Introduction

- Compared to conventional gravity infusions, infusion pumps have the capacity to generate and monitor a consistent flow rate, ensure the accuracy of infused volume and decrease the chance of errors.
- Mechanical stress on red blood cells and the resulting hemolysis is a concern associated with using infusion pumps for the administration of red cell concentrates (RCCs).
- Literature review from studies submitted to Health Canada for pump approval demonstrates no standard protocol and inadequate study design.
- This project investigates RBC quality after passage through four infusion pumps (one peristaltic, two linear peristaltic, and one piston pump) used across Canada.
- Useful lab measurements for the evaluation of pump safety and the significance of age/condition of RBCs for such evaluations were assessed.

Study Design and Methods

- 3 ABO matched RBC units
- RBC Storage
- Pool and split in 4 bags
- Connect each bag to a pump-specific infusion line
- Infusion via gravity or pump
- Connect end of lines to 22g catheters, positioned 18 cm above the level of pumps to simulate venous pressure of 15 mmHg.

Conditions

<table>
<thead>
<tr>
<th>Pumps</th>
<th>No pump</th>
<th>Linear Peristaltic 1</th>
<th>Linear Peristaltic 2</th>
<th>Peristaltic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity</td>
<td>50 mL/h</td>
<td>150 mL/h</td>
<td>300 mL/h</td>
<td></td>
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</tbody>
</table>

Sample

- A survey was sent to hospitals across Canada, excluding Quebec, to collect information on infusion pump usage for blood transfusions. According to the responses, five infusion pumps are currently being used in the country. Here, we study all of these pumps except Baxter Colleague CXE.
- The mechanism of the pumps is used in lieu of their brand names: Sigma Spectrum is called Linear peristaltic-1, Hospira Plum 360 is Plum, Alaris is Linear peristaltic-2 and Infusomat Space is Peristaltic pump.
- Hemolysis %, potassium and RMV levels were measured using our lab established methods. 1 LDH was measured by colorimetric LDH assay kit (abcam 102526). For MFI-measurement, a diluted (10% Hct) sample of RBC was rocked with stainless steel beads for 45 mins; the release of Hb as a result of the mechanical stress was measured.
- Data were analyzed by applicable parametric/non-parametric tests (n = 5-6); p<0.05 was considered statistically significant.

References:
1. Serrano K. et al. Transfusion 2017, 57, 3009

Acknowledgements

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Results

Hemolysis

- For all tested pump rates and RCC conditions, hemolysis levels of Piston and both Linear peristaltic samples were not different from hemolysis of corresponding gravity samples (Figure 1).
- Peristaltic samples, however, had significantly higher hemolysis compared to gravity. Peristaltic pump also showed significantly higher hemolysis than other pumps (maximum mean difference: 0.03%) (Figure 1).
- Hemolysis % for each RCC condition was significantly higher in d40 and I14d28 compared to d22 and I21d22 (Figure 2A).
- Change in hemolysis % due to pumping (Δ hemolysis %) was significantly higher in d40 and I21d22 RCCs than in d22 and I14d28 (Figure 2B).
- Pumping at 50 mL/h resulted in the highest hemolysis level (0.135 ± 0.015 in d22 and 0.299 ± 0.013 in d40).
- No combination of pumps and parameters led to hemolysis > 0.8%.

Potassium

- There was no significant difference between the extracellular potassium levels of RBCs after infusion with pumps versus Gravity, or among pumps at each rate and condition.
- There was no significant effect of rate on potassium level.
- When all rates combined, Linear peristaltic samples had significantly lower potassium levels compared to Piston and Peristaltic (Table 1).
- The increase in K⁺ level due to pumping (Δ K⁺) was significantly higher for I14d28 RCCs (4.0 ± 2.8 mM) compared to non-irradiated units; d22 (1.6 ± 1.1, p<0.0001) and d40 (2.6 ± 2.5, p<0.01).

RMV, MFI and Morphology

- RMV, MFI and morphology were not sensitive measures of pump effect.

LDH

- Besides hemolysis, LDH was the only marker that demonstrated some differences between infusion via pump versus Gravity (Figure 3).
- Consistent with hemolysis results, Peristaltic pump had significantly higher LDH levels than all other pumps (55% CI of mean difference: 3 to 13 mU/mL on d40).

Figure 3. LDH levels before infusion (Baseline) and after infusion via Gravity and the pumps at the rates of 50, 150 and 300 mL/h. A to D represent the 4 conditions of RCCs: d22(A), d40(B), I14d28(C) and I21d22(D). Individual values of data are shown. Pumps are marked by different symbols. Repeats numbers are shown on top of each graph. Significant differences between Gravity/rates of each pump are shown on the bottom of graph. Significant differences between pumps are shown on top of graph. P<0.01(**) p<0.005 (***) and P<0.0001 (****)

Conclusions

- The pump mechanism affects the degree of hemolysis. However, for all tested pumps and RCC conditions, this increase was deemed minimal and clinically insignificant.
- Hemolysis % and LDH measurement on red cell concentrates aged for 40 days and concentrates irradiated on day 21 and sampled on day 22 at 50 mL/h were concluded to be appropriate parameters for pump evaluation.