Usefulness of Warm Fluid in Acute Burn Resuscitation: An Experimental Study in Dogs

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Hypothermia is a common complication in patients with extensive burns, receiving massive volumes of fluid for resuscitation at ambient temperature. It is therefore important to maintain the body temperature of patients with extensive burns. The present study was performed to evaluate the usefulness of warm fluid for burn injury resuscitation. Ten dogs were used in this study. Full-thickness burns, involving 40% of the body surface, were generated in the backs of the animals. In the control group (n = 5), the fluid temperature was maintained at about 23°C, while in other group (n = 5), the temperature of the fluid was maintained at 39°C with a warming device. Cardiac output and urinary output were measured in both groups for up to 24 hours. The cardiac output decreased in all animals during the first two hours following injury. The cardiac dynamics remained depressed in the control group. By contrast, in animals treated with warm fluid, the cardiac output returned to the baseline level within 4 hours of resuscititative measures and then decreased slightly for the subsequent 20 hours. The urinary output was better in animals treated with warm fluid, indicating the improved hemodynamic state in these animals. These results suggested that the hemodynamic state in acute burn shock was ameliorated by the use of warm fluid. Therefore, warmed fluid resuscitation might be useful to perform immediate excision and grafting for the patients with extensive burns in acute burn shock.

It is important to maintain the body temperature of patients with extensive burns. For this purpose, it is usual to raise the ambient temperature and to warm the patient using a heating device. Hypothermia is a common complication in patients with extensive burns, receiving massive volumes of fluid for resuscitation at ambient temperature. In addition, coating of the burn wounds with massive amounts of disinfectant and ointment lowers the body temperature of these patients. Under these conditions, patients with extensive burns can suffer hypothermia at ambient temperatures less than 35°C. Hypothermia causes coagulopathy, delays drug metabolism, increases
oxygen consumption, and increases morbidity of infection (Roher and Natale 1992; Frank et al. 1993; Sessler 1993; Michelon et al. 1994; Kurz et al. 1996; Schmied et al. 1996). The present study was performed to evaluate the usefulness of warm fluid for burn injury resuscitation in laboratory animals.

MATERIALS AND METHODS

Surgical preparation of animals

Ten conditioned dogs of both sexes weighing between 9 and 13 kg were surgically prepared for study under halothane anesthesia. The right femoral artery was cannulated with a catheter for continuous measurement of systemic arterial pressure and intermittent sampling of arterial blood to measure base excess (mmol/L). The right femoral vein was cannulated for infusion. A Swan-Ganz thermal dilution catheter (model 93A-131-7F, Edwards Laboratories, Anasco, Puerto Rico) was introduced through the left femoral vein into the pulmonary artery for measurement of pulmonary arterial pressure (PAP), pulmonary wedge pressure (PWP), and central venous pressure (CVP). This catheter was also used for measurement of core body temperature. The needle probe of the thermometer was inserted into the skin of the hind paw for measurement of peripheral temperature. A Foley catheter was inserted into the urinary bladder for measurement of urinary output.

Their backs were shaved, and full-thickness flame burn injuries involving 40% of the body surface were generated by the gas burner in the backs of the animals. A warming blanket was used throughout the whole experiment to maintain the animals’ temperature.

All procedures were approved by the Ethical Review Committee of Animal Experiments of Tokyo Women’s Medical University (No. 005E).

Measurement of hemodynamics

Cardiac activities including cardiac output (CO), PAP, PWP, and CVP were measured. Total systemic vascular resistance (SVR) was determined by dividing the difference between the mean arterial pressure (MAP) and PWP by CO.

Experimental protocol

The ten dogs were divided equally into two groups. The volume of fluid required for resuscitation was calculated according to the Baxter formula. In the control group (n = 5), the fluid temperature was maintained at about 23°C, which was regulated by the air-conditioner in the laboratory room, while in the warmed fluid group (n = 5) the temperature of the fluid was elevated to 39°C using a warming device (HOTLINE™, Level 1 Technologies, Inc., Rockland, MA, USA) for the second group.

Statistical analysis

Results of CO, MAP, and SVR were calculated as
follows: rate of change (%) = (measured value after injury)/(baseline value) × 100

The results were analyzed as the means ± S.E.M. Statistical analyses of the data were performed by analysis of variance (ANOVA) followed by multiple comparison test (Fisher’s PLSD) using StatView (SAS Institute Inc., Cary, NC, USA).

RESULTS

CO was decreased for all animals during the first two hours following injury. The cardiac dynamics remained depressed in the control group treated with fluid at ambient temperature. In contrast, animals that received warm fluid showed the return of CO to the baseline level within four hours of resuscitative measures, and then, slight

![Graph of MAP change](image_url)

Fig. 2. Change in mean arterial pressure (MAP). MAP in both groups fell during the first hour, rose subsequently, and finally increased from 4 to 24 hours after injury in the warmed fluid group.

*Significance difference (p < 0.05).

![Graph of SVR change](image_url)

Fig. 3. Change in systemic vascular resistance (SVR). In both groups, SVR rose initially, then fell at 4 hours after injury.

*Significance difference (p < 0.05).
decreases were seen for the next 18 hours, and there was a significant difference between the two groups four hours after injury (Fig. 1).

MAP in both groups also fell during the first hour, rose subsequently, and finally increased from 4 to 24 hours after injury in the warmed fluid group. Significant differences were seen between the two groups at 8, 12, and 24 hours after injury (Fig. 2). In both groups, SVR rose initially, then fell at 4 hours after injury. There was a significant difference between the two groups at 4 hours after injury (Fig. 3).

The base excess decreased in both groups in the first hour, which reflects acidosis in circulatory shock, and then rose subsequently; there was a significant difference between the two groups at 24 hours after injury (Fig. 4). The difference between the core temperature measured with the Swan-Ganz catheter and the peripheral temperature measured from the hind paw in the warmed

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**Fig. 4.** Change in base excess. Both groups showed decrease in base excess in first hour, then rose subsequently.

*Significance difference ($p < 0.05$).

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**Fig. 5.** Change in the difference between core and peripheral temperature. The warmed fluid group showed smaller change than the control group did.
group was smaller than that in the control group (Fig. 5). The urinary output was better in animals treated with warm fluid, reflecting an improved hemodynamic state in these animals (Fig. 6).

**DISCUSSION**

It is important to maintain the body temperature of patients with extensive burns. Therefore, ambient room temperature should be kept warm and a warming device is usually applied to such patients to maintain adequate body temperature. However, patients with extensive burns usually require massive fluid resuscitation. Administration of fluid stored at room temperature is often associated with hypothermia in such patients and they suffer from shivering. Moreover, coating of burns with massive amounts of disinfectant and ointment also promotes hypothermia in these patients. It is not uncommon under these conditions for patients with extensive burns to develop prolonged hypothermia at ambient temperatures less than 35°C. This hypothermia in patients with extensive burns may have a number of deleterious effects. There have been many reports of the various dysfunctions caused by hypothermia (Roher and Natale 1992; Frank et al. 1993; Sessler 1993; Michelon et al. 1994; Kurz et al. 1996; Schmied et al. 1996). Rohrer and Natale (1992) reported that the series of enzymatic reactions of the coagulation cascade were strongly inhibited by hypothermia in an investigation of the isolated effects of alterations of temperature on the integrity of the coagulation cascade. Michelson et al. (1994) demonstrated that hypothermia inhibits human platelet activation in whole blood both in vitro and in vivo, and rewarming hypothermic blood completely reversed the activation defect. Schmied et al. (1996) reported that the maintenance of intraoperative normothermia (36.6°C) reduced blood loss and allogenic requirements in patients undergoing total hip arthroplasty as compared with mild hypothermia (35.0°C). Kurz et al. (1996) also concluded that maintaining normothermia intraoperatively was likely to decrease the incidence of infectious complications in patients undergoing colorectal resection and to shorten their period of hospitalization.

We found a warming device that could prevent hypothermia in patients with extensive burns. The “coil style” warming system used for blood transfusion in the operation room could not supply the massive amounts of fluid required for fluid resuscitation of patients with extensive burns. On the other hand, HOTLINE™ can warm fluid at 4°C or 18°C to more than 34°C and transfusion can be carried out at rates of 55 or 75 ml/min, re-
spectively. Yamauchi et al. (1997) reported the effects of the HOT LINE™ fluid warmer in patients undergoing cardiac or thoracic-aortic surgery and they concluded that this warming device was useful to prevent hypothermia in massive transfusions. Bernardo et al. (2001) also reported the effects of core and peripheral warming measures on body temperature and physiologic changes in injured children, and they concluded core warming with the Hotline Fluid Warmer (Sims Level 1, Inc., Rockland, MA, USA) appeared to be effective in preventing heat loss in this stable patient population. Wood and Carli 1991 reported that transfusion of 1,000 ml of fluid decreased body temperature by 0.25°C. Patients with extensive burns often require fluid transfusions of more than 10,000 ml within 24 hours after injury. These massive fluid transfusions may lead to decreases in body temperature of more than 2.5°C. Patients with extensive burns may also be exposed to various other factors that decrease body temperature, such as exposure of the whole body to the ambient temperature in the operating room or coating of burns with disinfectant. These findings suggest that fluid warming devices are useful for the prevention of hypothermia in patients with extensive burns along with maintenance of a high environmental temperature.

In this study, the group that received warmed fluid showed significant increases in cardiac output and mean arterial pressure and decreases in peripheral vascular resistance, as well as increases in urine output compared with the group that received fluid at room temperature. Morris and Trachtenberg (1968) also reported significant increases in core temperature, cardiac output, and arterial carbon dioxide tension, and decreases in peripheral resistance in patients who received warmed blood as compared with controls who received cold blood, and they hypothesized that these findings were due to the temperature of the transfused blood on the patients’ temperature-regulating mechanisms. Kassum and Thomson (1992) also reported the effects of the rewarming postoperatively on hemodynamic and temperature changes of the patients underwent aortocoronary bypass grafting. The cardiac index was depressed immediately postoperatively, again with substantial recovery within 8 hours. This improvement over time occurred not only because of recovery of intrinsic function but also because of reduction in myocardial work due to falling systemic vascular resistance. The latter was high immediately postoperatively and then consistently fell during the rewarming phase. During the first 8 hours postoperatively there were significant changes in temperature and cardiac and systemic vascular resistance indices. The hemodynamic data correlated strongly with changes in temperature (Kassum and Thomson 1992). Their clinical results are strongly consistent with the results in our study. Furthermore, Gentilello et al. (1997) reported that the persistent hypothermia in critically injured trauma patients increased fluid resuscitation requirements and increased the risk of early death, and decreasing the duration of hypothermia by aggressive core rewarming decreased overall fluid requirements and increased the likelihood of successful resuscitation. In our study, the warmed fluid group showed a significant increase in urine output more than the control group did despite of the same amount of fluid resuscitation. They speculated that hypothermia during initial resuscitation resulted in an increase in physiologic stress, and changes in oxygen delivery and consumption were a compensatory reaction to added circulatory and metabolic demands (Gentilello et al. 1997). Moreover, it reported that forced-air warming after cardiac surgery decreased the requirement for vasodilator drugs and might be beneficial in maintaining hemodynamic variables (El-Rahmany et al. 2000).

Recently, Kamlar et al. (2005) reported hypothermia markedly reduced microvascular perfusion, but was completely restored upon rewarming in their animal study to investigate whether reduced core temperature affects the damage to the microcirculation as evidenced by leukocyte adherence and edema formation.

We suggest that warmed fluid resuscitation might better ameliorate viscous blood in patients with extensive burns as compared with non-warmed fluid resuscitation. Though further studies are required to resolve this issue, these results
suggested the hemodynamic state in acute burn shock might be restored with the use of warm fluid in burn resuscitation. Therefore, warmed fluid resuscitation might be useful to perform immediate excision and grafting for the patients with extensive burns in acute burn shock.

References


