Hematopoietic cell transplantation for myelodysplastic syndromes

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ABSTRACT

For patients with myelodysplastic syndromes (MDS), allogeneic hematopoietic cell transplantation (HCT) is considered the only treatment with curative potential. However, its use is restricted to a selected group of patients, and transplant outcomes are influenced by a complex interaction of disease-related characteristics, patient-specific factors, and the HCT procedure. Since the publication of the previous Brazilian consensus, important advances have been made in the classification and risk stratification of MDS. In 2022, two new classification systems have been updated: the World Health Organization classification and the International Consensus Classification. In addition, the incorporation of molecular information through the Molecular International Prognostic Scoring System has further refined prognostic assessment and therapeutic decision making in patients with MDS. This article updates the Brazilian consensus published in 2021 for Brazilian Society of Cellular Therapy and Bone Marrow Transplantation, incorporating recent developments in the management of patients undergoing HCT. It aims to guide hematologists in transplant indication.

Keywords: Myelodysplastic syndromes; Hematopoietic stem cell transplantation; Hematology; Diagnosis; Classification; Therapeutics.

INTRODUCTION

Myelodysplastic syndromes (MDS) are a heterogeneous group of diseases characterized for defective hematopoiesis resulting in peripheral blood cytopenias, dysplasia, to a risk of progression to acute myeloid leukemia (AML)[1,2]. Currently, allogeneic hematopoietic cell transplantation (HCT) is the only treatment option with curative potential for patients with MDS, aiming to prevent leukemic transformation and prolong survival[3]. Given the substantial treatment-related toxicities associated with HCT and the older age profile of most patients with MDS, transplantation is generally recommended for younger and fit patients with higher-risk according to prognostic scoring systems[3].

The number of HCT procedures has increased globally in recent years, mainly due to the growing use of alternative donors and improvements in supportive care, which have made HCT feasible for patient

populations previously considered ineligible, such as older adults[4]. In Brazil, MDS represent the seventh most common indication for HCT according to the annual report of the Brazilian Society of Cellular Therapy and Bone Marrow Transplantation (SBTMO)[5].

The optimal timing of the procedure remains a crucial question, and several factors must be considered when evaluating HCT and its potential benefit in individual patients with MDS[1]. Currently, genomic profiling is used both for diagnosis and risk stratification in routine clinical practice, assisting clinical decision-making processes[1]. In 2022, both the World Health Organization (WHO)[6] and the International Consensus Classification (ICC)[7] allowed the diagnosis of MDS an AML in the presence of certain specific genetic mutations, regardless of blast count. Furthermore, the recently developed Molecular International Prognostic Scoring System (IPSS-M) provides more accurate prognostic predictions for all clinical outcomes compared with the Revised International Prognostic Scoring System (IPSS-R)[8].

Given these important advances in the molecular characterization and prognostic assessment of MDS, the aim of this article was to update the Brazilian consensus previously published by the SBTMO in 2021[9], incorporating recent developments in the clinical management of patients with MDS undergoing HCT to improve patient selection and support clinical decision-making.

CLASSIFICATION AND PROGNOSIS

Historically, the diagnosis and classification of MDS have been the assessment of persistent cytopenias, morphologic dysplasia, and the percentage of bone marrow blasts[10]. However, advances in the understating of the molecular pathogenesis of MDS have changed current disease classification. The recent MDS classifications, the WHO and ICC, both published in 2022, incorporated genetic abnormalities, recognizing biologically distinct disease entities beyond morphologic features alone[6,7] (Table 1). The current WHO classification incorporated genetic features into the diagnostic criteria, distinguishing MDS with defining genetic abnormalities and morphologically defined[6]. Although a bone marrow blast percentage of 20% has been historically used as the main criterion to differentiate MDS from AML, recent WHO and ICC classifications recognize that certain genetic abnormalities may define AML independently of blast count[1,11].

Table 1. Myelodysplastic syndromes (MDS) classification according to World Health Organization (WHO) and International Consensus Classification (ICC), 2022.

WHO 2022[6]	ICC 2022[7]
MDS, genetic abnormalities defined	
MDS with low blasts and isolated 5q deletion	MDS with del(5q)
MDS with low blasts and SF3B1 mutation*	MDS with mutated SF3B1
MDS with biallelic TP53 inactivation	MDS with mutated TP53
MDS, morphologically defined	
MDS with low blasts	
MDS-LB and single-lineage dysplasia	MDS, NOS without dysplasia
MDS-LB and multilineage dysplasia	MDS, NOS with single lineage
MDS with increased blasts 1	MDS with excess blasts
MDS with increased blasts 2	MDS/AML
MDS with ring sideroblasts	MDS, NOS with multilineage dysplasia
MDS, hypoplastic	
MDS with fibrosis	

*When SF3B1 mutation analysis is not available and ring sideroblasts constitute ≥ 15% of erythroid precursors; NOS: not otherwise specified. Source: adapted from Gurnari et al.[1], Khoury et al.[6], and Arber et al.[7].

Somatic mutation analysis represents important tool to the diagnostic evaluation of patients with suspected of having MDS. Germline genetic variants (*e.g.*, DDX41, GATA2, SAMD9/SAMD9L, RUNX1, and ETV6) are increasingly recognized as predisposing factors for MDS development. The identification of patients with an underlying genetic predisposition has important clinical implications, including guiding donor selection for HCT, therapeutic conditioning strategies, and genetic counseling for family members[1,10].

Recurrently mutated genes in MDS involve a broad range of biological pathways, including epigenetic regulators responsible for DNA methylation and histone modification, transcriptional regulators, RNA splicing factors, DNA repair, cohesin complex components, and signaling-related genes. Among them, TET2, ASXL1, and SF3B1 are the most frequently affected, each occurring in at least 20% of patients. Mutations in TP53, SRSF2, RUNX1, and DNMT3A are identified in approximately 10–20% of cases. Alterations in other genes are less common, and most patients harbor multiple coexisting mutations involving distinct molecular pathways[12].

In this context, a broader genomic panel is recommended for disease classification[1,12]. However, in settings in which comprehensive molecular testing is unavailable because of limitations related to infrastructure, cost, or reimbursement, evaluation of TP53 and SF3B1 mutations, in combination with conventional risk factors included in the IPSS-R, such as cytogenetic abnormalities, bone marrow blast percentage, peripheral blood counts, and clinical factors including transfusion dependence, may provide a practical approach for disease classification and risk assessment[1,11]. For prognostic stratification, particularly in patients undergoing allogeneic HCT, mutations involving TP53, RUNX1, ASXL1, and genes within the RAS signaling pathway are associated with an increased risk of post-transplant relapse and mortality[1].

Risk stratification and therapeutic decision-making for MDS can be performed using different scoring systems, such as the International Prognostic Scoring System (IPSS), the IPSS-R, the WHO-based Prognostic Scoring System, the MD Anderson score, and the IPSS-M[8,12–14]. The IPSS-R is the most used and incorporates hematologic parameters and cytogenetic abnormalities, classifying very low, low, and intermediate categories as lower-risk MDS, and high and very high categories as higher-risk disease[12]. More recently, the IPSS-M has been proposed as a novel clinical-molecular prognostic model. This model integrates 31 mutations, hematologic parameters and cytogenetic abnormalities, stratifies patients in six categories and demonstrates improved prognostic discrimination compared with IPSS-R[8,14].

TREATMENT

The treatment is based on the risk stratification of the patient at low-risk (LR) or high-risk (HR) categories, as well as transfusion requirements, bone marrow blast percentage, cytogenetic and molecular profiles, presence of comorbidities, and prior exposure to hypomethylating agents[15]. Therapeutic goals differ according to risk group and prior treatment response[15]. In LR patients, the main objectives are to delay progression to disease and to reduce transfusion dependence, whereas in HR patients, the primary goal is to prolong overall survival[1,15]. Individuals with HR MDS are potential candidates for allogeneic HCT, and transplantation should be pursued as early as clinically appropriate after diagnosis[1].

In LR MDS patients, HCT may be considered in cases of high dependence of transfusions, severe cytopenias, failure of conventional treatments or progressive disease. HCT is also recommended for patients with unfavorable disease characteristics, such as adverse molecular genetic findings or bone marrow fibrosis[15]. Clinical treatment, if necessary, is the best option, based on the use of erythropoietin and oral iron chelators in case of ferritin > 1,000 ng / mL or more than 20 transfusions[1]. In hypoplastic MDS, the indication for transplantation may be according to the severity of cytopenias, failure of immunosuppressive therapy and transfusion requirements[1,16].

ELIGIBILITY

The eligibility depends on patient-related and disease-related risk factors, together with the availability of an appropriate donor[1]. Disease-related factors include somatic mutations profiling, IPSS-M based risk

stratification, and clinical manifestations such as cytopenias, and the risk AML transformation. Factors related to the patient include age, comorbid conditions, performance status (Karnofsky performance status ≥ 80), frailty, and the presence of iron overload, which may warrant chelation therapy[17].

The chronological age alone should not serve as an exclusion criterion for transplantation eligibility in elderly patients[17,18]. Improvements in supportive care, infection management, and the adoption of reduced-intensity and nonmyeloablative conditioning regimens have significantly decreased non-relapse mortality (NRM) after allo-HCT, increasing the feasibility of transplantation in older individuals[18,19]. In a recent study, HCT in elderly patients was shown to be feasible, but it was associated with lower survival when related haploidentical and mismatched unrelated donors were used, as well as an increased risk of mortality with haploidentical and cord blood donors[18,20].

A comprehensive geriatric assessment (CGA) is ideally recommended for all patients and should include an evaluation of frailty, functional status, disease burden, comorbidities, prior therapies, and economic and psychosocial aspects[20]. The CGA is currently considered a fundamental criterion for defining eligibility and type of conditioning[11]. The composite health assessment model score is a novel tool for transplant decision-making in older patients, integrating geriatric assessment, comorbidities, and biomarkers to predict post-transplant NRM[21,22].

DONOR SELECTION

Human leukocyte antigen (HLA)-identical sibling donors continue to be the preferred donor source[23]. When such a donor is not available, alternative options should be considered including related haploidentical donors, matched unrelated donor, HLA-mismatched unrelated donors, and umbilical cord blood units[24]. In recent years, the increased use of haploidentical donors, along with the adoption of post-transplant cyclophosphamide and the growing recognition of the impact of donor age on transplant outcomes, has played a key role in refining donor selection strategies in MDS[23].

In HR patients, hypomethylating therapy should be considered as the initial approach, with azacitidine being the drug of choice, supported by level 1A evidence according to the National Comprehensive Cancer Network guidelines. This agent can be used in the pre-HCT setting while a compatible donor is being identified. The need for mandatory cytoreduction prior to HCT has been questioned, as retrospective studies have not demonstrated significant differences in transplant outcomes. Reducing the time between donor preparation and transplantation may be more clinically relevant[9].

In patients with MDS undergoing HCT, the selection of conditioning regimen and graft-*versus*-host disease (GvHD) prophylaxis is guided by factors such as age, performance status, and disease-related risk. Although reduced-intensity is associated with increased relapse rates and lower NRM compared with myeloablative conditioning, both strategies have shown comparable outcomes in terms of overall survival and progression-free survival[17].

STRATEGIES AFTER ALLOGENEIC HEMATOPOIETIC CELL TRANSPLANTATION

Relapse after HCT continues to represent a major challenge in patients with MDS and remains a significant contributor to post-transplant morbidity and mortality, requiring careful clinical management and ongoing assessment of treatment outcomes[25]. Strategies for relapse prevention include preemptive treatment of patients identified as HR before transplantation, as well as individuals with detectable measurable residual disease after HCT. Therapeutic options include supportive care, donor lymphocyte infusion, gradual reduction of immunosuppression, hypomethylating agents, and cellular immunotherapy[9,25].

Azacitidine has emerged as an important agent in the post-HCT setting due to its immunomodulatory effects and its ability to increase regulatory T-cell (Treg) populations, thereby helping to maintain remission. Some studies suggest that azacitidine may be initiated early in patients with evidence of declining chimerism, potentially preventing disease relapse[9].

The use of azacitidine after HCT may enhance graft-*versus*-leukemia effects without increasing GvHD. In this context, several novel agents have been investigated in MDS, including venetoclax-based combinations, azacitidine with eprenetapopt (APR-246), sabatolimab, magrolimab, tamibarotene, pevonedistat, and IDH inhibitors. Although these approaches showed encouraging efficacy in early-phase studies, subsequent randomized phase III trials have not demonstrated improvements in complete response rates or overall survival[2,26]. The VIALE-A study, a landmark in AML, demonstrated a significant survival benefit with venetoclax plus azacitidine, but similar results were not observed in MDS, as confirmed by the phase III VERONA trial[27].

Other strategies for patients at HR of relapse include maintenance approaches after allogeneic HCT, such as the combined use of hypomethylating agents and donor lymphocyte infusion, which may help reduce relapse risk in HR AML and MDS. This approach is currently being evaluated in the phase II of the GFM-DACORAL-DLI study[28]. Additionally, MDM2 inhibitors such as milademetan (DS-3032b) and APG-115 (alrizomadlin) are being explored in MDS, particularly in TP53 wild-type patients, aiming to restore p53 pathway activity. Early-phase trials have assessed these agents alone or in combination with azacitidine, venetoclax, or low dose of cytarabine. Nevertheless, their clinical benefit remains unproven, and these therapies are still under investigation without regulatory approval[29].

CONCLUSION

Allogeneic HCT should be considered in patients with higher-risk MDS who have preserved performance status and no significant comorbidities. Patients with lower-risk MDS according to IPSS-R may also be considered candidates for HCT in the presence of additional adverse risk factors, such as bone marrow fibrosis or HR molecular features as defined by IPSS-M. The decision to proceed to HCT should be based on a combination of disease-related and patient-related factors, as well as donor availability and graft source. Age *per se* should not be considered a contraindication. Clinical decision-making should balance the risks of transplantation against the life expectancy with or without the procedure, while also incorporating patient's preferences and values.

CONFLICTS OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable.

AUTHORS' CONTRIBUTIONS

Substantive scientific and intellectual contributions to the study: Barroso KSN, Silva RL, Gurgel LA, Leitão JPV, Pitombeira BSGS, Soares RDA and Betarello G. **Conception and design:** Duarte FB. **Acquisition of data:** Barroso KSN, Silva RL, Gurgel LA, Leitão JPV, Pitombeira BSGS, Soares RDA and Betarello G. **Analysis and interpretation of data:** Garcia YDO. **Manuscript preparation:** Garcia YDO. **Manuscript writing:** Duarte FB and Garcia YDO. **Critical revision:** Duarte FB, Garcia YDO, Barroso KSN, Silva RL, Gurgel LA, Leitão JPV, Pitombeira BSGS, Soares RDA and Betarello G. **Final approval:** Duarte FB.

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This manuscript was written by human authors. During the preparation of this work, the authors used ChatGPTto enhance the grammatical accuracy of the text. Following this assistance, all content was carefully reviewed by the authors, who take full responsibility for the final version of the manuscript.

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