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Original Article

Evaluation of leukocyte depletion of packed red blood cells for the prevention of clinically observed transfusion reactions at a medical center in Eastern Taiwan

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Abstract

Objectives: The incidence of febrile nonhemolytic transfusion reactions (FNHTRs) is correlated with the level of cytokines released by donor leukocytes in blood bags during storage, which is the most common transfusion reaction. The study aimed to reveal whether the use of leukocyte-poor red blood cells (LPRBCs) can reduce the incidence of transfusion reactions to promote patient safety. **Materials and Methods:** From January 2014 to June 2022, 158,122 blood transfusion reports were collected from a medical center in Eastern Taiwan. Data were categorized into three groups according to usage: prepromotion use of LPRBCs (January 2014–April 2016), promotion use of LPRBCs (May 2016 to February 2018), and full utilization of LPRBCs (March 2018 to June 2022). According to the American Association of Blood Bank Common Transfusion Reaction Reporting Form version 2.0 reporting system, FNHTRs were classified as moderate transfusion reactions. We used these data to analyze the association between LPRBC use and transfusion reaction rate. **Results:** At our hospital, the LPRBC usage rate from January 2014 to April 2016, May 2016 to February 2018, and March 2018 to June 2022 was 5.37%, 34.82%, and 56.45%, respectively. The total transfusion reaction rate from January 2014 to April 2016 was 1.66%, whereas the moderate reaction rate was 1.29%. The total transfusion and moderate reaction rates from May 2016 to February 2018 were 1.41% and 1.00%, whereas those from March 2018 to June 2022 were 0.95% and 0.63%, respectively. The total transfusion and moderate reaction rates from March 2018 to June 2022 decreased by 42.8% and 51.2%, respectively, compared with those from January 2014 to April 2016. We further compared the incidence of transfusion reactions caused by packed red blood cells (PRBC) and LPRBC products in different years. The results showed that between 2014 and 2022, the types of blood transfusion reaction caused using PRBC and LPRBC products are the mild transfusion reaction rate of 0.20%/0.20%, the moderate transfusion reaction rate of 1.61%/0.69%, the severe transfusion reaction rates 0.38%/0.16%, and the total transfusion reaction rates 2.19%/1.05%. **Conclusion:** Our study results indicate that both total transfusion and moderate reaction rates significantly decreased with increasing LPRBC usage rate. Based on our data analysis, LPRBC is more effective in reducing moderate and severe transfusion reactions than PRBC.

Keywords: *Febrile nonhemolytic transfusion reaction, Leukocyte-poor red blood cell, Transfusion reactions*

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Introduction

Blood transfusions are common procedures among hospitalized patients. Although blood transfusion therapy has shown success in the treatment of various diseases, the transfusion of all blood components may cause acute or delayed adverse reactions [1,2]. Most adverse transfusion

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reactions, including nonhemolytic fever, acute lung injury, platelet transfusion inefficacy, cytomegalovirus infection, and bacterial infection after surgery, are associated with allogeneic leukocyte transfusion [3-5]. Transfusion reactions can cause body discomfort and result in increased medical costs. In particular, the incidence of febrile nonhemolytic transfusion reactions (FNHTRs) is correlated with the level of cytokines released by donor leukocytes in blood bags during storage [6-8]. FNHTR is the most common transfusion reaction and occurs in approximately 1% of transfusion cases [4]. It is defined as a temperature increase of ≥1℃ above baseline within 3 h of transfusion. Previous studies have indicated that FNHTR is mainly caused by sensitivity to donor leukocytes [9]. Furthermore, human leukocyte antigen alloimmunization causes severe FNHTR in red blood cells (RBCs) [10-12].

Some studies have shown that leukocyte-reduced blood products can reduce the incidence of inflammation and transfusion reactions [5,13]. Subsequently, studies have demonstrated that blood products with reduced leukocyte content can effectively decrease the incidence of adverse reactions caused by blood transfusion by inhibiting the release of cytokines and activation of leukocytes [14,15]. According to the latest standards of the American Association of Blood Bank (AABB), the leukocyte content per unit of leukocyte-reduced products must be $<5 \times 10^6$. The production process is in accordance with the Pharmaceutical Inspection Co-operation Scheme of Good Manufacturing Practice guidelines and has a strict quality control system. After the standardization of the guidelines, previous studies have found that the use of leukocyte-reduced blood products can reduce the incidence of FNHTRs, risk of cytomegalovirus infection, development of allogeneic immunity in human tissues, and complications of patients after blood transfusion as well as shorten the disease course and relatively reduce medical costs [4].

Leukoreduction aims to attenuate transfusion-associated reactions by filtering donor leukocytes from packed RBC units. Leukocyte-reduced blood products can be classified into two types: "prestorage" and "poststorage." The "prestorage" type refers to products stored after reducing their leukocyte content using a leukocyte-removing filter [16]. This type of leukocyte-reduced blood product is also known as leukocyte-poor RBCs (LPRBCs) and is provided by the blood supply center in our country. The "poststorage" type of leukocyte-reduced blood products refers to products, in which the leukocyte content is reduced using a leukocyte-removing filter before blood transfusion. However, the "poststorage" products cannot remove cytokines released from donor leukocytes during storage [14,17,18]. Therefore, to reduce the incidence of blood transfusion reactions caused by leukocytes, the blood supply center has encouraged and promoted the use of LPRBC in recent years.

However, because of cost considerations in the past few years, LPRBCs are only transfused if the recipient experiences FNHTR after a blood transfusion packed red blood cells (PRBC). The use of LPRBCs is critical in improving the safety of blood transfusion. Moreover, it can reduce the workload of the nursing staff during filter operation. Therefore, recently, the National Health Insurance Agency has discontinued previous restrictions regarding the indications on the use of LPRBC.

To improve treatment quality, the use of LPRBCs was started in May 2016 and completely implemented in February 2018 in our hospital. Considering the diversity of clinical blood transfusion reactions, we analyzed the data collected from January 2014 to April 2016 and considered them as control, whereas data collected from May 2016 to February 2018 and from March 2018 to June 2022 were categorized into three groups to determine the correlation between the total transfusion reaction rate and LPRBC usage rate.

LPRBC usage has been extensively studied in several countries. Therefore, the current study aimed to reveal that LPRBCs can reduce the incidence of transfusion reactions and promote patient safety in clinical settings.

Materials and methods

Data collection

We used the blood supply report system to assess the monthly total blood consumption and blood transfusion reaction reports. Overall, 158,122 blood transfusion reports were collected from a medical center in Eastern Taiwan from January 2014 to June 2022. Data were classified into three groups according to usage: prepromotion use of LPRBCs (January 2014–April 2016), promotion use of LPRBCs (May 2016–February 2018), and full utilization of LPRBCs (March 2018–June 2022). The total number of reports collected from January 2014 to April 2016 and from May 2016 to February 2018 was 40,242 and 31,313, respectively, whereas that collected from March 2018 to June 2022 was 86,567.

During each blood transfusion reaction, the nursing staff input patient data and corresponding vital signs into the report system. Based on the report system classification, the degree of blood transfusion reaction was evaluated. The diagnostic categories of transfusion reactions were determined using the AABB Common Transfusion Reaction Reporting Form version 2.0, which is used by hospitals for communicating information about transfusion reactions to blood suppliers. According to the classification of transfusion reactions in our hospital [Table 1], FNHTRs were classified as moderate transfusion reactions. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Research Ethics Committee of Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation on April 16, 2024. (REC No.: IRB113-076-B). Informed consent was waived by the IRB.

Statistical analysis

Transfusion reaction rate = total number of blood units with reported transfusion reactions for a single blood product/ total usage of a single blood product.

All quantitative data were obtained using comparative analysis. Statistical analysis was performed using Student's *t*-test, and statistical data are presented as mean ± standard deviation (SD) A $P < 0.05$ indicates that the observed

phenotype was significantly different compared with the reference, whereas a $P > 0.05$ indicates that no significant difference was noted.

Results

Three groups of data were analyzed from January 2014 to June 2022. The total number of blood transfusion reports from January 2014 to April 2016 was 40,242, with total transfusion and moderate reaction rates of 1.66% and 1.29%, respectively. The total number of reports from May 2016 to February 2018 was 31,313, with total transfusion and moderate reaction rates of 1.41% and 1.00%, respectively. The total number of reports from March 2018 to June 2022 was 86,567, with total transfusion and moderate reaction rates of 0.95% and 0.63%, respectively. The total transfusion and moderate reaction rates decreased with an increase in LPRBC usage [Figure 1]. Based on the three intervals of LPRBC status, we calculated the usage rate by dividing total LPRBC or PRBC content by total blood consumption and obtained total transfusion and moderate reaction rates for 102 months from January 2014 to June 2022. The prepromotion, promotion, and full utilization periods of LPRBCs were 28, 22, and 52 months, respectively, and the mean SD values of total transfusion and moderate reaction rates for these three intervals were calculated. The relationship between the usage rate and transfusion reaction rate among the three periods was compared [Figure 1]. At our hospital, the LPRBC usage rate from January 2014 to April 2016, May 2016 to February 2018, and March 2018 to June 2022 was 5.37%, 34.82%, and 56.45%, respectively.

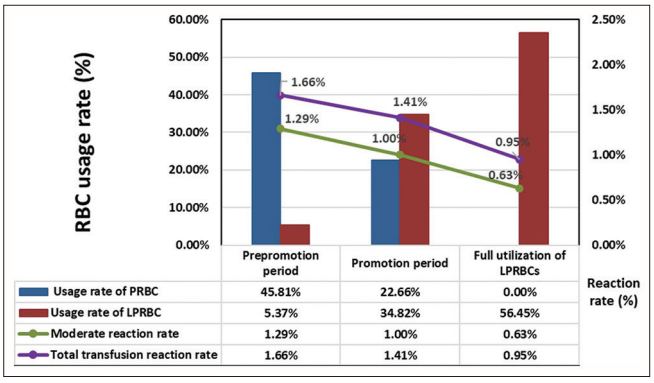

Figure 1: Transfusion reaction rate in three periods. We determined the transfusion reaction rate during the prepromotion, promotion, and full utilization periods of leukocyte-poor red blood cells (LPRBCs). We also calculated the usage rate by dividing LPRBC and poor red blood cell content by total blood consumption and obtained the total transfusion and moderate reaction rates in these three periods. We found that the total transfusion and moderate reaction rates significantly decreased with an increase in LPRBC usage

According to the statistical data on blood transfusion reactions in the past 8 years at our hospital, the LPRBC usage rate increased from 5.37% to 56.45%, whereas the total transfusion reaction rate decreased from 1.66% to 0.95%. Based on the data collected from our hospital, LPRBC products can effectively reduce the incidence of blood transfusion reactions [Figure 2]. Based on our results, we revealed that the LPRBC usage rate increased annually, whereas the transfusion reaction rate tended to decrease yearly [Figure 2]. The transfusion and moderate reaction rates were negatively correlated with the LPRBC usage rate.

The comparison of total blood transfusion and moderate reaction rates between the prepromotion and promotion periods as well as prepromotion and full utilization periods of LPRBCs was performed. Both the total transfusion and moderate reaction rates were significantly lower in the full utilization period of LPRBCs ($P < 0.001$) [Table 2].

Table 1: Classification of transfusion reactions

Mild	Moderate	Severe
Urticaria	Headache	Purpura
Itching	Chill	Shock
Nausea and vomiting	Fever	Bleeding
	Facial blushing	Delirium
	Mild symptoms lasting for >30 min	Chest pain
		Backache
		Dizziness
		Jaundice
		Dyspnea
		Amentia
		Hemoglobinuria
		Body temperature elevation over 2°C

At our hospital, most moderate transfusion reactions are classified as FNHTR. FNHTRs: Febrile nonhemolytic transfusion reactions

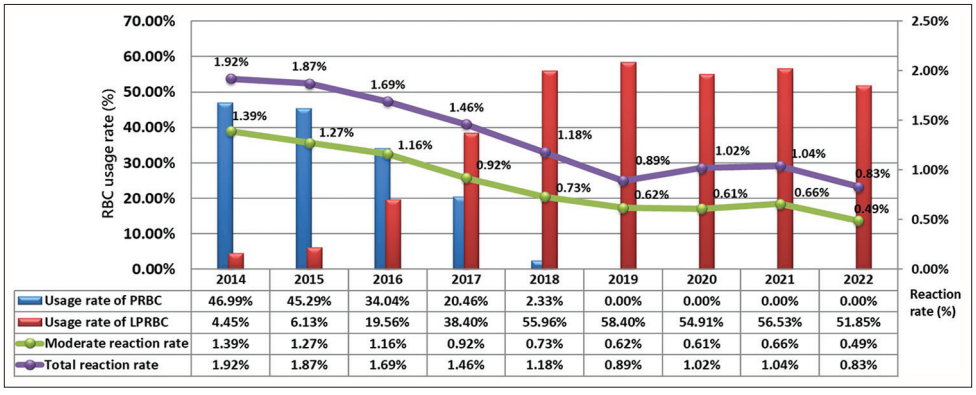

Figure 2: Correlation between leukocyte-poor red blood cell (LPRBC) usage and transfusion reaction rates. The total transfusion and moderate reaction rates decreased yearly with an increase in LPRBC usage rate

We compared the incidence rates of transfusion reactions caused by two RBC products in different years. Statistical data indicates that patients using LPRBC products have significantly lower transfusion reaction rates than PRBC [Figure 3]. The data shows that between 2014 and 2022, the types of blood transfusion reaction caused using PRBC and LPRBC products are the mild transfusion reaction rate of 0.20%/0.20%, the moderate transfusion reaction rate of 1.61%/0.69%, the severe transfusion reaction rates 0.38%/0.16%, and the total transfusion reaction rates 2.19%/1.05%. This result indicated that using leukocyte-depleted red blood products is most effective in reducing the rate of moderate transfusion reactions. To investigate the causes of severe transfusion reactions, we divided different types of symptoms into two groups. The first group is the acute immunity group, which includes allergy, FNHTR, transfusion-related acute lung injury, acute hemolytic transfusion reaction, and transfusion-associated dyspnea. The second group is the nonimmune group, which includes hypotension, transfusion-associated circulatory overload (TACO), nonimmune hemolysis, hypocalcemia, bacterial infections, and other illnesses such as cancer, schizophrenia, heavy bleeding, and drug interference. We analyzed the causes of severe transfusion reactions caused by PRBC and LPRBC from 2014 to 2022 [Figure 4a]. It has been observed that between 2014 and 2017, the frequency of FNHTR as a cause of severe transfusion reactions from using LPRBC decreased significantly. Moreover, data from 2018 have also indicated that more than half of the severe transfusion reactions are caused by nonimmune factors.

Because there are two platelet products commonly used in clinical practice, leukopenic platelets (LRP) and apheresis platelets (PL ph), we compared the response rates of these two products between 2014 and 2022. Between 2014 and 2022, the incidence rates of transfusion reactions for LRP were higher than PL ph, as shown in Figure 5. The result has shown that severe transfusion reaction rates do not significantly differ between LRP

Table 2: Statistical analysis of leukocyte-poor red blood cell usage and blood transfusion reaction rates in different periods

	Total transfusion reaction rate (%)	*P*	Moderate reaction rate (%)	*P*
Prepromotion period	1.66±0.35		1.29±0.34	
Promotion period	1.41±0.34	0.12	1.00±0.31	0.004
Full utilization period	0.95±0.27	<0.001	0.63±0.22	<0.001

Comparison of total blood transfusion and moderate reaction rates between the prepromotion and promotion periods as well as prepromotion and full utilization periods of LPRBCs. We found that the total transfusion and moderate reaction rates were significantly decreased with an increase LPRBC usage rate. LPRBCs: Leukocyte-poor red blood cells

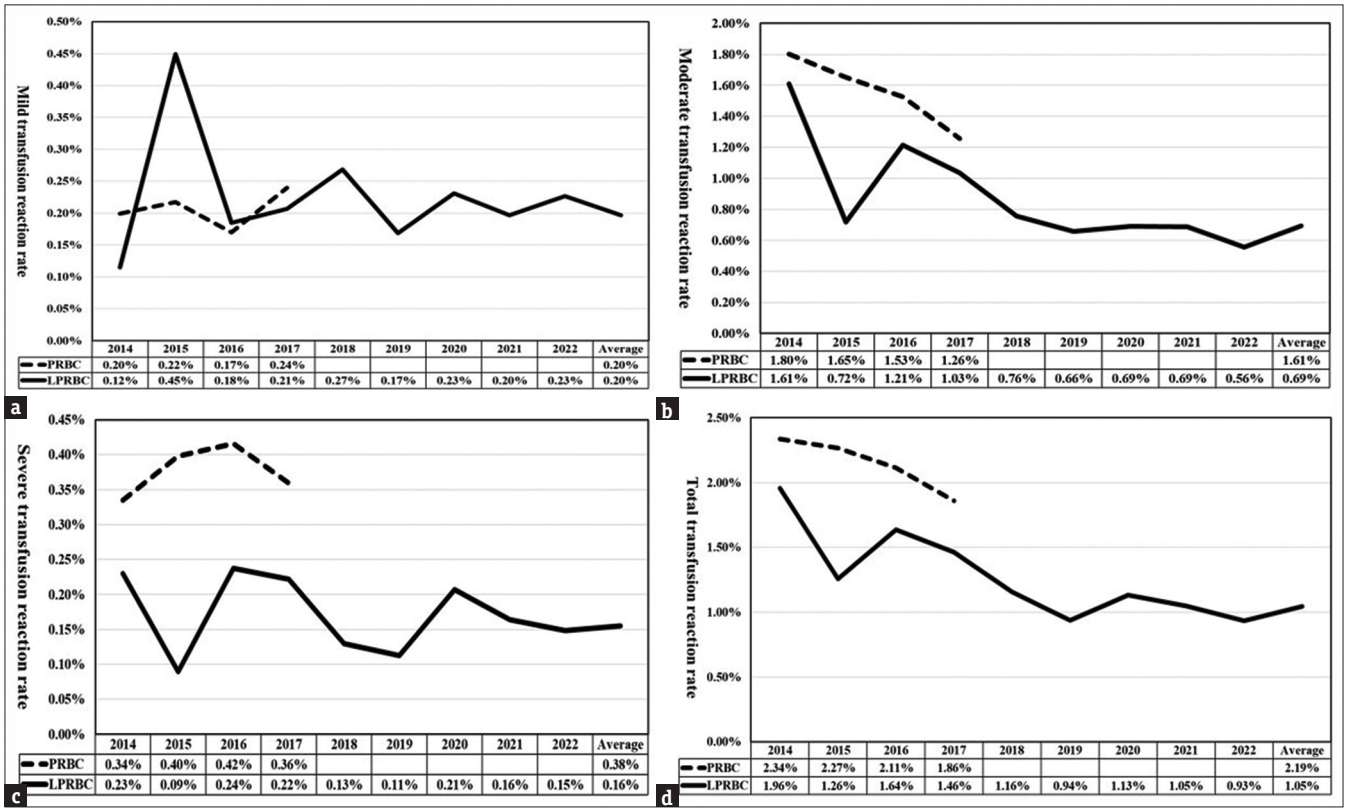

Figure 3: Comparison of various transfusion reaction rates between poor red blood cell (PRBC) and leukocyte-poor red blood cell (LPRBC) from 2014 to 2022 (a) Compare the mild transfusion reaction rates between PRBC and LPRBC. (b) Compare the moderate transfusion reaction rates between PRBC and LPRBC. (c) Compare the severe transfusion reaction rates between PRBC and LPRBC. (d) Compare the total transfusion reaction rates between PRBC and LPRBC

a

Severe transfusion reaction		2014		2015		2016		2017		2018		2019		2020		2021		2022	
		PRBC	LPRBC	PRBC	LPRBC	PRBC	LPRBC	PRBC	LPRBC	PRBC	LPRBC	PRBC	LPRBC	PRBC	LPRBC	PRBC	LPRBC	PRBC	LPRBC
immunity	Allergy	7	3	5	2	4					2		2		5		5		1
	FNHTR	7	1	6	1	6	3	7	3		2				3		2		1
	TRALI																		
	AHTR					1									1				
	TAD	1				3									1				
non-immune	Hypotension	1	1	1				1	1								1		
	TACO	1		1					2		3		2		2		2		
	non-immune hemolysis																		
	Hypocalcemia																		
	bacterial infections		1		1		1		1		1		4		4		1		5
	other illnesses								1		1		1				2		2

b

Severe transfusion reaction		2014		2015		2016		2017		2018		2019		2020		2021		2022	
		PL ph	LRP	PL ph	LRP	PL ph	LRP	PL ph	LRP	PL ph	LRP	PL ph	LRP	PL ph	LRP	PL ph	LRP	PL ph	LRP
immunity	Allergy	2	1	1	1		1						1						
	FNHTR	1				1						1							
	TRALI					1													
	AHTR													1					
	TAD									1	1						1		
non-immune	Hypotension															1			
	TACO															1	1		
	non-immune hemolysis																		
	Hypocalcemia																		
	bacterial infections				1	1						1					2		
	other illnesses																		

Figure 4: Analysis of the various causes of severe transfusion reactions in different blood products (a) Analysis of the severe transfusion reactions causes in poor red blood cell and leukocyte-poor red blood cell from 2014 to 2022. (b) Analysis of the severe transfusion reactions causes in PL ph and LRP from 2014 to 2022. FNHTR: Febrile nonhemolytic transfusion reaction, TRALI: Transfusion-related acute lung injury, AHTR: Acute hemolytic transfusion reaction, TAD: Transfusion-associated dyspnea, TACO: Transfusion-associated circulatory overload

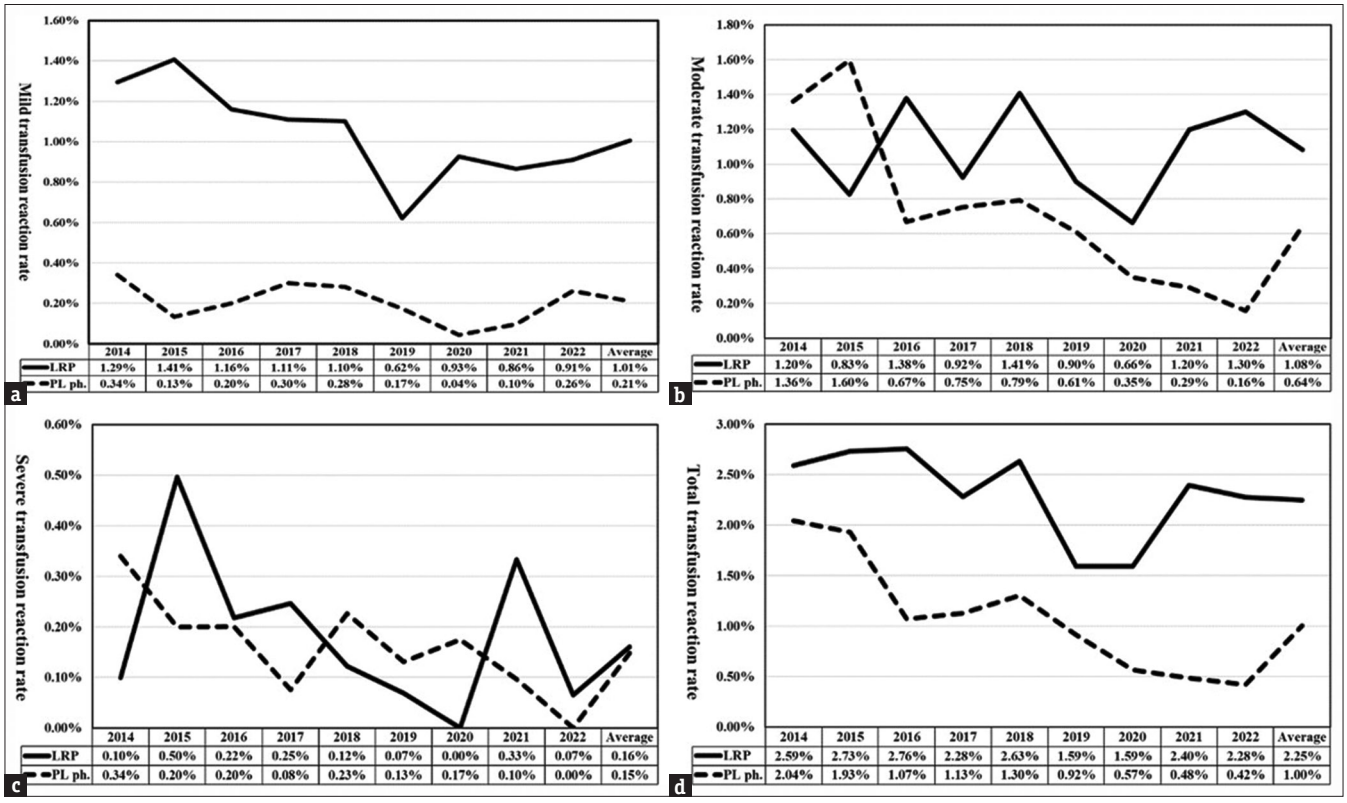

Figure 5: Comparison of various transfusion reaction rates between PL ph and LRP from 2014 to 2022 (a) Compare the mild transfusion reaction rates between PL ph and LRP. (b) Compare the moderate transfusion reaction rates between PL ph and LRP. (c) Compare the severe transfusion reaction rates between PL ph and LRP. (d) Compare the total transfusion reaction rates between PL ph and LRP

and PL ph. However, transfusion reaction rates are higher for mild and moderate reactions with LRP than PL ph. Figure 4b shows no significant difference in severe transfusion reaction causes between LRP and PL ph from 2014 to 2022.

According to the 2021 Taiwan Blood Safety Monitoring Network Annual Report provided by the Taiwan Blood Transfusion Association, more than half of the hospitals showed that transfusion reactions are more frequent with LRP than PL ph. This result indicated a similar trend to that of our hospital.

Discussion

Transfusion reactions can cause body discomfort and result in increased medical costs. In particular, the incidence of FNHTRs is correlated with the level of cytokines released by leukocytes in blood capsules. FNHTRs are classified as moderate transfusion reactions, which are often observed in hospitalized patients. However, statistical data from some studies have shown no significant difference in terms of discomfort after LPRBC product transfusion [13,19]. This inconsistent result may be attributed to the fact that early international definitions of blood preparations for reducing leukocytes were not unified [20-22]. Furthermore, blood transfusion after surgery is often encountered in clinical practice, and blood transfusion reaction, which is indicated by an elevated body temperature, is often caused by a common phenomenon after surgery. Based on our data analysis, LPRBC is more effective in reducing moderate and severe transfusion reactions than PRBC. Furthermore, our study reveals that immune-related issues do not cause the most severe transfusion reactions. Analysis shows that nearly half of the severe transfusion reactions following the use of LPRBC are caused by nonimmune reasons, such as TACO, bacterial infection, cancer metastasis pain, and drug interference. It is important to mention that although there was not a significant increase in severe transfusion reaction rates between 2020 and 2021, the number of severe transfusion reactions caused by allergy and FNHTR showed a slight upward trend. As this period coincided with the COVID-19 pandemic, it is unclear whether this phenomenon was caused by infection or vaccination, and further study is needed to determine the cause.

Apart from LPRBCs, the other plasma blood products include fresh frozen plasma, cryoprecipitate, and apheresis platelets, which cause a small number of allergic reactions after transfusion and are also classified as transfusion reactions [9,16,23].

The statistical results of LRP and PL ph transfusion reaction rates indicate that the use of LRP does not lower the incidence of transfusion reactions, regardless of their severity. We speculate that limited indications for use are the main reason for this phenomenon. The majority of patients eligible for LRP use generally fall into one of three categories, which include: (1) Patients who require long-term blood transfusions for medical conditions such as aplastic anemia, dyserthropoiesis, chemotherapy, and thalassemia. (2) Patients who have undergone organ or bone marrow transplantation, newborns, and those who have weakened immune systems. (3) Patients who have experienced more than two episodes of fever and chills caused by blood transfusions. Although leukocyte-reduced blood products have been used, patients eligible for LRP are already more susceptible to transfusion reactions.

Conclusion

The results of our hospital showed that the use of LPRBC can effectively reduce the incidence of transfusion reactions. Based on the findings of this study, the use of LPRBC is an effective strategy for reducing the risk of blood transfusion and improving patient safety. The success of LRP in reducing transfusion reactions depends on policy support and postimplementation data observation. Without these crucial factors, it is impossible to determine the effectiveness of LRP. Therefore, it is imperative that we prioritize policy support and data observation to ensure that LRP is a viable solution for reducing transfusion reactions and improving patient outcomes.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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