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Original article

An experimental study on RBC count and serum potassium concentration changes during compression transfusion of WBC-removal whole blood☆

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ABSTRACT

Objective: To observe changes in RBC count, changes, RBC morphology, and serum potassium during compressed transfusion of WBC-removal whole blood.
Methods: Prepared human WBC-removal whole blood and connected transfusion apparatus with different sizes of intravenous detaining needles (18G, 20G, 22G and 24G). Observed RBC count and serum potassium concentration under different pressures (100 mmHg, 200 mmHg, and 300 mmHg) as blood flowed out of the pinhead end of the intravenous detaining needle. Samples obtained with the 20G needle were smeared on glass slides, and RBC morphologic changes were observed under an oil immersion lens.
Results: RBC count and serum potassium changed slightly under different pressures with different sizes of intravenous detaining needles as blood flowed through the transfusion apparatus. In addition, the observation of blood samples under a common light microscope revealed that coarse-prick, oblong, and spindle cell counts in the visual fields increased gradually as the pressure increased. Additionally, a portion of cells had undergone splintering.
Conclusions: While applying 18G, 20G, 22G and 24G intravenous detaining needles for blood transfusion under less than 300 mmHg of pressure, no significant RBC count change was found in blood samples in the short term. However, there were significant RBC morphologic changes. The results could offer more basis to ensure the clinical safety of patients undergoing blood transfusion.
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1. Introduction

Blood transfusion is an important procedure for rescue and disease treatment of critically ill patients and is widely used in clinical practice. In certain circumstances, a blood infusion is urgently needed to correct hypovolaemia to ensure blood perfusion and improve the body's blood circulation as quickly as possible. However, due to the viscosity of blood products, the flow resistance of the blood increases with the viscosity increment of the blood, so that regular transfusion methods cannot satisfy a patient's needs. Therefore, compression, haemodilution and warming have been adopted to accelerate blood transfusion in clinical practice to quickly achieve the required blood volume in the patient.[1–3] Most reports do not mention the extent of the effect of change in the blood composition and biochemical indices on the human body after using a pressurizer. This study analyzed changes in RBC count, morphology, and serum potassium and the degree of blood composition during compressed transfusion of human WBC-removal whole blood in vitro using a transfusion apparatus with different sizes of intravenous detaining needles. The objective of this report is to provide an experimental basis for selecting the optimal compression transfusion method to ensure the clinical safety of patients undergoing blood transfusion.

2. Materials and methods

2.1. Blood specimen selection

The material is human WBC-removal whole blood mixed with a mixture of healthy blood and anticoagulants CPDA (Citrate-

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phosphate-dextrose solution with adenine), which stored between 2° C and 4° C within the period of validity. The blood volume in each bag was 400 ml.

2.2. Methods

2.2.1. Experimental instruments and equipment

The experimental instruments and equipment included the following: 100 mL measuring glasses, a blood transfusion apparatus (provided by Shandong Weigao Group Medical Polymer Co., Limited), closed intravenous detaining needles (18G, 20G, 22G, 24G) (provided by Suzhou Bidi Medical Instrument Company), stopwatch, test tubes (produced by United States of America BD Company), pressurizers (CFUSORTM 500 medexine, USA), electronic swing metre, 100 mL bags of sterile saline solution, 10 mL syringes, and infusion support.

2.2.2. Experimental methods

Put one bag of 400 ml blood at room temperature for 30 min and then placed it on the electronic shaker to shake slightly for 10 min until the colour is evenly distributed. Connected a number 12 puncture needle to the bag, and poured the blood into four small bags, approximately 100 ml per bag, which were marked as 1, 2, 3, and 4 in order. The blood sample was collected using 10 ml syringes and then injected into two test tubes as the basic control. Then, the test tubes were connected to the blood transfusion apparatus, intravenous detaining needle and exhaust using conventional methods. The height of the transfusion support was 80 cm with the clamp adjusted to the highest setting. The blood was collected into the measuring glass. Blood infusion was performed using the blood samples with numbers 1, 2, 3 and 4 in order. No pressure was exerted on sample no. 1 during the infusion process (P_0). For sample numbers 2, 3 and 4, the infusion process is performed with pressure maintained at 100 mmHg (P_1, 1 mmHg = 0.133 kPa), 200 mmHg (P_2), and 300 mmHg (P_3) respectively. The pressurizer was wound around the blood bag, and the inflatable bag was placed in the centre of the blood bag. After every infusion, 8 ml of blood was collected from the glass and mounted into two test tubes for determination of terminal values for this experiment. The collected samples were sent for inspection in a timely manner to determine the changes in RBC count, morphology and serum potassium concentration. Additionally, the required times of infusion for the four small bags of blood were recorded as the blood flows through the transfusion apparatus and indwelling needles, and the blood flow velocities with the different sizes of indwelling needles and under different pressures were calculated.

2.2.3. Observation parameters and measurement methods

2.2.3.1. RBC count. The KX-21N Sesmex instrument (model G6020) produced in Japan and provided by Jinan Sysmex Corporation was applied for the measurement of RBC count.

2.2.3.2. Ordinary light microscope slide production. Use a 20G needle to take blood sample, and to coat the surface of a glass slide in the routine manner. The Wright-Giemsa staining method was performed for 10 min with a buffer solution that is a mixture of KH_2PO_4 and $NaHPO_4$. Afterwards, the slide was washed with cool running water and air dried it. Due to the thickness of the blood membrane on the entire glass slide, three visual fields were selected at the end of the slide to observe the RBC morphological changes under an oil immersion lens (magnification 10×100).

2.2.3.3. Serum potassium concentration. Serum potassium concentrations were measured in the hospital biochemical examination room using the KX21N Sesmex instrument (provided by Jinan Sysmex Corporation, and produced in Japan).

2.2.4. Statistical analysis

The blood flow velocities were expressed as mean values ($\bar{x}$). RBC counts and serum potassium concentrations were expressed as means ± standard deviation ($\bar{x}\pm s$). Then, for the dependent variables that differed under different transfusion conditions, variance analysis was performed and then to check the distribution of the residual error. SAS software was used for further analyses.

3. Results

3.1. Blood flow velocity during compressed transfusion of WBC-removal whole blood using different sizes of intravenous detaining needles (Table 1)

Table 1
Blood flow velocity during compressed transfusion of WBC-removal whole blood using different sizes of intravenous detaining needles; ($\bar{x}$) mL/min.

Needle types	P_0	P_1	P_2	P_3
18G	35.580	99.762	135.762	171.405
20G	23.523	60.652	62.720	101.380
22G	14.013	43.469	53.391	64.871
24G	11.313	25.020	23.006	33.980

3.2. Changes in RBC count under different pressures and with different sizes of intravenous detaining needles (Table 2)

Differences in dependent variables between before and after transfusion were used for the variance analysis. The data were not normally distributed, with approximately 15% of data values being outliers after checking the residuals. Therefore, the classic variance analysis method could not be applied, and the robust method of M-estimate was applied as an alternative that is less affected by outliers using SAS software.

The results showed that RBC count was not statistically significantly different ($P = 0.1963$) under different pressures with the same size needle. Thus, RBC count does not change significantly with different pressures below 300 mmHg when using the same size intravenous detaining needle.

3.3. Observations under the ordinary light microscope

When blood is not pressurized, less poikilocytes appear in the field of vision during blood transfusion through the transfusion apparatus and needles. With increased pressure, the number of coarse, spiny, oval-shaped, spindle-shaped cells in the field of view gradually increased; some cells were even teardrop-shaped, and some cell debris was observed. The mean poikilocyte counts of samples obtained through a 20G intravenous detaining needle were determined using a light microscope and are presented in detail in Table 3.

3.4. Changes in serum potassium concentration under different pressures with different sizes of intravenous detaining needles (Table 4)

The differences in the potassium concentrations of samples obtained through different sizes of detaining needles under the same pressure were examined by analysis of variance ($F = 2.408$, $P = 0.076$). The differences in the potassium concentrations of samples obtained through the same size detaining needle under

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