesthetic leakage, we believe, plays an important role in determining the ESDR. This interpretation is consistent with our findings of a strong linear relationship between the total epidural anesthetic dose and calculated ESDR (ml/D/M). The same kind of strong linear relationship (r = 0.8512, $P < 0.001$) was found between total epidural anesthetic volume and ESDR when Bromage's data[11] were analyzed. Sharrock using 0.75 per cent bupivacaine also found that ESDR depended on the anesthetic volume injected (r = 0.949, $P < 0.0001$) in patients older than 50 years of age.[12] However, the value for ESDR did not vary with the volume injected in patients younger than 40 years of age. The difference between the two age groups has not been explained clearly. But all of these accumulated data suggest that ESDR calculated from variable anesthetic doses is limited and that ESDR calculated only from a fixed epidural dose be used for evaluation of factors that affect the epidural anesthetic spread, *i.e.*, age, pregnancy, arteriosclerosis, *etc.*

The increase in epidural anesthetic dose in this study produced increased anesthesia level as well as more intensified and longer lasting anesthesia. It appears that the anesthetic initially fills the epidural space where the pressure is negative,[10] and as additional volume is injected, positive pressure builds up in the epidural space

and the anesthetic apparently starts to leak out through the intervertebral foramina. This anesthetic that spreads laterally through the intervertebral foramina may be responsible for the intensified and prolonged anesthesia achieved with increased anesthetic doses. Our clinical impression is that whenever a high level of analgesia was produced by a small dose of local anesthetic, the block achieved became incomplete and its duration short, indicating an administration of inadequate anesthetic dose to each spinal segment. The question is then what is the minimal ESDR to achieve an adequate surgical anesthesia. Further investigation is needed to answer that question.

In conclusion, anesthesia levels achieved following epidural injection of either 10 or 15 ml of 1.5 per cent lidocaine with epinephrine (1:200,000) were significantly higher in patients older than 40 to 50 years of age than they were in younger patients. The calculated ESDR (ml/D/M) was not constant and changed in a linear manner with total epidural anesthetic dose injected. The number of spinal segments anesthetized was related to total epidural anesthetic dosage, but not in a linear manner. Thus, doubling the epidural anesthetic dose did not double the number of spinal segments anesthetized.

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