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Analysis of Causes and Countermeasures of Poor White Blood Cell Filtration in Whole Blood from a Nursing Perspective

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Abstract: *Purpose:* To analyze the causes and countermeasures of poor white blood cell filtration in whole blood from a nursing perspective. *Methods:* Research time: January 2023 to June 2023, research subjects: 76 blood donors who donated whole blood at the Red Cross Blood Center. After grouping according to the computer randomization method, the final results showed that they were divided into a control group and an intervention group of 38 cases each. The control group adopted routine nursing procedures, and the intervention group implemented targeted nursing intervention to explore the effects of the intervention in the two groups. *Results:* The poor filtration of leukocytes from whole blood was mainly due to donor factors such as nervousness of blood donors (32.89%) and poor venous conditions (21.05%); operational issues such as puncture technology (28.95%) and insufficient anticoagulation (25.00%); and equipment factors such as filter quality (10.53%). Compared with the control group, the intervention group had shorter filtration time, lower leukocyte residual volume, and lower blood scrap rate (2.63% vs. 18.42%), comparison $p < 0.05$. The clot-free rate of samples in the intervention group was 63.16%, while only 26.32% of the samples in the control group were clot-free, and no grade 3 clots occurred. Comparison $p < 0.05$. *Conclusion:* The application of targeted nursing intervention can effectively improve whole blood filtration efficiency and reduce clot formation, providing a practical clinical practice path for improving the quality of blood products.
Keywords: Whole blood filtration; Nursing intervention; Blood flow rate; Blood clot; Blood donation care

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1. Introduction

Whole blood filtration of leukocytes is a core step in the preparation process of blood products, and its smooth operation is directly related to the final quality and clinical application safety of blood products. In daily blood collection work, it is found that about 15–20% of blood donors experience varying degrees of flow slowdown during the filtration stage, and in severe cases, complete blockage occurs, which not only prolongs the blood preparation time, but also increases the possibility of scrapping blood products [1]. Through long-term observation and analysis of clinical cases, blood clot formation has been identified as a common cause of poor filtration. These tiny clots will gradually accumulate during the filtration process, eventually preventing blood from passing through the filter normally. An in-depth study of the causes found that the nervousness of blood donors can cause vasoconstriction and affect blood flow speed; poor puncture skills of blood collectors may lead to uneven mixing of blood and anticoagulants; irregular mixing of anticoagulants can easily cause local coagulation; the interaction of these factors jointly increases the risk of blood clot formation [2]. Therefore, from the perspective of nursing operations, systematically improving the above influencing factors has practical significance for improving whole blood filtration efficiency. In this regard, this study focuses on analyzing the related factors that affect whole blood leukofiltration and exploring the effects of targeted nursing intervention to provide a basis for optimizing the blood donation nursing process.

2. Materials and methods

2.1. General information

Research time: January 2023 to June 2023, research subjects: 76 blood donors who donated whole blood in our center. After grouping according to the computer randomization method, the final results showed that they were divided into a control group and an intervention group of 38 cases each. Statistics included 20 and 18 male and female blood donors in the control group; their age ranged from 18 to 45 years old, with an average of (28.64 ± 6.73) years; their weight ranged from 52 to 78 kg, with an average of (65.32 ± 8.45) kg; and the number of blood donations ranged from 1 to 15 times, with an average of (4.23 ± 2.56) times. There were 22 male and 16 male blood donors in the intervention group; their age ranged from 19 to 43 years old, with an average of (27.85 ± 6.92) years; their weight ranged from 50 to 80kg, with an average of (66.15 ± 9.02) kg; and the number of blood donations ranged from 1 to 14 times, with an average of (4.56 ± 2.78) years. Comparison of baseline data between the 2 groups, $p > 0.05$.

2.1.1. Inclusion criteria

(1) Meet the national health examination requirements for blood donors;
(2) Participate voluntarily;
(3) Donate 400 mL of whole blood;
(4) Use the same batch of filtration consumables.

2.1.2. Exclusion criteria

(1) Taking drugs that affect coagulation function in the past week;
(2) Having a history of hemorrhage or adverse reactions to blood donation;
(3) Hemoglobin < 120 g/L (men) or < 115 g/L (females);
(4) Difficulty in puncture due to poor venous conditions;
(5) Dropping out midway.

2.2. Method

The control group received routine blood donation care procedures, starting with health consultation and conducting standardized consultations, including the collection of basic information such as past medical history, medication use and living habits, and then completing basic physical examination items such as blood pressure, pulse measurement and hemoglobin rapid testing. Nursing staff conduct routine psychological counseling before blood collection. The puncture operation is performed by the nurse on duty that day. The median cubital vein is selected for puncture in accordance with the requirements of the blood collection manual. Blood collection needles and blood collection bags of the same specification are used. The anticoagulant is mixed using conventional methods. After blood collection is started, the blood is mixed 3–5 times per minute. The frequency of mixing and the range of movements are not precisely controlled. After the blood collection, the patient will be instructed on the conventional compression method and the compression time will be 3–5 minutes. After observing that there is no active bleeding, the patient will be covered with a dressing. Basic post-donation precautions will be given orally. The entire nursing process will be carried out in strict compliance with the basic operating specifications established by the blood station.

The intervention group implemented targeted intervention measures on the basis of routine care:

(1) Psychological intervention

Use the Self-rating Anxiety Scale (SAS) 30 minutes before donating blood to evaluate the mental state of all blood donors. For those with SAS scores ≥ 50, a dedicated person will be assigned to conduct 20 minutes of progressive muscle relaxation training to guide them to relax the whole-body muscle groups in order. Each muscle group should be kept tense for 5 seconds and then relaxed for 30 seconds. At the same time, we cooperate with cognitive behavioral intervention to correct misunderstandings related to blood donation, explain the blood collection process and safety measures in detail, and help establish correct understandings. Maintain verbal communication throughout the blood collection process, distract attention through conversation, observe changes in facial expressions and body language, and soothe nervousness in a timely manner. For those with signs such as pale face, clammy palms, etc., the blood collection operation will be suspended until the vital signs are stable.

(2) Vascular care

15 minutes before blood collection, use a 40 °C constant temperature moist hot towel to apply hot compress to the median cubital vein and forearm cephalic vein area for 5 minutes. The hot compress area is about 10 cm × 10 cm. Two nurses in charge used a combination of visual inspection and palpation to evaluate blood vessel conditions, record parameters such as vein diameter, elasticity, depth, etc., and select blood vessels with a diameter of ≥ 3 mm, straight running, and good elasticity as the puncture site. For those with poor vein conditions, they were instructed to make fist movements and upper limb drooping movements to promote blood vessel filling. Tourniquets were used to assist positioning when necessary. The temperature of the blood collection room is controlled at 24–26 °C to avoid vasoconstriction caused by low temperature. After the preparation stage is completed, the disinfection range reaches 8 cm × 8 cm to ensure aseptic operation standards.

(3) Puncture technical specifications

The puncture operation is performed by a nurse in charge with more than 5 years of blood collection experience, using an 18G disposable blood collection needle and standard blood collection bag system. When puncturing, keep the bevel of the needle upward and insert the needle at an angle of 30° to the skin. After blood returns, lower the needle to an angle of 15° and continue to advance 2 mm. Make sure the needle is in the center of the blood vessel to prevent the needle tip from sticking to the wall and affecting blood flow. During the blood collection process, fix the needle wing to avoid mechanical damage caused by movement. For those whose blood flow rate is < 50 mL/min, check the needle position, fine-tune the angle if necessary, and strictly control the success rate of a single puncture. If the first attempt is unsuccessful, immediately change the operator, and record the actual number of punctures for each blood donor and include it in the quality analysis data.

(4) Anticoagulant care

Use a blood collection bag containing CPDA-1 anticoagulant. Timer immediately after blood collection starts. In the first 30 seconds, gently invert and mix 8–10 times at a frequency of 30 times/min to ensure full contact between the blood and the anticoagulant. Then adjust to complete 6–8 mixing actions per minute, and the mixing angle reaches 180° each time to avoid hemolysis caused by violent shaking. Observe the color change of the blood in the blood collection bag when mixing. Normally it should be uniform dark red. The appearance of stratification or floc indicates insufficient anticoagulation. Establish an anticoagulation effect evaluation form, record the time and action standard of each mixing cycle, and appropriately increase the mixing frequency to 10–12 times/min for blood donors in a hypercoagulable state.

(5) Flow rate monitoring

Use an electronic flow monitor to record the blood flow rate in real time throughout the blood collection process.

The normal range should be maintained at 50–70 mL/min. When the flow rate drops by more than 20% for 30 seconds, immediately check the cause and intervene: instruct the blood donor to adjust the arm position to avoid joint flexion; check whether the pipeline is compressed or twisted; evaluate whether the needle position is offset; confirm the mixing of the anticoagulant. Record the average flow rate data every 5 minutes, and mark specific handling measures for abnormal situations. The blood collection time is controlled to 7–9 minutes to complete the collection of 400 mL of whole blood. If it exceeds 12 minutes, it is considered a delay in blood collection, and special processing procedures need to be initiated.

(6) Post-harvest care

After the blood collection is completed, instruct the blood donor to use three-finger parallel pressure to continuously press the puncture point with moderate pressure and avoid rubbing. The pressing area covers the skin puncture point and blood vessel puncture point, and the pressing time is no less than 5 minutes. After observing no bleeding for 10 minutes, replace the breathable dressing with instructions to keep the dressing dry for 24 hours and avoid lifting heavy objects on the arm on the puncture side. Issue written reminder cards indicating possible adverse reactions and response methods, and establish a 24-hour telephone follow-up system to record the occurrence of complications such as local hematomas and bruises. For those with hematomas > 2 cm in diameter, provide guidance on the treatment of early cold compresses and later hot compresses. All nursing operations are performed in accordance with standard operating procedures and complete nursing records are maintained.

2.3. Observation indicators

(1) Analysis of the causes of poor white blood cell filtration in whole blood statistics;

(2) Whitening effect

Record the whitening time in detail: the time from the start of filtration to completion; the remaining amount of white blood cells: detected by a blood cell analyzer; blood scrap rate: the proportion of blood scrapped due to poor whitening filtration.

(3) Assess the grading of blood clots

Grade 0: no visible clots; Grade 1: tiny clots (< 3 mm), number ≤ 3; Grade 2: medium clots (3–5 mm), number 4–6; Grade 3: large clots (> 5 mm) or multiple clots (> 6).

2.4. Statistical methods

The SPSS26.0 software was used to process the data involved in the study. Measurement data were represented by "($\bar{x} \pm s$)" and tested by "*t*"; count data were represented by "[n/(%)]" and tested by "Chi-square". $p < 0.05$ indicated that the difference was of significant significance.

3. Results

3.1. Analysis of the causes of poor white blood cell filtration in whole blood

Poor leukocyte filtration from whole blood is mainly due to donor factors such as nervousness of blood donors (32.89%) and poor venous conditions (21.05%); operational issues such as puncture technology (28.95%) and insufficient anticoagulation (25.00%); and equipment factors such as filter quality (10.53%). **(Table 1)**

Table 1. Analysis of causes of poor white blood cell filtration in whole blood [n = 76 (%)]

Reason	Specific factors	Incidence rate (%)	Typical case description
Blood donor factors	Stress causes blood vessels to constrict	32.89	First-time blood donors appear pale and have sweaty palms
	Poor venous condition	21.05	Those with thin veins and poor elasticity may experience slow blood flow after puncture
	Improper posture	15.79	Bend of the arm blocks blood flow
Operating factors	Puncture technical issues	28.95	The bevel of the needle sticks to the wall causing poor blood flow
	Insufficient mixing of anticoagulant	25.00	In the early stage of blood collection, fibrin filaments appeared due to insufficient mixing.
	Insufficient mixing of anticoagulant	18.42	In the early stage of blood collection, fibrin filaments appeared due to insufficient mixing.
Device factors	Filter quality issues	10.53	Multiple cases of clogging occurred in the same batch of filters
	Pipe connection problems	7.89	Air leakage at joints interrupts blood flow

3.2. White filtering effect

Compared with the control group, the intervention group had shorter filtration time, lower leukocyte residual volume, and lower blood scrap rate (2.63% vs. 18.42%), comparison $p < 0.05$. **(Table 2)**

Table 2. Comparison of the whitening effects of the two groups

Group	n	Filter time (min)	Residual amount of white blood cells ($\times 10^6$/U)	Blood scrap rate (%)
Control group	38	31.42 ± 3.56	0.21 ± 0.06	7 (18.42)
Intervention group	38	23.15 ± 2.87	0.12 ± 0.04	1 (2.63)
t/χ^2		11.149	7.694	5.029
p		0.000	0.000	0.025

3.3. Blood clot situation

The clot-free rate of samples in the intervention group was 63.16%, while only 26.32% of the samples in the control group were clot-free, and no grade 3 clots occurred. Comparison $p < 0.05$. **(Table 3)**

Table 3. Comparison of blood clot conditions between the two groups [n (%)]

Group	n	Level 0	Level 1	Level 2	Level 3
Control group	38	10 (26.32)	14 (36.84)	9 (23.68)	5 (13.16)
Intervention group	38	24 (63.16)	10 (26.32)	4 (10.53)	0 (0.00)
χ^2			13.354		
p			0.004		

4. Discussion

Filtration of leukocytes from whole blood is a key step to ensure the safety of blood products. The smoothness of its operation directly affects blood quality and clinical use [3]. The results of this study show that the reasons for poor leukocyte filtration can be summarized into three categories: blood donor factors, operational factors and equipment factors. The nervousness of blood donors causes vasoconstriction, and poor venous conditions affect blood circulation. The puncture effect accounts for about 53.94%; poor puncture technique or insufficient anticoagulant mixing during the operation causes local coagulation, accounting for 54.37%; equipment factors such as filter quality problems account for a relatively low proportion, but they cannot be ignored. These factors interact to form tiny clots that gradually accumulate, eventually blocking the filter and reducing the filtering efficiency [4].

Although the routine blood donation care process is standardized, it lacks pertinence. For example, psychological counseling is mostly a formality and cannot effectively alleviate the anxiety of blood donors; vascular assessment and puncture technology rely on the operator's experience and have not formed unified standards; anticoagulation mixing frequency and actions lack quantitative standards, which can easily lead to insufficient local anticoagulation [5]. In the control group, 26.32% of the samples were clotted and the blood scrap rate was 18.42%, reflecting the lack of detail control in routine care.

The core of targeted nursing intervention is to dynamically optimize each link. Psychological intervention identifies high-risk groups through SAS scores, and combines progressive muscle relaxation training and cognitive behavioral intervention to alleviate vasoconstriction; vascular care uses constant temperature hot compress and precise assessment to improve the puncture success rate; anticoagulation care ensures even distribution of anticoagulants through standardized mixing frequency and angle [6]. This study showed that the filtration time of the intervention group was shortened to 23.15 minutes, the blood scrap rate dropped to 2.63%, the clot-free rate increased to 63.16%, and no grade 3 clots occurred. It is confirmed that targeted care can effectively reduce the risk of clot formation from the source by reducing the stress response of blood donors, optimizing operational accuracy, and standardizing the anticoagulation process. The improvement in white filtering effect is closely related to the reduction of clots. The residual amount of white blood cells in the intervention group is lower, indicating that after the blood fluidity is improved, the filter clogging is reduced and the filtration efficiency is improved. The obvious difference in clot grading further proves that standardized anticoagulation mixing and puncture technology can effectively avoid fibrin aggregation, suggesting that refined improvements in nursing quality can be directly transformed into improvements in the quality of blood products, providing a stronger guarantee for clinical blood transfusion safety [7].

In summary, the application of targeted nursing intervention can effectively improve whole blood filtration efficiency and reduce clot formation, providing a practical clinical practice path for improving the quality of blood products.

Disclosure statement

The author declares no conflict of interest.

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