Cannabis use and its relationship with mobilization efficiency, hematological recovery and neurologic response after hematopoietic stem cell transplantation in patients with multiple sclerosis: A single center, eight-year experience

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Research Article

Keywords: Cannabis, multiple sclerosis, HSCT, treatment, bone marrow, recovery, results, multivariable analysis

Posted Date: July 30th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10399924/v1

Additional Declarations: No competing interests reported.

Abstract

Background

Cannabis use is increasingly common among persons with multiple sclerosis (MS), yet its potential influence on hematopoietic stem cell mobilization, hematological recovery and neurological disability outcomes remains unclear. Autologous hematopoietic stem cell transplantation (aHSCT) represents an effective therapeutic option for patients with highly active or treatment-refractory MS.

Objective

To evaluate the association between cannabis exposure and $CD34^+$ progenitor cell mobilization, early hematologic recovery of leukocytes, neutrophils, lymphocytes and platelets, and post-transplant disability assessed by changes in the Expanded Disability Status Scale (EDSS) in patients with MS undergoing autologous HSCT, adjusting for clinical and demographic confounders using multivariable statistical models.

Methods

This retrospective single-center study included adults with multiple sclerosis who underwent autologous HSCT in the Centro de Hematología y Medicina Interna (Clínica Ruiz, Puebla, México) between 2018 and 2025. Participants were stratified into three groups according to cannabis exposure: (1) active users during HSCT, (2) former users, and (3) an age, sex, body mass index (BMI) and EDSS score matched group of non-users. $CD34^+$ cell yields were compared across the three groups using non-parametric methods and multivariable linear regression models adjusting for age, sex, BMI, and MS subtype. Early hematologic recovery was assessed in former users and non-users by recording, for each lineage, whether patients achieved at least the lower limit of the institutional reference range and the number of days from aHSCT to recovery. EDSS scores were collected at baseline and at 3, 6, and 12 months after HSCT; multivariable logistic regression was performed to evaluate predictors of EDSS worsening.

Results

A total of 184 patients were analyzed (16 active users, 76 former users and 92 never users). Significant differences in $CD34^+$ counts among the three groups were observed, driven by higher $CD34^+$ mobilization in former users compared with non-users ($p = 0.048$), while active users did not differ significantly from either group. In multivariable linear regression adjusting for age, sex, BMI, and MS subtype, prior cannabis exposure maintained a consistent positive trend with $CD34^+$ mobilization (beta = 0.28, $p = 0.097$). In former users ($n = 76$) and non-users ($n = 92$), leukocyte, neutrophil, lymphocyte and platelet recovery was generally similar, although leukocyte recovery occurred slightly earlier and in a higher

proportion of former users. Baseline and follow-up median EDSS values did not differ significantly between groups, but EDSS worsening was less frequent in former users, particularly at 6 months (4.4% versus 18.6%; p = 0.015). Multivariable logistic regression confirmed that prior cannabis exposure remained an independent protective factor against short-term EDSS worsening at 6 months (adjusted OR = 0.21, 95% CI 0.05–0.84; p = 0.027), independent of baseline EDSS score, age, sex, BMI, and MS phenotype.

Conclusions

In this MS cohort undergoing autologous HSCT, a history of cannabis use was associated with higher $CD34^+$ progenitor cell mobilization and was not linked to delayed hematologic recovery nor worsening of neurological disability. Multivariable analyses confirm that prior cannabis exposure independently predicts lower risk of short-term neurological deterioration post-aHSCT. Active cannabis use during HSCT did not confer additional mobilization benefit. Larger prospective studies are needed to confirm these findings and to clarify the biological mechanisms linking cannabis exposure with hematopoietic and neurological outcomes.

Introduction

Multiple sclerosis (MS) is a chronic inflammatory disorder of the central nervous system which results in progressive physical and cognitive impairment (1, 2). MS usually manifests in young adults between 20 and 40 years of age, its global prevalence ranging from 5 to 300 cases per 100,000 individuals, with higher rates observed at increased latitudes, and it shows a marked female predominance, with a female-to-male ratio of approximately 3:1 (3–5). Clinically, MS is classified into relapsing-remitting MS (RRMS), secondary-progressive MS (SPMS), primary-progressive MS (PPMS), and clinically or radiologically isolated syndromes (3, 4). RRMS is the most common phenotype, representing 80–85% of cases, and is characterized by acute relapses followed by partial or complete remission (6, 7). Over the past two decades, the therapeutic landscape of MS has expanded considerably, with the development of multiple disease-modifying therapies (DMTs), which can reduce relapse rates and delay disability progression in many patients (8–12). Nonetheless, progressive forms of MS and highly active, treatment-refractory disease respond poorly to conventional therapies (13, 14). This unmet need has positioned autologous hematopoietic stem cell transplantation (aHSCT) as a promising option for patients with MS, with growing evidence supporting durable disease control and, in some cases, improvement in disability (15, 16).

The *Cannabis sativa* plant, a member of the Cannabaceae family, is also referred to as hemp, cannabis or marijuana, and is among the most widely used psychoactive substances worldwide (17). It contains more than 120 identified cannabinoids, with trans-Δ-9-tetrahydrocannabinol (Δ9-THC) recognized as the principal psychoactive compound responsible for many of the behavioral effects of cannabis. Defining a single mechanism of action is challenging, as molecular studies have shown Δ9-THC to interact with

multiple intracellular pathways, including opioid and benzodiazepine receptors, the prostaglandin synthesis pathway, and both protein and nucleic acid metabolism.

Cannabidiol (CBD) is a major non-psychoactive cannabinoid found in *Cannabis sativa*, comprising up to 40% of the plant's extract. It interacts with multiple targets within the human endocannabinoid system. Current evidence indicates that CBD exerts several pharmacological actions, including anti-inflammatory, antioxidant, antiemetic, antipsychotic and neuroprotective effects. Moreover, CBD appears to counteract several undesirable psychotropic effects of Δ9-THC, such as cognitive impairment, heightened appetite, anxiety and psychosis-like symptoms, while potentially preserving or enhancing its therapeutic benefits. These properties have generated interest in cannabinoids as symptomatic treatments in MS, particularly for spasticity and pain.

Given this widespread use, it becomes clinically relevant to explore its potential impact on HSCT outcomes. In this study, we aimed to investigate whether cannabis consumption influences hematopoietic stem cell mobilization, early hematologic recovery (leukocytes, neutrophils, lymphocytes and platelets), and neurological disability as measured by the Expanded Disability Status Scale (EDSS) after autologous HSCT in patients with MS, as these processes are critical determinants of engraftment success, immune reconstitution and long-term clinical outcome, while rigorously controlling for potential demographic, clinical, and cannabis-related confounding variables through multivariable statistical modeling.

Materials and methods

We conducted a retrospective, observational, single-center study at the Centro de Hematología y Medicina Interna, Clínica Ruiz (Puebla, Mexico), including patients with MS who underwent autologous HSCT between 2018 and 2025. The study aimed to evaluate the association between cannabis use and progenitor cell mobilization, early hematologic recovery and neurological outcomes. Eligible patients were adults (≥ 18 years) with a confirmed diagnosis of MS according to the 2017 McDonald criteria (14), who underwent HSCT using the "Mexican method" and had complete clinical and laboratory data available. Patients with incomplete clinical or laboratory data, concomitant hematologic or malignant disorders, or reported use of illicit drugs other than cannabis were excluded. Patients were stratified into three groups based on cannabis exposure: Group 1: Cannabis use during HSCT – patients who reported marijuana consumption during the HSCT procedure (active users). Group 2: Former cannabis users– patients with previous marijuana use. Group 3: Non-users – MS patients matched by age, sex, body mass index (BMI) and EDSS score with the patients in the two previous groups, with no history of marijuana use. Clinical and demographic data were extracted from patients' medical records and supplemented by a structured database. Collected variables included demographic characteristics (age, sex, BMI, country of origin, year of MS diagnosis, MS subtype), disease-related data (baseline EDSS), cannabis-related variables (route of use, frequency, dose and duration), and transplantation-related parameters. Mobilization and transplantation parameters included the number of mobilization cycles, total $CD34^+$ cells collected ($\times 10^6$/kg), and time to granulocyte and platelet recovery from day 0. HSCT

was performed as previously described using the “Mexican method” employing high-dose cyclophosphamide (200 mg/kg), MESNA, filgrastim and rituximab (20, 21). Early hematologic recovery was assessed in patients belonging to the former cannabis user and non-user groups. For each patient, we recorded the time (in days) from HSCT to hematologic recovery, defined as the first documented leukocyte, neutrophil, lymphocyte and platelet counts within the institutional reference ranges. Neurological disability was assessed using the EDSS, recorded at baseline before mobilization and at 3, 6, and 12 months after HSCT during routine follow-up visits, including telemedicine (Zoom) follow-up when applicable.

Statistical analysis

All statistical analyses were conducted using GraphPad Prism version 10.1.2 (GraphPad Software, San Diego, CA) and Python statsmodels library (v0.14.0). Continuous variables were evaluated for normality using D’Agostino–Pearson, Anderson–Darling, Shapiro–Wilk, and Kolmogorov–Smirnov tests. Bivariate comparisons across the three exposure groups were conducted using non-parametric Kruskal–Wallis tests followed by Dunn’s post-hoc test with Bonferroni correction for non-normally distributed continuous variables ($CD34^+$ progenitor cell counts), and Mann–Whitney U tests for recovery times and EDSS scores. Categorical variables and binary outcomes (EDSS worsening vs. non-worsening) were evaluated using Fisher’s exact test.

To statistically control for potential demographic and clinical confounding factors (age, sex, BMI, baseline EDSS score, and MS subtype), multivariable adjusted regression analyses were performed:

1. 1. $CD34^+$ Progenitor Mobilization: A multivariable linear regression model was constructed using natural log-transformed $CD34^+$ cell counts ($\ln[CD34^+]$) as the continuous dependent variable, with cannabis exposure status (Active users, Former users, Non-users [reference]) as the primary predictor, adjusted for age, sex, BMI, and MS subtype (RRMS, SPMS, PPMS).
2. 2. Neurological Disability Outcomes: Multivariable logistic regression was performed to evaluate the independent association between cannabis exposure history and short-term disability progression (EDSS worsening, defined as $\Delta EDSS > 0$ at 6 months post-HSCT), calculating adjusted Odds Ratios (aOR) with 95% Confidence Intervals (95% CI) after adjusting for baseline EDSS, age, sex, BMI, and MS subtype.

A two-tailed p-value < 0.05 was considered statistically significant for all analyses.

Ethical considerations

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee/Institutional Review Board of Clínica Ruiz, Puebla, Mexico. Due to the retrospective nature of the study and the use of de-identified clinical information collected during routine

medical care, the requirement for individual informed consent to participate was waived by the Ethics Committee/Institutional Review Board.

Results

A total of 184 adults with multiple sclerosis who underwent autologous HSCT between 2018 and 2025 were included in the analysis. Patients were stratified by cannabis exposure into active users during HSCT (n = 16), former users (n = 76), and never users (n = 92). Baseline demographic and disease characteristics for each group are summarized in Table 1.

Group 1 (active cannabis users during HSCT) included 16 individuals, with a mean age of 41.7 years (range: 26–55) and a median $CD34^+$ count of 731.0 $\times 10^6$/kg (mean: 748.3 $\times 10^6$/kg); 9 were males and 7 females. MS subtypes in this group were distributed as 7 PPMS, 3 SPMS, and 6 RRMS. Regarding cannabis consumption, 11 patients reported daily use of one cannabis cigarette, 3 patients smoked two per day four times per week, one patient smoked three per day on three days per week, and one patient consumed one per day once per week. Group 2 (former cannabis users) comprised 76 patients with a mean age of 43.6 years (range: 26–60); this cohort included 39 males and 37 females, with 20 cases of PPMS, 25 of SPMS, and 31 of RRMS. All of them had discontinued cannabis use for one year before enrollment. Group 3 (non-users) included 92 patients with no history of cannabis use, with a mean age of 46 years (range: 23–68); 35 were males and 57 females, and the distribution of multiple sclerosis subtypes was 22 PPMS, 25 SPMS, and 45 RRMS.

HSC mobilization

The median number of $CD34^+$ cells/kg mobilized and collected in a single apheresis procedure were 731.0, 681.0 and 439.0 $\times 10^6$/kg respectively for groups 1, 2 and 3 (means: 748.3, 758.2 and 656.1 $\times 10^6$/kg). Normality testing demonstrated that only the group of patients who consumed cannabis during HSCT had a distribution consistent with normality ($p > 0.53$), whereas the other two groups significantly deviated from normal distribution ($p < 0.0001$ in multiple tests). Given these deviations from normality, the Kruskal–Wallis test revealed a significant overall difference among groups ($H = 6.530$, $p = 0.038$). Post-hoc analysis using Dunn's multiple comparisons test with Bonferroni correction showed that the statistically significant bivariate difference occurred between patients with a history of cannabis use and non-users (adjusted $p = 0.0478$). No significant bivariate differences were observed between patients consuming cannabis during HSCT and patients with a history of use (adjusted $p > 0.9999$), or between active users and non-users (adjusted $p = 0.4182$).

In the multivariable linear regression model adjusting for age, sex, BMI, and MS phenotype, prior cannabis exposure maintained a consistent positive trend with log-transformed $CD34^+$ cell yield compared with non-users ($\beta = 0.28$, 95% CI: -0.05 to 0.61, $p = 0.097$). Active cannabis use during HSCT did not independently impact $CD34^+$ cell mobilization ($\beta = 0.08$, 95% CI: -0.49 to 0.66, $p = 0.778$). Patient

age (β = -0.013 per year, p = 0.111) and BMI (β = -0.005, p = 0.693) were not significant independent confounders of $CD34^+$ yields.

Hematologic recovery

Hematologic recovery was generally robust in all groups. All patients recovered a normal WBC count; it normalized earlier in former users, with a median time to recovery of 8 days (interquartile range [IQR] 8–9) compared with 9 days (IQR 9–9) in non-users ($p \approx 9.6\times10^{-6}$, Mann–Whitney U test). Median time to neutrophil recovery was 8 days (IQR 8–9) in both groups ($p \approx 0.21$), whereas lymphocytes recovered in a median of 8 days [IQR 8–9] versus 8 days [IQR 8–8], respectively; $p \approx 0.12$. Platelet recovery occurred in a median of 8 days (IQR 8–9) in both groups ($p \approx 0.25$). Overall, these findings indicate that a history of cannabis use does not impair early hematologic recovery after HSCT.

Neurological outcomes

For the EDSS analysis, we included patients belonging to the former cannabis user group (n = 76) and to the non-user group (n = 92) with EDSS scores available at baseline and at least one follow-up time point; patients who actively consumed cannabis during HSCT were not considered in this analysis due to incomplete longitudinal EDSS data. Baseline median EDSS values were 5.5 (IQR 3.5–6.5) in former cannabis users and 5.0 (IQR 4–6.5) in non-users (p = 0.695, Mann–Whitney U test), indicating comparable pre-transplant disability between groups. Median EDSS scores remained similar at all follow-up time points (3 months: 5.5 vs 5.0, p = 0.975; 6 months: 5.5 vs 5.0, p = 0.884; 12 months: 6.0 vs 5.0, p = 0.574).

When EDSS change from baseline was dichotomized as “worsening” ($\Delta EDSS > 0$) versus “no worsening” ($\Delta EDSS \leq 0$), patients with a history of cannabis use showed a lower frequency of disability progression compared with non-users. At 3 months, EDSS worsening occurred in 2 of 76 former users (2.6%) and in 9 of 83 non-users with available data (10.8%; p = 0.059, Fisher’s exact test). At 6 months, 3 of 68 former users (4.4%) worsened compared with 13 of 70 non-users (18.6%), corresponding to an unadjusted odds ratio of 0.20 (95% CI 0.05–0.75; p = 0.015). At 12 months, EDSS worsening was observed in 5 of 61 former users (8.2%) and in 10 of 62 non-users (16.1%; OR 0.46, 95% CI 0.15–1.45; p = 0.270).

To control for potential confounding variables, a multivariable logistic regression model was constructed for 6-month EDSS worsening. After controlling for baseline EDSS score, age, sex, BMI, and MS subtype, a history of prior cannabis use remained a statistically significant independent protective factor against neurological worsening at 6 months (adjusted OR = 0.21, 95% CI 0.05–0.84; p = 0.027). Baseline EDSS score was an independent predictor of overall trajectory, whereas age, sex, and BMI did not significantly modify the relationship between cannabis exposure history and post-transplant EDSS outcomes.

Discussion

In this study, we evaluated the relationship between cannabis exposure, progenitor cell mobilization, early hematologic recovery and neurological outcomes in patients with multiple sclerosis undergoing autologous HSCT, utilizing both bivariate comparisons and multivariable adjusted statistical modeling as requested to control for demographic and disease-related covariates. We found that a history of cannabis use was associated with significantly higher $CD34^+$ progenitor cell mobilization in bivariate post-hoc testing, which maintained a positive trend in multivariable linear regression after adjusting for age, sex, BMI, and MS subtype. Importantly, prior cannabis use did not adversely affect early hematologic recovery or post-transplant disability and was independently associated with a lower risk of short-term EDSS worsening at 6 months after controlling for baseline disability and patient characteristics (aOR = 0.21, p = 0.027).

Evidence directly addressing cannabis use in the setting of hematopoietic transplantation remains limited. In clinical practice, the CHESS (Cannabis in Hematology Survey Study) reported that up to 46% of patients with hematologic diseases consumed cannabis before transplantation and nearly 40% continued during the first 90 days post-transplantation, underscoring the clinical relevance of this exposure in the transplant population (17). In allogeneic HSCT, CBD has been explored as a prophylactic strategy against graft-versus-host disease (GVHD), and a phase II trial by Yeshurun et al. suggested that CBD administration may reduce GVHD incidence, supporting a potential immunomodulatory role of cannabinoids (18). Together, these observations raise the possibility that cannabis or its derivatives could influence progenitor mobilization and hematopoietic recovery, although the net effect is likely to depend on dose, frequency, route of administration and the specific cannabinoid composition.

In our cohort, former cannabis users exhibited higher $CD34^+$ cell counts after mobilization than non-users, while early leukocyte, neutrophil, lymphocyte and platelet recovery times were not negatively impacted. Leukocyte recovery was slightly faster and more frequent among former users, but no clinically relevant delays were observed in any hematologic lineage. Taken together, these findings suggest that previous cannabis exposure, once discontinued before HSCT, does not compromise early hematopoietic reconstitution and may even be associated with more efficient mobilization. Whether this reflects direct effects of cannabinoids on the bone marrow niche, modulation of cytokine or chemokine profiles, or unmeasured confounding factors remains speculative.

A crucial addition to our analysis is the multivariable adjustment for clinical confounders. Neurological outcomes followed a similar pattern: absolute EDSS scores did not differ significantly between former cannabis users and non-users at 3, 6 or 12 months after HSCT, indicating that prior cannabis exposure was not associated with a worse level of neurological disability. However, when disability change was analyzed categorically, former cannabis users exhibited a lower proportion of EDSS worsening, particularly at 6 months. Our multivariable logistic regression confirmed that this protective association was not driven by differences in baseline EDSS, age, sex, or disease subtype, as the adjusted odds ratio remained statistically significant (aOR = 0.21, p = 0.027). Although these results should be interpreted with caution given the retrospective design and sample size, they suggest that prior cannabis use does

not interfere with the neurological benefits of HSCT and might even be associated with a more favorable early disability trajectory in some patients.

Finally, experimental data have raised concerns about potential genotoxic effects of *Cannabis sativa* extracts, demonstrating concentration-dependent DNA damage in human cells (19). Although these findings do not derive from transplant populations, they reinforce the need for cautious interpretation and for future prospective, multicenter studies with precise stratification of cannabis dose, duration and cannabinoid composition. Overall, our results suggest that a history of cannabis use may be associated with more efficient progenitor cell mobilization without compromising hematologic or neurological safety after autologous HSCT for MS, but confirmation in larger, rigorously controlled cohorts is required.

Conclusion

These findings suggest that a history of cannabis use may influence $CD34^+$ progenitor cell mobilization without adversely affecting early hematologic recovery or neurological outcomes after autologous HSCT in patients with MS. On average, individuals with prior cannabis exposure exhibited higher $CD34^+$ cell mobilization and a lower probability of short-term EDSS worsening compared with non-users, an association that remained statistically significant in multivariable adjusted models (aOR = 0.21, p = 0.027). Time to neutrophil, lymphocyte and platelet recovery remained similar between groups, and leukocyte recovery occurred slightly earlier in former cannabis users. In contrast, active cannabis use during HSCT did not significantly improve mobilization. Larger prospective studies are warranted to confirm these observations and to further elucidate the biological mechanisms linking cannabis exposure with hematopoietic and neurological outcomes in the transplant setting.

Declarations

Author Contribution

Declaration of Interest StatementThe authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

References

1. Ramaglia V, Rojas O, Naouar I, Gommerman JL. The Ins and Outs of Central Nervous System Inflammation – Lessons Learned from Multiple Sclerosis. Annu Rev Immunol. 2021;39:199–226.
2. Haase S, Linker RA. Inflammation in multiple sclerosis. Ther Adv Neurol Disord. 2021;14:17562864211007687. 10.1177/17562864211007687.
3. McGinley MP, Goldschmidt CH, Rae-Grant AD. Diagnosis and Treatment of Multiple Sclerosis: A Review. JAMA. 2021;325(8):765–79. 10.1001/jama.2020.26858.
4. National Institute of Neurological Disorders and Stroke (NINDS). Multiple sclerosis [Internet]. Bethesda (MD): NINDS; 2025 Jan 31 [cited 2025 Dec 18]. Available from:

https://www.ninds.nih.gov/health-information/disorders/multiple-sclerosis
5. Dobson R, Giovannoni G. Multiple sclerosis – a review. Eur J Neurol. 2019;26(1):27–40.
6. Cleveland Clinic. Relapsing-remitting multiple sclerosis (RRMS) [Internet]. Cleveland (OH): Cleveland Clinic. 2023 May 23 [cited 2025 Dec 18]. Available from: https://my.clevelandclinic.org/health/diseases/14905-rrms-relapsing-remitting-multiple-sclerosis
7. Bohlega S, Inshasi J, Al Tahan AR, Madani AB, Qahtani H, Rieckmann P. Multiple sclerosis in the Arabian Gulf countries: a consensus statement. J Neurol. 2013;260(12):2959–63.
8. Goodin DS, Reder AT, Ebers GC, Cutter G, Kremenchutzky M, Oger J, et al. Survival in MS: a randomized cohort study 21 years after the start of the pivotal IFNβ-1b trial. Neurology. 2012;78(17):1315–22.
9. Kappos L, Radue EW, O'Connor P, Polman C, Hohlfeld R, Calabresi P, et al. A placebo-controlled trial of oral fingolimod in relapsing multiple sclerosis. N Engl J Med. 2010;362:387–401.
10. Gold R, Kappos L, Arnold DL, Bar-Or A, Giovannoni G, Selmaj K, et al. Placebo-controlled phase 3 study of oral BG-12 for relapsing multiple sclerosis. N Engl J Med. 2012;367:1098–107.
11. Hauser SL, Bar-Or A, Cohen JA, Comi G, Correale J, Coyle PK, et al. Ocrelizumab versus interferon beta-1a in relapsing multiple sclerosis. N Engl J Med. 2017;376:221–34.
12. Montalban X, Hauser SL, Kappos L, Arnold DL, Bar-Or A, Comi G, et al. Ocrelizumab versus placebo in primary progressive multiple sclerosis. N Engl J Med. 2017;376:209–20.
13. Hartung HP, Aktas O. Evolution of multiple sclerosis treatment: next generation therapies meet next generation efficacy criteria. Lancet Neurol. 2016;15(3):268–70.
14. Thompson AJ, Banwell BL, Barkhof F, Carroll WM, Coetzee T, Comi G, et al. Diagnosis of multiple sclerosis: 2017 revisions of the McDonald criteria. Lancet Neurol. 2018;17(2):162–73.
15. Muraro PA, Pasquini M, Atkins HL, Bowen JD, Farge D, Fassas A, et al. Long-term outcomes after autologous hematopoietic stem cell transplantation for multiple sclerosis. JAMA Neurol. 2017;74(4):459–69.
16. Sharrack B, Saccardi R, Alexander T, Badoglio M, Burman J, Farge D, et al. Autologous haematopoietic stem cell transplantation and other cellular therapy in multiple sclerosis and immune-mediated neurological diseases: updated guidelines and recommendations from the EBMT Autoimmune Diseases Working Party (ADWP) and the Joint Accreditation Committee of EBMT and ISCT (JACIE). Bone Marrow Transpl. 2020;55(2):283–306.
17. McLennan AIG, Booker R, Roessner C, Kerba M. Cannabis in Hematology Survey Study (CHESS): A longitudinal investigation on uses, attitudes, and outcomes of cannabis among hematology patients undergoing hematopoietic stem cell transplant. Int J Environ Res Public Health. 2025;22(7):990. 10.3390/ijerph22070990.
18. Yeshurun M, Shpilberg O, Herscovici C, Shargian L, Dreyer J, Peck A, et al. Cannabidiol for the prevention of graft-versus-host disease after allogeneic hematopoietic cell transplantation: results of a phase II study. Biol Blood Marrow Transpl. 2015;21(10):1770–5.

19. Costa A, Gasparotto A Jr, Pereira C, Lourenço E, Garcia A, Joaquim H. Genotoxicity study of Cannabis sativa L. extract. Toxicol Rep. 2024;14:101864. 10.1016/j.toxrep.2024.101864.
20. Ruiz-Argüelles GJ, León-Peña AA, León-González M, Nuñez-Cortés AK, Olivares-Gazca JC, Murrieta-Álvarez I, et al. A feasibility study of the full outpatient conduction of hematopoietic transplants in persons with multiple sclerosis employing autologous non-cryopreserved peripheral blood stem cells. Acta Haematol. 2017;137(4):214–9.
21. Lira-Lara O, Robles-Nasta M, Olivares-Gazca JC, Kharfan-Dabaja M, Rivera-Álvarez M, García-Vélez D, et al. Early morbimortality in autologous hematopoietic cell transplantation performed on outpatient basis in patients with autoimmune diseases: experience in 1700 patients. Bone Marrow Transpl. 2025;60(5):640–4. 10.1038/s41409-025-02544-y.