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Succinylcholine-induced Hyperkalemia in Patients with Ruptured Cerebral Aneurysms

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Succinylcholine (SCh)-induced hyperkalemia has been reported to occur in patients with severe burns[1], massive trauma,[2,3] spinal-cord injury,[4] and some neuromuscular diseases.[5] The hyperkalemic response has also been seen in patients with cerebral damage due to cerebral vascular accidents,[5] increased cerebral pressure,[6,7] and encephalitis.[8]

We were interested in determining whether the damage to the central nervous system caused by a rupture of a cerebral aneurysm initiates the SCh-induced hyperkalemic reaction. Accordingly, the changes in serum potassium following administration of SCh were examined in patients with cerebral aneurysms during the induction of anesthesia for repair of the aneurysms.

MATERIALS AND METHODS

Twenty-two patients (ten male, 12 female) undergoing general anesthesia for repair of cerebral aneurysms were included in this study. Ages of the patients ranged from 33 to 67 years, and body weights from 45 to 80 kg (58.8 ± 8.4 kg, mean ± SD). In seven patients loss of consciousness lasted more than an hour after the attack (major attacks; Patients 4, 11, 12, 13, 15, 16, and 19 in table 1). In three patients loss of consciousness lasted less than an hour (moderate attacks; Patients 1, 2, and 6), while in 12 patients consciousness was unchanged (minor attacks). Hemiplegia persisted until the day of operation in Patients 4, 11, 15, and 16; durations of hemiplegia were 6, 7, 10, and 1 day(s), respectively. Patient 19 had had hemiplegia for 96 days, but it abated seven days prior to operation. Patients 1 and 2 experienced muscle weakness of the lower extremities persisting only on the day of the attack. The exact durations of bed rest of these patients after attacks are unknown, but there was no noticeable loss of weight or muscle atrophy. Those patients who had minor attacks showed no neuromuscular disorder, and were performing regular daily work after a few days of bed rest.

TABLE 1. Serum Potassium (K^+) Values of All Patients

	Min after Injection of SCh					Highest K^+ (mEq/l)	Maximum + ΔK^+ (mEq/l)
	0	1	3	5	10		
	Femoral Venous Blood K^+ (mEq/l)						
Patient 1	3.9	10.0	5.7	5.4	4.6	10.0	6.1
Patient 2	3.5	4.7	4.7	4.4	4.1	4.7	1.2
Patient 3	3.6	3.9	4.2	4.3	4.1	4.3	0.7
Patient 4	4.2	4.5	4.4	4.3	4.5	4.5	0.3
Patient 5	3.6	3.7	3.9	4.1	4.1	4.1	0.5
Patient 6	3.9	9.2	7.1	6.3	4.8	9.2	5.3
Patient 7	4.3	4.3	4.8	4.6	4.5	4.8	0.5
Patient 8	4.6	4.4	5.4	5.0	4.6	5.4	0.8
Patient 9	3.8	6.3	5.6	5.0	4.5	6.3	2.5
Patient 10	3.3	3.6	3.7	3.6	3.7	3.7	0.4
Patient 11	4.6	4.7	4.9	5.1	5.1	5.1	0.5
Patient 12	3.8	3.8	4.2	4.2	3.9	4.2	0.4
Patient 13	3.6	3.6	3.5	4.0	3.8	4.0	0.4
Patient 14	4.1	4.1	6.7	6.1	5.0	6.7	2.6
Patient 15	4.6	4.7	5.2	5.2	5.2	5.2	0.6
Patient 16	3.5	3.6	5.2	4.8	4.4	5.2	1.7
Patient 17	4.0	4.1	4.3	4.3	4.2	4.3	0.2
Patient 18	3.6	3.7	3.8	3.9	3.9	3.9	0.3
Patient 19	3.6	5.4	5.6	5.0	4.2	5.6	2.0
Patient 20	4.0	4.0	4.3	4.4	4.7	4.7	0.7
Patient 21	4.1	4.4	4.4	4.7	4.8	4.8	0.7
Patient 22	3.5	5.8	5.0	4.7	4.3	5.8	2.3
MEAN	3.9	4.8	4.8	4.7	4.4	5.3	1.4
SD	0.1	0.4	0.2	0.1	0.1	0.3	0.3

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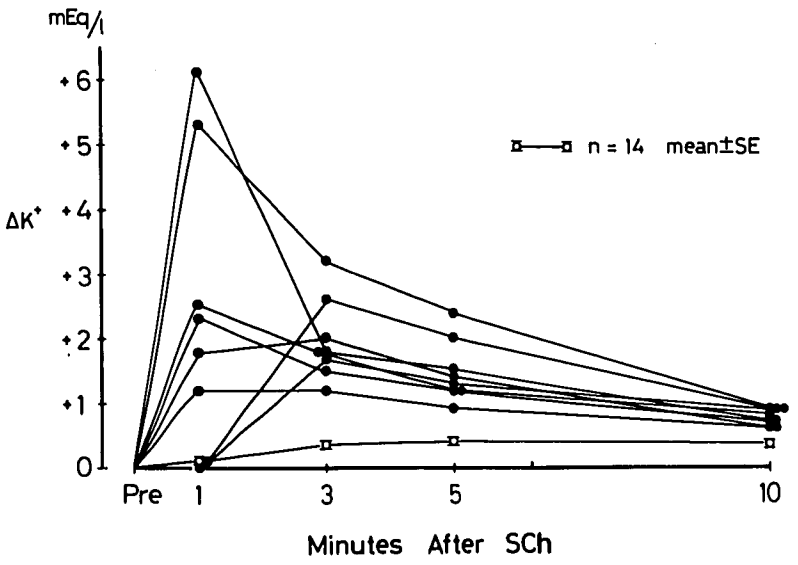

FIG. 1. Time course of changes in serum K^+ values (ΔK^+) after injection of succinylcholine (SCh). The ΔK^+ values of eight patients whose maximum ΔK^+ values were more than +1.0 mEq/l are described individually, and those of other 14 patients are expressed by mean ± SE.

Every patient was premedicated with 0.5 mg atropine and 35–50 mg meperidine an hour prior to induction of anesthesia. Anesthesia was induced with 6 mg/kg thiopental, and the trachea intubated following injection of SCh, 80 mg, iv. Then halothane, 0.5–1.0 per cent, with 30–50 per cent N_2O was given for maintenance with controlled ventilation. Blood for measurement of potassium (K^+) was sampled from the femoral vein prior to and 1, 3, 5, and 10 min after SCh injection. Arterial blood gases were analyzed 3–5 min after injection of SCh: *p*H was 7.53 ± 0.06, and Pa_{CO_2} was 25.2 ± 6.7 torr (mean ± SD). Lead I or II of the ECG was continuously monitored on an oscilloscope.

RESULTS

Serum K^+ values of more than 6 mEq/l were observed in four patients, and increases (ΔK^+) to more than 1.0 mEq/l were found in eight patients, after injection of SCh (table 1). The increases in ΔK^+ reached the maximum 1–3 min and returned to normal 10 min after SCh injection (fig. 1). The relation between ΔK^+ and the number of days from an attack of cerebral aneurysm to operation is shown in figure 2. In the four cases in which serum K^+ rose above 6 mEq/l, this interval was ten to 50 days. Fifty per cent (6/12) of the patients within this interval of ten to 50 days had ΔK^+ values of more than 1.0 mEq/l. No relationship was observed between ΔK^+ and the severity of loss of consciousness or the presence of motor nerve paralysis (fig. 3,*A* and *B*). Neither was elevation of ΔK^+ related to the dose of SCh expressed per kg body weight (fig. 3*C*).

Extreme fasciculation or contracture were not observed following injection of SCh in any patient. ECG monitoring showed no obvious change in rhythm or

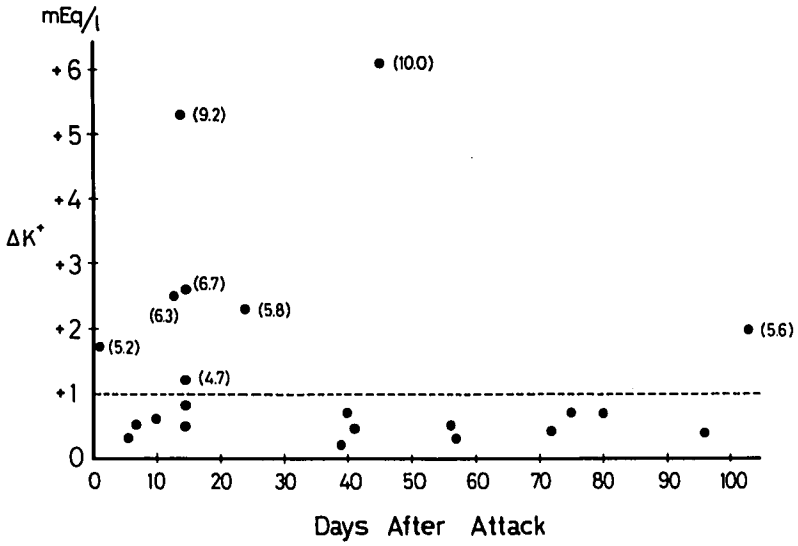

FIG. 2. The relationship between ΔK^+ and number of days from an attack of cerebral aneurysm to operation in all patients. The numeral beside a given point is an actual serum concentration of K^+ in mEq/l.

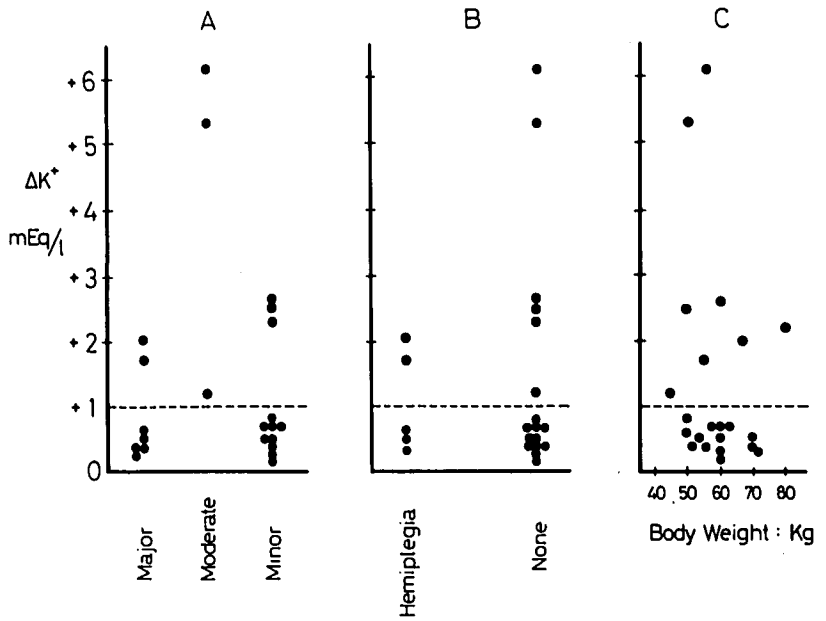

FIG. 3. Relationships between ΔK^+ and severity of the attack (*A*), presence or absence of hemiplegia (*B*), and body weights of the patients (*C*). Every patient received 80 mg succinylcholine.

configuration even in those patients with high K^+ values. Cardiovascular collapse did not occur in any patient during this study.

DISCUSSION

This study demonstrates a hyperkalemic reaction following administration of SCh in patients who have had subarachnoid hemorrhage due to ruptured cerebral aneurysms. It is a striking feature that these reactions were observed even in patients without motor nerve disturbance, and this observation is contradictory to previous reports which described hyperkalemia related to cerebral lesions as being associated with upper motor neuron lesions.[5–8]

The mechanisms responsible for SCh-induced hyperkalemia in our patients are not clear. Hypersensitization of skeletal muscle to the effects of SCh by denervation[4,8,9] has been suggested in other reports, and damage of the basement membrane of muscle[3,5] has also been suggested. Muscle atrophy is also considered to be a contributing factor in the SCh-induced hyperkalemic reaction.[9,10] These mechanisms do not suitably explain the reactions in our patients, especially those with only minor attacks. Acidemia has been associated with increased serum K^+,[11] but in this study all patients were rather alkalemic when the hyperkalemic reaction occurred. The relationship between SCh-induced hyperkalemia and the time interval from the attack to operation suggests a vulnerable period, lasting 10 to 50 days, in these patients. The other common factor that may relate to the hyperkalemic response in this study is subarachnoid hemorrhage, because patients who have brain lesions not associated with bleeding into the cerebrospinal fluid (such as ischemic brain disease and brain tumors) have a very low incidence of hyperkalemic reactions to SCh. None of ten patients without hemiplegia and only one of ten with hemiplegia showed this effect (unpublished data). However, the possible association of subarachnoid hemorrhage with a hyperkalemic reaction is a subject for future study.

That cardiovascular collapse was not observed in this study suggests that the use of SCh is relatively safe. In fact, we have used SCh for cerebral aneurysm repair in about 1,000 cases without major cardiovascular complications. However, since we realized that SCh might induce hyperkalemia, we have paid close attention to use of SCh for patients with cerebral aneurysms, especially during the ten to 50 days after hemorrhage.

In summary, SCh-induced hyperkalemia may occur in patients with ruptured cerebral aneurysms independently of the presence of motor nerve disturbance.

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Alteration of Hemoglobin Measurement by Fluorescein

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Sodium fluorescein is an orange-red, water-soluble dye that emits a green fluorescence when exposed to ultraviolet light. The dye can be used to evaluate the adequacy of tissue blood flow and tissue viability.[1–3] When administered intravenously, fluorescein readily diffuses from the capillaries and is rapidly distributed throughout the extracellular fluid.[4] To determine tissue viability, the area in question is observed for fluorescence under ultraviolet light after intravenous injection of fluorescein.

We observed that hemoglobin concentration, as measured by the OSM2 Hemoximeter®,§ was falsely elevated in a patient who received fluorescein intraoperatively. The following case report demonstrates the apparent increase in hemoglobin concentration after fluorescein. An evaluation of the accuracy of hemoglobin measurements in blood samples containing fluorescein is also presented.

REPORT OF A CASE

A 79-year-old woman was scheduled for a radical neck dissection, hemiglossectomy, and pectoral myocutaneous pedicle flap for treatment of squamous-cell carcinoma of the tongue. After insertion of intravenous and radial-artery catheters, anesthesia was induced with morphine and diazepam. The trachea was intubated and anesthesia was maintained with enflurane, nitrous oxide, and oxygen. After induction, hemoglobin was 12.3 g/dl as measured by the OSM2 Hemoximeter. During the surgical procedure, a blood loss of about 250 ml was replaced with lactated Ringer's solution. Immediately prior to the administration of fluorescein, 1 g, iv, hemoglobin was 12.0 g/dl. The perfusion of the tissue flap was assessed 15 minutes later and, although no blood had been transfused, the hemoglobin concentration in a sample taken at this time was reported to be 15.0 g/dl. The hematocrit of the same blood specimen was 35 per cent. Additional hematocrit determinations during the remainder of the operation and with the patient in the recovery room showed no change.

METHODS

To assess the effect of sodium fluorescein on hemoglobin concentration as measured by the OSM2 Hemoximeter, various amounts of fluorescein sodium¶ were added to 10-ml aliquots of blood by use of a micropipette. All blood came from one well-mixed unit of human blood in citrate–phosphate–dextrose solution. The maximum volume of fluorescein added to the 10-ml samples was 0.08 ml. All measurements were made on two samples in duplicate, and the four hemoglobin values obtained were averaged. Similar measurements of hemoglobin were made using the 282 Co-oximeter.**

RESULTS

The hemoglobin concentration of the blood without fluorescein was 11.1 g/dl. The hemoglobin concentrations measured with the OSM2 Hemoximeter after the addition of fluorescein are shown in figure 1. As the concentration of fluorescein in the blood was increased, the hemoglobin concentration as measured by the OSM2 Hemoximeter increased linearly. When fluorescein (100 mg/ml) without blood was injected into the OSM2 Hemoximeter, a hemoglobin concentration of 47.9 g/dl was reported. When hemoglobin concentrations were measured with the 282 Co-oximeter there was no change after the addition of fluorescein dye to the sample.

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