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TRANSFUSÃO DE COMPONENTES SANGUÍNEOS NA COLHEITA DE PHSP: ESTUDO RETROSPETIVO DE UM ÚNICO CENTRO

BLOOD TRANSFUSION IN PERIPHERAL BLOOD STEM CELL COLLECTION: A SINGLE CENTRE RETROSPECTIVE STUDY

TRANSFUSIÓN DE COMPONENTES SANGUÍNEOS EN LA OBTENCIÓN DE PHSP: ESTUDIO RETROSPECTIVO DE UN ÚNICO CENTRO

Liliana Fonseca[1] *https://orcid.org/0000-0001-7294-8077*
Catarina Almeida[2] *https://orcid.org/0009-0004-7071-9368*
Pedro Leite-Silva[3] *https://orcid.org/0000-0001-7015-242X*
Ana Salselas[3] *https://orcid.org/0009-0002-3410-5735*
Sara Lopes[3] *https://orcid.org/0000-0001-7957-6237*
Susana Roncon[3] *https://orcid.org/0000-0002-1605-6573*

[1] Unidade Local de Saúde Viseu Dão-Lafões, Viseu, Portugal
[2] Unidade Local de Saúde da Região de Aveiro, Aveiro, Portugal
[3] Instituto Português de Oncologia do Porto, Porto, Portugal

Liliana Fonseca - lilianapvfonseca@gmail.com | Catarina Almeida – catarina.falmeida@hotmail.com | Pedro Leite-Silva – pedro.silva@ipoporto.min-saude.pt | Ana Salselas – ana.salselas@ipoporto.min-saude.pt | Sara Lopes - sarapblopes@gmail.com | Susana Roncon - sroncon@ipoporto.min-saude.pt

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Corresponding Author:
Liliana Fonseca
Av. Rei Dom Duarte
3504-509 – Viseu - Portugal
lilianapvfonseca@gmail.com

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RESUMO

Introdução: A colheita de Progenitores Hematopoiéticos de Sangue Periférico (PHSP) é essencial no transplante autólogo. Embora geralmente segura, pode provocar alterações hematológicas transitórias com necessidade ocasional de transfusão de concentrados eritrocitários ou plaquetários. Os fatores preditores da necessidade transfusional permanecem indefinidos.
Objetivo: Caracterizar as necessidades transfusionais associadas à colheita de PHSP e identificar fatores clínicos e procedimentais associados.
Métodos: Estudo retrospetivo de um único centro, incluindo todos os procedimentos de aférese de PHSP realizados para transplante autólogo no IPO-Porto entre janeiro de 2020 e dezembro de 2023. Foram analisados dados demográficos, parâmetros laboratoriais, regimes de mobilização, características do procedimento e dados transfusionais. As associações foram analisadas por métodos não paramétricos e testes de correlação.
Resultados: Foram analisados 571 procedimentos em 364 doentes (42 pediátricos e 322 adultos). As transfusões de concentrado eritrocitário foram pouco frequentes (2,1%) e associaram-se a valores baixos de hemoglobina pré-colheita, ocorrendo apenas em adultos submetidos a múltiplos procedimentos. As transfusões plaquetárias foram mais frequentes (28,5%) e correlacionaram-se com contagens plaquetárias basais, número de sessões e débito de colheita. Nos doentes pediátricos observaram-se volumes processados inferiores, mas maior duração procedimental. Não se registaram eventos hemorrágicos nem reações transfusionais graves.
Conclusão: As necessidades transfusionais durante a colheita de PHSP dependem sobretudo dos valores basais de hemoglobina e plaquetas e da carga procedimental cumulativa, sendo limitado o impacto hematológico da mobilização com G-CSF.

Palavras-chave: aférese; transfusão; progenitores hematopoiéticos do sangue periférico; transplante autólogo de células hematopoiéticas

ABSTRACT

Introduction: Peripheral Blood Stem Cell (PBSC) collection is central to autologous stem cell transplantation (ASCT). Although generally safe, it may cause transient haematological changes requiring red blood cell (RBC) or platelet transfusions, and predictors of transfusion need in mixed adult–paediatric cohorts remain poorly characterised.
Objective: To characterise transfusion requirements during PBSC collection and identify associated clinical and procedural factors in adult and paediatric patients**.**
Methods: Retrospective single-centre study including all PBSC apheresis procedures for autologous transplantation at IPO-Porto (January 2020–December 2023). Demographics, laboratory parameters, mobilisation regimens, procedural characteristics, and transfusion data were collected. Haematological values were assessed pre-mobilisation, immediately before, and immediately after collection. Associations were evaluated using non-parametric and correlation analyses.
Results: We analysed 571 procedures in 364 patients (42 paediatric, 322 adult). RBC transfusions were uncommon (2.1%) and strongly associated with lower pre-collection haemoglobin, occurring exclusively in adults undergoing multiple procedures. Platelet transfusions were more frequent (28.5%) and correlated with lower pre-collection platelet counts, number of collection sessions, and flow rate. Paediatric procedures involved lower processed blood volumes but longer durations, likely due to procedural constraints. No patients developed clinical anaemia or bleeding, and no severe transfusion-related adverse events occurred.
Conclusion: Transfusion requirements during PBSC collection are mainly determined by baseline haemoglobin and platelet counts, cumulative procedural burden and flow-related factors, while the haematological impact of G-CSF mobilisation is modest.

Keywords: apheresis; transfusion; peripheral blood stem cells; autologous stem cell transplantation.

RESUMEN

Introducción: La obtención de progenitores hematopoyéticos de sangre periférica es esencial en el trasplante autólogo. Aunque generalmente segura, puede producir alteraciones hematológicas transitorias que ocasionalmente requieren transfusión de hematíes o plaquetas. Los factores predictivos de la necesidad transfusional no están completamente definidos.
Objetivo: Caracterizar los requerimientos transfusionales durante la obtención de progenitores hematopoyéticos de sangre periférica e identificar factores clínicos y procedimentales asociados.
Métodos: Estudio retrospectivo de un único centro que incluyó todos los procedimientos de aféresis realizados para trasplante autólogo entre enero de 2020 y diciembre de 2023. Se analizaron variables demográficas, parámetros hematológicos, regímenes de movilización, características del procedimiento y datos transfusionales. Los valores se evaluaron antes y después de la obtención y se analizaron mediante pruebas no paramétricas y correlación.
Resultados: Se analizaron 571 procedimientos en 364 pacientes (42 pediátricos y 322 adultos). Las transfusiones de hematíes fueron infrecuentes (2,1%) y se asociaron a hemoglobina basal baja, ocurriendo solo en adultos con múltiples sesiones. Las transfusiones plaquetarias fueron más frecuentes (28,5%) y se correlacionaron con recuento plaquetario basal, número de sesiones y flujo de aféresis. En pediatría se observaron menores volúmenes procesados, pero mayor duración del procedimiento. No se registraron eventos hemorrágicos ni reacciones transfusionales graves.
Conclusión: Los requerimientos transfusionales dependen principalmente de los valores basales de hemoglobina y plaquetas y de la carga procedimental acumulada, siendo limitado el impacto hematológico de la movilización con G-CSF.

Palabras clave: aféresis; transfusión; progenitores hematopoyéticos de sangre periférica; trasplante autólogo de progenitores hematopoyéticos

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INTRODUCTION

Autologous Stem Cell Transplantation (ASCT) is an effective treatment for patients with haematological diseases, such as myeloma or lymphoma (Baertsch et al., 2017). Peripheral blood stem cell (PBSC) collection is a well-established procedure in ASCT, offering advantages such as faster neutrophil and platelet recovery, reduced procedural morbidity, and lower costs compared to bone marrow collection (Bojanic et al., 2019; Carson et al., 2016; Delamain et al., 2008). The mobilisation of haematopoietic progenitors into the peripheral blood is primarily achieved by administering granulocyte colony-stimulating factor (G-CSF), which substantially increases circulating CD34+ cell counts and improves collection success (Baertsch et al., 2017; Dill et al., 2024; Dräger et al., 1998). Alternative mobilisation strategies, including chemomobilisation and dose-adjusted plerixafor, have been studied to balance efficacy and toxicity, and to rescue poor mobilisers (Baertsch et al., 2017; Dill et al., 2024; Gutiérrez-Aguirre et al., 2019; Ikeda et al., 2004).

Although PBSC apheresis is generally safe, mobilisation and extracorporeal processing may cause transient haematological perturbations: decreases in platelet counts and, to a lesser extent, haemoglobin are frequently observed and can lead to the need for red blood cell (RBC) or platelet transfusion (Gutiérrez-Aguirre et al., 2019; Lanza et al., 2013; Lee et al., 2024). Platelet reductions of 27-49% per procedure have been consistently reported, with variability depending on device type, collection protocols, and processed blood volume (Lanza et al., 2013; Lee et al., 2024). Moreover, Shima et al. (2021) demonstrated that lower pre-apheresis platelet counts were significantly associated with greater post-procedure platelet depletion, and that platelet-rich plasma return has been reported to mitigate this decline in selected settings. This decline can be clinically relevant, as it may necessitate prophylactic or therapeutic transfusions to maintain safe levels during repeated collections. Importantly, G-CSF itself contributes to thrombocytopenia mainly by impairing megakaryocyte differentiation, thereby limiting platelet production in addition to the consumption related to the apheresis process (Li et al., 2019; Lu et al., 2019). Case reports even describe severe thrombocytopenia in otherwise healthy donors, highlighting G-CSF's biological effects on platelet homeostasis (Li et al., 2019).

Transfusion practice around PBSC collection remains heterogeneous. Due to the heterogeneity of patient populations, disease characteristics, and institutional practices, it remains difficult to draw definitive conclusions from published studies. Most PBSC collection programmes adopt pragmatic pre-collection safety limits slightly above restrictive transfusion triggers (Murugesan et al., 2019), commonly requiring haemoglobin ≥8 g/dL (24-25% haematocrit) and platelet counts ranging between 20-50 × 10^9/L, depending on institutional policy, vascular access, and bleeding risk (Dräger et al., 1998; Rajsp et al., 2022; Sanderson et al., 2016). When patients present with lower counts, clinicians often perform pre-collection optimisation through transfusion or postpone the procedure until recovery. Baseline haemoglobin and platelet levels, therefore, may predict transfusional burden and act as operational constraints that delay or modify PBSC collection (Rajsp et al., 2022; Sanderson et al., 2016). Furthermore, lower pre-mobilisation platelet counts have been associated with suboptimal $CD34^+$ cell yields, emphasising their relevance as both biological markers and operational determinants in PBSC collection (Dräger et al., 1998; Rajsp et al., 2022; Takeyama & Ohto, 2004; Yuan et al., 2016).

Beyond baseline counts and the biological effects of mobilisation, a range of patient- and procedure-related variables influence transfusion need. Equipment- and technique-related factors, including collection mode (continuous- vs intermittent-flow collection), blood flow rates and processed blood volume, affect platelet depletion and collection efficiency; device-specific reports and single-centre series document variability in how these factors translate into transfusion consumption (Lanza et al., 2013; Lee et al., 2024; Takeyama & Ohto, 2004; Yuan et al., 2016; Yuan & Wang, 2016). In paediatric practice, small circulating blood volumes and technical constraints increase the likelihood of transfusion support and require tailored approaches (Lee et al., 2024).

Although several studies have explored mobilisation efficiency, $CD34^+$ cell yield, and technical optimisation, evidence directly addressing transfusion requirements during PBSC collection remains limited and fragmented. Few reports have examined how pre-collection haemoglobin and platelet levels, alongside mobilisation regimen and apheresis parameters, affect the need for red blood cell or platelet support. Moreover, haematological thresholds for initiating collection are inconsistently defined across institutions, often delaying procedures in patients with borderline counts and potentially impacting transplant timelines. This uncertainty underscores the need for robust data to guide safe and efficient practice.

Importantly, transfusion practices in the setting of PBSC collection are not guided by universally accepted, procedure-specific recommendations. While international bodies such as the AABB, British Society for Haematology, and European Society for Blood and Marrow Transplantation provide general transfusion guidance, they do not define procedure-specific haemoglobin or platelet thresholds tailored to PBSC apheresis. This lack of consensus contributes to significant inter-centre variability in transfusion strategies, including pre-collection optimisation and peri-procedural support. In this context, studies addressing real-world transfusion requirements and associated risk factors are essential to inform clinical decision-making and may contribute to the future harmonisation of practice, particularly regarding transfusion thresholds and pre-procedural optimisation strategies.

Therefore, this study aims to characterise transfusion requirements associated with PBSC collection in both adult and paediatric populations and to identify clinical and procedural factors associated with the need for red blood cell and platelet support.

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1. METHODS

We conducted a retrospective, single-centre observational study at the Instituto Português de Oncologia do Porto (IPO-Porto), including all paediatric and adult patients who underwent PBSC apheresis procedures for autologous transplantation between January 2020 and December 2023. Clinical, laboratory, and procedural data were retrieved from electronic medical records and apheresis unit documentation.

The database included demographic variables (age, sex, diagnosis), laboratory parameters (haemoglobin, haematocrit, and platelet counts), mobilisation regimen (G-CSF alone or G-CSF plus plerixafor), G-CSF dose, apheresis parameters, and transfusion requirements and reactions. PBSC collection was routinely performed on the fifth day of mobilisation with G-CSF. In patients requiring augmented mobilisation, plerixafor was administered either on day -4 or on the evening of day 5, according to institutional protocols and peripheral blood $CD34^+$ cell counts.

Procedures were performed using the Spectra Optia® apheresis system (Terumo BCT, Lakewood, CO, USA), operating in either continuous-flow or intermittent-flow mode, according to patient size and clinical considerations. Anticoagulation was provided with acid–citrate–dextrose solution A (ACD-A) alone or in combination with unfractionated heparin, and flow rates were adjusted based on patient age, vascular access, procedure type, and anticoagulation strategy.

Transfusion support followed institutional guidelines for PBSC collection: red blood cell transfusion was indicated for haemoglobin ≤7 g/dL and platelet transfusion for platelet counts ≤50 × 10^9/L. Both pre-procedure and peri-procedural transfusions (intra- or post-collection) were recorded.

To assess the impact of procedural burden on haematological changes and transfusion needs, procedures were stratified according to whether they occurred in the context of a single apheresis session or multiple (1 vs. ≥2 sessions), and paediatric and adult procedures were analysed separately and also in pooled analyses.

Continuous variables were summarised using means, standard deviations, medians, and ranges. Categorical variables were expressed as frequencies and percentages. Comparative analyses included the Mann-Whitney U test for between-group comparisons of continuous variables, Fisher's exact test for associations between categorical variables, and Spearman's rank correlation coefficient to assess correlations between G-CSF dose, flow rate, and haematological changes or transfusion requirements. A two-sided p-value <0.05 was considered statistically significant.

All statistical analyses were performed using IBM SPSS Statistics (version 28.0, IBM Corp., Armonk, NY, USA). Ethical approval for the study was obtained from the institutional ethics committee of IPO-Porto.

2. RESULTS

A total of 571 apheresis procedures performed in 364 patients were analysed, comprising 42 paediatric and 322 adult patients. The cohort included 201 (55.2%) males and 163 (44.8%) females, with a median age at the time of PBSC collection of 56 years (range 1-78). Paediatric patients had a median age of 7 years (range 1-17), while adult patients had a median age of 58 years (range 20-78). Among adult patients, multiple myeloma was the most frequent underlying diagnosis (n=166, 51.6%), followed by non-Hodgkin lymphoma (n=95, 29.5%). In the paediatric population, neuroblastoma (n=15, 35.7%) and Ewing sarcoma (n=12, 28.6%) were the most common indications for PBSC collection. Baseline demographic and clinical characteristics are reported per patient and are summarised in Table 1.

Table 1 - Demographic and clinical characteristics of the study population.

	Paediatric (n=42)	Adult (n=322)	Overall (n=364)
Sex			
Male, n (%)	21 (50.0)	180 (55.9)	201 (55.2)
Female, n (%)	21 (50.0)	142 (44.1)	163 (44.8)
Underlying diagnosis			
Multiple myeloma, n (%)	0 (0.0)	166 (51.6)	166 (45.6)
Hodgkin Lymphoma, n (%)	6 (14.3)	38 (11.8)	44 (12.1)
Non-Hodgkin Lymphoma, n (%)	2 (4.8)	95 (29.5)	97 (26.6)
Neuroblastoma, n (%)	15 (35.7)	0 (0.0)	15 (4.1)
Ewing Sarcoma, n (%)	12 (28.6)	0 (0.0)	12 (3.3)
Other, n (%)	7 (16.7)	23 (7.1)	30 (8.2)
Age at PBSC collection, y			
Mean (SD)	8.1 (5.6)	54.8 (12.4)	49.2 (19.1)
Median [Min, Max]	7 [1, 17]	58 [20, 78]	56 [1, 78]

All subsequent analyses of haematological parameters are reported per apheresis procedure. Haematological parameters assessed at predefined time points differed between age groups. Paediatric patients presented lower haemoglobin levels than adults at both the pre-mobilisation outpatient assessment and immediately before PBSC collection, while platelet counts were

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broadly comparable between cohorts at mobilisation. In both groups, platelet counts declined from pre-mobilisation to pre-collection and decreased further immediately after apheresis. Haemoglobin levels also showed a modest reduction from immediately before to immediately after collection. Full descriptive statistics are presented in Table 2.

Table 2 - Haemoglobin and platelet count measured at predefined time points: pre-mobilisation (outpatient assessment), pre-collection (on the day of apheresis, immediately before the procedure) and post-collection (on the day of apheresis, immediately after the procedure).

	Paediatric (n=73)	Adult (n=498)	Overall (n=571)
Haemoglobin pre-mobilisation, g/dL			
Mean (SD)	10.2 (1.4)	12.2 (1.8)	11.9 (1.9)
Median [Min, Max]	10.2 [6.6, 13.9]	12.3 [7.1, 16.7]	12.1 [6.6, 16.7]
Platelet count pre-mobilisation, $x10^9$/L			
Mean (SD)	230.1 (91.4)	230.7 (91.6)	207.1 (92.0)
Median [Min, Max]	228 [25, 576]	193 [11, 539]	195 [11, 576]
Haemoglobin pre-collection, g/dL			
Mean (SD)	10.4 (1.4)	11.8 (1.7)	11.6 (1.7)
Median [Min, Max]	10.2 [6.8, 13.9]	11.9 [7.5, 17.2]	11.6 [6.8, 17.2]
Platelet count pre-collection, $x10^9$/L			
Mean (SD)	181.3 (110.6)	154.2 (85.3)	157.6 (89.4)
Median [Min, Max]	150 [42, 580]	140.5 [21, 442]	141 [21, 580]
Haemoglobin post-collection, g/dL			
Mean (SD)	10.2 (1.3)	10.7 (1.6)	10.6 (1.6)
Median [Min, Max]	10.0 [7.4, 13.2]	10.8 [5.5, 16.0]	10.7 [5.5, 16.0]
Platelet count post-collection, $x10^9$/L			
Mean (SD)	112.1 (49.5)	89.9 (42.6)	92.7 (44.1)
Median [Min, Max]	99 [44, 367]	78 [21, 264]	82 [21, 367]

Most apheresis procedures were performed following mobilisation with G-CSF alone (80.0%), while one-fifth required G-CSF plus plerixafor. The majority of procedures were performed in patients undergoing two or more apheresis sessions (65.5%), with a mean of 1.7 sessions per patient. Procedural characteristics differed by age group. Paediatric procedures were characterised by lower processed blood volumes, but longer procedure durations compared with adult procedures (median processed volume 1,431 mL vs. 4,260 mL; median duration 327 min vs. 255.5 min, respectively). Continuous-flow apheresis predominated overall (90.2%), whereas intermittent-flow procedures were more frequently used in the paediatric population.

Anticoagulation practices varied across age groups. ACD-A alone, predominantly used in paediatric procedures, was associated with lower median flow rates, whereas the combination of ACD-A plus heparin – more commonly used in adult procedures – permitted higher flow rates, as expected from the enhanced anticoagulation effect (Table 3).

Table 3 - Mobilisation and apheresis-related characteristics.

	Paediatric (n=73)	Adult (n=498)	Overall (n=571)
Mobilisation			
G-CSF, n (%)	63 (86.3)	394 (79.1)	457 (80.0)
G-CSF + Plerixafor, n (%)	10 (13.7)	104 (20.9)	114 (20.0)
Apheresis sessions			
1, n (%)	16 (21.9)	181 (36.3)	197 (34.5)
≥ 2, n (%)	57 (78.1)	317 (63.7)	374 (65.5)
Mean (SD)	1.7 (0.8)	1.7 (0.8)	1.7 (0.8)
Median [Min, Max]	2.0 [1.0, 4.0]	2.0 [1.0, 4.0]	2.0 [1.0, 4.0]
Apheresis characteristics			
Processed blood volume, mL			
Mean (SD)	2108.4 (1516.0)	4423.4 (825.9)	4127.5 (1218.1)
Median [Min, Max]	1431 [640, 9036]	4260 [2704, 7767]	4145 [604, 9036]
Procedure duration, min			
Mean (SD)	364 (73.0)	171 (73.0)	226 (75.1)
Median [Min, Max]	327 [145, 428]	255.5 [85, 442]	260 [85, 442]
Method			
continuous, n (%)	17 (23.3)	498 (100.0)	515 (90.2)
intermittent, n (%)	56 (76.7)	0 (0.0)	56 (9.8)
Flow rate, mL/min			
ACD-A, n (%)	53 (72.6)	64 (12.9)	117 (20.5)
Mean (SD)	18.3 (10.5)	55.6 (9.6)	38.7 (21.2)
Median [Min, Max]	14.1 [9.1, 49.1]	55.3 [36.8, 89.1]	45.6 [9.1, 89.1]
ACD-A + Heparin, n (%)	20 (27.4)	434 (87.1)	454 (79.5)
Mean (SD)	52.8 (17.1)	80.7 (14.3)	79.5 (15.5)
Median [Min, Max]	48.3 [32.0, 104.0]	78.7 [36.0, 129.0]	78.2 [32.0, 129.0]

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RBC transfusions were uncommon, occurring in 12 of 571 procedures (2.1%), whereas platelet transfusions were more frequent, being required in 163 procedures (28.5%).

In the paediatric cohort, three RBC transfusions were administered (two following a single procedure and one in the context of multiple sessions); due to the small number of events, paediatric RBC transfusions were excluded from comparative analyses. Among adult procedures, all nine RBC transfusions occurred in the group of patients undergoing two or more apheresis sessions. Platelet transfusions were more frequent in paediatric procedures and were largely confined to the group of two or more apheresis sessions. In adults, platelet transfusions were required in 137 procedures, including seven single-procedure collections and 130 performed in the context of repeated apheresis. These data are summarised in Table 4.

Table 4 - Red blood cell and platelet transfusion requirements according to age group and number of apheresis procedures.

	1 apheresis procedure		≥ 2 apheresis procedures		
	Paediatric (n=16)	**Adult (n=181)**	**Paediatric (n=57)**	**Adult (n=317)**	**Overall (n=571)**
RBC transfusion, n (%)	2 (12.5)	0 (0.0)	1 (1.8)	9 (2.8)	12 (2.1)
Platelet transfusion, n (%)	1 (6.3)	7 (3.9)	25 (36.3)	130 (35.0)	163 (28.5)

Note*:* percentages are calculated within each subgroup of apheresis procedures. Transfusion events are reported per apheresis procedure. Interpretation of percentages in paediatric subgroups should consider the small number of procedures.

All transfusions were triggered by predefined laboratory thresholds, and no patients, paediatric or adult, presented with clinical signs of anaemia or bleeding. Premedication was administered to patients with a prior history of transfusion reactions. No transfusion-related severe adverse events were reported in this cohort.

No statistical association was observed between the number of apheresis procedures and the need for RBC transfusion ($p=0.952$). In contrast, the number of procedures was significantly associated with platelet transfusion in adult procedures ($p<0.001$), in paediatric procedures ($p=0.002$), and in the overall cohort ($p<0.001$). Pre-collection haemoglobin levels were significantly associated with RBC transfusion among the group of two or more apheresis sessions ($p<0.001$); the single-procedure subgroup was too small for meaningful analysis. Pre-collection platelet counts were significantly lower in procedures requiring platelet transfusion compared with those that did not ($p<0.001$). Post-collection haemoglobin values were also associated with RBC transfusion in the group with two or more procedures ($p<0.001$).

Apheresis method (continuous vs intermittent-flow) showed no association with RBC ($p=1.000$) or platelet transfusion ($p=0.784$). Among adults undergoing a single apheresis session, G-CSF dose was significantly associated with the decline in platelet count from mobilisation to collection ($p=0.003$). In adults undergoing two or more procedures, collection flow rate was associated with both RBC transfusion ($p=0.045$) and platelet transfusion ($p<0.001$).

3. DISCUSSION

In this study, we analysed transfusion requirements and haematological dynamics in a large, mixed paediatric–adult cohort undergoing PBSC collection for autologous transplantation. We identified clinical and procedural variables associated with red blood cell and platelet transfusions. The findings indicate a clear and clinically distinct relevant pattern in which baseline patient factors predominantly drive anaemia-related transfusion needs, whereas thrombocytopenia is more sensitive to the procedural burden of apheresis and cumulative exposure to repeated collections.

These findings should be interpreted in the context of the current lack of standardised, procedure-specific transfusion guidelines for PBSC collection. While organisations such as the AABB, British Society for Haematology, and European Society for Blood and Marrow Transplantation provide general transfusion guidance, none define procedure-specific haemoglobin or platelet thresholds tailored to PBSC apheresis. This contributes to substantial inter-centre variability and highlights the relevance of identifying predictors of transfusion need in real-world practice.

RBC transfusions were uncommon overall and were strongly associated with lower pre-collection haemoglobin levels, particularly in patients undergoing two or more apheresis sessions. This aligns with previous evidence showing that peri-apheresis haemoglobin levels are a primary determinant of RBC support, with procedural factors modulating but not replacing the predictive weight of baseline values (Lanza et al., 2013; Rajsp et al., 2022). The association we observed between higher flow rates and RBC transfusion in adults undergoing multiple procedures suggests that device-related mechanical stress and cumulative extracorporeal exposure across repeated collections, rather than longer individual procedures, may accentuate haemoglobin decline. Although this association has been inconsistently reported in the literature, some device-specific studies have described similar trends in high-volume or repeated procedures (Lee et al., 2024; Takeyama & Ohto, 2004).

Importantly, all RBC transfusions in our cohort were triggered by predefined laboratory thresholds rather than clinical symptoms of anaemia, underscoring the predominantly prophylactic nature of transfusion support in this setting.

In contrast, platelet transfusion requirements were more frequent and showed robust associations with pre-apheresis platelet counts, number of collection sessions, and flow rate. These results reinforce the cumulative nature of platelet depletion during

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repeated PBSC collections, consistent with reports documenting 27-49% reductions per procedure and amplified decline in multi-session collection (Lanza et al., 2013; Lee et al., 2024). The clear predictive value of pre-collection platelet levels agrees with published observations that lower baseline counts increase both fractional depletion and transfusion likelihood (Shima et al., 2021; Takeyama & Ohto, 2004). The link between flow rate and platelet transfusion may reflect the interplay between anticoagulation strategy, device efficiency, and shear-mediated platelet activation or sequestration, as previously suggested in mechanistic studies of apheresis platforms (Lanza et al., 2013; Yuan & Wang, 2016). This effect appeared particularly relevant in adult procedures, where higher flow rates were routinely employed.

Despite established evidence that G-CSF mobilisation contributes to thrombocytopenia through impaired megakaryocyte maturation and increased peripheral consumption (Li et al., 2019; Lu et al., 2019), the mobilisation-related platelet decline in our cohort was modest. This may reflect the predominance of G-CSF alone mobilisation, careful monitoring of counts, and implementation of conservative thresholds that pre-empt excessive depletion immediately before collection. These findings suggest that, in routine clinical practice, procedural factors may outweigh mobilisation-related biological effects in determining peri-collection thrombocytopenia.

Notably, paediatric procedures were characterised by lower processed blood volumes but longer procedure durations, a finding that is best explained by procedural differences rather than biological vulnerability. In children, apheresis was more frequently performed using intermittent-flow systems and ACD-A alone, which necessitate lower flow rates. In adult procedures, ACD-A was commonly combined with heparin, permitting higher flow rates and consequently shorter collection times for larger processed volumes. Importantly, the absence of severe transfusion-related reactions and the very low rate of RBC transfusion support the overall safety of PBSC apheresis across age groups.

These observations have relevant clinical implications. Optimisation of haemoglobin and platelet levels before collection, particularly in patients expected to require multiple sessions, may reduce transfusion requirements and procedural interruptions. In addition, procedural individualisation — including adjustment of flow rates and anticoagulation strategy — may mitigate haematological losses while preserving collection efficiency. With growing pressure to streamline autologous transplant pathways, minimising transfusion burden may also shorten mobilisation-to-transplant intervals and improve overall transplant pathway efficiency.

This study has limitations. Its retrospective, single-centre nature introduces potential variability in decision thresholds, device selection, and transfusion practice. Additionally, although the sample size is large and includes both paediatric and adult patients, certain subgroup analyses (e.g., paediatric RBC transfusion) were constrained by low event numbers. Furthermore, transfusion triggers were protocol-driven and may not be directly generalisable to centres using different laboratory thresholds. Nevertheless, comprehensive capture of laboratory data, mobilisation strategies, and detailed procedural parameters strengthens the validity of the associations identified.

Future research should focus on prospective validation of transfusion risk prediction models incorporating baseline haematological parameters, peripheral blood $CD34^+$ cell counts, and procedural characteristics. Stratification by age group and expected procedural burden may further refine risk prediction. Comparative studies across different apheresis platforms and anticoagulation strategies may also clarify device-specific contributions to platelet loss.

CONCLUSION

Transfusion requirements during PBSC collection are mainly determined by pre-collection haemoglobin and platelet counts, cumulative procedural exposure, and flow-related factors, whereas the haematological impact of G-CSF mobilisation appears less pronounced than previously suggested. When guided by predefined laboratory thresholds and appropriate procedural tailoring, PBSC apheresis can be performed safely with a low incidence of clinically significant transfusion-related complications, supporting timely progression to autologous transplantation.

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AUTHORS´ CONTRIBUTION

Conceptualization, L.F., C.A., P.L.S., A.S., S.L. and S.R.; data curation, P.L.S.; formal analysis, P.L.S.; investigation, L.F., C.A., A.S., S.L. and S.R.; methodology, L.F. and C.A.; project administration, L.F., C.A. and S.R.; resources, A.S. and S.R., supervision, A.S. and S.R.; validation, A.S., S.L. and S.R.; writing – original draft, L.F. and S.R.; writing – revision & editing, L.F., C.A., P.L.S., A.S. and S.R.

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CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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