CORRESPONDENCE

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Comment:—The letter from Dr. Gronert and the reply from Dr. MacLennan *et al.* were also sent to Dr. Jeevendra Martyn, a well-known expert on the subject of nicotinic cholinergic receptor upregulation. His reponse follows.

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In Reply:—MacLennan *et al.*[1] probably have taken the more conservative and safer approach when they suggest that succinylcholine should not be used beyond 24 h after a burn injury. However, there are no reports in the literature of succinylcholine-induced hyperkalemia in humans occurring within 1 week after a burn injury. Based on published human studies, some other investigators might therefore assert that succinylcholine is safe up to 1 week after burn injury. Nevertheless, it is important to point out that these studies, relative to succinylcholine and burns, were performed almost 30 yr ago.[2-4] In these reports, the number of patients studied within 1 week after burn injury totaled only three in the three publications.

The treatment modality at that time (three decades ago) was that most burn patients, especially those with big burns, did not undergo excision and grafting procedures until the burn eschar had separated from the wound. This spontaneous separation of eschar takes at least 2 weeks. Early excision and grafting of burns, especially of major burns, was not routine at that time. Therefore, it is not surprising that only a total of three-patient studies were reported for the first week in three publications. Most likely, the three patients reported suffered only minor burns.

In contrast to the conservative approach to treatment of burns of the past, current practice advocates early excision and grafting of burn wounds, especially of patients with major burns.[1] The upregulation of acetylcholine receptors (AChRs) after burns occurs at sites immediately beneath and distant from the burn[5*]; a positive correlation between AChR number and the intensity of the hyperkalemia after succinylcholine has been confirmed.[6] The upregulation of AChRs that occurs in muscles beneath the area of the burn is as profound as after denervation and occurs as early as 72 h after burn.* Evidence for upregulation of the immature isoform has also been provided by assessment of messenger RNAs for the γ-subunit. When depolarized, the immature isoform has a prolonged open channel time, which may exaggerate the K^+ efflux that occurs with depolarization. We have recently reconfirmed this AChR upregulation with expression of the γ-subunit as early as 3 days after a 5% burn over the tibialis anterior muscle in the rat (unpublished). Thus, the potential for profound, denervation-type upregulation of AChRs is present as early as 3 days after burn injury when the burn-injured area is adjacent to muscle. The dramatic upregulation of AChRs on all muscles beneath the burn is also accompanied by the expression of the immature isoform of the receptor. In fact, burn injury of a single limb (8-9% body surface area) is sufficient to cause potentially lethal hyperkalemia.[4] The concomitant presence of immobilization with and without prolonged administration of muscle relaxants can accentuate the upregulation of AChRs.[6] Immobilization alone can induce modest upregulation as early as 3-4 days.[7]

Thus, the lack of clinical reports of hyperkalemia before 7 days after burn injury is probably a result of the following: (1) the previous treatment philosophy of not treating major burns aggressively with early excision and grafting did not provide the opportunity for challenge of major burns with succinylcholine within the first week; and (2) increased awareness of the dangers of hyperkalemia with succinylcholine has resulted in its lack of use in burn patients as early as 1 week during early excision and grafting of major burns.

Thus, it is my view that succinylcholine is probably safe up to 48 h after burn injury, but it may be wise to avoid it beyond that period. Patients may be particularly vulnerable if they have been immobilized in bed because of severity of illness or concomitant disease (*e.g.*, inhalation injury and fractures) or if they have received prolonged muscle relaxant therapy to facilitate mechanical ventilation.[6]

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Venous Access for Pediatric Liver Transplantation

To the Editor:—We read with interest the report by Henderson *et al.*[1] The authors attributed "spurious arterial blood gas findings and abnormal pulse oximetry readings" to distal arteriovenous connections caused by chronic liver failure. They site as evidence for this mechanism a venogram of the distal upper extremity and "experience with other children."[2] We differ in our interpretation and would propose that two more important conclusions from this case be emphasized.

Arteriovenous shunting is a relatively common complication of chronic liver disease in adult patients, as manifested by cutaneous ("spider") angioma and arterial hypoxemia caused by intrapulmonary venous admixture. However, this problem is infrequently encountered in children. In caring for approximately 300 infants and children undergoing liver transplantation, we have not observed evidence of this phenomenon in patients younger than 2 yr of age.

Henderson *et al.*[1] mentioned two alternative explanations for their clinical findings: (1) retrograde flow through capillary beds due to "extremely high venous pressures" caused by pressurized infusion of blood, and (2) relaxation of precapillary and postcapillary sphincters caused by general anesthesia. We find these explanations, particularly the former, far more likely to account for the localized arterial hypoxemia observed than the effects of endogenous vasodilators due to hepatic failure. The authors chose to cannulate distal peripheral veins at the base of each thumb for the purpose of intraoperative transfusion. We wonder whether blood transfusion under high pressure might result in the abnormalities in arterial oxygen tension and saturation observed even in patients without liver disease.

We believe that small distal veins should not be used for rapid transfusion except under extraordinary circumstances. More appropriate sites include antecubital and femoral veins, as well as internal and external jugular veins. That a fasciotomy was performed because of swelling of the distal extremity serves to substantiate the inadvisability of reliance on more distal veins in this setting.

Another important conclusion relates to the administration of calcium chloride. Calcium chloride 10% causes severe tissue injury when injected subcutaneously. We have observed and reviewed cases of tissue injury that required skin grafting after administration of calcium chloride 10% through a peripherally placed intravenous catheter, even when no other overt signs of extravasation were present. Although there is no mention of whether the fasciotomy was performed on the same extremity in which it was administered, calcium chloride 10% should not be administered through distal, peripheral veins, especially when a central venous catheter is available.

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