Hemolysis with rapid transfusion systems in the trauma setting

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Objective: Rapid infusion system allows rapid infusion of resuscitation fluids at body temperature in trauma patients. Packed red blood cells are subjected to high external pneumatic pressure (up to 300 mm Hg) and rapid infusion rates through a 170-µm filter. This study was conducted to outline hemolysis that may occur in the setting of massive transfusion (> 10 units). **Methods and materials:** Measurements of various parameters were made before and after infusion of 17 units of outdated (38–82 d) packed red blood cells through a Level 1 Rapid Infuser, including lactate dehydrogenase (LDH), potassium, plasma hemoglobin, hematocrit and total hemoglobin. Hemolysis, expressed as a percentage, was calculated from these parameters. **Results:** Hemolysis observed in this experiment ranged from near 0 to 0.05%. All the units had plasma potassium concentrations of 15 mmol/L or more. **Conclusion:** Transfusion of 17 units with the Level 1 Rapid Infuser did not cause a clinically significant amount of hemolysis.

Objectif : Un système de perfusion rapide permet l'infusion accélérée de liquides de réanimation à la température du corps chez les patients traumatisés. Des globules rouges concentrés sont soumis à une pression pneumatique externe élevée (jusqu'à 300 mm de Hg) et à des taux d'infusion rapide à l'aide d'un filtre de 170-µm. Cette étude vise à décrire l'hémolyse possible en cas de transfusion massive (> 10 unités). **Méthodes et matériel :** Divers paramètres ont été mesurés avant et après l'infusion de 17 unités de globules rouges concentrés périmés (38–82 d) à l'aide d'un Level 1 Rapid Infuser (appareil de perfusion rapide), y compris de la lactate déshydrogénase (LDH), du potassium, de l'hémoglobine plasmatique, de l'hématocrite et de l'hémoglobine totale. L'hémolyse, exprimée en pourcentage, a été calculée à l'aide de ces paramètres. **Résultats :** L'hémolyse observée dans cette expérience se chiffrait à près de 0 jusqu'à 0,05 %. Toutes les unités avaient des concentrations de potassium plasmatique de 15 mmol/L ou plus. **Conclusion :** La transfusion de 17 unités à l'aide du Level 1 Rapid Infuser n'a pas produit un taux d'hémolyse important sur le plan clinique.

Rapid fluid administration is an essential part of initial care for trauma patients in hemorrhagic shock. Fluid repletion depends on sufficient venous access, a rapid infusion rate and an appropriate choice of resuscitation fluid. Complications of rapid fluid resuscitation with conventional methods include untoward physiologic effects such as hypothermia, acidosis and coagulopathy.[1] To achieve adequate, rapid fluid resuscitation with minimal complications, a Rapid Infusion System (RIS) is used in trauma.[2]

The RIS was initially developed in 1982 for resuscitation in liver transplantation patients.[2] After much development, the first was produced by Hemonetics Corporation (Braintree, Mass.). It is now widely available commercially and has been shown to

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be an excellent method of fluid resuscitation in trauma patients.[3]

The Level 1 Rapid Infuser is an RIS used in many centres, equipped with a 2-chamber compression unit, a heat exchanger and a 170-µm filter that traps the macroaggragates and the air bubbles. Various types of fluids, including commercial resuscitation fluids, erythrocytes and platelets, can be administered through the system. The infusate is hung in the compression unit, subjected to a pneumatic pressure of 300 mm Hg and then propelled through the countercurrent heat-exchange system and a filter before being introduced at rates of up to 950 mL/min at body temperature.

Increased use of this infusion device for blood transfusion has raised interests in its effect on the integrity of the erythrocyte being infused at such rates. Studies have looked at various factors such as infusion rate,[4,5] cannula size and external pneumatic pressure[6] that may lead to hemolysis with use of this device, and have found it to be safe for blood transfusions. However, there is dearth of information about hemolysis that may occur in the setting of massive transfusion (>10 units) when a large volume of red blood cells is passed through the same filter in the system. The aim of this study was to outline the effects of the Level 1 Rapid Infuser on the integrity of red blood cells in the setting of massive transfusion through 1 filter, to aid clinicians in determining when the filter should be changed to avoid transfusing patients with hemolyzed blood.

Methods and materials

Packed red blood cells

Seventeen units of outdated packed red blood cells (38–82 d old) from the Canadian Blood Services were used for the experiment. The packed erythrocytes were prepared from whole blood that was collected into citrate phosphate double-dextrose (CP2D), leukofiltrated and preserved in AS-3 (Nutricel). Three units of type O packed cells were infused, followed by 14 units of type AB. The experiment was then repeated with 16 units of packed erythrocytes, with 3 units of type O cells followed by 5 units of type A and 8 units of type AB.

Apparatus

A rapid infusion system consisting of Level 1 System 1000 (Smiths Industries Medical Systems, Rockland, Mass.), intravenous blood tubing and a 16-gauge angiocath was used. Before infusion, samples were drawn from each unit of packed erythrocytes for lab measurements of plasma lactate dehydrogenase (LDH), potassium, hemoglobin, total hemoglobin and hematocrit. The packed cells were placed in the compression chambers and subjected to pressures up to 300 mm Hg, passed through the infusion system and collected into transfer packs (Baxter Healthcare Corporation, Deerfield, Ill.). As the 17 units of packed cells were infused, the system was flushed with 0.9% NaCl between each unit to simulate a real trauma situation. The second set of infusions was made with 16 units of packed red blood cells.

Measurements

Pre- and postinfusion concentrations of plasma hemoglobin, hematocrit and potassium were measured at the laboratories of the London Health Sciences Centre (London, Ont.). Hemoglobin was measured by the calorimetric method with a plasma hemoglobin kit (Sigma Diagnostics Inc., St. Louis, Mo.). Hematocrit and hemoglobin values were measured with the Coulter STKS. Plasma potassium and LDH values were measured with a Beckman LX20.

Calculations

The degree of hemolysis was expressed as % hemolysis, calculated as follows:

$$\%\text{ hemolysis} = \frac{(\Delta\text{ Hb})\dfrac{(1-\text{HCT})}{100}}{(\text{total Hb})\times 1000}\times 100$$

where

Δ Hb = postinfusion plasma hemoglobin – pretransfusion (mg/dL)

HCT = mean of pre- and post-transfusion hematocrit (%)

total Hb = mean of pre- and post-transfusion hemoglobin (g/L)

The degree of hemolysis observed in the 2 trials was combined as a mean value.

Results

As shown in Fig. 1, all values for amount of hemolysis observed fell between near-0 and 0.05%. The degree of hemolysis did not increase as more units of packed erythrocytes were infused. Older units of packed cells did not consistently yield higher degree of hemolysis.

The LDH values observed in the study followed no particular trend. The change in plasma LDH ranged from 6 U/L to 330 U/L. Potassium values were all >15 mmol/L.

Discussion

This study was conducted to outline the pattern of hemolysis from use of a Level 1 Rapid Infuser in the setting of massive transfusion to help clinicians determine when the filter needs to be changed. Hemolysis in up to 17 units was small enough to be clinically insignificant. The maximum amount of hemolysis observed, 0.05%, is equivalent to a change in hemoglobin from 120 to 119.88 g /L. The amount of hemolysis observed in our study was lower than the 4% observed by Frelich and Ellis[6] when packed red blood cells were subjected to an external pneumatic pressure of 300 mm Hg and infused through a 22-gauge angiocath, and slightly greater than 0.01% observed at a lower infusion rate of 999 mL/h by Burch and colleagues.[4] Our study, in conjunction with aforementioned studies, supports the opinion that

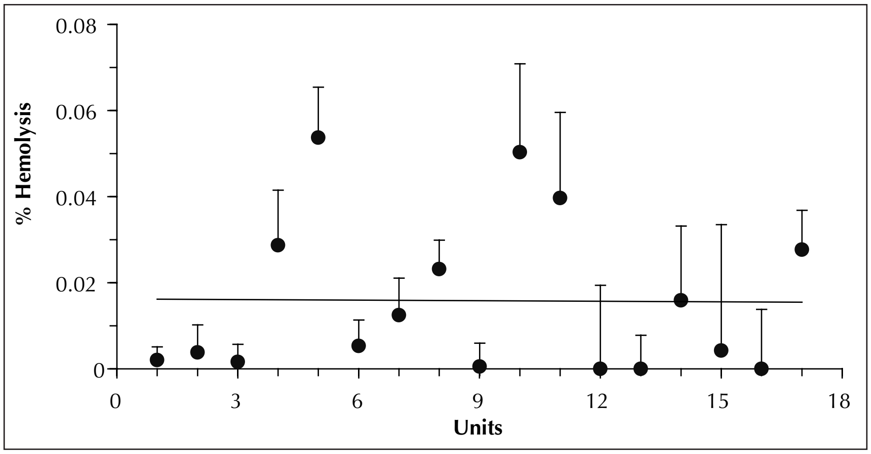

FIG. 1. Degree of hemolysis with increasing numbers of units of packed red blood cells infused through the Level 1 Rapid Infuser. The horizontal line indicates the mean value.

factors such as high pneumatic pressure and high infusion rate together do not result in clinically significant hemolysis even when the same filter is used during a massive transfusion. Considering the age of the units of outdated blood used in this experiment, the erythrocytes maintained membrane integrity; however, it should be noted that their oxygen-unloading capacity is decreased. The age of transfused blood is an independent risk factor for postinjury organ failure, especially in acute respiratory distress syndrome.[7,8]

As it was shown in this experiment, when packed red blood cells are stored for long, the potassium concentration in the plasma rises. A unit of 35-day-old packed red blood cells (with total plasma volume in these units being approximately 70 mL) can have potassium concentrations up to 78.5 mmol/L.[9] On average, packed erythrocytes aged more than 5 days contain 20–30 meq/L of potassium and have a pH of 6.5.[10] The human body cannot cope with hyperkalemia if delivery exceeds the circulatory system's ability to equilibrate. The threshold rate for saturation of the distribution mechanism is 0.3 mL/kg/min.[11] Hyperkalemic arrests have been reported, and it becomes a concern when more than 1 Rapid Infusion System is being used and when only packed red blood cells are being infused.[12]

Conclusions

Because there no clinically significant degree of hemolysis occurred with transfusion of up to 17 units of packed red blood cells through the Level 1 Rapid Infuser, the filter does not need to be changed. Older packed erythrocytes maintain cell-membrane integrity even after storage for longer than 38 days.

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