Ventilatory Reserve and Level of Motor Block During High Spinal and Epidural Anesthesia

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Eighteen subjects were successively given spinal anesthesia with 50 to 75 mg. lidocaine, and epidural anesthesia with 15 to 35 ml. of 2 per cent lidocaine containing 1:200,000 epinephrine. Mean levels of cutaneous analgesia (pin prick) and motor block (electromyography) were T 2.3 ± 1.8 and T 5.1 ± 2.4, respectively, with spinal anesthesia, and T 3.6 ± 1.2 and T 8.2 ± 2.6 with epidural anesthesia. Mean inspiratory capacity fell 8 per cent with spinal anesthesia and 3 per cent with epidural anesthesia. Mean expiratory reserve volume fell 48 per cent with spinal anesthesia and 21 per cent with epidural anesthesia.

ALTHOUGH high spinal and epidural anesthesia do not diminish resting pulmonary ventilation,[1,2,3] they reduce ventilatory reserve as shown by a decrease in maximal positive and negative airway pressures and a fall in vital capacity, inspiratory capacity and expiratory reserve volume.[4,5] Presumably the degree of such ventilatory impairment is dependent upon the level of motor nerve block, but work reported thus far has related changes only to the sensory level of anesthesia, and only limited information exists concerning the separation of motor and sensory block levels during spinal and epidural anesthesia.[6]

This paper reports measurements of inspiratory capacity and expiratory reserve volume made during spinal and epidural anesthesia. These measurements of ventilatory reserve were correlated with the level of motor block determined electromyographically, and the relation of motor level with that of skin analgesia to pin prick, as used clinically, is presented. Administration of both types of anesthesia successively to each subject made it possible to compare the difference between the levels of sensory and motor nerve block obtained with either anesthetic techniques.

Methods

Studies were performed on 18 fasting, unmedicated subjects, 11 males and 7 females, aged 21 to 64 years. Nine were volunteers and 9 were patients scheduled for minor surgical procedures; all were studied while supine. After a period of rest, control measurements of inspiratory capacity and expiratory reserve volume were made using a 9 liter Collins spirometer, a mouthpiece and a nose clip. A catheter with wire stylet was introduced into the epidural space at the fourth lumbar interspace and advanced cephalad for approximately 5 cm. Eleven subjects were first given an epidural block, and 30 minutes after skin analgesia had disappeared, a subarachnoid block. In the other 7 subjects the sequence of the blocks was reversed. For epidural anesthesia 15 to 25 ml. of 2 per cent lidocaine with 1:200,000 epinephrine was used. Four subjects required an additional 10 ml. for fifth thoracic minimum sensory levels. For spinal anesthesia, 50 to 75 mg. of 5 per cent lidocaine with dextrose was injected through a 22-gauge needle introduced at the third lumbar interspace.

Following stabilization of the level of skin analgesia to pin prick, spirometry was repeated, and the level of motor block was determined electromyographically from concentric needle electrodes placed in the rectus abdominis and intercostal muscles; the amplified signals were photographed from the screen of an oscilloscope. The subjects were

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Table 1. Levels of Sensory and Motor Nerve Block, and Changes in Inspiratory Capacity and Expiratory Reserve Volume with Spinal and Epidural Anesthesia

Subject	Spinal Anesthesia: Sensory and Motor Block Levels		Spinal Anesthesia: Insp. Cap. Liters Block/Control	Spinal Anesthesia: Exp. Res. Vol. Liters Block/Control	Epidural Anesthesia: Sensory and Motor Block Levels		Epidural Anesthesia: Insp. Cap. Liters Block/Control	Epidural Anesthesia: Exp. Res. Vol. Liters Block/Control
1	C_8	T_1	2.95 / 3.35	0.00 / 0.60	T_1	T_4	3.30 / 3.40	0.10 / 0.60
2	T_4	T_6	2.60 / 2.65	0.35 / 0.70	T_5	T_8	2.60 / 2.60	0.60 / 0.70
3	C_8	T_3	1.25 / 1.60	0.25 / 0.50	T_1	T_4	1.15 / 1.60	0.20 / 0.45
4	T_1	T_4	1.90 / 2.30	0.20 / 0.60	T_5	T_{10}	2.35 / 2.40	0.50 / 0.60
5	T_5	T_7	3.20 / 3.20	0.35 / 0.45	T_4	T_9	3.20 / 3.30	0.40 / 0.45
6	T_4	T_6	2.80 / 2.90	0.50 / 0.70	T_4	T_8	2.80 / 2.90	0.65 / 0.70
7	T_1	T_4	1.85 / 2.30	0.15 / 0.50	T_2	T_4	2.00 / 2.30	0.30 / 0.55
8	T_5	T_{10}	2.25 / 2.25	0.35 / 0.40	T_4	T_{11}	2.20 / 2.30	0.40 / 0.40
9	T_3	T_5	2.20 / 2.40	0.40 / 0.65	T_4	T_9	2.35 / 2.35	0.65 / 0.70
10	T_3	T_5	3.50 / 3.95	0.45 / 0.85	T_5	T_{12}	4.05 / 4.00	0.85 / 0.90
11	T_4	T_{10}	4.75 / 4.80	0.55 / 0.55	T_4	T_8	4.70 / 4.75	0.45 / 0.55
12	T_1	T_5	3.55 / 4.05	0.35 / 0.90	T_3	T_7	4.00 / 4.10	0.55 / 0.95
13	C_8	T_2	2.55 / 2.80	0.00 / 0.70	T_4	T_{10}	2.80 / 2.80	0.50 / 0.65
14	T_2	T_3	3.25 / 4.00	0.15 / 0.75	T_3	T_6	3.75 / 3.95	0.55 / 0.80
15	T_1	T_4	3.30 / 3.75	0.45 / 0.80	T_3	T_8	3.70 / 3.80	0.65 / 0.75
16	T_1	T_3	2.80 / 3.15	0.55 / 1.20	T_4	T_9	2.95 / 3.00	0.95 / 1.15
17	T_2	T_4	4.25 / 4.40	0.75 / 1.20	T_5	T_{10}	4.50 / 4.45	1.15 / 1.25
18	T_5	T_8	3.80 / 3.80	1.20 / 1.35	T_3	T_9	3.80 / 3.80	1.10 / 1.30
Mean and S.D.	$T_{2.3}$ ±1.8	$T_{5.1}$ ±2.4	2.93 ± 0.88 / 3.20 ± 0.87	0.38 ± 0.28 / 0.74 ± 0.27	$T_{3.6}$ ±1.2	$T_{8.2}$ ±2.6	3.12 ± 1.07 / 3.22 ± 0.87	0.59 ± 0.28 / 0.75 ± 0.27

Insp. Cap. = Inspiratory Capacity.
Exp. Res. Vol. = Expiratory Reserve Volume.

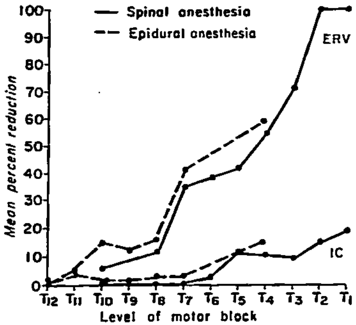

FIG. 1. Effect of level of motor nerve block during spinal and epidural anesthesia on inspiratory capacity (IC) and expiratory reserve volume (ERV). Changes in ventilatory parameters are plotted as percentage reductions from control.

asked to perform the following maneuvers: head raising, deep breathing, and expulsive efforts against a closed glottis following a deep inspiration. The segmental level at which muscle action potentials were first detected was defined as the level of motor block. Values of inspiratory capacity and expiratory reserve volume represent the average of 3 measurements. Student's t test for paired data was used for statistical analysis.

Results

Table 1 shows the levels of cutaneous analgesia and motor nerve block for each subject, and the accompanying changes in inspiratory capacity and expiratory reserve volume with spinal and epidural anesthesia. During spinal anesthesia the mean level of cutaneous analgesia was T2.3 (Range C8-T5) and of motor block T5.1 (Range T1-T10). During epidural anesthesia the mean level of cutaneous analgesia was T3.6 (Range T1-T5) and of motor block T8.2 (Range T4-T10). The level of motor block was 2.8 segments lower than the sensory level during spinal anesthesia, and 4.6 segments lower during epidural anesthesia. The greater separation of sensory from motor level with epidural anesthesia was statistically significant ($P < 0.01$).

The relation between level of motor block and the decrement in ventilatory reserve is illustrated in figure 1. Mean inspiratory capacity fell by 8 per cent with spinal anesthesia and by 3 per cent with epidural anesthesia. Mean expiratory reserve volume fell by 48 per cent with spinal anesthesia and by 21 per cent with epidural anesthesia. These changes were greater with spinal than with epidural anesthesia because the former produced a higher motor block than the latter technique.

Discussion

During spinal anesthesia the level of motor block was approximately 2.8 neurotomes below the level of cutaneous analgesia. This is greater than the 1.8 segment separation reported by Walts *et al.*[6] but the difference may be explained by their use of touch rather than pin prick as a sensory end point. The 4.6 neurotome separation between the levels of sensory and motor block during epidural anesthesia was 1.8 segments greater than during spinal anesthesia, although in 3 subjects the separation was actually less with epidural than with spinal anesthesia.

Figure 1 shows that block of thoracic motor nerves was associated with a relatively small reduction in inspiratory capacity. Total thoracic motor block caused inspiratory capacity to decrease only 19 per cent, which reveals the preponderant role of the diaphragm in inspiration and explains why resting pulmonary ventilation is unaffected by high thoracic spinal or epidural anesthesia. In contrast, expiratory reserve volume was greatly reduced by motor block above T8, falling to zero with a total thoracic block.

Though resting pulmonary ventilation is not affected by a reduction in expiratory muscle power, the ability to cough is diminished. Egbert *et al.*[4] found that during high spinal anesthesia maximal expiratory airway pressure was reduced to 50 per cent of control, but Moir[5] reported that peak expiratory flow rate fell only 10 per cent during similar sensory levels of epidural anesthesia. The difference between these findings could have resulted from dissimilar levels of motor block, which in neither case were determined.

The decreased ability to cough should rarely be a matter of concern during surgery since cough is generally undesirable; unless more drug is injected near the end of the operation, little impairment of cough will persist into the postoperative period. Nor should it be a matter of concern when conduction anesthesia is used for postoperative pain relief, since the concentration of anesthetic required for analgesia produces minimal motor block and correspondingly less effect on the ability to cough.

Summary

Levels of cutaneous analgesia (pin prick) and motor nerve block (electromyography), and changes in ventilatory reserve were studied on 18 subjects given both spinal and epidural anesthesia. Mean levels of sensory and motor nerve block were T2 and T5, respectively, during spinal anesthesia, and T4 and T8 during epidural anesthesia. Inspiratory capacity was reduced by 8 per cent with spinal anesthesia and by 3 per cent with epidural anesthesia. Expiratory reserve volume was reduced by 48 per cent with spinal anesthesia and by 21 per cent with epidural anesthesia.

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Anesthesia

REGIONAL LIDOCAINE A technique of intravenous regional anesthesia with lidocaine tagged with carbon-14 was used in adult monkeys. Levels of radioactivity after determined time intervals were obtained from specimens of extremity muscles, blood levels, and organs at autopsy. The anesthetic rapidly perfused throughout the tissue proximal to the site of injection and was held within the area bounded by the tourniquet until release. Within 30 minutes after release it was found throughout the body tissues. The concentration of the anesthetic present intravascularly within the anesthetized forelimb did not diminish significantly over a 90-minute period, and, therefore, release of the tourniquet may allow a significant concentration of lidocaine to suddenly enter the systemic circulation. Symptoms of systemic toxicity on tourniquet release are possible 90 minutes following injection of the local anesthetic. (*Knapp, R. B., and Weinberg, M.: Drug Distribution Following Intravenous Regional Anesthesia, J.A.M.A. 199: 760 (March) 1967*).