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Laboratory Note

Pharmacokinetics of Bolus Potassium Injections for Cardiac Arrhythmias

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THE INTRAVENOUS administration of a 2-mEq bolus of potassium (K) has been advocated as a test dose for potassium-responsive arrhythmias during anesthesia.[1] "An obvious placebo" is the initial reaction of many clinicians to such an intervention. However, from a few simple calculations (*i.e.*, cardiac output of 5 l/min, 3,000 ml of which is plasma, most of the K bolus is distributed in less than ⅓ of this minute volume or 2 mEq K in 500 ml), a peak plasma concentration of 8 mEq/l can be predicted.

Potassium decreases the rate of spontaneous diastolic depolarization,[2] along with other electrophysiologic effects [3] which contribute to antiarrhythmic activities and potential toxicity as well. Potassium is often used in the treatment of paroxysmal atrial tachycardia (PAT) and PAT with block associated with digitalis. In addition, premature ventricular contractions often respond to K, particularly when the serum K is low or low-normal. Thus, the following experiments were done in dogs to correlate moment-to-moment changes in serum potassium after bolus injections with changes in the electrocardiogram and blood pressure.

Materials and Methods

Six mongrel dogs, weighing 9.8–13.0 kg, were anesthetized using pentobarbital, 25–30 mg/kg, intravenously. pH, P_{CO_2} and P_{O_2} were controlled using a Harvard respirator. A femoral vein and artery were cannulated for injections and continuous monitoring of arterial pressure. A catheter was inserted into the right common carotid artery and placed at the base of the aorta for blood sampling in order to assure serum K concentrations representative of coronary blood flow. Heparin, 2 mg/kg, iv, was given. The electrocardiogram was monitored continuously using the equivalent of a standard lead II. Electrical interference precluded interpretation of the EKG's in three dogs at one dose or another. Consequently, experiments with continuous monitoring of the EKG were done in three additional dogs.

Potassium chloride was administered iv in bolus injections of 3, 10, 30, 100, and 200 μEq/kg. Aortic blood was sampled continuously at a rate of 2 ml/4 sec for 40 seconds, then 2 and 5 minutes, after each injection. Plasma was separated immediately by centrifugation at 300 × *g* for 20 minutes at 4 C. Sodium and potassium were measured by an Instrumentation Laboratory flame photometer. Student's t test was used to test for significance of differences from control values.

Results and Discussion

The results are summarized in figure 1 and table 1. The peak plasma K concentration was obtained 14 seconds after intravenous administration, the approximate arm-to-tongue circulation time in man. Ten μEq/kg produced a statistical significant elevation of serum K, and there were proportionately greater increases with larger bolus injections. The 2,000 μEq K (2 mEq) per 50-kg person, or 40 μEq/kg, would be expected to increase serum K by 2 to 4 mEq/l. The larger bolus dose of 5 mEq sometimes used clinically [1] could be expected to cause significantly higher elevations of serum K. The electrocardiographic changes first noted occurred at the 100 μEq/kg dose and consisted of peaked T waves. At 200 μEq/kg,

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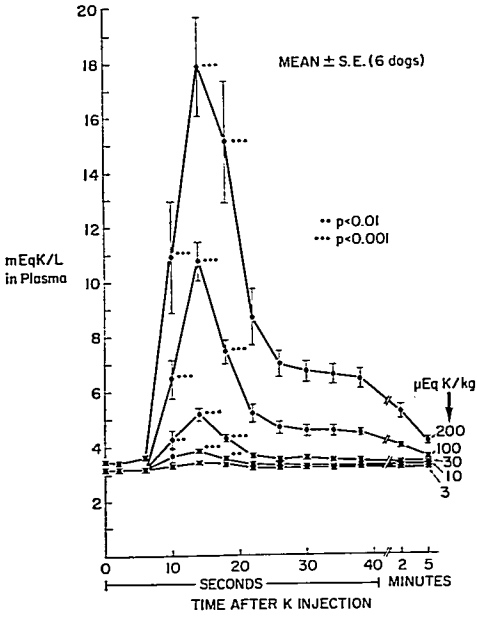

FIG. 1. Elevation of plasma potassium after intravenous bolus injections in dogs.

TABLE 1. Peak Plasma Potassium Levels in Individual Dogs after Bolus Injections of KCl*

	K, 3 μEq/kg		K, 10 μEq/kg		K, 30 μEq/kg		K, 100 μEq/kg		K, 200 μEq/kg	
	Control	Peak K	Control	Peak K	Control	Peak K	Control	Peak K	Control	Peak K
Dog 1	3.4	3.6 (106)	3.4	4.7 (138)	3.5	5.2 (149)			3.6	19.4 (539)
Dog 2	3.1	3.4 (110)	3.2	3.7 (116)	3.2	5.5 (172)	3.2	12.2 (381)	3.6	21.0 (538)
Dog 3	3.1	3.3 (106)	3.0	3.9 (130)	2.9	6.0 (207)	3.0	12.5 (417)	3.5	25.1 (738)
Dog 4	2.9	3.2 (110)	3.0	3.7 (123)	3.0	4.5 (150)	3.1	8.7 (281)	3.1	16.2 (523)
Dog 5	3.4	3.6 (106)	3.3	3.9 (118)	3.2	5.2 (163)	3.2	10.5 (328)	3.3	15.3 (464)
Dog 6	3.2	3.5 (109)	3.2	3.2 (119)	3.2	5.0 (156)	3.4	9.9 (291)	3.6	16.9 (469)
Mean ± SE	3.2	3.4 (108)	3.2	4.0 (124)	3.2	5.2 (166)	3.2	10.8 (340)	3.4	19.0 (553)
	0.07	0.06 (0.8)	0.06	0.15 (3.5)	0.08	0.20 (8.8)	0.06	0.71 (26.1)	0.08	1.49 (41.3)

* Per cent of control given in parentheses.

the QRS complex was significantly widened, and in one animal ventricular tachycardia occurred. No attempt was made to reverse this arrhythmia. Four hundred μEq/kg K were necessary in seven of nine dogs to induce fatal arrhythmias.

Intravenously administered potassium appears to have therapeutic merit in the control of postoperative arrhythmias [3, 4] and is potentially of value for ischemic arrhythmias.[5] The availability of a safe, rapid test such as the "2 mEq K push" for potassium-responsive arrhythmias may be highly useful. However, the potential for higher serum potassium concentrations must be considered in low-output states. For example, with a cardiac output of only 2,500 ml/min, the calculations described above suggest a theoretical peak K of 12 mEq/l. Thus, before widespread application of the 2 mEq K push, the safety of this technique should be established by monitoring of serum K and EKG in carefully controlled studies in man similar to that reported herein.

Summary

Potassium chloride was administered intravenously as a bolus to each of six anesthetized dogs in doses ranging from 3 to 400 μEq/kg. Plasma potassium was monitored continuously in blood obtained from the root of the aorta. The standard electrocardiographic lead II and direct systemic arterial pressure were recorded continuously. Peak dose-related increases in plasma potassium occurred at 14 seconds. A 30-μEq/kg dose of K (equivalent to 2 mEq in a 70-kg adult) can be given to the dog without EKG changes. The first EKG change consisted of peaked T waves following administration of the 100 μEq/kg dose.

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Obstetrics

CARDIAC OUTPUT BEFORE AND AFTER CESAREAN SECTION Hemodynamic measurements were made in 13 normal term pregnant women undergoing cesarean section during epidural anesthesia without epinephrine. Only minor alterations in maternal cardiovascular function were encountered. Following the administration of anesthesia there was a transient decline in blood pressure, but it remained constant throughout the surgical procedure. The maximum increase in cardiac output was found immediately after delivery, but it was only 1.46 l/min (25 per cent above control values). No significant heart rate change occurred, and stroke volume increased by a maximum of only 19 ml (28 per cent above control values) 10 minutes post partum. This hemodynamic stability has not been achieved previously with other anesthetic techniques. (*Ueland, K., and others: Maternal Cardiovascular Dynamics. VI. Cesarean Section under Epidural Anesthesia Without Epinephrine, Am. J. Obstet. Gynecol. 114: 775–780, 1972.*) EDITOR'S COMMENT: "Stability" is a euphemism for "no observed change," applied too often to the clinical situation. One could just as easily argue that removal of the fetus and placenta should have decreased maternal flow requirements but the changes were prevented by the persisting effect on systemic vascular resistance secondary to epidural anesthesia.