

## CORRESPONDENCE

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### Hypothermia and Serum Potassium Concentration

*To the Editor:*—In the northern states during the winter months, hypothermia from environmental exposure is frequently encountered. The survival and extent of recovery in people who become severely hypothermic is difficult to predict. A recent study suggested that high concentrations of serum potassium in severely hypothermic patients are an ominous prognostic sign, a "marker of death."<sup>1</sup> This issue can have significant impact on anesthesiologists who are involved with resuscitation of hypothermic patients in the emergency department or the operating room. A better understanding of potassium homeostasis during hypothermia can help explain the adverse outcome in hyperkalemic hypothermia patients.

One would expect to find hyperkalemia in severe hypothermia because of progressive acidosis and decreased sodium-potassium adenosine triphosphatase ( $\text{Na}^+$ ,  $\text{K}^+$ -ATPase) activity, the major enzyme maintaining intracellular  $\text{K}^+$  concentration.<sup>2</sup> However, the opposite usually is found. As hypothermia deepens, there is a progressive decrease in serum  $[\text{K}^+]$ .<sup>2,3</sup> We recently reported in animals a nonlinear relationship between decrease in body temperature and decrease in serum  $[\text{K}^+]$  during acute cooling, as well as return to normal serum  $[\text{K}^+]$  after rewarming.<sup>4</sup> We also demonstrated that correcting serum  $[\text{K}^+]$  in hypothermic hypokalemic rats resulted in severe hyperkalemia on acute rewarming.<sup>4</sup> Similar results have been presented by Koht *et al.* in humans.<sup>5</sup>

Decrease in serum  $[\text{K}^+]$  in mild hypothermia (from 35–31° C) may be attributed to increased sympathetic tone and stimulation of  $\beta_2$ -adrenergic receptors.<sup>5</sup> The decrease of serum  $[\text{K}^+]$  in deeper hypothermic stages (25° C and lower) cannot be explained with this  $\beta$ -adrenergic mechanism because nonselective  $\beta$ -blockade does not affect hypokalemia at 25° C when compared to non- $\beta$ -blocked animals.\* Also, urinary loss of  $\text{K}^+$  is not a factor since bilateral ureter ligation or nephrectomies in animal studies did not inhibit the hypokalemic response to hypothermia.<sup>2</sup> Moreover, deep hypothermia induces acidosis, which is expected to increase serum  $[\text{K}^+]$  mildly,<sup>2</sup> suggesting that acid-base imbalance is not the mechanism responsible for hypothermic hypokalemia. Shida *et al.*<sup>6</sup> also showed the lack of correlation between metabolic acidosis during hypothermia and serum  $[\text{K}^+]$ . Kanter postulates that in deeper stages of hypothermia, intracellular pH decreases relatively more than does extracellular pH, with a resultant extracellular movement of  $\text{H}^+$  and intracellular movement of  $\text{K}^+$ .<sup>2</sup> This theory is contrary to findings of depleted intracellular  $[\text{K}^+]$  in myocardial and skeletal muscle in hypothermia,<sup>8,9</sup> which would be consistent with the decrease in ion exchange across cell membranes in the energy-depleted state of severe hypothermia.

The exact mechanism of hypokalemic hypothermia is little understood. Increased  $[\text{K}^+]$  in liver cells during hypothermia<sup>7,8</sup> indicates that this organ may have a prominent role in  $\text{K}^+$  homeostasis. The ability of hepatocytes, despite decreased energy stores, to increase intracellular  $[\text{K}^+]$  compared to other tissues may be due to insulin. Insulin, a known potent stimulator of membrane  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase is found in high concentrations around hepatic portal areas.<sup>9</sup>

In the context of the above findings, we hypothesize that the pathogenesis of hypothermic hyperkalemia may lie in the failure of hepatic uptake of extracellular  $\text{K}^+$ . In addition, severe tissue injury by deep and prolonged hypothermia may irreversibly damage membranes, leading to massive release of intracellular  $\text{K}^+$ , overwhelming any mechanism that is responsible for maintaining  $\text{K}^+$  balance. Thus, hyperkalemia in hypothermia may indicate of a more severe and irreversible stage of tissue destruction, whereas hypokalemia indicates that

cellular mechanisms for maintaining  $\text{K}^+$  homeostasis are still functioning.

\* Sprung J, Gamulin S, Bosnjak JZ, Kampine JP. Cardiotoxicity of acute potassium administration and adrenergic blockade in normothermic and hypothermic rats. Proceedings of the 12th Annual Meeting of Cardiovascular Anesthesiologists. Orlando, Florida, May 1990, p 178.

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#### REFERENCES

1. Schaller MD, Fischer AP, Perret CH: Hypokalemia: a prognostic factor during acute severe hypothermia. *JAMA* 264:1842–1845, 1990
2. Kanter GS: Regulation of extracellular potassium in hypothermia. *Am J Physiol* 205:1285–1289, 1963
3. Koht A, Cane R, Cerullo LJ: Serum potassium levels during prolonged hypothermia. *Intensive Care Med* 9:257–277, 1983
4. Sprung J, Gamulin S, Bosnjak ZJ, Kampine JP: Potassium correction of hypothermic hypokalemia induces hyperkalemia after rewarming. *Can J Anaesth* 37:S69, 1990
5. Leduc J: Catecholamine production and release in exposure and acclimation to cold. *Acta Physiol Scand* 53(Suppl 183):1–8, 1961
6. Shida H, Morimoto M, Sugeno H, Seki T, Inokawa K: Changes of serum electrolyte at open heart surgery with simple profound hypothermia: relation between transient hypopotassemia and metabolic acidosis. *Jpn J Thorac Surg* 26:723–726, 1973
7. Asaumi S. Studies on electrolytes metabolism in serum and tissues during extracorporeal circulation and the surface cooling. *Jpn J Thorac Surg* 23:191–203, 1975
8. Machida S, Ohta S, Itoh N. Changes in tissue distribution of potassium during simple hypothermia. *Jpn J Thorac Surg* 30:413–418, 1977
9. Craig AB Jr, Mendell PL. Blockade of hyperthermia and hyperglycemia induced by epinephrine in frog liver and in cats. *Am J Physiol* 197:52–54, 1959

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