

## Age-related Changes in Blood Pressure and Duration of Motor Block in Spinal Anesthesia

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Changes in blood pressure, heart rate and the time necessary for recovery from motor block after spinal anesthesia were compared in 65 children, aged 8 months to 15 years, and 17 adult patients. All patients had similar levels of sensory anesthesia (T5-T3) following tetracaine, 0.3 mg/kg, plus phenylephrine, 0.075 mg/kg. Children less than 5 years of age showed little or no change in blood pressure and heart rate following spinal anesthesia, but children more than 6 years old had widely variable decreases in blood pressure. The decreases of blood pressure in the older children resembled those in adults. The time needed to regain motor function increase with age; in children less than 2 years of age, motor function returned in about a fifth of the time needed in adults. It is suggested that 1) the small proportions of the lower extremities and immaturity of the sympathetic nervous system in young children are responsible for the cardiovascular stability observed in these children during spinal anesthesia; 2) age-related differences in duration of motor block reflect physical and physiologic differences, including amount of cerebrospinal fluid, diameter and surface area of the spinal cord and nerve roots, and rate of absorption of local anesthetics from the subarachnoid space. (Key words: Anesthetic techniques, spinal. Age factors. Anesthesia, pediatric.)

THE USE of regional anesthesia in children is not well established. There have been few descriptions of spinal anesthesia for pediatric surgery.<sup>1-3</sup> The general impression, however, is that children regain motor function more rapidly than do adults, and children experience a lower incidence of hypotension. Robson<sup>1</sup> and Berkowitz and Greene<sup>2</sup> described the stability of a child's blood pressure during spinal anesthesia, but no statistically valid study dealing with the effects of age on the cardiovascular responses to spinal anesthesia has been reported. Similarly, although clinical impression holds that duration of spinal anesthesia is directly related to age, no objective data are available to quantitate this. The present study was designed

to determine whether children and adults differ with respect to 1) incidence or severity of hypotension following spinal anesthesia; 2) time necessary for recovery of motor function following spinal anesthesia.

### Methods

Spinal anesthesia performed for minor surgical procedures was studied in 65 children between 8 months and 15 years of age, and in 17 adults between the 29 and 65 years of age. Informed consent had been obtained from the parents or the patients. Patients who had histories of respiratory, circulatory, peripheral or central nervous system disorders or those whose weights or heights were outside the normal ranges were excluded from this study. Body weight, height and the distance from the spinous process of the seventh cervical vertebrae to the sacral hiatus were measured and body surface area was calculated according to DuBois' formula.<sup>4</sup>

In preparation for anesthesia and operation, children less than 2 years of age were given a clear-liquid diet until three hours, older children until four hours, and adults until six hours prior to induction of anesthesia. Secobarbital (6 mg/kg in children, not to exceed 100 mg; 150 mg in adults) and atropine, 0.01-.015 mg/kg, were given intramuscularly one hour prior to induction of anesthesia. Children more than 2 years of age and adults were divided arbitrarily into two groups: Group I, subarachnoid puncture performed with use of local anesthesia; Group II, halothane and nitrous oxide administered prior to and during lumbar puncture. (Children less than 2 years of age were assigned to group I.)

### GROUP I

Control measurements of blood pressure and heart rate (precordial stethoscope or electrocardiogram) were made with the patients supine on the operating table. An intravenous catheter was placed for infusion of dextrose, 5 per cent, in water at a rate of 8 ml/kg/hour. Following sterile preparation and draping of the lumbar region with the patient in the lateral decubitus position, a 24-gauge spinal needle was inserted through the L4-L5 intervertebral space. Following demonstration of free flow of clear cerebrospinal fluid, tetra-

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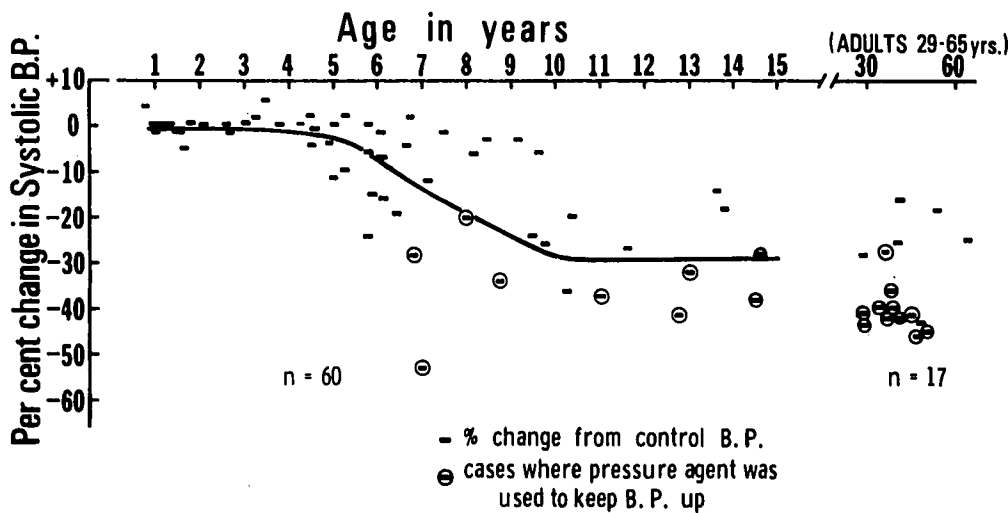


FIG. 1. Scattergram of percentage changes in systolic blood pressure from control plotted against age in years. - = maximal per cent change in systolic blood pressure following spinal anesthesia. o = a case in which a pressor agent was given to prevent further decrease in blood pressure.

caine, 0.3 mg/kg, prepared by dissolving crystalline tetracaine chloride, 20 mg, in 3 ml of dextrose, 10 per cent in water, plus phenylephrine, 1 ml of 0.5 per cent, were injected in 40–50 sec. A Montoux syringe was used when body weight was less than 10 kg, a 3-ml glass syringe for older children and a 5-ml glass syringe for adults. Aspiration of cerebrospinal fluid was performed after completion of the injection to confirm correct needle position.

Following subarachnoid injection, the patient was placed in the supine position with the head slightly flexed. Blood pressure and heart rate were measured

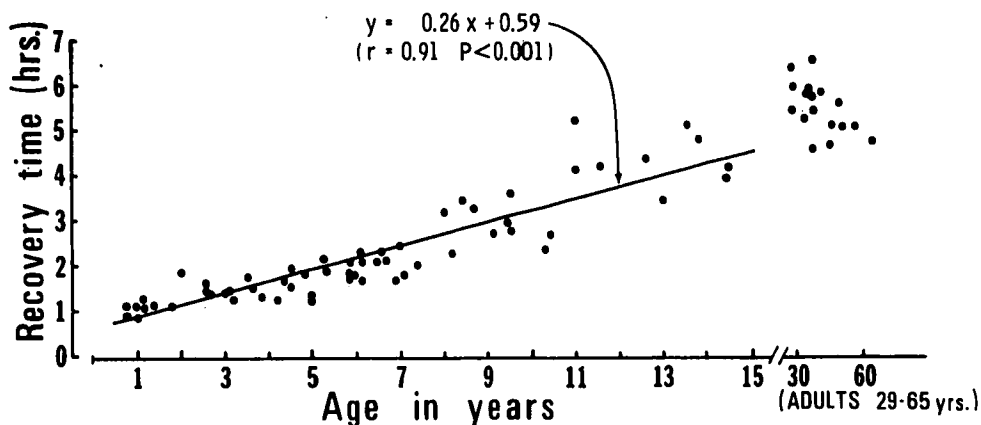
at one-minute intervals; the level of analgesia was measured at five-minute intervals using the response to pin-prick. The level of analgesia at 20 min was recorded as the maximal sensory level. Systolic blood pressure of less than 75 torr was treated with ephedrine, 0.1–0.17 mg/kg, iv, and bradycardia (less than 75 per cent of control heart rate) with atropine, 0.2 to 0.4 mg, iv. Blood pressure and heart rate just before these agents were given were recorded as the maximum changes from control. After the operation, toe movement in response to command or painful stimulation of the leg that had been dependent during the sub-

TABLE 1. Characteristics of Patients and Results (Mean  $\pm$  SD)

Age Range	Patients			Sensory Level	Systolic Blood Pressure (torr)		Heart Rates (Beats/Min)		Recovery Time Motor Block (Min)
	Number	Age (Years)	Weight (kg)		Control	After SAB	Control	After SAB	
0–2 years Group II	10	1.2 $\pm$ 0.4	10 $\pm$ 1.3	T3.7 $\pm$ 0.7	101 $\pm$ 5.2	100 $\pm$ 5.3	108 $\pm$ 7.2	106 $\pm$ 8.5	69 $\pm$ 13.3
2–5 years Group I	6	4.1 $\pm$ 0.6	16 $\pm$ 2.0	T4.6 $\pm$ 1.9	104 $\pm$ 12.1	102 $\pm$ 10.0	103 $\pm$ 6.2	101 $\pm$ 3.9	92 $\pm$ 12.8
Group II	7	3.2 $\pm$ 0.9	14 $\pm$ 1.7	T3.7 $\pm$ 0.8	104 $\pm$ 13.6	107 $\pm$ 13.6	107 $\pm$ 5.6	101 $\pm$ 7.5	
5–8 years Group I	11	6.3 $\pm$ 0.8	20 $\pm$ 3.1	T4.3 $\pm$ 0.7	112 $\pm$ 10.6†	96 $\pm$ 19.7*	98 $\pm$ 8.6	94 $\pm$ 8.8	114 $\pm$ 18.3
Group II	7	5.8 $\pm$ 0.5	20 $\pm$ 3.5	T4.0 $\pm$ 1.2	101 $\pm$ 6.0†	92 $\pm$ 8.0	94 $\pm$ 9.4	87 $\pm$ 8.4	
8–15 years Group I	13	10.9 $\pm$ 2.2	33 $\pm$ 9.5	T3.9 $\pm$ 1.0	120 $\pm$ 13.4	94 $\pm$ 17.6*	87 $\pm$ 9.4	72 $\pm$ 10.4*	215 $\pm$ 51.9
Group II	6	10.9 $\pm$ 2.3	32 $\pm$ 7.3	T3.4 $\pm$ 0.5	116 $\pm$ 6.7	82 $\pm$ 10.1*	88 $\pm$ 8.1	73 $\pm$ 8.5*	
Adults (29–65 years) Group I	11	41.6 $\pm$ 8.9	54 $\pm$ 5.5	T4.1 $\pm$ 1.4	124 $\pm$ 9.0	81 $\pm$ 11.8*	80 $\pm$ 7.5	66 $\pm$ 8.5*	336 $\pm$ 44.8
Group II	6	41.0 $\pm$ 11.9	57 $\pm$ 6.0	T3.6 $\pm$ 0.8	118 $\pm$ 7.6	73 $\pm$ 7.3*	81 $\pm$ 6.1	65 $\pm$ 4.5*	

\* Significant difference from control,  $P < 0.05$ .  
† Significant difference between two groups,  $P < 0.05$ .

FIG. 2. Relationship between the time (hours) necessary for recovery from motor block and age in years. In adults there was no correlation between these variables.



arachnoid injection was checked every 10 min. Recovery time of motor function was defined as the time elapsed from the time spinal anesthesia was introduced into the subarachnoid space to the time of the first movement of the great toe.

#### GROUP II

General anesthesia was induced with halothane, 1 per cent inspired concentration, nitrous oxide, 66 per cent, and oxygen, with a mask, using a non-rebreathing technique for small children and a semiclosed circle system for larger children and adults. After establishment of intravenous infusion and injection of local anesthetic at the site of subarachnoid tap, halothane was discontinued (average time of halothane anesthesia 6 min) nitrous oxide was decreased to 50 per cent, and ventilation was manually assisted. Fifteen minutes later control values for blood pressure and heart rate were recorded, and spinal anesthesia was induced. The measurements were performed in the same manner as in Group I. In Group II and in some children in Group I, the level of anesthesia was determined by measuring the level at which pin-prick or pinching of the skin no longer elicited movement. We have little difficulty in obtaining the exact margin between sensitive and analgesic skin.

During the operation, most of the children less than 6 years of age were given nitrous oxide by mask for adequate sedation. All data were tested with the Student *t* tests for paired data and for unpaired data between Group I and Group II. *P* values of 0.05 or less were regarded as indicating statistical significance. Data are expressed as means  $\pm$  1 standard deviation (SD).

#### Results

The mean heights of sensory blocks in both groups were between T4 and T3 skin dermatomes 10 to 15

min after subarachnoid injection of local anesthesia. Motor block of the legs was achieved within 15 min after injection. In three children less than 2 years of age, sensory block was adequate but motor block of the lower extremities failed to develop, and total-level blocks were seen in a 16-year-old boy and a 14-year-old girl; all data from these five patients were excluded from this study.

Little or no decrease in systolic blood pressure following spinal anesthesia occurred in children less than 5 years of age (table 1 and fig. 1). However, children 5 to 8 years of age in Group I showed statistically significant decreases in blood pressure ( $16 \pm 19.6$  per cent from control), whereas those in Group II did not ( $8 \pm 9.6$  per cent). Three children showed decreases in blood pressure greater than 20 per cent; each was treated by ephedrine. In the children more than 8 years of age and in adults, systolic blood pressures decreased significantly following spinal anesthesia;  $23 \pm 12$  per cent in children,  $36 \pm 9$  per cent in adults. Six of the 19 children and 11 adults were given ephedrine intravenously to prevent further decreases in blood pressure. In all patients the maximum decrease in blood pressure observed following spinal anesthesia was seen 3–5 min after injection.

Heart rate did not change following spinal anesthesia in children less than 5 years old (table 1). In children more than 8 years old and adults, heart rates decreased significantly to below control levels; three patients were given atropine intravenously for bradycardia.

Times to recovery from motor blockade were directly related to age ( $r = 0.91$ ,  $P < 0.001$ ; table 1 and fig. 2). The times to recovery also correlated significantly with other variables such as height, body weight, body surface area, and distance from the spinous process of the seventh cervical vertebrae to the sacral hiatus (D); however, each of these correlated less well with

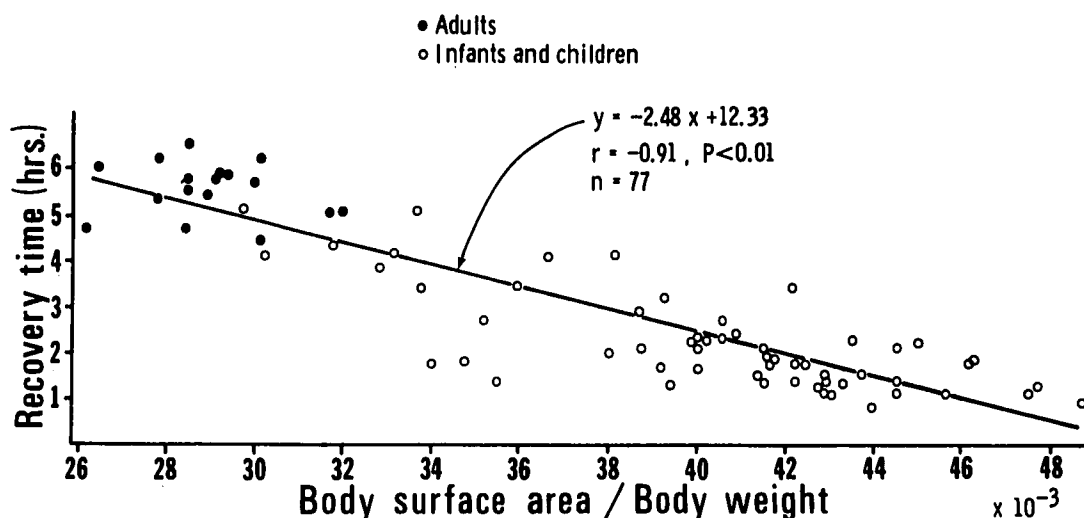


FIG. 3. Linear correlation between the time necessary for recovery from motor block and the ratio of body surface area (BSA) to body weight. Since a dosage of tetracaine was given on a weight-for-weight basis, this means that the higher the ratio of BSA to unit mg of tetracaine, the shorter the recovery time.

recovery time than did age. There was a significant inverse linear correlation between times to recovery and ratio of body surface by body weight ( $r = -0.91$ ; fig. 3).

There was no significant difference in any variable between Groups I and II except for control blood pressure for the 5–8-year-olds, as shown in table 1. Also, no difference between age distributions of the patients, body weights, heights, body surface areas, or the distances D in two groups was found.

### Discussion

The level of sympathetic block is the most important factor that influences the changes in blood pressure following spinal anesthesia,<sup>5,6</sup> while the changes of heart rate are related more to the development of arterial hypotension than to cardiac accelerator denervation.<sup>5</sup> In the present study, the sensory levels were nearly the same in all age groups; most of the patients might have had almost complete preganglionic sympathetic block, because the mean sensory level was T4–T3<sup>7</sup> and preganglionic B-fibers are more readily blocked than any other fiber group, even three times more sensitive than nonmyelinated C-fibers.<sup>8</sup> Therefore, even if the younger children had had a lesser intensity of spinal blockade than did the adults, sympathetic block could have occurred equally in all patients studied. Since there was no difference between the two groups of patients in each age range more than 2 years of age, we believe that the differences in changes in blood pressure and heart rate between children and

adults following spinal anesthesia were not significantly influenced by premedication, residual effects of halothane anesthesia, or intravenous fluid administration. There is also no evidence that high spinal anesthesia depresses respiration.<sup>10</sup>

For adults, the dosage for spinal anesthesia has been calculated according to height of the patient, whereas for young children body weight has been used.<sup>1–3</sup> When the dosage of tetracaine for young children is based on height or length of the spinal column D, overdose will occur. For example, the calculated doses of tetracaine for a 1-year-old child weighing 10 kg, 75 cm in height and 30 cm in D would be 3.0 mg based on weight, 7.5 mg based on height, and 8.3 mg based on D; those for an average 3-year-old child would be 4.1, 9.4 and 9.3 mg, respectively (assuming a dose of tetracaine of 0.3 mg/kg for an average adult of 57 kg weight, 165 cm height, and 60 cm D). This suggests that the dosage of tetracaine is better calculated on the basis of body weight. Tetracaine, 0.3 mg/kg, produced sensory block to T4–T3 in almost all patients studied.

We confirmed a clinical impression that young children experience little or no change in blood pressure following spinal anesthesia. The reasons for this are undoubtedly many, and one can only speculate on those physiologic features that distinguish infants and children from adults. These may include a less well-developed sympathetic nervous system than the adult, or a lower-extremity blood volume that is a smaller fraction of the total blood volume than that in the

adult. Both of these factors, if present, would tend to lessen the effects of sympathetic blockade on circulation following spinal anesthesia.

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