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Author

de Melo Mendes, Maria Teresa, de Lima Jacinto, Amanda Karina, Kusahara, Denise Miyuki, Sorgini Peterlini, Maria Angelica, Goncalves Pedreira, Mavilde da Luz, Machado Avelar, Ariane Ferreira

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Hemolysis markers of blood administered in non-valved peripherally inserted central catheter*

Marcadores de hemólise em concentrado de hemácias administrados por cateter central de inserção periférica não valvulado

Marcadores de hemólisis en concentrado de eritrocitos administrados por catéter central de inserción periférica sin válvula*

Maria Teresa de Melo Mendes[1]
Amanda Karina de Lima Jacinto[1]
Denise Miyuki Kusahara[1]
Maria Angélica Sorgini Peterlini[1]
Mavilde da Luz Gonçalves Pedreira[1]
Ariane Ferreira Machado Avelar[1]

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Abstract
Objective: To evaluate the change in hemolysis markers in packed red blood cells, administered by gravity infusion in non-valved PICC lines, according to different sizes.
Methods: Experimental study carried out in laboratory under controlled conditions of temperature and humidity. The sample had 36 blood aliquots from 10 packed red blood cells bags with A positive blood type; gravity infusion was used in six 3 French (Fr) PICC and in six 4Fr PICC, totaling 12 experiments divided in three moments: Basal, Free Flow and Controlled Flow. Degree of hemolysis, total and free hemoglobin values, lactic dehydrogenase and potassium were analyzed.
Results: There was an average increase of free hemoglobin (p=0.01) and degree of hemolysis (p=0.01) after Free Flow infusion, with 0.04 average elevation of potassium (p<0.01) and decrease of total hemoglobin (p=0.01) in Controlled Flow. The packed red blood cells infused in 4Fr PICC had average elevation of degree of hemolysis (p=0.03) in Free Flow, and potassium (p=0.03) and degree of hemolysis (p=0.05) in the Controlled Flow. The 3Fr PICC had significant average increase in the degree of hemolysis (p=0.03) and free hemoglobin (p=0.01) after flow control.
Conclusion: The 4Fr PICC were associated to higher changes in hemolysis markers. We infer that the larger size can provide a turbulent flow, contributing to a larger clash among red blood cells.

Resumo
Objetivo: Identificar as variações nos níveis de marcadores de hemólise em CH administrados por CCIP segundo o calibre do cateter.
Método: Estudo experimental realizado em laboratório com condições de temperatura e umidade controladas. A amostra teve 36 alíquotas de sangue de 10 bolsas de hemácias com tipo de sangue A+; infusão de gravidade foi utilizada em seis CCIP de 3Fr (French) e seis de 4Fr, totalizando 12 experimentos divididos em três tempos: basal, fluxo livre e fluxo controlado. Analisou-se grau de hemólise, valores totais e livres de hemoglobina, desidrogenase láctica e potássio.
Resultados: Houve aumento da média de hemoglobina livre (p=0,01) e grau de hemólise (p=0,01) após infusão de fluxo livre, com média de elevação de 0,04 de potássio (p<0,01) e redução de hemoglobina total (p=0,01) em fluxo controlado. O concentrado de hemácias aplicadas em 4Fr CCIP teve média de elevação de grau de fluxo. O CCIP de 3Fr teve aumento médio significante em grau de hemólise (p=0,03) e hemoglobina livre (p=0,01) após controle do fluxo.
Conclusão: O CCIP de 4Fr foram associados a maiores mudanças nos marcadores de hemólise. Maior dimensão do calibre pode proporcionar fluxo turbulento, contribuindo para um maior choque entre as hemácias.

Resumen
Objetivo: Identificar las variaciones de los niveles de marcadores de hemólisis en CE administrados por CCIP según el calibre del catéter.
Método: Estudio experimental realizado en laboratorio en condiciones de temperatura y humedad controladas. La muestra tenía 36 alícuotas de sangre de 10 bolsas de eritrocitos con tipo de sangre A+; fue utilizada infusión por gravedad en seis CCIP de 3 FR (French) y seis de 4 FR, un total de 12 experimentos divididos en tres tiempos: basal, flujo libre y flujo controlado. Se analizó el nivel de hemólisis, valores totales y libres de hemoglobina, deshidrogenasa láctica y potasio.
Resultados: Hubo un aumento del promedio de hemoglobina libre (p=0,01) y nivel de hemólisis (p=0,01) después de infusión de flujo libre, con promedio de elevación de 0,04 de potasio (p<0,01) y reducción de hemoglobina total (p=0,01) en flujo controlado. El concentrado de eritrocitos aplicados en 4 FR CCIP tuvo promedio de elevación de nivel de flujo. El CCIP de 3 FR tuvo un aumento promedio significativo en nivel de hemólisis (p=0,03) y hemoglobina libre (p=0,01) después de control de flujo.
Conclusión: El CCIP de 4 FR fue asociado a mayores cambios en los marcadores de hemólisis. Mayor dimensión del calibre puede proporcionar flujo turbulento, lo que contribuye a un mayor choque entre los eritrocitos.

Corresponding author
Ariane Ferreira Machado Avelar
https://orcid.org/0000-0002-1882-891X
E-mail: ariane.machado@unifesp.br

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[1]Escola Paulista de Enfermagem, Universidade Federal de São Paulo, São Paulo, SP, Brasil.
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Introduction

The packed red blood cells (PRBC) are one of the blood components most used in hemotherapy.[1] Despite wide administration for therapeutic purposes, the use of PRBC is not risk-free. We estimate that, even though rare, one in every 1000 blood transfusions are related to complications, such as hemolytic reactions.[2,3]

The rupture of red blood cells activates the inflammatory cascade that may cause endothelial dysfunction, as well as infusion of microblisters, resulting in an anticoagulant and inflammatory reaction in the human body.[4] Studies relate hemolysis with splenic microcirculation changes, increasing the risk of intestinal ischemia in septic adults and of necrotizing enterocolitis in newborns, besides acute anemia caused by rupture of balance between functions of hematopoiesis and hemofiltration.[5,6]

Hemolysis is usually identified in blood products due to the presence of plasma free hemoglobin (PFHb) that reacts with oxygen and nitric oxide, resulting active forms of iron and free heme, able to activate the immune response of macrophages and monocytes. Additionally, lactate dehydrogenase isoenzymes (LDH) of types 1 and 2 are released, which are widely distributed in the cytoplasm of red blood cells, since they catalyze metabolic reactions. Potassium, predominant ion in the intracellular milieu, is then released into the plasma, which can trigger hyperkalemic effects.[7-9]

Research attribute the occurrence of hemolytic effects to size and length of the catheter, infusion rate, infusion equipment used and physical properties of the blood bag, such as viscosity and storage time.[10,11]

Therefore, the relationship between degree of hemolysis after transfusion and the characteristics of the vascular device used such as size, length and type of catheter cause questions on patient safety during this therapy.[12]

In hemotherapic practice in neonatology and pediatrics, we perceive the increasingly frequent use of peripherally inserted central catheter (PICC) in neonatal intensive care units (NICU).[13] The PICC contributes to reduce the number of peripheral venous punctures and costs of materials and professionals involved in this procedure.[14] Also, factors such as prolonged length of stay, less traumatic peripheral insertion and reduced risk of complications, when compared to other central catheters, makes it the first option after umbilical catheter removal.[15]

Elements such as infusion rate, size and length of the catheter used, method of administration, storage time of red blood cells, as well as the hematocrit (HcT) value are factors that may influence on the quality of the blood product administered. However, they are still little explored in literature. Thus, the study had as objective to evaluate the change in hemolysis markers in PRBC, administered by gravity infusion in non-valved PICC lines, according to different sizes.

Methods

Experimental in vitro study, carried out in the Laboratory of Experiments in Nursing (LEEnf – Laboratório de Experimentos em Enfermagem), from a public university of São Paulo, after approval by the Research Ethics Committee of the institution (CAAE 19102613.4.0000.5505), simulating the clinical practice of administration of PRBC in children and adults using PICC.

The sample of PRBC were taken from 10 A+ blood bags, subjected to research conditions. PRBC bags used attended to the following criteria: preserved in CPDA-1 with storage term equal or under 35 days; with no previous use in human beings, with HcT equal or under 75% before experiments, characterized as storage surplus or due to viability loss to therapeutic use, which would have as a destiny the disposal and incineration.

Infusion method and catheters

Gravity infusion was the method used to administer PRBC bags, with macrodrop equipment developed in polyvinyl chloride (PVC) specific to infuse hemocomponents, with filters from 170 to 260 micron coupled to retention of blood clots and aggregates.

PICCs used were made in silicone, with teflon guide wire, 3Fr size, equivalent to 20G, and 4Fr

(18G), single lumen, with 60cm of length, from the same manufacturer. The sequence of different catheters in experiments was random and in triplicate, following a prior randomization.

Experiment Description and analysis of the markers

Before the beginning of the experiments, three nurses who participating in the research project were trained from August to September 2013, in partnership with the Blood Bank of Universidade Federal de São Paulo - UNIFESP and the Associação Beneficente de Coleta de Sangue (COLSAN), for the correct management of the equipment and the aliquot collection, as well as performance and interpretation of the analyzes. For the organization of the experiments the researchers used a protocol developed for this study and a data collection instrument, both previously validated in a pre-test with ten experiments. It should be emphasized that the researchers had the technical supervision of a biochemical professional during all stages of data collection.

PRBC bags, stored under refrigeration from 2 to 4 ºC, were taken from the refrigerator 45 minutes before the beginning of the experiments. To register the evaluation of the temperature and the humidity, every 15 minutes were checked these data through digital thermo hygrometer, to analyze the environment, and to the blood bag temperature, using infrared thermometer, placed 10 cm from its center.

Three samples of PRBC bags were collected in three different moments. The first sample named "Basal" was obtained after opening the bag, based on 0.5 mL of blood dripping through the test tube walls and 5mL in tube with clot activator gel to enable the analysis of potassium, PFHb, THb, HcT, degree of hemolysis and LDH.

To obtain the second sample, named "Free Flow", an administration set was connected to the bag and filled with blood. The bag was placed on metal support to maintain the height of 80 cm from the drip chamber to the final infusion line. The PICC selected for the experiment was then filled with physiological saline (NaCl 0.9%) and connected to the distal portion of the equipment. After such connection, the clamp of the equipment was fully opened, to the extent that the blood freely flowed through the catheter, being then discarded twice the internal volume of the catheter aiming to ensure that all the material collected, as of this moment, suffered the system influence. Subsequently, this sample was submitted to the same previous analyses.

The third and final sample named "Controlled Flow" represented the study on the rate of infusion effect markers, being obtained after the drip control to 10 mL/h or until maximum rate found after the elevation of the infusion system up to 132 cm. The drip flow was controlled for 1 minute using the stopwatch, and certified in intervals of 10 min, being adjusted as necessary, to provide a constant rate.

To collect the second and the third samples of PRBC infused, we observed a mean infusion time of 19.8 minutes for the 4Fr PICCs and 33 minutes for the 3Fr PICCs.

Environmental variables of temperature and humidity, as well as temperatures of PRBC bags were gauged before beginning of each collection (Basal, Free Flow and Controlled Flow). Moreover, the time of each experiment was strictly controlled, given the risk of bacterial contamination in prolonged infusions.

For HcT analysis, the microhematocrit centrifuge and hematocrit reader were used, being analyzed by two researchers after centrifuge of the capillary filled up to ¾ of its capacity for 4 minutes at 3600 rotations per minute.

An absorption spectrophotometer for the analyses of other markers was used, being employed the colorimetric principle to THb, PFHb and potassium and kinetic principle to LDH. The THb reading occurred in 540nm wavelength after dilution of the blood with reagent through the cyanmethemoglobin method.

Analysis of PFHb, potassium and LDH occurred after centrifugation of the tube with clot activator gel in serological centrifuge. Solutions with plasma and deionized water were read at wavelengths 370, 415, 510, 577 and 600nm for later PFHb calculation.[16] The plasma fractions for potassium analysis

were initially deproteinized and added to sodium tetraphenylborate and sodium hydroxide; the reading was held at 580nm.

The methodology adopted for LDH analysis followed the principle of chemical kinetics reaction, measuring the decomposition rate of the reagent used caused by the addition of LDH to the solution. LDH concentration was determined due to drop of absorptivity at 340 nm for three minutes.[17]

The degree of hemolysis was calculated after obtaining the values of HcT, THb and PFHb, according to the equation: Degree of hemolysis(%) = (100-HcT) xPFHb/THb.[16]

Data analysis

The data was stored and analyzed through the program Microsoft Excel® 2010 e IBM SPSS versão 22.0. Regarding the parametric design, the distribution verification was carried out according to the method proposed by Kolmogorov & Sminorv. Subsequently, the proximity between values of mean, median and graphical distribution of the aforementioned markers were evaluated. Thus, the mean variation of hemolysis markers through the moments (Basal with Free Flow and Basal with Controlled Flow) of the experiments was evaluated through the Paired t-test. The Mann-Whitney U test was used for comparison of the behavior of markers between 3Fr and 4Fr catheters. Those with type I error probability lower than 5% were considered statistically significant findings.

Results

A total of 36 PRBC aliquots were obtained: 12 aliquots in Basal moment, 12 in Free Flow (FF) and 12 in Controlled Flow (CF); 12 randomized experiments were carried out, six with 3Fr PICC and six 4FR. The average time of storage bags was 17 days. It should be noted that the inclusion of bags according to time of storage was at random, so that 67% of the 3Fr PICC experiments occurred with PRBC with less than 14 days, while in 4Fr PICC these were used in 83% of the experiments. The thermal conditions of the laboratory were controlled, in a way that the environment temperature during the moments of analysis had variation lower than 1 °C, being held between 23 and 24 °C. The bag temperature increased approximately 4 °C in the course of the experiments, varying between 20 and 24 °C and the relative air humidity had average reduction of 0.8%. When the effect of rate of infusion on makers of hemolysis was analyzed, regardless of the catheter size, we observed statistically significant variation in the degree of hemolysis, THb and PFHb in both Free Flow and Controlled Flow (Table 1).

Subsequently, the behavior of hemolysis indicators according to size of the catheter and three moments of collection was verified (Table 2). No statistically significant difference was evidenced in hemolysis markers in free flow when the 3Fr PICC was used. In 4Fr catheters, there was significant increase in the degree of hemolysis (p=0.03) and marginally significant in PFHb (p = 0.06). After establishment of the flow control in 3Fr PICC, there was significant increase in the degree of hemolysis (p=0.03) and PFHb (p=0.01). In 4Fr catheters, there was an increase in the degree of hemolysis (p=0.05) and potassium levels (p=0.03), with concomitant THb mean decrease (p=0.04). Marginally significant increase in PFHb levels (p=0.07) was identified.

We can observe an increasing development of both sizes studied. However, in 4Fr catheters, the

Table 1. Variation of the measures of central tendency and dispersion (mean ±standard deviation) of hemolysis markers, in the three moments of the experiment (n=24), according to type of infusion flow

	Basal	Free flow	Mean difference (CI 95%)	p*	Basal	Controlled flow	Mean difference (CI 95%)	p-value*
HcT[1] (%)	72.50 ±2.11	72.83 ±1.94	0.33 (- 0.40 to 1.06)	0.33	72.50 ±2.11	72.75 ±2.00	0.25 (-0.73 to 1.23)	0.58
Degree of hemolysis (%)	0.135 ±0.138	0.187 ±0.178	0.05 (0.01 to 0.09)	0.01	0.135 ±0.138	0.197 ±0.190	0.06 (0.02 to 0.09)	<0.01
THb[2] (g/dL)	28.17 ±5.46	25.76 ±3.16	-2.40 (-4.75 to -0.05)	0.04	28.17 ±5.46	24.74 ±2.59	-3.42 (-5.91 to -0.92)	0.01
Potassium (mmol/L)	39.64 ±5.12	40.55 ±5.23	0.91 (-0.46 to 2.28)	0.17	39.64 ±5.12	40.90 ±5.27	1.26 (-0.02 to 2.55)	0.05
PFHb[3] (g/dL)	0.146 ±0.16	0.189 ±0.20	0.04 (0.01 to 0.07)	0.01	0.146 ±0.16	0.190 ±0.20	0.04 (0.01 to 0.07)	<0.01
LDH[4](U/L)	888.2 ±404.4	1068.5 ±696.5	180.3 (-105.6 to 466.3)	0.19	888.2 ±404.4	1277.2 ±1206.8	389.0 (-254.7 to 1032.7)	0.21

**Paired t-test;* 1: hematocrit; 2: total hemoglobin; 3: free hemoglobin; 4: lactate dehydrogenase isoenzymes

Table 2. Influence of the PICC size in hemolysis markers according to measures of central tendency and dispersion (mean ±standard deviation) in three moments of the experiment (n=24)

	Basal	Free flow	Mean difference (CI 95%)	p*	Basal	Controlled flow	Mean difference (CI 95%)	p-value*
3 Fr								
HcT[1] (%)	71.50 ±1.97	72.33 ±2.06	0.83 (-0.71 to 2.37)	0.22	71.50 ±1.97	72.16 ±1.94	0.66 (-1.39 to 2.73)	0.44
Degree of hemolysis (%)	0.108 ±0.07	0.166 (± 0.14)	0.05 (-0.02 to 0.14)	0.14	0.108 ±0.07	0.158 ±0.10	0.50 (0.00 to 0.09)	0.03
THb[2] (g/dL)	28.65 ±7.02	25.70 ±3.41	-2.94 (-7.50 to 1.61)	0.15	28.65 ±7.02	24.84 ±2.82	-3.81 (-9.09 to 1.46)	0.12
Potassium (mmol/L)	38.03 ±4.03	39.39 ±4.99	1.36 (-1.81 to 4.54)	0.32	38.03 ±4.03	39.96 ±5.06	1.93 (0.99 to 4.86)	0.15
PFHb[3] (g/dL)	0.115 ±0.10	0.161 ±0.15	0.04 (-0.01 to 0.10)	0.11	0.115 ±0.10	0.149 ±0.11	0.03 (0.00 to 0.05)	0.01
LDH[4] (U/L)	756.4 ±421.8	791.5 ±407.3	35.07 (-43.6 to 113.8)	0.30	756.4 ±421.8	779.8 ±414.9	23.3 (-148.4 to 195.2)	0.74
4 Fr								
HcT (%)	73.50 ±1.87	73.33 ±1.86	-0.16 (-0.59 to 0.26)	0.36	73.50 ±1.87	73.33 ±2.06	-0.16 (-1.19 to 0.86)	0.69
Degree of hemolysis (%)	0.162 ±0.18	0.209 ±0.21	0.04 (0.00 to 0.86)	0.03	0.162 ±0.18	0.36 ±0.25	0.07 (0.00 to 0.15)	0.05
THb (g/dL)	27.68 ±3.97	25.82 ±3.22	-1.85 (-5.26 to 1.55)	0.22	27.68 ±3.97	24.65 ±2.61	-3.02 (-6.03 to -0.17)	0.04
Potassium (mmmol/L)	41.25 ±5.74	41.71 ±5.66	0.45 (-0.34 to 1.25)	0.20	41.25 ±5.74	41.85 ±5.78	0.59 (0.08 to 1.10)	0.03
PFHb (g/dL)	0.177 ±0.21	0.217 ±0.25	0.04 (-0.00 to 0.08)	0.06	0.177 ±0.21	0.231 ±0.26	0.05 (0.00 to 0.11)	0.07
LDH (U/L)	1019.9 ±374.4	1345.5 ±846.9	325.5 (-329.3 to 980.5)	0.25	1019.9 ±374.4	1774.6 ±1561	754.6 (-696.0 to 2205.3)	0.23

**Paired t-test;* 1: hematocrit; 2: total hemoglobin; 3: free hemoglobin; 4: lactate dehydrogenase isoenzymes

Table 3. Comparison of hemolysis markers in experiments, according to catheter size (n=24)

	3 Fr Median (min-max)	4 Fr Median (min-max)	p*
HcT[1] (%)	0.0 (-2.0 – 3.0)	0.0 (-2.0 – 1.0)	0.15
Degree of hemolysis (%)	0.03 (0.0 – 0.22)	0.03 (0.01 – 0.19)	0.77
THb[2] (g/dL)	-1.39 (-9.94 – 1.60)	-1.54 (-8.24 – 1.01)	0.86
Potassium (mmol/L)	0.81 (-1.88 – 7.17)	0.39 (-0.48 – 1.51)	0.18
PFHb[3] (g/dL)	0.02 (0.0 – 0.16)	0.19 (0.01 – 0.15)	0.95
LDH[4] (U/L)	59.36 (-296.8 – 156.5)	55.31 (-37.78 – 3502.4)	0.50

**Mann-Whitney;* 1: hematocrit; 2: total hemoglobin; 3: free hemoglobin; 4: lactate dehydrogenase isoenzymes

basal moment initially had higher markers when compared to the 3Fr. It can be justified by the larger use of PRBC with prolonged storage time on catheters of larger size. When comparing both catheters, regardless of the flow established, there was no statistical difference between catheters, as shown in table 3.

Discussion

We identified as possible limitations of the study the restricted number of PRBC and PICC, and the absence of uniform distribution of PRBC storage period in relation to the different calibers and infusion rates, which could provide more robust results according to the exclusive influence of the caliber, infusion rate and physical characteristics of the experiment.

The 4Fr PICC had more evident changes in markers, with significant elevation in the degree of hemolysis when free flow infusion was carried out and after the flow control. During the controlled flow, larger release of potassium and reduction of THb occurred, both statistically significant. The PRBC administered by PICC with 3Fr size had no changes in free flow, however it had variation on PFHb with subsequent increase in the degree of hemolysis in controlled flow.

In our experiments, we could observe a significant increase in the degree of hemolysis and PFHb. We noted that to the extent that larger PFHb release occurs, there is a decrease in the THb values, and these latter molecules have a tetramethric form and a high molecular weight and in the presence of an erythrocyte trauma they dissociate into dimers, causing its free shape with low molecular weight, allowing its rapid spread in the organism.[18]

There is no consensus in literature regarding the value of reference to PFHb, with variability among authors. Latest evidence relate the occurrence of symptoms dependent on the concentration, after infusion of limits higher than 2g of PFHb.[19]

In our study, there was a 30% increase in PFHb values after establishment of flow control, being that these values are much lower than the aforementioned in the literature.

The experimental study simulated neonatal transfusion practice, in which PRBC with two and nine days of storage subjected to rates of 10.6, 20.5 and 70 mL/h in peripheral catheters through syringe infusion pump were used, identified a sig-

nificant variation and maximum values of 0.05 g/dL and potassium of 29,3mmol/L in red blood cells with longer period of storage and infused with the lower flow rate.[10] Similar result was obtained in a research that added the influence of sizes in the PFHb release, 21 to 27G catheters were used at a 20, 50, and 100 mL/h rate. Hemolysis was not significant for any test performed, however the PFHb release was prominent in total blood volume samples, with storage lower than 24 hours, infused by 27G catheters at 20 mL/h.[20]

We observed a significant increase in the degree of hemolysis ($p<0.05$) associated to the larger size during free flow infusion. PFHb and potassium values were higher than those highlighted by the aforementioned research. We emphasize that such result refers only to the influence of the catheter without considering the flow control.

Other research examined the influence of 20 and 22G sizes with 8.9 cm length, in the loss of PRBC erythrocyte irradiated with HcT between 60 to 80%, infused via infusion pump. The reduced size of the catheters and high hematocrit values were associated with higher rates of hemolysis, with maximum concentrations 0, 075g/dL of PFHb.[21] It is known that the HcT elevation generates a higher viscosity to PRPBC, which may provide a stronger flow resistance and the consequent increase in pressure and shear stress between the red blood cells, generating higher cell loss.[22] We can observe that the HcT in samples infused by 4Fr PICC had a median discreetly higher than that checked in 3Fr catheters.

Researchers correlated the LDH increase and haptoglobin reduction in PRBC infused at high rates for small size catheters, being the erythrocyte trauma associated with the increased shear stress and presence of turbulent flow inside the system.[23]

Smaller size PICCs had significant increase in values of PFHb and degree of hemolysis after the flow control was established.

Researchers evaluated the influence of size and constitutive material of the catheter, three different sizes were used: 14, 18 and 22G made in polyurethane, Teflon® and stainless steel, and concluded that the hemolysis was related to larger size catheters and the use of stainless steel device, with values of 0.1 g/dL of PFHb.[24] The authors add that features inherent to the blood product may be related to cell trauma, such as increased hematocrit with consequent prolongation of infusion time and friction in the pipe wall caused by the increased number of cells.[24]

A similar result was found in a study with two groups of red blood cells: fresh (recently collected) and with 7 days of storage, infused by 18, 22 and 26G size catheters.[23] Highest PFHb value found was 0, 445g/dL and was associated with the infusion of red blood cells stored in 18G size catheters.[25] Some researchers attribute the occurrence of hemolysis to turbulent flow generated by the increase in the radius of the catheter.[26]

We found a similar result in 4 Fr PICC, which were associated with a significant increase of hemolysis when PRBC were infused in free flow. We emphasize that these catheters had less flow resistance, requiring less pressure to generate effective infusions. The fastest rate also was related to these devices, as well as the increase of the hemolysis markers.

The 3Fr PICCs had an opposite behavior, with minor changes in the levels of hemolysis markers in free flow, with significant change after the flow control. We can infer that the erythrocyte damage caused by such catheters occurred during low flows. In this case, the increase in erythrocyte trauma was possibly associated with higher friction between cells for longer periods of time, while the 4Fr largest size provided a dispersal of cells to the periphery generating a greater contact of such with the catheter wall, more evident in faster flows with tendency to turbulence.

The silicone PICCs have thicker walls and smaller internal lumens when compared to polyurethane catheters.[27] The first ones have a higher flow resistance, especially in the presence of the biofilm that may contribute to the turbulent flow and variations of infusion rate throughout the device.[27]

In a recent survey in the major databases, we identified three researches that address the PICC use for infusion of blood products. However, all used only catheters with sizes smaller than 1.9Fr,

and infusion pumps of syringe to administrate the RPBC. The RPBC, with up to nine days of storage, which were transfused with rates 2.5 mL/h in 1.2Fr size and 30cm length devices, had significant variation in degree of hemolysis and PHFb, with values of 0.13% and 0.06 g/dL, respectively.[28] Similar results could be identified in our study, however the PFHb level obtained was considerably higher, which can be justified by the use of red blood cells with longer storage.

A clinical study examined the feasibility of transfusion of RPB for 1.2 Fr catheters in newborns, the clinical parameters of heart rate and blood pressure remained stable during the procedure and there was no significant increase of potassium.[29] However, the catheter obstruction occurred in 33% of cases in which there was an infusion of blood parallel to vasoactive drugs and parenteral nutrition. Such substances can raise the osmolarity of the final solution, as well as interact with anticoagulant present in the bag, decreasing its effectiveness and predisposing coagulation.[29]

In the USA, the American Association of Blood Banks and the INS report that during the choice of the appropriate catheter for transfusion procedures, the professional should take the venous network into consideration, as well as the patient's clinical features and they add that the use of devices with size lower than 20G can be used safely for children and adults.[30] The Royal College of Nursing Australia adds that the PICC is a choice for transfusion, however, they contraindicate the gravity infusion method and recommend the use of electronic devices of volumetric infusion.[31]

Literature brings contradictory data about what in fact influences on erythrocyte trauma during blood administration. Most studies were carried out between the 80s and 90s and, in this time, intravenous catheters were made with more thrombogenic materials, with thick walls to provide strength and durability and consequent reduction of the inner lumen of the catheter.[32] These factors reflected in a low time of permanence, as well as in the reduction of the infusion rate, especially with regard to hemocomponents.[32]

Conclusion

The PFHb and degree of hemolysis increase, as well as THb decrease occurred during PRBC infusion, clarify the presence of damage to red blood cells associated with PICC use. The results do not make 3Fr and 4Fr PICC unviable for transfusion, since the values of hemolysis observed were lower than those recommended by the associations of blood banks; however, the use of such device to PRBC administration must be carefully evaluated by the nurse, as well as the infusion method used to do so, since the gravity infusion can become extremely long.

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Collaborations

Mendes MTM, Jacinto AKL, Kusahara DM, Peterlini MAS, Pedreira MLG and Avelar AFM declare participating in the conception of the study, data analysis and interpretation, drafting the manuscript, critical review of the content and approval of final version to be published.

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