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Performance comparison of improvised prehospital blood warming techniques and a commercial blood warmer

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ABSTRACT

Introduction: Prehospital transfusion of packed red blood cells (PRBC) may be life saving for hypovolaemic trauma patients. PRBCs should preferably be warmed prior to administration but practical prehospital devices have only recently become available. The effectiveness of purpose designed prehospital warmers compared with previously used improvised methods of warming has not previously been described.
Materials and methods: Expired units of PRBCs were randomly assigned to a warming method in a bench study. Warming methods were exposure to body heat of an investigator, leaving the blood in direct sunlight on a dark material, wrapping the giving set around gel heat pads or a commercial fluid warmer (Belmont Buddy Lite). Methods were compared with control units that were run through the fluid circuit with no active warming strategy.
Results: The mean temperature was similar for all methods on removal from the fridge (4.5 °C). The mean temperatures (degrees centigrade) for all methods were higher than the control group at the end of the circuit (all $P \leq 0.001$). For each method the mean (95% CI) temperature at the end of the circuit was; body heat 17.2 (16.4–18.0), exposure to sunlight 20.2 (19.4–21.0), gel heat pads 18.8 (18.0–19.6), Buddy Lite 35.2 (34.5–36.0) and control group 14.7 (13.9–15.5).
Conclusions: All of the warming methods significantly warmed the blood but only the Buddy Lite reliably warmed the blood to a near normal physiological level. Improvised warming methods therefore cannot be recommended.

Introduction

Trauma is a leading cause of death with approximately 5 million people worldwide dying from traumatic injury each year [1]. Early trauma related death is associated with haemorrhage in approximately 30% of cases with a resulting emphasis on haemorrhage control in trauma resuscitation [2]. In patients where haemorrhage control is not possible or where blood loss has already exceeded physiological reserves early transfusion of blood products is a critical component of treatment. The incidence of coagulopathy after major trauma is high and is an independent predictor of mortality [3]. Key factors in the development of traumatic coagulopathy include the injury severity, hypothermia, hypocalcaemia, acidosis, continued bleeding with consumption of clotting factors, haemodilution from aggressive crystalloid resuscitation and activation of fibrinolysis [4]. These factors can be simplified and combined creating what is often referred to as the trauma triad of death; coagulopathy, acidosis and hypothermia [5].

It is becoming increasingly common for emergency medical services (EMS), particularly helicopter EMS (HEMS) to carry packed red blood cells (PRBC) for prehospital transfusion in critical trauma patients. CareFlight operates a rapid response physician staffed HEMS in the greater Sydney area of New South Wales (NSW), Australia and has carried PRBCs since 1986. In keeping with the Australian National Blood Authority guidelines, these are stored in a purpose designed cool box (Series 4-EMT 21 Credo System, Minnesota Thermal Science, MN, USA) at 4 °C with tight temperature regulation. The PRBC are typically used in patients with severe injuries, with haemodynamic compromise and are generally administered as a rapid bolus. These patients are already at risk

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of developing traumatic coagulopathy and the use of rapidly infused cold PRBCs may exacerbate the risk. Previous studies have shown the rapid infusion of similar volumes of cold crystalloid fluids will cause a drop in core body temperature of approximately 1.3 °C [6]. This is a group already at risk of hypothermia, as was demonstrated in previous studies showing 50% of major trauma patients presented to the emergency department with a core temperature of less than 36 °C [7,8]. Post-traumatic hypothermia has also been shown to be an independent predictor of mortality in numerous retrospective and prospective studies [9–11].

The risk of exacerbating post traumatic hypothermia and coagulopathy, and the previous lack of commercially available portable blood warming devices have lead clinicians to use various improvised methods to warm PRBCs prior to prehospital transfusion. These methods include using the body heat of a rescuer, leaving the blood in direct sunlight on a dark material and wrapping the giving set around gel heat pads. We are not aware of any previous reports validating the effectiveness or safety of these techniques. Recently a commercial blood warming device that is small enough to use prehospital became available on the Australian market, the Buddy Lite (TM, Belmont Instrument Corporation, MA, USA). We therefore proposed to compare the effectiveness of common improvised methods with this new commercial device, as there was no other available comparable literature. The study was approved by the Sydney Children's Hospital Network Human Research Ethics Committee, Australia.

Objective

To compare the change in temperature of PRBCs achieved by the use of three improvised methods of blood warming (body heat, direct sunlight and gel heat pad), a commercially available device (Belmont Buddy Lite) and a control (no device or active warming strategy) in a simulated pre-hospital environment.

Study design

Prospective randomized bench test study of blood warming techniques (Belmont Buddy Lite, body heat, and direct sunlight and gel pads) in a simulated pre-hospital environment.

Setting

This research was conducted at the Perfusion Laboratory at The Children's Hospital at Westmead, Sydney, Australia.

Methods

Donated units of PRBCs that had expired and could no longer be used for human transfusion were used in this study. Units were stored in a temperature controlled fridge at 4 °C to simulate the PRBCs coming directly from the temperature controlled cool box used by our prehospital teams. Five study arms were assessed:

1. Body Heat Method: PRBCs were placed in either axilla of one of the researchers for a period of five minutes prior to infusion.
2. Warming Gel Pad Method: The blood giving set was wrapped around a thermal gel pad which had been activated at the start of each test run. The distal section of the giving set was wrapped around the gel pad 5 times to give maximal surface area contact while replicating the pragmatic need for separation of the PRBC unit and the patient as in prehospital clinical practice. The gel pads are approximately 90 ml in volume, contain 88% sodium acetate, 12% water and are activated by pressing a metal disk, generating an internal temperature of 54 °C. (Kathmandu, Melbourne, Victoria, Australia)
3. Direct Sunlight Method: PRBCs were placed on a black carbon spinal board in direct sunlight for a period of five minutes prior to infusion.
4. Belmont Buddy Lite (Fig. 1): PRBCs were delivered with this battery-powered fluid warmer placed in line as per manufacturer's instructions.
5. Control group (no active warming technique employed): PRBCs were infused via the standard investigation giving set.

Fig. 1. Belmont Buddy Lite™. The battery is not included in this image.

The order of methods was randomized using a computer generated randomization sequence performed by one of the investigators (AL) not involved in the laboratory experiment using PASS software version 11 (NCSS, Kaysville, UT). A consecutive numbered sealed opaque envelope was opened just before a bench test occurred.

Blood was infused using a standardised giving set. A Baxter Colleague 3 Volumetric Infusion Pump (Baxter, Deerfield, IL, USA) within the circuit was used to regulate flow rates to ensure a constant flow rate of 50 ml/min. Flow rates were confirmed with a 3/16″ Transonic flow probe (Transonic Systems, Inc., Ithaca, NY, USA). This flow rate was chosen as it complies with maximum recommended flow rates set by the manufacturers of the Belmont Buddy Lite for fluids given at under 10 °C.

The PRBCs were delivered via a standardised circuit as detailed in Fig. 2. Following infusion through this standardised giving set, the blood was delivered to a collection reservoir and subsequently pumped through a heat exchanger, to allow re-cooling to 4 °C, then back to the collection bag for subsequent reuse. Units were re-used to maximise experimental efficiency and reduce wastage.

Temperature was measured at three different points in the standardised giving set and collection circuit using Capiox® Leur Thermisters (Terumo, Corporation, Tokyo, Japan).

1. Just distal to the collection bag
2. Prior to entering inline blood warming devices (where present)
3. Immediately distal to the giving set (prior to entering the collection reservoir). This represented the temperature at which blood would usually enter the patient's circulation.

Ambient temperature was measured for all experimental runs using an Esis, hygrochron temperature/humidity logger (Esis Pty Ltd., Sydney, Australia). For the direct sunlight method the temperature in the sunlight was also be recorded. Each of the methods were tested three times with two units of blood used on each run.