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ORIGINAL PAPER

Autologous hematopoietic stem cell transplantation in multiple myeloma and lymphoma: an analysis of factors influencing stem cell collection and hematological recovery

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Abstract Autologous stem cell transplantation is standard treatment for newly diagnosed younger patients with multiple myeloma and for relapsed or refractory Hodgkin or non-Hodgkin lymphoma. Patient characteristics influencing the yield from stem cell collection and time from transplant to platelet recovery were retrospectively analyzed in 630 consecutive patients, attempting to define adequate amounts of CD34+ cells to collect and reinfuse; 509/630 patients (81%) mobilized the requested CD34+ cell number. Factors influencing the harvest yield were age ($P < 0.001$) and gender, where 85% of men and 78% of women ($P < 0.02$) attained the requested stem cell amount. Time to platelet recovery was significantly faster for multiple myeloma patients compared to all other diagnoses (14.6 days compared to 19.8, $P < 0.0001$). Multiple myeloma patients were older than lymphoma patients but received stem cell transplant up-front as opposed to second line therapy for other patient groups. Multivariate analysis revealed that the most important factor influencing platelet recovery was diagnosis, followed by the amount of reinfused CD34+ cells ($P < 0.001$, $P < 0.05$). Blood group O+ had the fastest platelet recovery, whereas blood group A harvested the highest cell amounts. In conclusion, we demonstrate a significant importance of the number of reinfused CD34+ cells on the time to platelet recovery.

Keywords Chemotherapy · Outcome · CD34+ hematopoietic stem cell · Peripheral autologous stem cell harvest

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Introduction

In current clinical practice, high-dose chemotherapy followed by autologous stem cell transplantation (ASCT) is the standard first-line treatment for multiple myeloma [1–5], mantle cell lymphoma, and (arguably) peripheral T cell lymphoma in younger patients. High-dose chemotherapy and ASCT is also the standard of care for patients with relapsed and refractory diffuse large B-cell lymphoma (DLBCL) and Hodgkin lymphoma [6–8], as well as an important therapeutic element of transformed or frequently relapsing indolent lymphomas.

The goal of CD34+ cell mobilization is to collect enough cells to achieve a rapid and sustained hematopoietic recovery after high-dose therapy, since delayed hematopoietic recovery correlates with increased toxicity

[9]. Three recent large retrospective studies showed that depending on the cut off for mobilization failure, 10–20% of patients fail to mobilize peripheral stem cells, or harvest poorly (<2 × 10^6 CD34+ cells/kg) [10–12].

Regarding optimal CD34+ cell numbers to reinfuse, it has been demonstrated that high CD34+ cell doses (>3 or >5 × 10^6/kg) are associated with faster hematological recovery and lower incidence of infectious and bleeding complications [13–16]. Doses <2 × 10^6/kg are associated with slower recovery and worse outcomes [13–16]. Similarly, at reinfused CD34+ cell numbers below 5 × 10^6/kg, engraftment time can be delayed, especially for platelets [17], which requires increased red blood cell and platelet support.

In a recent study, doses of CD34+ cells at >5 or >6.5 × 10^6/kg significantly shortened the time to platelet and leukocyte recovery, although they conclude that stable engraftment seems to be achieved with 2 × 10^6/kg [12]. Additionally, there have been reports that CD34+ cell doses over 15 × 10^6/kg after high-dose melphalan administration can eliminate severe thrombocytopenia [9, 18]. This has lead to the current practice requiring a minimal dose of 2 × 10^6 CD34+ cells/kg body weight and an optimal dose of around 5 × 10^6/kg. The International Myeloma Working Committee (IMWG) has suggested a minimum target of 4 × 10^6 and, if feasible, an average of 8–10 × 10^6/kg should be collected, allowing most myeloma patients to undergo at least two autografts during the course of their disease [4]. In a recent consensus statement from the IMWG, it was concluded that prospective studies are required, although retrospective studies suggest a strong dose–response relationship between cell dose and rate of hematological recovery [4]. There have been contradictory reports on the influence of blood group on hematological recovery, with one study finding a delayed platelet recovery for blood group O [19], speculating that fucosylated glycans including H antigen (expressed on CD34+ progenitor cells and committed megakaryocytes) are important for hematopoietic cell homing. Opposing data from DiMatteo et al. did not find any correlation between blood group and engraftment [20].

In the current study, data from 630 patients planned for ASCT between 2000 and 2009 were retrospectively reviewed, assessing factors of importance for CD34+ progenitor cell collection as well as platelet recovery after transplantation in an attempt to define adequate amounts of CD34+ cells to collect and to reinfuse.

Materials and methods

Study population

Data from all adult patients with multiple myeloma, lymphoma, plasma cell leukemia, CLL, and AL amyloidosis ($n = 630$) scheduled for stem cell collection and subsequent ASCT between January 2000 and December 2009 at the Karolinska University Hospital, Stockholm, Sweden, were analyzed. Seven hundred and ten harvest attempts were made in the 630 patients. When analyzing the harvest data, all 710 attempts were included. Five hundred and eighty-eight patients subsequently received a stem cell transplant. Only the first transplant was included in calculations. The Regional Ethical Review board in Stockholm approved the retrospective data analysis.

Mobilization of PBSC

Peripheral blood stem cells (PBSC) were mobilized by chemotherapy followed by G-CSF at 10 μg/kg. All patients with multiple myeloma received high-dose cyclophosphamide (2,000 mg/m^2) on day 1, and G-CSF therapy from day 4, as mobilization regimen. In patients with lymphoma, disease-specific regimens were used, such as DHAP (cisplatin, cytarabine, and dexamethasone) or high-dose cytarabine followed by G-CSF therapy from day 4 to 10. In AL amyloidosis, either G-CSF was used alone or after chemomobilization with cyclophosphamide (2,000 mg/m^2). The different mobilizing regimens used are shown in Table 1.

Monitoring for CD34+ cells in peripheral blood started on day 10 after the end of chemotherapy for most patients. Apheresis was initiated at >20 × 10^6 CD34+ cells/l peripheral blood and collection continued daily until target cell dose was obtained. In patients who were difficult to mobilize, harvesting was authorized also at CD34+ levels of 10–20 × 10^6 CD34+ cells/l. PBSC collection was performed using two types of blood separators, CS3000 (Baxter Healthcare, Fenwall Laboratories) program 6 or 7 Special or Cobe Spectra (Caridian BCT, Lakewood, CO, USA) software version 7.

Response

Platelet recovery was defined as attaining a stable post-nadir platelet count of >50 × 10^9/l. We also analyzed time to a leukocyte count >1 × 10^9/l, neutrophil count of >0.5 × 10^9/l, and neutrophil count of >1 × 10^9/l. However, as G-CSF was used post-PBSCT for some of the lymphoma patients, and significantly influences the time to leukocyte engraftment, we used platelet count >50 × 10^9/l for the statistical calculations.

Study endpoints

The primary endpoint was to correlate the amount of the reinfused CD34+ cells (prefreeze value) to platelet recovery, and the secondary endpoint was to correlate the

Table 1 Upper part; effect of chemotherapy regimen on stem cell harvest for DLBCL

Chemo used as mobilization regimen in DLBCL	*n*	Harvested CD34 × 10^6	
		Mean collected CD34+ cells × 10^6/kg	Std dev
Ara-C*	21	13.01	11.20
CHOEP	4	9.81	4.94
CHOP	13	6.60	2.62
DHAP	38	6.60	3.39
MIME	59	7.33	5.93
Cyclophosphamide	14	5.10	2.86
Unkown	0	–	–

Chemo:	Cyclo	Ara-C	GCSF**	CHOEP	MIME	DHAP	CHOP	Unknown
Multiple myeloma	310	–	–	–	–	–	–	–
DLBCL	See table above							
Follicular cell lymphoma	4	2	–	–	11	6	3	2
T cell lymphoma	3	2	–	14	4	1	5	1
Plasma cell leukemia	6	–	–	–	1		1	1
CLL	3	–	–	1	–	–	1	–
Mantel cell lymphoma	0	36	–	–		2	1	–
Hodgkin lymphoma	2	–	–	–	40	3	–	1
AL amyloidosis	9	–	4	–	–	–	–	1
Total number of patients	351	61	4	19	115	50	24	6

* = $P < 0.05$ to all other individually

Lower part; mobilization regimens used for the 630 patients. *Cyclo* cyclophosphamide, *Ara-C* high-dose cytarabine based, *CHOEP* cyklophoshpamide, prednisolone, oncovine, doxorubicine, and etoposide, *CHOP* the same without etoposide, *MIME* ifosfamide based. *SD* standard deviation ** GCSF as only therapy

type of hematological malignancy, age, gender, blood group, and mobilization regime to the amount of harvested CD34+ progenitor cells.

Statistical analysis

Multiple comparisons of continuous data were performed by analysis of variance, ANOVA. In the case of a statistically significant result in the ANOVA, statistical comparisons between two arbitrary groups were made by use of the post-hoc test proposed by Fisher to control for multiplicity. Statistical comparisons in order to test differences between two independent groups were made by use of the Student's *t* test for uncorrelated means, after validation for normal distribution by use of the Shapiro–Wilk test. In order to evaluate hypotheses of variables in contingency tables, the chi-square test was used or in the case of small expected frequencies, Fisher's exact test. The Pearson correlation coefficient was used in order to test independence between variables. Time to recovery was calculated from the 1 day after conditioning to the day of attaining recovery. Patients who did not attain recovery at day 90 or died before recovery were considered failures. Time to recovery was evaluated using Kaplan–Meier curves and the log-rank test, using logistic regression. All analyses were carried out by use of statistic software (SAS system for Windows 9.2 SAS Institute Inc, Xary, NC, USA). A *P*-value of <0.05 was considered as significant.

Results

Clinical characteristics of the 630 patients are shown in Table 2. CD34+ progenitor cell collection was started at a mean 10.3 days (range 6–21) after chemotherapy.

In 179/310 multiple myeloma patients, the target was 10×10^6 CD34+ cells/kg, to allow a possible second transplantation. For the remaining patients ($n = 451$), the stem cell collection goal was 5×10^6 CD34+ cells/kg body weight. Most patients attained CD34+ numbers well above the requested amount: 366/451 (81%) achieved the 5×10^6 goal and 143/179 (80%) achieved the 10×10^6 goal.

The correlation was strong between circulating numbers of CD34+ cells/l blood at the 1 day of leukapheresis and the total CD34+ harvested cell amount ($r^2 = 0.66$, $P < 0.01$), 509 of the 630 (81%) patients reached the requested cell amount, of which 493 at the first attempt.

Table 2 Patient characteristics of the 630 patients harvested for subsequent transplantation

Diagnosis	Sex	*n*	Age mean (SD)	Weight kg mean(SD)	Harvested CD34+/kg median (range)	Days of harvest, median(range)
Multiple myeloma	Women	116	58.2 (9.3)	69 (12.9)	10.4 (1.0–33.7)	2 (1–5)
	Men	194	58.6 (7.9)	80.2 (13.1)	11.2 (0.5–87))	1 (1–5)
DLBCL	Women	54	53.8 (9.7)	67.7 (14.9)	5.5 (1.4–13.6)	2 (1–5)
	Men	95	54.7 (10.2)	83.0 (14)	6.6 (0.5–42)	2 (1–6)
Follicular lymphoma	Women	14	52.2 (12.5)	65.9 (13)	5.1 (2.7–16.0)	2 (1–3)
	Men	14	56.2 (6.7)	84.10 (10.7)	6.0 (2.1–19.7)	1 (1–5)
Hodgkin lymphoma	Women	21	41.7 (13.3)	72.3 (15.6)	7.5 (2.6–23.8)	1 (1–5)
	Men	25	40.6 (14.3)	81.9 (17.1)	7.4 (2.6–38)	1 (1–5)
AL amyloidosis	Women	8	64.2 (6.8)	78 (22.1)	10.2 (2.3–22.8)	1 (1–3)
	Men	6	64.8 (1.6)	76.8 (11.7)	9.55 (1.5–20.9)	2.5 (1–3)
Mantle cell lymphoma	Women	9	59.4 (7.6)	65.0 (7.9)	7.6 (4.5–14.6)	2 (1–3)
	Men	30	56.4 (6.7)	85.2 (13.7)	8.4 (3–30.0)	1.5 (1–3)
T cell lymphoma	Women	14	55.1 (9.8)	60.3 (8.6)	6.4 (2.8–10.6)	1 (1–3)
	Men	16	48.3 (14)	79.0 (10.0)	10.2 (4.7–23.9)	1 (1, 2)
Plasma cell leukemia	Women	3	59.8 (4.5)	70.0 (17.6)	8.6 (5.8–13.9)	1 (1–5)
	Men	6	69.0 (0.2)	72.2 (7.9)	7.4 (2.6–11.3)	2 (1–3)
CLL	Women	2	55.1 (0.5)	84.0 (0)	5.1 (4.9–5.2)	3.5 (3–4)
	Men	3	59.9 (4.3)	86.7 (14.6)	3.2 (0.3–6.9)	3 (2–4)

However, of the 121 patients who failed to reach the requested cell amount, the majority ($n = 79$) proceeded to stem cell transplant anyway, with cell doses of median 3,8 (range 1.7–4.9) for requested 5×10^6 and median 9,1 (range 2.6–9.8) for requested 10×10^6. Thus, 588 of 630 patients proceeded to transplantation. The most common cause for not proceeding to HSCT was progression of the underlying disease; only five patients did not proceed to transplantation due to insufficient harvest.

Chemotherapy

Patients with DLBCL were harvested after various chemotherapy regimens. When comparing the groups with regard to chemotherapy used, high-dose cytarabine gave significantly better yield in the number of harvested CD34+ cells compared to all other chemotherapy regimens, including DHAP containing lower dose cytarabine (Table 1).

Age

Younger patients harvested significantly higher amounts of CD34+cells/kg, (cut off either 45 or 50 years), for patients aiming at 5×10^6 CD34+ cells/kg (Table 3). In the patient group aiming at 10×10^6 CD34+ cells/kg, no difference was seen in any age group (results not shown). Age also significantly influenced the number of days required

Table 3 The effect of age on harvested CD34+ cells and number of days until harvest completed, for patients aiming at 5×10^6 CD34+ cells/kg

Age (years) and harvests (%)		5×10^6 CD34 demanded			Number of harvest days		
Age	*n (%)*	Mean harvested CD34 $\times 10^6$	Std dev	*P*	Mean	Std dev	*P*
<40	14	11.25	8.90	0.0061	1.39	0.58	0.0012
≥40	**86**	**8.42**	**7.74**		**1.78**	**0.94**	
<45	22	10.19	7.71	0.0423	1.42	0.60	<0.0001
≥45	**78**	**8.43**	**8.00**		**1.81**	**0.96**	
<50	32	9.93	10.68	0.0348	1.56	0.80	0.0055
≥50	**68**	**8.29**	**6.22**		**1.81**	**0.94**	
<55	42	9.51	9.86	0.1085	1.63	0.84	0.0611
≥55	**58**	**8.33**	**6.24**		**1.79**	**0.94**	
<60	63	9.00	8.52	0.5138	1.68	0.91	0.1703
≥60	**37**	**8.51**	**6.91**		1.80	**0.89**	

Table 4 Influence of age and gender on stem cell harvest (n = number of harvests) for patients with a harvest goal of 5 × 10^6 CD34+ cells/kg (totally 512 harvests in 451 patients)

	Total n (%)	<3 × 10^6	P-value	<5 × 10^6	P-value
Age					
≥45 years	374 (78%)	38 (10%)	n.s.	99 (26%)	0.012
≥50 years	326 (68%)	32 (9.8%)	n.s.	88 (27%)	0.020
Gender					
Women	190 (41%)	25 (13%)	0.045	53 (28%)	n.s.
Men	278 (59%)	21 (8%)		59 (21%)	

The multiple myeloma patients aiming at harvesting 10 × 107 CD34+/kg (n = 198 harvests in 179 patients) are not included in the table; however, in these patients, there was no difference in age or gender

for harvest, for patients aiming for 5 × 10^6CD34+/kg (Table 3).

Gender

When analyzing the entire cohort of 630 patients, there was a significantly better yield in CD34+ cells/kg body weight for men than for women. The fractions of men and women who attained ≥5 × 10^6 CD34+ cells/kg were 85 and 78%, respectively ($P = 0.02$), and the fractions of men and women who attained ≥3 × 10^6/kg were 94 and 90%, respectively ($P = 0.04$) (Table 4).

Multivariate analysis

When analyzing the three largest groups, DLBCL, multiple myeloma, and Hodgkin lymphoma, comparing the influence of diagnosis on CD34+ progenitor cell harvest, we excluded multiple myeloma patients that requesting 10 × 10^6/kg CD34+ cells. When diagnosis, gender, age, and body weight were analyzed, there was no difference in harvested cell amount between multiple myeloma, DLBCL, and Hodgkin lymphoma. However, there was a tendency for better harvest yields in multiple myeloma (80% achieved > 5 × 10^6/kg) compared to DLBCL patients (71% achieved > 5 × 10^6/kg, $P = 0.070$).

When analyzing DLBCL patients for factors affecting the amount of CD34+/kg harvested, age ≤50 years ($P = 0.04$) and gender ($P = 0.001$) came out as significant variables. Similarly, for multiple myeloma age ≤50 years ($P = 0.02$) and gender ($P = 0.003$) were significant variables.

Influence of blood groups on the harvest yield

The possible influence of blood group antigens on progenitor cell harvest was tested for 0 (37%), A (46.5%), AB (6%), and B (10.5%), revealing a significantly better harvest in blood group A patients compared to AB; 70% achieved > 5 × 10^6/kg compared to 14.4%, $P = 0.02$ for the whole patient material, also significant when including only patients with a target of 5 × 10^6/kg. Patients with group AB harvested the lowest amount of cells and also needed more days of harvest 2.2 days compared to 1.64–1.94 for other blood groups. Rh± showed no statistical difference.

Factors influencing the time to hematological recovery

Time to platelet recovery, measured as platelet reaching >50 × 10^9/l without transfusion, was significantly faster in multiple myeloma than all other patient groups (14.6 days compared to 18.9 for DLBCL ($P < 0.01$), 17.8 days for Hodgkin lymphoma ($P < 0.05$), and 19.8 days for all other diagnoses together ($P < 0.01$)). When using a cut off at transplanted CD34+ cells/kg at <3 × 10^6/kg ($n = 26$) compared to ≥3 × 10^6/kg ($n = 500$) or <5 × 10^6/kg ($n = 143$) to ≥5 × 10^6/kg ($n = 383$), there was a statistically significant impact of the infused cell number on the time to hematological recovery (Table 5). Age and gender had no influence on time to platelet recovery. Platelet and

Table 5 Importance of infused CD34+ cell dose, gender, and age, on platelet recovery, in the whole patient population, $n = 588$

Factors	n(%)	Days to platelet >50	P-value
Infused CD34+			
<3 × 106	4.9	26.5	<0.05
≥3 × 106	95	16.5	
<5 × 106	27	21.3	<0.05
≥5 × 106	73	15.4	
Gender			
Women	36	17.5	n.s.
Men	64	16.8	
Age			
<45 years	16	16.0	n.s.
≥45 years	84	17.2	
<50 years	25	16.0	n.s.
≥50 years	75	17.4	

Table 6 Platelet and neutrophil recovery depending on reinfused CD34+/kg, total $n = 588$

Reinfused CD34 $\times 10^9$/kg	*n (%)*	Mean (days to recovery)	Std dev
Analysis variable: Neutr 0.5 $\times 10^9$/l			
<2	0.9	12.3	1.0
2 to <4	9.8	13.8	3.5
4 to <6	52	13.4	3.9
6 to <8	31	13.2	3.0
8 to <10	4.9	12.9	2.9
≥10	1.2	12.6	2.1
Analysis variable: Neutr 1.0 $\times 10^9$/l			
<2	0.9	13.0	0.8
2 to <4	9.8	15.7	5.2
4 to <6	52	15.8	6.5
6 to <8	31	14.8	3.8
8 to <10	4.9	14.7	5.3
≥10	1.2	14.0	3.7
Analysis variable: TRC 50 $\times 10^9$/l			
<2	0.9	19.0	8.0
2 to <4	9.8	26.4	20.7
4 to <6	52	16.5	9.5
6 to <8	31	15.4	5.5
8 to <10	4.9	15.9	6.8
≥10	1.2	13.9	3.0

neutrophil recovery with reinfused CD34+ cells as a dependent factor are shown in Table 6.

Multivariate analysis of factors influencing platelet recovery was applied for the two largest patient groups, DLBCL ($n = 113$) and myeloma ($n = 276$) patients. Factors significant in univariate analysis (age, gender, diagnosis, and amount of reinfused CD34+ cells) were modeled. Analyzing the 276 multiple myeloma patients separately, comparing infused cells at 3×10^6 and 5×10^6, at age at a cut off 45 years, age came out as a significant factor determining platelet recovery, $P < 0.05$. For DLBCL, using cut off 45 years or 50 years and infused cells 5×10^6, infused cell number was significant, $P < 0.05$. When including both multiple myeloma and DLBCL in the multivariate analysis, diagnosis ($r^2 = 0.0346$, $P < 0.0001$) as well as infused cell number ($r^2 = 0.060$, $P < 0.05$) were independent significant variables for platelet recovery for age cut off at 45 or 50 years.

The correlation between time to platelet recovery and amount of reinfused CD34+ cells is shown in Fig. 1. The cumulative time to platelet recovery for multiple myeloma, DLBCL, and follicular lymphoma is shown in Fig. 2a–c. When studying the effect of blood group and Rh± on platelet recovery, O+ had the quickest recovery (15.7 days SD 7.9), significantly quicker than A+ that were the slowest to recovery (17.7 days SD 12.2), $P < 0.05$.

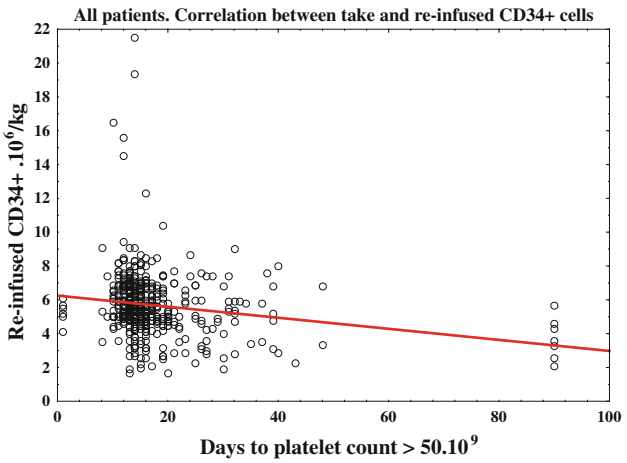

Fig. 1 All patients who underwent transplantation ($n = 588$). Correlation between platelet recovery (>50 $\times 10^9$/l) and infused CD34+ $\times 10^6$/kg cell dose

Discussion

PBSC collection and subsequent ASCT plays a central role in primary treatment of younger myeloma patients and relapsed Hodgkin and non-Hodgkin lymphoma. A good mobilization of hematopoietic stem cells into the circulation is pivotal, reducing the days of monitoring stem cell count before harvest start as well as the number of apheresis procedures required to harvest the requested cell amount. Several factors, including age, previous radiation therapy, and exposure to alkylating agents, could be considered as risk factors for poor mobilization in patients with hematological malignancies [13, 21–23]. In our study, 509 of 630 patients (81%) harvested readily the requested amount of cells (commonly 5×10^6/kg, for some myeloma patients 10×10^6/kg), data similar to recent reports where 10–20% fail to attain the requested (2×10^6/kg) CD34+ cells [10–12].

In multivariate analysis, we found that age and gender were independent significant factors determining a successful harvest. Younger patients were more likely to achieve the harvest goal and required fewer harvest days, and men harvested significantly better than women. However, the latter may at least partially be explained by men having a larger blood volume than women.

The patients with DLBCL were harvested with a variety of chemotherapy regimens. Cytarabine-based therapy gave a significantly higher amount of subsequently harvested CD34+ cells than other regimens. This is presumably due to a short and intense myeloablative effect. One must, however, take into account that this finding may be biased as the patient population is heterogenous, and we did not look further into the possible difference in patient characteristics between chemotherapy groups.

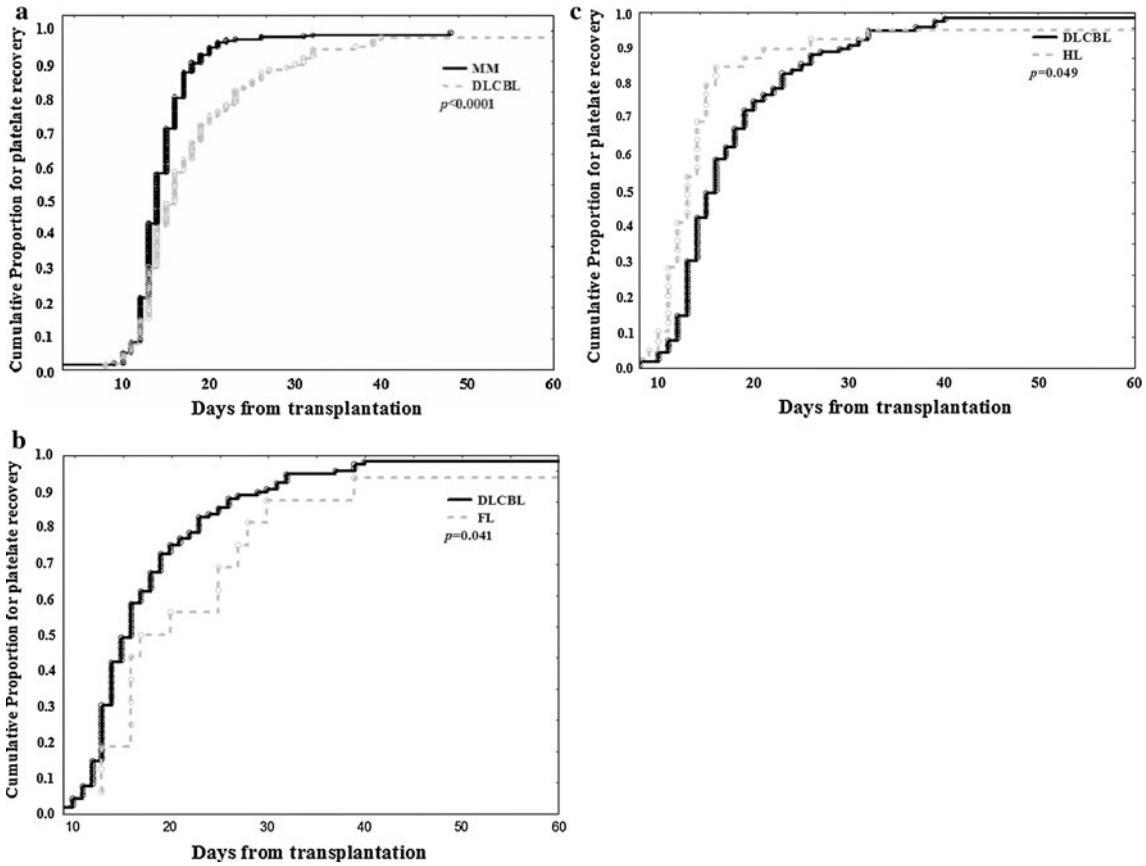

Fig. 2 Cumulative proportion of patients achieving platelet recovery measured as days from transplantation, for multiple myeloma patients compared to DLBCL **a**, DLBCL and follicular lymphoma **b**, and DLBCL and Hodgkin lymphoma **c**

Blood group was investigated because of contradictory reports in the literature that blood group O may [19] or may not [20] have delayed platelet engraftment. We found no support of this; rather in our study, blood group O+ patients had the fastest platelet recovery. Comparing harvest yields, group AB patients harvested the lowest cell amount, while group A patients harvested the highest amounts.

There is an ongoing debate about the optimal number of cells to harvest and reinfuse, where the recommendation from IMWG is to harvest at least $4x10^6$/kg [4]; however, faster hematological recovery seems to occur with higher amounts of reinfused stem cells [9, 12–14, 16, 18]. This is in line with the major finding in our study, namely that the infused cell dose correlated significantly to time to platelet recovery, in all diagnosis groups.

However, some caution must be taken when aiming at harvesting large cell numbers, as there is some evidence that tumor cell contamination may increase by increasing the number of apheresis days (over 5–6 days), which can be needed for higher CD34+ yield [24, 25]. This was recently confirmed by Malik et al., demonstrating a significant worse survival for patients undergoing 5 or more days of apheresis, owing to higher relapse mortality [26]. In patients that are difficult to harvest, the CXCR4 chemokine receptor blocker plerixafor may be used. Plerixafor improves stem cell yield and can be administered the evening before apheresis [27, 28]. However, it is currently unclear which patients to treat.

Multiple myeloma had a significantly quicker time to platelet recovery compared to all other diagnosis groups, despite being older. This is possibly due to multiple myeloma patients being treated upfront and not being heavily pretreated. Additionally, the multiple myeloma conditioning regimen is high-dose melphalan compared to the more toxic BEAM (carmustine, etoposide, cytarabine, and melphalan) regimen used in non-Hodgkin lymphoma. Multivariate analysis identified diagnosis as the most powerful predictor of platelet recovery, followed by infused cell dose. For all patients regardless of diagnosis, infused CD34+ cell amount correlated to platelet recovery.

In conclusion, we demonstrate a significant independent importance of the number of infused CD34+ cells on the time to platelet recovery. Platelet recovery was significantly faster for multiple myeloma patients compared to all other diagnoses. However, this is a retrospective analysis, and for clear conclusions, a prospective study is needed.

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Conflict of interest None of the authors have any conflict of interest to declare.

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