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Does Hyperkalemia Contraindicate the Use of Bupivacaine or the Use of Succinylcholine to Treat Bupivacaine-induced Toxicity in Humans?

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Data from animal experiments indicate that mild hyperkalemia, as compared with the normokalemic state, results in cardiotoxicity at a significantly lower dose of bupivacaine,[1] and that hyperkalemia may be a factor in enhancing bupivacaine's negative chronotropic effects on the heart.[2] Furthermore, in humans with renal failure and acidosis, slight elevations in potassium levels (but still within normal limits) have been cited as one possible reason for cardiotoxicity associated with bupivacaine administered to a patient receiving brachial plexus blocks.[3]

Therefore, two questions arise: 1) does hyperkalemia enhance the possibility of a systemic toxic reaction from bupivacaine; and 2) does succinylcholine used in the treatment of convulsions produce hyperkalemia and is it therefore contraindicated for this purpose?

METHODS

To answer the first question, we investigated 10 patients with renal insufficiency in whom dialysis shunts were to be inserted using bupivacaine for supraclavicular brachial plexus blocks (table 1). Patient consent was obtained, as was approval of our Human Rights Committee. Venous potassium levels were determined in these 10 patients immediately before and 30 min after completion of the block. The 5-ml blood samples were drawn from the arm not blocked after: 1) stopping the intravenous fluids (which were running in a hand or wrist vein) for 30 s; 2) applying a Penrose drain tourniquet on the arm; 3) inserting the needle attached to a 5-ml syringe (single-use) into either the cephalic or the basilic vein in the cubital fossa; and 4) releasing the tourniquet. Postblock sampling times for the plasma levels of potassium were selected to correlate with the maximum plasma levels of a bupivacaine–epinephrine solution following a supraclavicular brachial plexus block.[4]

Then, to approach question two, we reviewed three patients in whom: 1) potassium levels had been determined from blood obtained from a vein in the cubital fossa prior to surgery; 2) bupivacaine was employed for the blocks; 3) convulsions resulted; 4) succinylcholine alone along with oxygen was administered; 5) blood was drawn from the femoral artery during the systemic toxic reaction; and 6) the potassium levels of the blood were determined (table 2).

RESULTS

None of the 10 patients developed signs of systemic toxicity from the bupivacaine solutions, although they had significant hyperkalemia (table 1).

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TABLE 1. Potassium Levels Prior to and after Supraclavicular Brachial Plexus Block Using Bupivacaine 60 ml (300 mg) with 1:240,000 Epinephrine + 150 TRU of Hyaluronidase*

No. of Patients	K+ (mEq/l) Immediately Prior to Block†	Time of Sampling (min)‡	K+ (mEq/l) after Block†
10	5.5–7.6	30	5.5–7.6

* TRU = turbidity reducing units.
† Our normal range for potassium is 3.5–5.3 mEq/L.
‡ Sampled at approximately peak plasma levels of bupivacaine.[4]

Of the three patients who convulsed, patients 1 and 2 did so approximately 10 min after completion of the blocks (table 2). Both patients had satisfactory anesthesia, which indicates a reaction from a high blood level of the drug due to absorption from the intercostal grooves of the ribs. Patient 3 convulsed within approximately 1 min after the injection of the therapeutic dose, and no anesthesia resulted, which indicates an unintentional intravascular injection (table 2). None of them had hyperkalemia prior to anesthesia. After the administration of the succinylcholine, the potassium levels in one patient stayed the same, in one it decreased slightly, and in the other it increased slightly (table 2). In none of them did an untoward sequelae occur.

DISCUSSION

Since none of the patients who had dialysis shunt developed systemic toxicity (table 1), hyperkalemia probably does not put them at a greater risk to develop convulsions from bupivacaine than normokalemic patients. However, whether they are more susceptible to cardiac arrest than the normokalemic patient in the event of a systemic toxic reaction that is promptly recognized and rapidly and correctly treated, is not known, since none occurred before, during, or after this investigation.

Also, since, in general, the differences between venous and arterial potassium levels are insignificant or nonexistent‡ and because only one of three patients who convulsed had a rise in potassium, which was insignificant (table 2), it is doubtful that succinylcholine produces a sufficient increase in serum potassium that might result in a cardiac arrest, as it can in patients "who have sustained thermal trauma or those who have neurologic diseases involving motor deficits, including tetanus."[5] In addition, Nigrovic *et al.* studied 12 humans (ASA Class 1 or 2) who were not convulsing and who did not have thermal trauma or neurologic motor deficits and showed that a single dose of succinylcholine produced no significant rise in potassium.[6]

Systemic toxic reactions are significantly less from peripheral nerve blocks when absorption is the usual etiology as compared with those from accidental intravascular injecion during epidural block. From 1966 to 1983, the incidence of systemic toxic reactions from bupivacaine following peripheral nerve block was N = 5 in 11,767 blocks (0.04%) and that from accidental intravascular injection during epidural block was N = 31 in 15,337 blocks (0.2%). During this period of time, no systemic toxic reaction has followed the 1,522 brachial

TABLE 2. Bupivacaine-induced Convulsions

Type of Block, Dosage, and Times (min)	K+ (mEq/L) Venous* (controls)	K+ (mEq/L) Arterial (during and after convulsions)
Bilateral intercostal nerve (80 ml of 0.5% [400 mg] with 1:320,000 epinephrine):		
Patient 1		
Control	3.6	
0905 block completed		
0914 convulsions, 100% O_2 + 30 mg succinylcholine iv, blood sampled, convulsions recurred, 100 mg succinylcholine iv		3.8
0917 convulsions ceases		
0919 blood sampled		3.8
0940 blood sampled		3.9
Patient 2		
Control	3.9	
0730 block completed		
0740 convulsions, 100% O_2 + 60 mg of succinylcholine iv		
0741 blood sampled		3.6
0742 convulsions ceased		
0743 blood sampled		3.6
0800 blood sampled		3.6
Intermittent-injection lumbar epidural (18 ml of 0.75% [135 mg] with 1:200,000 epinephrine):		
Patient 3		
Control	4.0	
1500 test dose (3 ml)†		
1504 therapeutic dose (15 ml)		
1505 convulsions, 100% O_2 + 40 ml succinylcholine iv		
1506 blood sampled		4.0
1507 convulsions ceased		
1508 blood sampled		4.0
1515 blood sampled		4.0
1540 blood sampled		4.0

* Drawn 12–24 h prior to block.
† Test dose monitored by palpation of radial artery, not ECG, and judged to be negative.

‡ Barron EJ: Associate Director of Clinical Laboratories, The Virginia Mason Medical Center, personal communication.

plexus blocks with bupivacaine with and without epinephrine, of which 742 (49%) were administered with 250–300 mg of bupivacaine. Of the 5,593 intercostal nerve blocks done with bupivacaine with and without epinephrine, 4,042 (72%) were done with 250–400 mg. While following such blocks with over 300 mg, five patients had systemic toxic reactions (four convulsions, one cardiac arrest), no sequelae resulted. Therefore, bupivacaine 250–400 mg for a regional block, as used in this report, has proven in our hands to be a reasonable dose.

To conclude, hyperkalemia appears not to contraindicate the use of bupivacaine, and succinylcholine can be used to terminate bupivacaine-induced convulsions without the fear that hyperkalemia may result, which could enhance the cardiotoxicity of bupivacaine.

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Changes in Serial Platelet Counts Following Massive Blood Transfusion in Pediatric Patients

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Massive blood transfusion, defined as the transfusion of one or more blood volumes, commonly occurs in children undergoing major orthopedic, tumor, or burn wound surgery. One of the many problems associated with massive blood loss is dilutional thrombocytopenia.[1–7] Several studies have addressed this issue in the adult population, but none has examined this problem in children. We therefore undertook a prospective analysis of serial platelet counts during surgical procedures involving extensive blood loss and correlated the changes in serial platelet counts with blood volumes transfused and signs of clinical bleeding.

Methods

This study was approved by the Subcommittee on Human Studies at Massachusetts General Hospital (MGH). Pediatric patients at both MGH and Shriners Burns Institute (SBI) who were to undergo major surgical procedures were candidates for study. The anesthetic technique, anesthetic agents, monitoring, and blood product management were left to the discretion of the anesthetizing team. The estimated blood volume (EBV) was assumed to be 75 ml/kg for all children younger than 1 year of age and for all burned children; all others were assumed to have an EBV of 70 ml/kg.[8,9] Attempts were made to maintain a constant blood volume as judged by urine output, central venous pressure, and contour of the arterial wave form. Coagulation profiles, including a platelet count (laser beam ELT-800),§ prothrombin time (PT),¶ and partial thromboplastin time (PTT),¶ were obtained at the beginning of anesthesia and during the surgical procedure after transfusion of blood products equivalent to 1, 2, 3, 4, or 5 blood

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§ Ortho Diagnostics.
¶ Optical densitometry General Diagnostics X-2.