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BMH Medical Journal 2014;1(3):40-46 **Review Article**

Rapid Admixture Blood Warming: Fast, Safe & Inexpensive

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Abstract

The international standard for banked blood, including packed red blood cells (PRBCs), requires keeping it at 4ºC. Patients who need rapid PRBC unit transfusions benefit tremendously from blood being warmed to body temperature (37ºC), since hypothermia resulting from rapid infusion of cold blood is a major risk factor in exanguinating patients. It increases morbidity and mortality as well as often producing other adverse reactions, including those simulating transfusion reactions. Ideally, methods to warm blood for rapid transfusion should bring the unit to body temperature (37ºC), and be rapid, safe and inexpensive.

In most centres, clinicians' ability to adequately warm PRBC units suffers from the time constraints of needing to infuse blood quickly, the frequent need to infuse blood simultaneously through multiple IV lines, and the cost and availability of blood-warming equipment. There are three methods available for re-warming PRBC units: passive warming towards room temperature (inadequate), in-line warming (slow or extremely expensive), and pre-warming.

This paper describes a safe, rapid and inexpensive method to pre-warm PRBC units. The only piece of capital equipment needed for this process is a standard 70ºC laboratory incubator in which to preheat 250 0.9% normal saline (NS) bags. Only one incubator, which generally lasts for decades, is needed for an emergency department, operating room, or intensive care unit; if they are in close proximity, only one is needed for all of them.

Published studies and extensive clinical experience have shown that this method not only is safe and easy to use, but also preserves erythrocyte integrity and survival time. Rapid admixture blood warming is so inexpensive, simple, safe, and fast that it can and should be the primary method used for blood warming in most parts of the world.

Case

Three young men arrive in the ED after being struck by a bus. They are hypotensive and have injuries requiring immediate rapid blood transfusions. They will clearly need additional packed red

blood cells (PRBCs) units during surgery. The emergency clinicians place two 16-guage intravenous (IV) catheters in each patient to quickly infuse the blood. They now face the problem of how to simultaneously give the blood to the three patients (using both available lines in each patient) without causing hypothermia.

Introduction

The four goals for blood (PRBC) warming for rapid transfusions are that the process should:

1. Bring the unit to body temperature (**37ºC**).
2. Be **rapid**.
3. Be **safe**.
4. Be **inexpensive**. [1,2]

The international standard for banked blood, including PRBCs, requires keeping it at 4ºC. Patients needing rapid PRBC unit transfusions benefit tremendously from blood being warmed to body temperature (37ºC), since hypothermia resulting from rapid infusion of cold blood is a major risk factor in exanguinating patients. In addition, rapidly infusing cold blood may produce other adverse reactions, including those simulating transfusion reactions. However, clinicians' ability to warm PRBC units suffers from the time constraints of needing to infuse blood quickly, the frequent need to infuse blood simultaneously through multiple IV lines, and the cost and availability of blood-warming equipment.

Common Improvised Blood Re-warming Methods

Clinicians commonly use three methods of re-warming PRBC units: passive warming towards room temperature, in-line warming, and pre-warming.

Passive warming. Due to time constraints, a lack of equipment or a disregard for the consequences of administering cold blood, clinicians commonly rely on PRBC units passively warming to room temperature during administration. Even with slow infusions, however, this rarely results in significant warming.

In-line warming. A simple, slow method of blood warming is to add extra lengths of IV tubing between the PRBC units and the patient. Clinicians often place a coil of IV tubing into a bucket containing warm water of varying temperature. However, due to the slow passage of the cells through the tubing, erythrocytes can be damaged if the water temperature is higher than 40ºC.[2] Commercial in-line warmers are also available, although they are very expensive and can be used for only one IV line in one patient at a time.

Pre-warming. One of the most common blood warming methods used throughout the world is to simply lay the PRBC units bag (often of variable quantity) in a pan of tap water at about room temperature for 10 to 15 minutes. While the resulting temperature of this pre-warming method is unpredictable, this process will not harm the red cells and may provide some patient benefit. This method also dilutes the unit, leading to faster infusions and fewer complications. However, to avoid infection the transfusions should be completed within 30 minutes after warming the PRBC units to body temperature.

Rapid Admixture Blood Warming Technique

The following method of "rapid admixture blood warming" is a safe, easy-to-use, and inexpensive method for rapidly pre-warming PRBC units to 37ºC that can be employed anywhere a blood bank

exists. This method has been used at major medical centres for decades with great success and no complications. Unlike other rapid blood warming techniques, it can be used simultaneously for multiple lines in one patient or for multiple patients-even if they are in different hospital units (e.g., emergency department, operating theatre, intensive care unit).

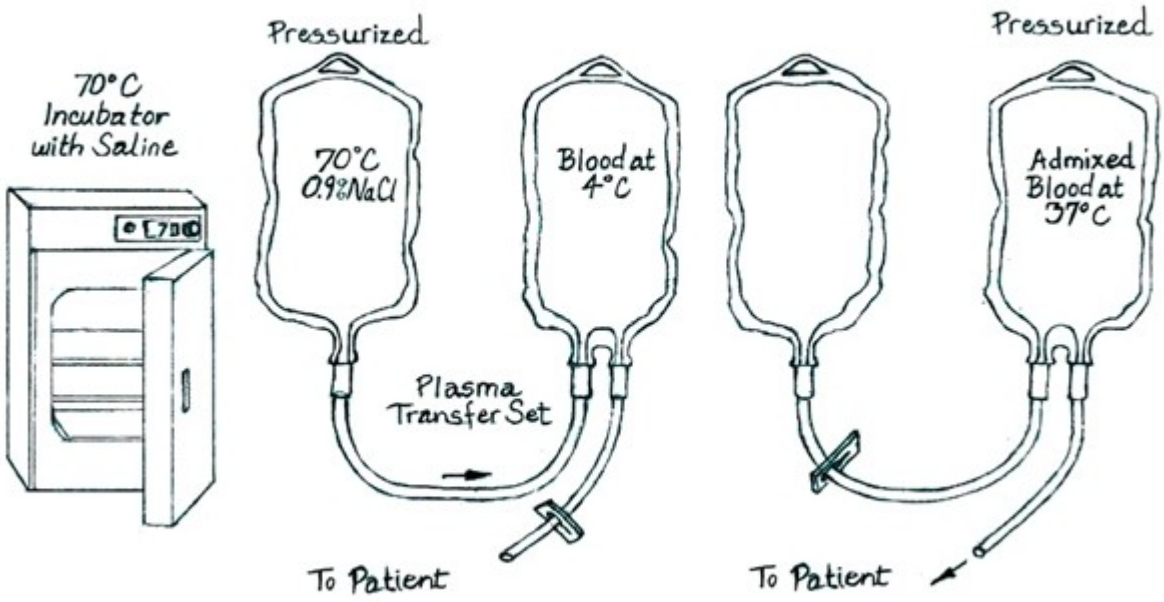

Figure 1: Rapid Admixture Blood Warming using a Plasma Transfer Set

The **Method** is:[3]

1. A 70ºC incubator holding multiple pre-warmed 250 mL bags of 0.9% normal saline (NS) for IV infusion is kept in an area where frequent rapid PRBC unit transfusions are required. (Do not use Ringers Lactate or Hartmann's Solution, since they are incompatible with blood.)
2. When a PRBC unit needs to be re-warmed for infusion, remove a 250 mL NS bag from the incubator. Check the bag for clarity, discoloration, particulates, obvious decreased volume, and cracking of the outer wrapper. Discard the bag and use another one if any of these problems are found.
3. "Spike" the PRBC unit from the blood bank with one "male" end of a Plasma Transfer Set (Fenwal, Inc., Three Corporate Drive, Lake Zurich, IL, USA; Catalogue #4C2243). Blood banks in many parts of the world commonly use the inexpensive Plasma Transfer Sets. Spike the other "male" end of the Plasma Transfer Set into the 70ºC 250 mL NS bag. Open the clamp, raise the saline bag above the level of the PRBC bag, and manually squeeze (or use external pressure device) the NS into the PRBC bag. A towel or pot-holder-type kitchen glove is useful if manually squeezing the bag, since it is very warm to touch.[4]

Note: If the Plasma Transfer Set cannot be obtained (since it is not sold in all countries), a slightly more cumbersome method is to use standard "Y" blood infusion IV tubing.[**Figure 2**] After shutting off flow to the patient, spike the 250 mL 70ºC NS bag with one arm of the "Y" and the blood unit with the other arm. Transfer the NS into the PRBC bag and close the "Y" arm to the empty saline bag. Then open the IV tubing to the patient so the warm PRBCs can be administered.

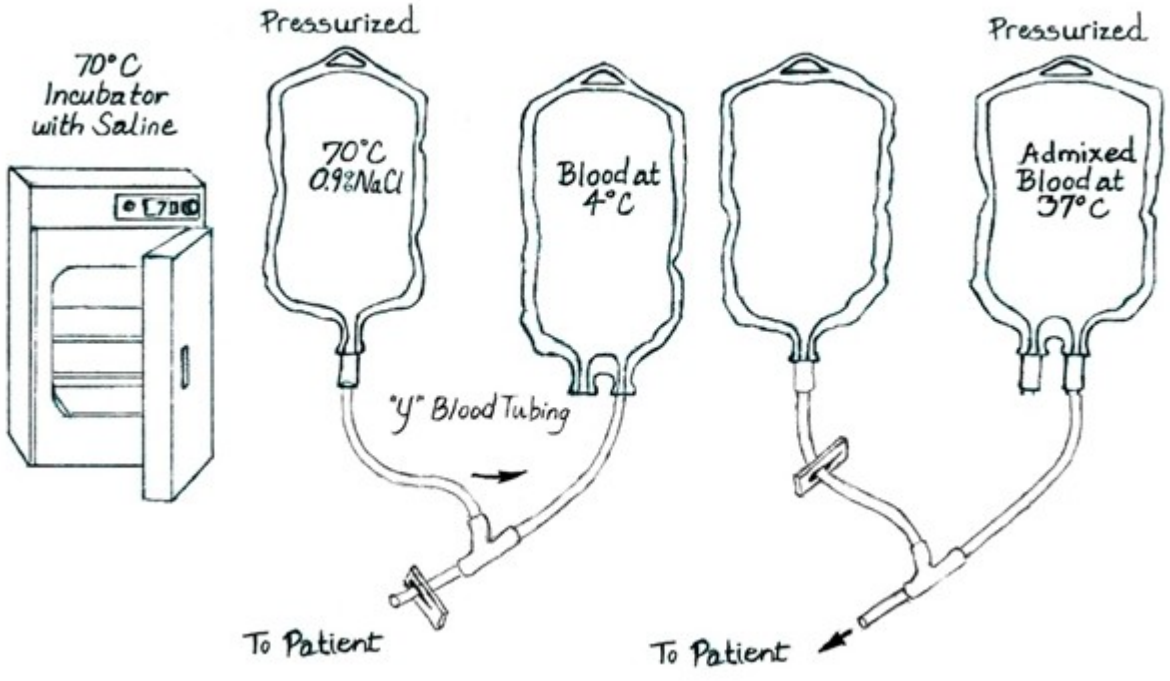

Figure 2: Rapid Admixture Blood Warming using the "Y-Tubing" from a standard blood administration set

4. After all the 70ºC NS is transferred into the PRBC bag, tightly close the clamp on the transfer set tubing. To prevent contamination, do not remove the transfer set tubing spike from the PRBC bag. The now-empty NS bag may be removed from the other end of the transfer set and discarded.
5. Spike the unused port on the PRBC bag (now at about 37ºC) with one limb of a "Y-type" blood set already attached to the patient.
6. Close the clamp on the other limb of the Y-set, which has been infusing warm or room temperature NS (not Ringers Lactate or Hartmann's Solution) into the patient.
7. Pressurize the PRBC bag, if rapid infusion is desired, and open the clamp on the PRBC admixed bag to begin infusion into the patient.
8. Infuse the bag as rapidly as necessary. For safety, try to infuse blood within 30 minutes after warming to body temperature.

The following **Quality Control** measures provide a level of additional safety:

A. Label each NS bag with the date it is placed in the incubator.
B. Discard all saline bags remaining in the incubator on the 1st and 15th day of each month and replace them with new bags.
C. Put a sign on the incubator door reading: "For admixture with cold blood only. Not for direct patient infusion."

Equipment

The only piece of capital equipment needed for this process is a standard 70ºC laboratory incubator in which to preheat the NS bags. Only one incubator is needed for an emergency department, operating theatre, or intensive care unit; if they are in close proximity, only one is needed for all of them. These incubators last a long time, with the first incubator used at a university medical center for this process lasting nearly 25 years! These incubators can often be found in stores of discarded or unused medical equipment. The cost of tubing is minimal.

A major benefit of this procedure is that the nursing staff needs little time to learn the method, since it uses standard procedures. Standard IV equipment is used, so all of a patient's lines can have warmed PRBC units using this method. The main issue is that all personnel must be warned that the 70ºC NS must never be used for direct infusion.

Safety [3,5]

Erythrocyte Survival

Rather than damaging erythrocytes, in vivo human studies demonstrated that after rapid admixture warming, red blood cells survive at least as long as transfused PRBCs normally do. In one study [6], PRBCs from five normal male subjects were stored in CPDA-l at 4ºC for 14 days. They were then warmed via admixture with an equal amount of saline heated to 70. Osmotic fragility and supernatant haemoglobin and potassium levels of the warmed RBCs were not significantly different from baseline values. Aliquots of the warmed RBCs were labelled with 51Chromium and transfused into autologous donors. Mean radiolabelled RBC survival at 24 hours was > 90%, and mean radiolabelled RBC survival time was > 25 days. These results are within the normal range for RBCs stored for 14 days. This study suggests that RBC survival after transfusion is not impaired by admixture blood warming using saline at 70ºC.

Standard Saline Bolus

Studies have also addressed questions concerning the use of a standard bolus of 250 ml 70ºC 0.9% NaCl to be added to each unit of 4ºC erythrocytes to be rapidly warmed. Is this amount of fluid adequate to warm the blood? Will it overheat some units (80ºC)? Will it expand the erythrocyte bags beyond their physical capacity?

To answer these questions, > 1000 successive units of erythrocytes, prepared by the American Red Cross in a standardized fashion for, and delivered to adult patients, were weighed. Standard blood bank technique is to equate 1 g with 1 ml of erythrocytes. A unit of outdated (42-day) CPDA-l erythrocytes equivalent to the lightest erythrocyte unit in the series was prepared by removing an aliquot of blood. The remainder of the unit was retained as a control. The unit was infused with 250 ml 70ºC saline through Y-blood tubing with hand-generated external pressure. A similar unit was prepared replicating the heaviest unit in the series, but only used for temperature studies. The weights of 1000 successive PRBC units ranged from 220 grams to 410 grams (mean 305 grams). After admixture with 70ºC saline, the maximum temperature with the smallest unit reached 44ºC; the minimum temperature with the largest unit reached 30ºC. No PRBC bag leaked with the addition of 250 mL NS.

A proportionate amount of room-temperature 0.9 NaCl was added to the control sample in the same manner as with the erythrocyte unit. Samples of both the erythrocyte unit and control were obtained for determinations of plasma Hgb, osmotic fragility, and K. These tests were performed using standard laboratory techniques. Osmotic fragility curves between admixed and control PRBC units were not significantly different.

Uniformity and Speed of Admixture Warming

To test the uniformity and speed of admixture warming, erythrocyte units of varying weights surrounding the 1000-unit mean were monitored using a thermographic camera and internal thermocouple probes (calibrated to 0.1ºC) with temperature sensing every 1 cm, which were connected to a recording computer that acquired temperature data points every 2 seconds during the admixture process. The rapid admixture process was repeated with the erythrocyte units in an upright

and inverted position, and using both standard large bore IV tubing (Fenwal Y-type blood recipient set with large bore tubing) and IV tubing specifically designed for more rapid infusion (Medex Hi-Flo Trauma Bifurcated Set). No agitation other than the normal admixture turbulence was used to admix the fluids. Tubing was also tested with and without additional in-line filters (Pall Blood Transfusion Filter). Thermographic imaging with the PRBC bags upright showed uniform mixing without agitation of the bag. Within 30 seconds of beginning admixture, there was a temperature gradient of >0.5ºC across the bag.

Maintaining Saline Bags at 70ºC

The manufacturers claim that saline bags kept in their overwraps are stable up to 2 weeks at 70ºC [7]. To test this, 23 standard 250 mL 0.9 NaCl bags, still in their factory overwrap, were weighed, labelled, and placed in the incubator used to warm the bags for erythrocyte admixture at 70ºC. The bags were repeatedly weighed and inspected at l-week intervals.

Seven bags were opened and sampled for electrolyte analysis and osmolality testing at the end of weeks 1 through 6 and week 8. Volumes of the 250 mL saline bags remained constant over a 2-week period. After that time, cracks appeared in some bags, nearly all had diminished volume, and there were changes in their electrolyte concentrations and osmolality.

Case

Using rapid admixture blood warming, the emergency department staff immediately and simultaneously transfuse three 37ºC PRBC units into the first two men and four units into the third man during the ten minutes they are in the emergency department. The operating theatre, with its own warming oven, 70ºC NS bags and plasma transfer sets, is able to continue rapid blood warming during surgery and, in one case, in the post-operative recovery room.

Conclusion

Rapid admixture blood warming is so inexpensive, simple, safe, and fast that it can and should be the primary method used for blood warming in most parts of the world.

Acknowledgement

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