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Serum Potassium Concentrations after Succinylcholine in Patients with Renal Failure

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Increases in serum potassium concentration after administration of succinylcholine in patients with renal failure were compared with those in normal subjects. The mean maximal increases in serum potassium were 0.5 mEq/l in both groups of patients. Prior administration of *d*-tubocurarine did not prevent this increase. (Key words: Renal failure; Succinylcholine; Serum potassium; *d*-Tubocurarine; Uremia.)

FOR SOME YEARS it has been known that administration of depolarizing neuromuscular blocking agents increases serum potassium levels in animals.[1, 2] More recently, such elevations have been found in man.[3, 4] Exaggerated increases in circulating potassium have been reported in patients suffering from severe burns,[5, 6] massive trauma,[4, 7, 8] tetanus,[9] and neurologic lesions.[10, 11] Cardiac arrest[9] and ventricular tachycardia[12] in several patients with chronic renal failure have been attributed to succinylcholine-induced hyperkalemia. We therefore sought to obtain direct measurements of the increases in potassium produced by succinylcholine in patients with renal failure who were receiving hemodialysis and to compare the increases with those in a control group of patients. Since *d*-tubocurarine has been shown to limit the increase in potassium seen when succinylcholine is given to the traumatized patient,[4] the effect of pretreatment with *d*-tubocurarine was examined as well.

Experimental Design

The proposed procedure was explained to each patient and all agreed to participate in the study.

The patients were divided into two groups, patients with chronic renal failure and controls. The surgical procedures in the patients with renal failure included bilateral nephrectomies, renal allografts, parathyroidectomies, and one total hip replacement. All patients in this group received hemodialysis the day before surgery. The patients in the control group were classified as ASA physical status I, and were to have general anesthesia with endotracheal intubation.

By means of a table of random numbers, control and renal groups were each subdivided into patients given *d*-tubocurarine, 4.5 mg, iv, 3 minutes before an intubation dose of succinylcholine, 1 mg/kg, and those not given *d*-tubocurarine.

The age and sex composition of the groups is given in table 1. The ages were similar in all groups. A Chi-squared analysis of the sex distribution showed asymmetry, which resulted from a preponderance of men in the group with renal failure. This does not reflect the sex distribution of the diseases underlying chronic renal failure; we do not know why more men came to operation during the study.

Patients were usually premedicated with pentobarbital, 100–200 mg, and atropine, 0.4–0.6 mg, im, about an hour before operation. Anesthesia was induced with thiopental (100–350 mg) and maintained with nitrous oxide (60–75 per cent)–halothane (1–3 per cent)–oxygen in a semiclosed circle system with a CO_2 absorber. Intubation was performed when patients were in stage III, plane 1 anesthesia (usually about 10 minutes after induction). Following administration of succinylcholine, 100 per cent oxygen was given and respiration was controlled for approximately a minute before the trachea was intubated. When intubation was difficult, with multiple attempts or with a prolonged period of apnea, the results from that patient were not included in

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TABLE 1. Distribution of Patients by Sex, Age, and Initial Serum Potassium Level

	Subgroups	Number			Age (Years, Mean ± SD)	Initial Potassium Concentration (mEq/l, Mean ± SD)
		Male	Female	Total		
Patients without renal failure	No *d*-tubocurarine	6	5	11	37.2 ± 10.6	4.2 ± 0.5
	d-Tubocurarine-pretreated	4	7	11	35.5 ± 11.4	4.1 ± 0.3
Patients with renal failure	No *d*-tubocurarine	15	2	17	31.5 ± 11.1	4.4 ± 0.8
	d-Tubocurarine-pretreated	12	5	17	35.5 ± 10.2	3.8 ± 0.6

the study. The electrocardiogram was monitored visually from a cathode-ray oscilloscope throughout induction and maintenance of anesthesia.

Blood samples were obtained from a catheter placed in an antecubital vein. Five milliliters of blood were drawn before induction of anesthesia, immediately before administration of succinylcholine, and 1, 3, 5, and 10 minutes after succinylcholine had been given. Fluid administration was limited to less than 50 ml of 5 per cent dextrose in water until all blood samples had been drawn. The clotted blood samples were centrifuged for 15 minutes to separate the serum. Potassium level was measured on a flame photometer, calibrated with solutions of known potassium concentration before each sample was analyzed. Samples showing any visible sign of hemolysis were rejected.

Groups were compared in a 2 × 2 cross-classification analysis of variance with the analysis appropriate to proportional or unequal class sizes as necessary.[13]

Results

As the index of the effect of succinylcholine we used the maximal increase in serum potassium concentration above the level measured after halothane and before succinylcholine was given. Potassium values immediately before anesthesia are given in the last column of table 1. There was no difference among means but, as might be expected, there was a suggestion of greater variation among the patients with renal failure. A summary of the increases is given in table 2. Whether or not *d*-tubocurarine was given beforehand, patients with chronic renal failure showed no greater increase in serum potassium concentration than did the control patients.

Although the mean increases in potassium concentration were lower in both groups of patients who received *d*-tubocurarine, the difference was not significant. No patient who received *d*-tubocurarine showed visible signs of fasciculation following succinylcholine; apparently, therefore, blocking fasciculation *per se* will not appreciably reduce the rise in potassium.

We considered one other possible explanation why *d*-tubocurarine failed to reduce the increase in serum potassium: a competitive agent, by antagonizing succinylcholine, would lead to less neuromuscular block. The patient, therefore, might react more to tracheal intubation. In particular, catecholamines might be released and lead to increases in serum potassium. In fact, signs of stimulation such as coughing were observed in half of the patients receiving *d*-tubocurarine, as opposed to only four controls. We therefore subdivided the patients receiving *d*-tubocurarine into four groups, as shown in table 3. Analysis of variance showed no differences among groups.

TABLE 2. Peak Increases in Plasma Potassium Concentration Produced by Succinylcholine, 1 mg/kg, iv (mEq/l, mean ± SD)

	Patients without Renal Failure	Patients with Renal Failure
No *d*-tubocurarine	0.51±0.17 (n = 11)	0.52±0.21 (n = 17)
d-Tubocurarine-pretreated (4.5 mg, iv)	0.45±0.11 (n = 11)	0.46±0.24 (n = 17)

TABLE 3. Relation of Coughing to the Effect of *d*-Tubocurarine on Potassium Increases Produced by Succinylcholine (mEq/l, mean ± SD)

	Patients without Renal Failure	Patients with Renal Failure
No coughing	0.38 ± 0.11 (n = 5)	0.52 ± 0.27 (n = 9)
Coughing	0.52 ± 0.08 (n = 6)	0.40 ± 0.19 (n = 8)

Subjects of the systematic study described above were patients receiving thiopental–halothane–nitrous oxide anesthesia. However, a few patients with renal failure who received other types of anesthesia were studied also. Three patients were given thiopental–fluroxene–nitrous oxide and a fourth was intubated immediately after administration of thiopental–succinylcholine. The increases in serum potassium levels were 0.3, 0.4, 0.5, and 0.5 mEq/l, respectively. These results are comparable to those in table 2.

When examining serum potassium changes during induction of anesthesia, List[3] noted that halothane reduced serum potassium concentrations. We found an overall decrease of 0.08 ± 0.055 mEq/l (mean ±95 per cent confidence limits) following halothane. This decrease, although significant, is considerably less than the average of 0.4 mEq/l reported by List.

Discussion

The increases in serum potassium concentrations produced by succinylcholine in patients with renal failure fell within the normal range. Thus, chronic renal failure does not lead to the exaggerated response seen in patients with burns, massive trauma, or neurologic lesions.

On the other hand, cardiac arrests following administration of succinylcholine to patients with renal failure have been reported. We do not think there is a conflict here. To illustrate, consider the preoperative serum potassium concentrations. The two patients reported by Roth[9] who suffered cardiac arrest within minutes after administration of succinylcholine both had high initial levels of potassium (6.2 and 6.5 mEq/l, respectively). In the series reported by Compamanes *et al.*,[14] all three cardiac arrests occurred in patients with known elevated serum potassium levels. Hampers *et al.*[15] reported a series of 44 patients on maintenance hemodialysis and scheduled for operation. Of their two patients who had preoperative potassium concentrations between 6.1 and 6.5 mEq/l, one died following administration of succinylcholine for tracheal intubation. The other received spinal anesthesia.[16] Of the six patients who had preoperative potassium concentrations between 5.5 and 6.0 mEq/l, only two received succinylcholine; one of these had a cardiac arrest. (This same patient subsequently received succinylcholine without incident; the potassium concentration this time was 4.8 mEq/l).[16] A high potassium concentration was not the only abnormality present in the patients who suffered cardiac arrests. Nevertheless, a high preoperative concentration of serum potassium seems to be associated with a much higher probability of cardiac arrest following administration of succinylcholine. Presumably, the reason potassium increases of the same magnitude are toxic in some patients and not in others is simply that a higher *peak* level is reached if the initial level is greater. For some years it has been the policy in this hospital not to administer general anesthesia to patients with chronic renal failure whose preoperative serum potassium concentrations are above 5.5 mEq/l. Cardiac arrhythmias (other than sinus tachycardia) were not seen in any patient in this study, and none occurred in another series of 100 patients who had bilateral nephrectomies in this hospital in the past three years.[17]

Powell[12] reported ventricular tachycardia after succinylcholine in a uremic patient, and went so far as to suggest that depolarizing blocking agents be contraindicated in the presence of renal failure. His patient, however, received three successive doses of succinylcholine. One of our patients who happened to receive a second administration of succinylcholine seven minutes after the first had an additional increase of 1.0 mEq/l potassium within 3 minutes. The initial increase had been only 0.2 mEq/l. We did not attempt to investigate cumulative effects further because of the known dangers of repeated doses of succinylcholine administered at close intervals.

d-Tubocurarine, 0.3 mg/kg, has been shown to prevent succinylcholine-induced hyperkalemia in the dog.[1] *d*-Tubocurarine, 0.1 mg/kg, has been shown to limit the extent of succinylcholine-induced hyperkalemia in digitalized and traumatized patients,[4] but not in normal patients.[18] In our series, *d*-tubocurarine had no appreciable effect in either control patients or those with renal failure. Two of the renal-failure patients served as their own controls, *i.e.*, each received *d*-tubocurarine before succinylcholine for one of two anesthesias. We found *d*-tubocurarine to cause no difference in the increases in serum potassium concentrations in these two patients. Possibly an effect of *d*-tubocurarine can be demonstrated only with exaggerated increases in serum potassium concentrations.

In conclusion, we have no reason to believe that a single dose of succinylcholine is dangerous in patients with renal failure with levels of serum potassium below 5.5 mEq/l. *d*-Tubocurarine administered before the succinylcholine prevents muscle fasciculation but does not prevent the moderate increase in serum potassium seen in either normal patients or those with chronic renal failure.

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