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The Effect of Myeloid-Derived Suppressor Cells in Graft-versus-Host Disease

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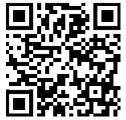

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ABSTRACT

Objective: Myeloid-derived suppressor cells (MDSCs) are immature myeloid progenitors, including monocytic and granulocytic subgroups (M-MDSCs and PMN-MDSCs). They exhibit immunoregulatory and immunosuppressive properties by limiting immune-mediated pathology and protecting the host from destructive inflammatory damage. Graft-versus-host disease (GVHD) comprises a series of immune-mediated inflammatory events in which donor-derived T cells target the tissues and organs of the transplant recipient. This study aims to evaluate the behavior of MDSCs during GVHD in patients undergoing allogeneic hematopoietic stem cell transplantation (HSCT).

Materials and Methods: Fifteen patients who underwent allogeneic HSCT were included in the study. MDSCs and their subsets were identified and characterized by flow cytometry on days 0, 30, 60, and 90 post-engraftment.

Results: The median frequency of monocytic MDSCs (M-MDSCs) on the first day of engraftment was significantly higher in patients without GVHD than in those who developed GVHD. Furthermore, the expansion of M-MDSCs occurred significantly earlier than that of the other MDSC subset.

Conclusion: Monocytic MDSCs play a key regulatory role in limiting GVHD and may serve as potential therapeutic targets for GVHD prevention or treatment.

Keywords: Allogeneic stem cell transplantation, graft-versus-host disease, immunoregulatory cells, monocytic myeloid-derived suppressor cells, myeloid-derived suppressor cells.

INTRODUCTION

Allogeneic hematopoietic stem cell transplantation (HSCT) is a current and promising treatment for hematological malignancies, particularly leukemia. In the post-transplant period, an optimal

immune balance between the recipient and the graft is required to enable donor lymphohematopoietic cells (the graft) to engraft (i.e., settle in the recipient and produce new blood cells) while preventing tumor recurrence. Patients who undergo allogeneic HSCT face a 30% risk of developing acute graft-versus-host disease (GVHD).[1] GVHD comprises a series of immune-mediated inflammatory events and tissue damage driven by donor-derived T cells in the recipient's body. It is a complication of HSCT that can lead to graft failure, cause severe organ damage, or even be fatal.

Myeloid-derived suppressor cells (MDSCs) are immature cells of myeloid origin with predominant regulatory and suppressive properties and incomplete development and differentiation.[2,3] MDSCs are often increased in immunocompromised conditions such as cancer, chronic diseases, and inflammation. These cells may be considered predictors of adverse outcomes because they are associated with increased tumor growth through angiogenesis and metastasis. On the other hand, MDSCs suppress dynamic immune responses through the cytokines they secrete, thereby limiting immune-mediated pathology and protecting the host from destructive inflammatory damage. Based on their phenotypic and morphological characteristics, MDSCs are classified into monocytic (M-MDSC) and polymorphonuclear/granulocytic (PMN-MDSC) subsets. These cells are typically present at very low levels in peripheral blood but can be induced and expanded with granulocyte colony-stimulating factor (G-CSF) stimulation.[4] As their regulatory roles and biology become better understood, *in vitro* production and therapeutic applications may emerge as areas of interest.

This study aims to explore the relationship between GVHD and MDSCs in patients undergoing allogeneic HSCT.

MATERIALS AND METHODS

In this prospective study, 15 patients who underwent allogeneic HSCT at the Hematology and Bone Marrow Transplant Unit of Erciyes University Hospital were included. The following inclusion criteria were applied: age 18–65 years, Eastern Cooperative Oncology Group (ECOG) performance score ≤1, and adequate parenchymal organ function, defined as total bilirubin ≤2× the normal value; AST, ALT, and ALP ≤5× the normal value; creatinine ≤2× the normal value; and creatinine clearance >35 mL/min. Acute GVHD was graded according to the IBMTR/Keystone consensus criteria.[5] Patients with grade II–IV acute GVHD were classified as GVHD-positive. For GVHD prophylaxis, all patients received immunosuppressive therapy consisting of cyclosporine and a short course of methotrexate according to institutional standard protocols.

During post-transplant follow-up, peripheral venous blood samples were collected on days e0, e30, e60, and e90, starting on the first day of neutrophil engraftment (e). Antibody markers used to identify MDSCs were measured by flow cytometry: HLA-DR (PB), CD11b (PE), CD45 (KrO), CD66b (FITC), CD15 (FITC), CD33 (PE), and CD14 (PC5). The analysis was performed using a Beckman Coulter Navios flow cytometer and Kaluza analysis software. After flow cytometric analysis, neutrophils and monocytes were selected, and the mean fluorescence intensity (MFI) values of cells identified as MDSCs were obtained.

For PMN-MDSCs, CD14-negative cells were selected from CD45-positive cells. CD11b-positive cells were then isolated from the CD14-negative population. The MFI of CD66b-positive cells among CD11b-positive cells was measured, and these cells were identified as PMN-MDSCs.[6] For M-MDSCs, CD11b-positive and CD15-negative cells were selected from CD45-positive cells. CD14-positive cells were also selected from CD33-positive cells, and HLA-DR-negative cells were defined as M-MDSCs.[6] Figures 1 and 2 present representative flow cytometry images from patient 9.

Chimerism analysis was performed at the Genetics Unit of Erciyes University using a 3500 Genetic Analyzer for fragment analysis following PCR, with subsequent analysis using GeneMapper Generic software. Informed consent was obtained from all patients.

The study was funded by the Scientific Research Projects (BAP) Unit of Erciyes University (Project No: TYL-2017-7831), and ethical approval was granted by the Erciyes University Clinical Research Ethics Committee (Approval Number: 2017/441, Date: 29.09.2017).

For statistical analysis, continuous variables were expressed as mean±standard deviation (SD) or median (minimum–maximum), and categorical variables were presented as counts and percentages (%). Histograms, Q–Q plots, and the Shapiro–Wilk test were used to assess data normality. The Mann–Whitney U test was applied to compare two independent groups of quantitative variables. For comparisons involving more than two repeated measurements, the Friedman test was used, with Bonferroni adjustment applied to control for

KEY MESSAGES

- Myeloid-derived suppressor cells play a major role in limiting inflammation.
- Monocytic MDSC recovery occurs earlier than that of other immunologic cells after allogeneic transplantation.
- The risk of GVHD is inversely proportional to the recovery of monocytic MDSCs.

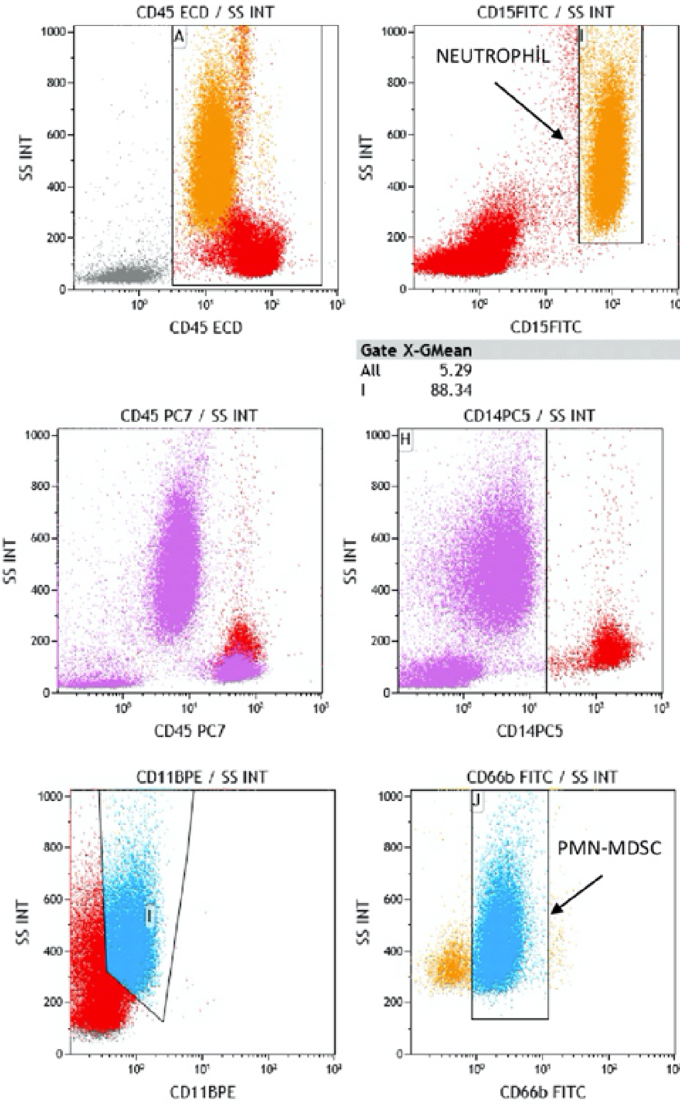

Figure 1. Example of flow cytometry graphics of PMN-MDSC (patient 9). Representative flow cytometry analysis of polymorphonuclear myeloid-derived suppressor cells (PMN-MDSCs) from a representative patient (patient 9). PMN-MDSCs were identified within the neutrophil population based on surface marker expression.

multiple testing. Spearman's correlation test was performed to assess associations between continuous variables. Based on repeated-measures analysis, the overall post hoc observed power was calculated as 63%, using the observed effect size, sample size, and an alpha level of 0.05. Data were analyzed using TURCOSA Cloud (Turcosa Ltd Co, www.turcosa.com.tr) statistical software.[7] A p-value<0.05 was considered statistically significant.

Table 1. Baseline demographic and clinical characteristics of the study population

	Total (n=15) n (%)
Gender (female)	7 (47)
Age, mean (years) ±SD	39.13±16.23
Underlying disease	
AML	6 (40)
AA	3 (20)
MDS	3 (20)
HL	1 (6.7)
MM	1 (6.7)
ALL	1 (6.7)
Donor type	
Full-matched	12 (80)
Haploidentical	3 (20)
Conditioning regimen	
Myeloablative	12 (80)
Nonmyeloablative	3 (20)
Acute GVHD (grade II–IV)	5 (33)
Survival (first 100 days)	12 (80)

Data are presented as number (%) or mean±standard deviation, as appropriate. AML: Acute myeloid leukemia; AA: Aplastic anemia; MDS: Myelodysplastic syndrome; HL: Hodgkin lymphoma; MM: Multiple myeloma; ALL: Acute lymphoblastic leukemia; GVHD: Graft-versus-host disease.

RESULTS

The study included 15 patients who underwent allogeneic transplantation for various hematological diseases. The mean age of the patients was 39 years, and 8 were male. The most common underlying indication for transplantation was acute leukemia, particularly acute myeloid leukemia (AML) (40%). Patients' demographic characteristics and transplantation data are presented in Table 1.

The median engraftment times for neutrophils and platelets were 19 and 17.5 days, respectively. Grade II–IV GVHD developed in 5 (33%) patients (GVHD-positive) (P4, P6, P13, P14, P15) during the 100-day follow-up period. Three of these patients (P13, P14, P15) died of GVHD within the first 100 days. Twelve patients completed the 100-day follow-up. All but one patient had first-month chimerism ranging from 95–100% (complete chimerism). Chimerism in P6 was 61.2; this patient died 7 months after day e90 blood collection due to relapse of the primary disease, diagnosed as MDS. Another patient, P4, who developed GVHD, died from GVHD 6 months after transplantation.

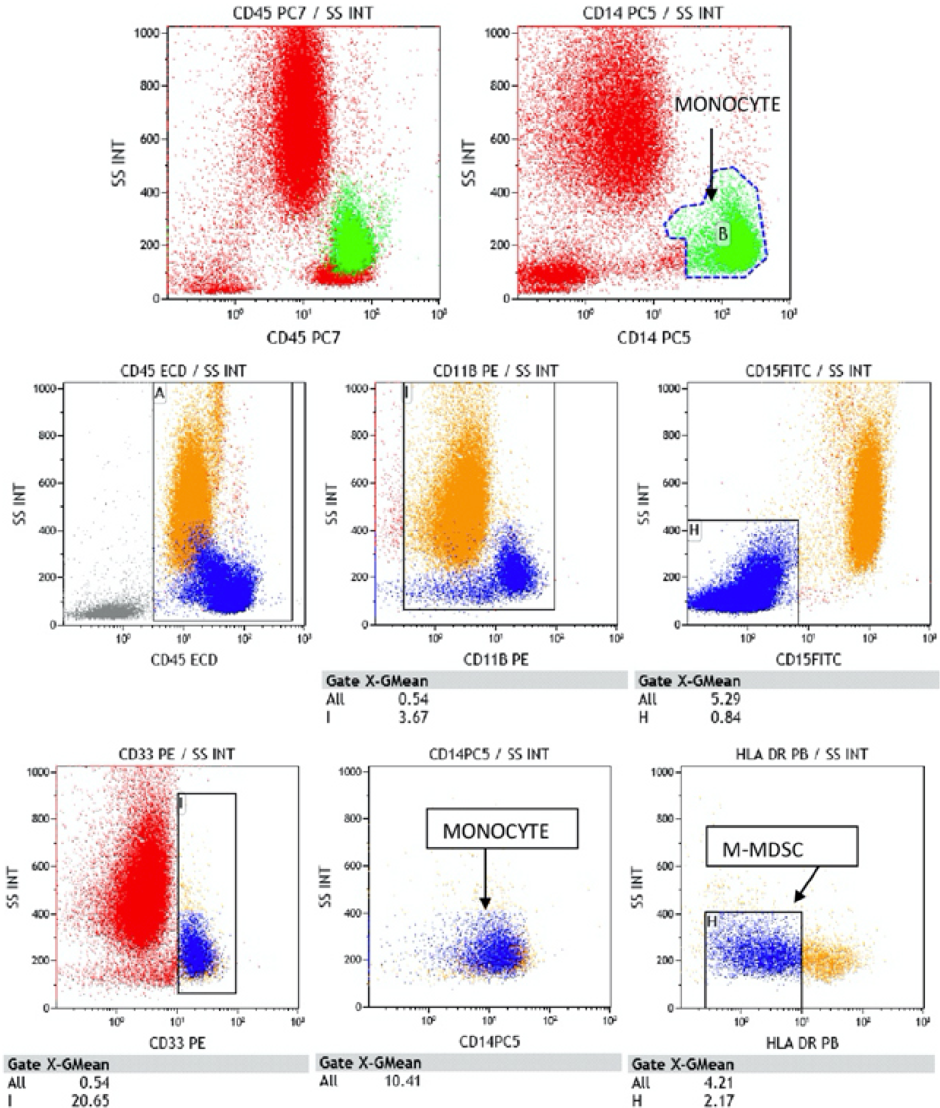

Figure 2. Example of flow cytometry graphics of M-MDSC (patient 9). Representative flow cytometry analysis of monocytic myeloid-derived suppressor cells (M-MDSCs) from a representative patient (patient 9). M-MDSCs were gated within the monocyte population according to characteristic immunophenotypic features.

Laboratory values, including flow cytometry, blood counts, and chimerism parameters, as well as their changes over time, are presented in Table 2. Changes in M-MDSC and lymphocyte values over time were statistically significant (p=0.039 and p=0.010). Changes in the remaining parameters did not reach statistical significance (CD14/MFI p=0.183, CD15/MFI p=0.896, PMN-MDSC/MFI p=0.071, M-MDSC/MFI p=0.039, WBC p=0.183, neutrophils p=0.281, monocytes p=0.409, lymphocytes p=0.010, thrombocytes p=0.689). Chimerism was preserved in these patients.

In the correlation analysis, a moderate, statistically significant positive correlation was observed between platelet engraftment time (Plt-e) and CD14+ cells (r=0.556, p=0.039). A moderate negative correlation was observed between neutrophil engraftment time (Neu-e) and CD15+ cells (r=-0.472, p=0.076); however, this did not reach statistical significance. No statistically significant correlations were observed between neutrophil or platelet engraftment times and PMN-MDSCs or M-MDSCs (Plt-e and PMN-MDSC r=0.409, p=0.147; Plt-e and M-MDSC r=0.152, p=0.603; Neu-e and PMN-MDSC r=-0.074, p=0.793; Neu-e and M-MDSC r=-0.018, p=0.949).

Table 2. Flow cytometry and blood count parameters across engraftment time points

Parameter	e0 (n=15) Median (IQR)	e30 (n=15) Median (IQR)	e60 (n=13) Median (IQR)	e90 (n=11) Median (IQR)	p
CD14/MFI	14.8 (11.4–90.5)	21.7 (15.7–36.5)	25.0 (18.2–71.3)	104.9 (34.2–143.0)	0.183
CD15/MFI	30.4 (23.4–74.8)	46.9 (28.3–99.9)	61.3 (30.3–86.3)	43.5 (18.9–88.9)	0.896
PMN-MDSC/MFI	147.3 (23.4–250.0)	201.6 (151.6–352.0)	189.2 (145.0–242.0)	191.4 (173.4–293.8)	0.071
M-MDSC/MFI	1.4 (0.9–1.8)[a]	2.0 (1.8–2.6)[b]	2.1 (1.2–2.3)[ab]	1.7 (0.8–2.9)[ab]	0.039
WBC (10^3/µL)	3.3 (1.8–4.9)	3.9 (3.5–4.9)	3.3 (2.8–5.8)	5.3 (3.3–5.7)	0.183
Neutrophils (10^3/µL)	1.8 (1.1–3.2)	3.0 (1.8–3.4)	1.7 (1.3–4.0)	3.5 (1.8–3.7)	0.281
Monocytes (10^3/µL)	0.6 (0.5–1.1)	0.5 (0.4–0.6)	0.4 (0.3–0.6)	0.5 (0.3–0.7)	0.409
Lymphocytes (10^3/µL)	0.5 (0.3–0.7)[a]	0.8 (0.5–1.1)[ab]	1.1 (0.9–1.4)[b]	0.9 (0.7–1.2)[ab]	0.010
Thrombocytes (10^3/µL)	97.0 (42.0–161.0)	126.0 (111.0–159.0)	143.0 (121.0–186.0)	154.0 (115.0–177.0)	0.689

Longitudinal changes in flow cytometry parameters and peripheral blood counts at predefined engraftment time points (e0, e30, e60, and e90). Data are presented as median and interquartile range (IQR). P values indicate overall differences between time points. The same letters within a row indicate similarity between time points, whereas different letters indicate statistically significant differences. e0: Engraftment day; e30: 30th day of engraftment; e60: 60th day of engraftment; e90: 90th day of engraftment; CD: Cluster of differentiation; MFI: Mean fluorescence intensity; PMN-MDSC: Polymorphonuclear myeloid-derived suppressor cell; M-MDSC: Monocytic myeloid-derived suppressor cell; WBC: White blood cell.

The median M-MDSC level measured on day e0 was significantly higher in GVHD-negative patients than in GVHD-positive patients ($p<0.02$). No statistically significant differences were observed for the other parameters with respect to GVHD status and time ($p>0.05$) (Table 3).

The change in lymphocyte levels over time in the GVHD-negative group was statistically significant ($p<0.01$). The median value on day e60 was higher than that on day e0 (Table 3).

DISCUSSION

In normal physiology, when a pathological threat arises—such as infection, tissue damage, or malignant transformation—myelopoiesis is stimulated, leading to myeloid expansion aimed at eliminating the threat. As inflammation and myeloid expansion persist, the morphology of myeloid cells shifts toward a more immature state. These immature cells, defined as MDSCs, possess immunosuppressive capacities and thus prevent excessive tissue damage by suppressing the immune response.[8,9] MDSCs exert immunosuppressive and anti-inflammatory effects through the cytokines they secrete. In the pathogenesis of many solid tumors, an increase in the MDSC population is observed, and elimination of MDSCs enhances the immune response, strengthens anti-tumor activity, and shifts the balance against the tumor. However, in HSCT, suppression of the immune response may represent a therapeutic target.

Notarantonio et al.[10] recently published a study examining the effects of MDSCs on disease relapse in patients who underwent allogeneic stem cell transplantation. In this study, they suggested that MDSCs reduce GVHD development through their immunosuppressive effects and are associated with relapse by impairing the immune system's ability to identify and eliminate blastic cells. Fan et al.[11] demonstrated in a study of allogeneic stem cell recipients with different primary hematological malignancies that bone marrow–derived grafts contained higher numbers of MDSCs than peripherally derived stem cells and that the number of MDSCs in the graft was negatively correlated with the incidence and severity of GVHD. Li et al.[12] conducted a study comparing pegylated G-CSF with conventional G-CSF in relation to GVHD. In this study, severe GVHD was less frequent in patients receiving peg-G-CSF, and the beneficial effects of peg-G-CSF grafts were attributed to increased numbers of M-MDSCs.

In another study investigating the role of MDSCs in immune reconstitution after allogeneic HSCT, 26 patients were followed during the first three months after transplantation.[13] Both MDSC subsets were found to recover within 2–4 weeks, well before the recovery of T and B lymphocytes. MDSCs have been shown to suppress the differentiation of Th1 cells and promote the development of regulatory T (Treg) lymphocytes.[13] Functional MDSCs contribute to the early post-transplant regulatory cell population after HSCT. Monocytes are among the first cells to recover after successful allogeneic transplantation, followed by granulocytes and platelets. In contrast, lymphocyte recovery, along with coordinated immune reconstitution, generally does not occur until approximately 100 days after HSCT.[10,14] The aforementioned study demonstrated that MDSCs begin to recover within the first month after HSCT, with M-MDSCs recovering 1–2 weeks earlier than PMN-MDSCs. This finding is consistent with

Table 3. Comparison of flow cytometry and blood count parameters according to GVHD status

Parameter	Time	GVHD positive (n=5) Median (IQR)	GVHD negative (n=10) Median (IQR)	p*
CD14/MFI	e0	21.7 (11.4–46.9)	16.8 (6.3–159.9)	0.859
	e30	36.8 (21.2–132.5)	21.7 (7.2–80.5)	0.129
	e60	18.1 (15.5–119.9)	24.9 (13.7–200.1)	0.573
	e90	108.2 (74.5–141.9)	104.9 (14.2–257.8)	0.999
	p	0.494	0.392	
CD15/MFI	e0	48.1 (15.3–79.4)	30.1 (14.7–85.1)	0.859
	e30	38.0 (9.8–107.6)	42.2 (9.5–108.6)	0.953
	e60	66.2 (16.1–87.4)	46.3 (13.4–93.3)	0.692
	e90	69.4 (43.5–95.2)	24.7 (12.1–111.4)	0.436
	p	0.896	0.954	
PMN-MDSC/MFI	e0	169.8 (93.0–355.0)	141.0 (5.3–297.0)	0.513
	e30	249.4 (170.0–446.0)	171.6 (101.8–352.0)	0.075
	e60	216.8 (30.2–242.0)	177.0 (82.6–374.0)	0.811
	e90	130.7 (35.4–226.0)	191.4 (101.0–377.2)	0.436
	p	0.308	0.115	
M-MDSC/MFI	e0	0.8 (0.5–1.2)	1.6 (0.1–2.7)	0.028
	e30	1.2 (0.7–2.6)	2.0 (1.1–2.9)	0.440
	e60	1.1 (0.5–2.3)	2.1 (0.7–3.3)	0.287
	e90	1.0 (0.8–1.3)	1.9 (0.7–3.0)	0.327
	p	0.145	0.145	
Neutrophils (10^3/μL)	e0	3.2 (2.3–7.9)	1.6 (0.9–4.8)	0.055
	e30	4.2 (1.7–6.9)	3.0 (1.8–4.3)	0.440
	e60	1.2 (1.2–4.0)	1.7 (1.2–6.8)	0.217
	e90	3.0 (2.5–3.6)	3.5 (1.2–10.8)	0.999
	p	0.896	0.268	
Monocytes (10^3/μL)	e0	1.3 (0.6–2.6)	0.6 (0.2–2.0)	0.075
	e30	0.5 (0.4–0.9)	0.5 (0.2–1.2)	0.513
	e60	0.2 (0.2–0.6)	0.4 (0.1–0.8)	0.371
	e90	0.6 (0.3–0.8)	0.5 (0.3–1.1)	0.582
	p	0.308	0.706	
Lymphocytes (10^3/μL)	e0	0.6 (0.0–0.7)	0.5 (0.2–2.0)[a]	0.953
	e30	0.9 (0.4–1.6)	0.7 (0.2–1.7)[ab]	0.310
	e60	1.1 (0.4–1.2)	1.2 (0.6–1.8)[b]	0.469
	e90	0.7 (0.5–1.0)	0.9 (0.2–2.0)[ab]	0.727
	p	0.112	0.013	

Comparison of flow cytometry parameters and peripheral blood counts between patients with and without acute GVHD at different engraftment time points. Data are expressed as median and interquartile range (IQR). p* indicates the significance of differences between groups, and p indicates the significance of differences over time. The same letters within a column indicate similarity between time points, whereas different letters indicate statistically significant differences. # In the GVHD group, the sample size was n=3 for e60 and n=2 for e90, as three patients died before the respective sampling time points. In the non-GVHD group, the sample size was n=9 for e90, as one patient died before the sampling time point. e0: Engraftment day; e30: 30th day of engraftment; e60: 60th day of engraftment; e90: 90th day of engraftment; CD: Cluster of differentiation; MFI: Mean fluorescence intensity; PMN-MDSC: Polymorphonuclear myeloid-derived suppressor cell; M-MDSC: Monocytic myeloid-derived suppressor cell; WBC: White blood cell.

previous data indicating that monocytes recover earlier than granulocytes following HSCT. The study also emphasized the potentially important role of PMN-MDSCs in HSCT. PMN-MDSCs were noted to be more abundant numerically, to exert stronger suppressive effects on lymphocyte proliferation, to show a positive correlation with other components of the immune system, and to potentially serve as predictors of acute GVHD.[13,14]

In the present study, neither neutrophil nor platelet engraftment times correlated with MDSCs. However, the number of M-MDSCs increased significantly earlier than that of other subsets during the first month after transplantation ($p<0.05$). A significant increase in lymphocyte counts was observed at the end of the second month. Baseline M-MDSC levels were higher in patients who did not develop GVHD than in those who did. This finding is consistent with previous data suggesting that M-MDSCs may serve as predictive biomarkers for acute GVHD.[15] However, unlike the findings of Storek et al.,[14] similar parameters were not found to be significant for PMN-MDSCs.

The recovery of MDSCs during the early post-transplant immune process is thought to depend on growth factors and proinflammatory cytokines.[4] Therefore, changes in clinical practice, such as post-transplant growth factor administration, may influence both the quantity and function of MDSCs in the microenvironment, potentially explaining differences in GVHD outcomes associated with the use of hematopoietic growth factors. A better understanding of the physiological behavior of MDSCs in patients with GVHD will provide valuable insights to guide future studies on the use of these cells to limit the uncontrolled immune response central to GVHD pathophysiology. As cellular therapies continue to advance toward clinical application, MDSCs may represent a promising therapeutic tool.

In addition, age-related immune changes may influence the interpretation of MDSC dynamics in the post-transplant setting. Aging is associated with inflammaging, a chronic low-grade inflammatory state that contributes to immunosenescence-related alterations in hematopoiesis, including myeloid skewing and increased generation of MDSCs in the bone marrow.[16] Consequently, age-related variability in MDSC levels may represent a confounding factor when evaluating immune profiles in transplant recipients. However, the age distribution of our cohort was relatively narrow, as all patients were eligible for allogeneic hematopoietic stem cell transplantation. The mean age of the study population was 39.1±16.2 years, reflecting a relatively young and selected patient population. Therefore, the potential impact of age-related variation in MDSC levels is likely to be limited in this cohort.

The major limitation of this study was the relatively small sample size, including only 15 patients, which inevitably affected the statistical power of some analyses and the generalizability of the findings. In addition, the relapse rate was very low, limiting the ability to assess the potential impact of MDSCs on disease relapse. The overall observed power for the repeated-measures analysis was moderate (63%), reflecting the limited number of cases. Therefore, the findings should be interpreted with caution, considered preliminary, and validated in larger prospective cohorts.

Despite these limitations, the prospective design and serial measurements during the early post-transplant period provide preliminary evidence that M-MDSCs may serve as an early biomarker for acute GVHD.

CONCLUSION

In conclusion, the monocytic subtype of MDSCs plays a predominant role in limiting GVHD and may represent a potential therapeutic target for the prevention or treatment of GVHD.

Ethics Committee Approval: Ethics committee approval was obtained from Erciyes University Clinical Research Ethics Committee (Approval Number: 2017/441, Date: 29.09.2017).

Informed Consent: Informed consent was obtained from all patients.

Conflict of Interest: The authors have no conflicts of interest to declare.

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REFERENCES

1. Ferrara JL, Levine JE, Reddy P, Holler E. Graft-versus-host disease. Lancet 2009;373(9674):1550-61. [CrossRef]
2. Fan R, De Beule N, Maes A, De Bruyne E, Menu E, Vanderkerken K, Maes K, et al. The prognostic value and therapeutic targeting of myeloid-derived suppressor cells in hematological cancers. Front Immunol 2022;13:1016059. [CrossRef]

3. Gabrilovich DI. Myeloid-Derived Suppressor Cells. Cancer Immunol Res 2017;5(1):3-8. [CrossRef]

4. Demosthenous C, Sakellari I, Douka V, Papayanni PG, Anagnostopoulos A, Gavriilaki E. The Role of Myeloid-Derived Suppressor Cells (MDSCs) in Graft-versus-Host Disease (GVHD). J Clin Med 2021;10(10):2050. [CrossRef]

5. Przepiorka D, Weisdorf D, Martin P, Klingemann HG, Beatty P, Hows J, et al. 1994 Consensus Conference on Acute GVHD Grading. Bone Marrow Transplant 1995;15(6):825-828.

6. Lv M, Wang K, Huang XJ. Myeloid-derived suppressor cells in hematological malignancies: friends or foes. J Hematol Oncol 2019;12(1):105. [CrossRef]

7. TURCOSA Cloud Statistics Software (Version 2025). Turcosa Analytics, Istanbul, Türkiye. https://www.turcosa.com.tr Accessed March 18, 2026.

8. Yang Y, Li C, Liu T, Dai X, Bazhin AV. Myeloid-Derived Suppressor Cells in Tumors: From Mechanisms to Antigen Specificity and Microenvironmental Regulation. Front Immunol 2020;11:1371. [CrossRef]

9. Vladimirovna IL, Sosunova E, Nikolaev A, Nenasheva T. Mesenchymal Stem Cells and Myeloid Derived Suppressor Cells: Common Traits in Immune Regulation. J Immunol Res 2016;2016:7121580. [CrossRef]

10. Notarantonio AB, Bertrand A, Piucco R, Fievet G, Sartelet H, Boulangé L, et al. Highly immunosuppressive myeloid cells correlate with early relapse after allogeneic stem cell transplantation. Exp Hematol Oncol 2024;13(1):50. [CrossRef]

11. Fan Q, Liu H, Liang X, Yang T, Fan Z, Huang F, et al. Superior GVHD-free, relapse-free survival for G-BM to G-PBSC grafts is associated with higher MDSCs content in allografting for patients with acute leukemia. J Hematol Oncol 2017;10(1):135. [CrossRef]

12. Li L, Yin J, Li Y, Wang C, Mao X, Wei J, et al. Allogeneic Hematopoietic Stem Cell Transplantation Mobilized With Pegylated Granulocyte Colony-Stimulating Factor Ameliorates Severe Acute Graft-Versus-Host Disease Through Enrichment of Monocytic Myeloid-Derived Suppressor Cells in the Graft: A Real World Experience. Front Immunol 2021;12:621935. [CrossRef]

13. Guan Q, Blankstein AR, Anjos K, Synova O, Tulloch M, Giftakis A, et al. Functional Myeloid-Derived Suppressor Cell Subsets Recover Rapidly after Allogeneic Hematopoietic Stem/Progenitor Cell Transplantation. Biol Blood Marrow Transplant 2015;21(7):1205-14. [CrossRef]

14. Storek J, Geddes M, Khan F, Huard B, Helg C, Chalandon Y, et al. Reconstitution of the immune system after hematopoietic stem cell transplantation in humans. Semin Immunopathol 2008;30(4):425-37. [CrossRef]

15. Kim TW, Park SS, Lim JY, Min GJ, Park S, Jeon YW, et al. Predictive Role of Circulating Immune Cell Subtypes Early after Allogeneic Hematopoietic Stem Cell Transplantation in Patients with Acute Leukemia. Int J Stem Cells 2018;12(1):73-83. [CrossRef]

16. Salminen A, Kaarniranta K, Kauppinen A. The role of myeloid-derived suppressor cells (MDSC) in the inflammaging process. Ageing Res Rev 2018;48:1-10. [CrossRef]