Sickle cell disease

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ABSTRACT

Sickle cell disease (SCD) is known as the most common hemoglobin disorder, with severe forms of thalassemia syndromes following closely. Current standard treatments, including transfusions, hydroxyurea, and L-glutamine, still do not significantly improve life expectancy and quality of life for patients. Allogeneic hematopoietic cell transplantation (HCT) remains the only curative option, showing overall survival and event-free survival rates over 90%, especially in patients under 16 years old. However, only 15% of SCD patients have access to an unaffected family donor. To increase donor availability, alternative sources such as matched unrelated donors, unrelated umbilical cord blood, and haploidentical donors have become viable options for patients without a matched related donor. The aim of this article was to update the Brazilian consensus previously published by the Brazilian Society of Cellular Therapy and Bone Marrow Transplantation in 2021, highlighting the latest developments in the treatment and monitoring of patients with SCD undergoing HCT.

Keywords: Anemia, Sickle Cell. Hematopoietic Stem Cell Transplantation. Hematology. Pediatrics.

INTRODUCTION

Sickle cell disease (SCD) is the most common hemoglobin disorder, followed by severe forms of thalassemia syndromes. It is caused by a single point mutation in the adult β-globin (HBB) gene, resulting in a glutamate to valine amino acid substitution in the β-globin chain (βS-globin). The sickle hemoglobin (HbS, α2βS2) tends to polymerize under deoxygenated conditions, forming sickle-shaped red blood cells (RBCs). Sickle RBCs cause hemolytic anemia and block small blood vessels, which impair oxygen delivery to tissues and can result

in multiple organ damage, severe pain, and early mortality[1]. Standard care treatments, such as transfusions, hydroxyurea, and L-glutamine, are still associated with reduced life expectancy and quality of life[2]. Currently, the only available curative treatment for SCD patients is allogeneic hematopoietic cell transplantation (HCT), which offers overall survival and event-free survival rates exceeding 90%[2–4].

PRE-TRANSPLANT CARE

Patients eligible for HCT should have their organ function evaluated (Table 1) and be assessed for complications related to SCD. Previous patient complications can also guide the screening process.

Table 1. Pre-hematopoietic cell transplantation (HCT) evaluation.

Organ/system	Exams	Chronic complications
Hematological system Hemotherapy	Anti-HLA antibody test (mismatch) Extended erythrocyte phenotype Number of transfusions received Ferritin HbS% < 30% before HCT Reticulocyte count Fetal hemoglobin	Alloimmunization DSA Iron overload
Lung	Pulmonary function test Chest X-ray	Previous ACS Thromboembolism Restrictive lung disease Obstructive lung disease Asthma
Heart	Echocardiogram with tricuspid valve evaluation Electrocardiogram	Cardiomegaly Pulmonary hypertension Heart failure Increased left ventricular mass Left ventricular diastolic dysfunction
Central nervous system	Brain MRI Angio MRI Transcranial Doppler ultrasound (up to 16 years old) Neuropsychiatric evaluation	Neurodysfunction Sequelae of previous stroke Stenosis Moya-Moya (no contraindication for transplantation)
Liver and spleen	Liver MRI T2* (according to the number of transfusions and serum ferritin) Abdominal ultrasonography	Gallstones/biliary disease Hyperbilirubinemia Sickle hepatopathy, transfusional hemosiderosis Hepatic fibrosis/cirrhosis Autosplenectomy
Kidney	Glomerular filtration rate Urinalysis Microalbuminuria-creatinine ratio	Albuminuria Hematuria Kidney injury
Routine blood exams	Serologic assay All routine exams pre-HCT	Screening for diseases transmitted by blood transfusion
Endocrine function	Adolescents: ovarian and testis function Thyroid function	Hypogonadism Hypothyroidism Low ovarian reserve Low sperm count
Gynecology-obstetrics	Discussion on the risk of infertility	If considering fertility preservation
Eyes	Ophthalmologist and retina evaluation	Retinopathy
Bone health	Orthopedist	Osteonecrosis Avascular necrosis
Skin	Dermatologist Wound healing team	Ulcers
Multidisciplinary evaluation	Social worker Psychology Psychiatry School Odontologist Nutrition status Pain team — anesthesia	Home and care conditions Anxiety, depression Difficult to learn Treat dental injuries Malnutritional Vaso-occlusive crisis and chronic pain

Source: Elaborated by the authors. HLA: human leukocyte antigen; HbS: sickle hemoglobin; DSA: donor-specific antibodies; ACS: acute chest syndrome; MRI: magnetic resonance imaging.

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RELATED HUMAN LEUKOCYTE ANTIGEN IDENTICAL DONORS

The results of HCT from matched related donors (MRD) for SCD are quite favorable, especially in those under 16 years of age. Five-year overall survival (OS) and event-free survival (EFS) have been reported to be 91–100% and 73–100%, respectively[3]. Additionally, we observed that outcomes (OS and EFS) are still better in patients younger than 5. Consequently, MRD HCT should be provided early in life, prior to the onset of complications[3]. Bone marrow (BM) or umbilical cord blood units (UCB) provide an adequate source of stem cells. Major ABO incompatibilities should be avoided, although their use is not prohibitive[5]. A sickle cell trait donor is acceptable.

In children, myeloablative conditioning (MAC) is the standard and mostly busulfan based. Historically, busulfan (Bu) and cyclophosphamide (Cy) were the mainstay of conditioning for HLA-matched HCT for pediatric patients, with excellent outcomes but significant toxicity. Therefore, to achieve less toxic conditioning in SCD, Cy was replaced with fludarabine (Flu), with outstanding results in the MRD setting in pediatric cohorts[6]. Adding anti-thymocyte globulin has further improved the outcome and is now mandatory[7]. Adults and/or patients with comorbidities can benefit from reduced intensity conditioning (RIC) or non-myeloablative (NMA) to decrease toxicity[5].

Considering the previously published consensus[8], we recommend MAC for patients with MRD, as indicated in Table 2, and BM as the preferred stem cell source (target cell dose of 4 to 5 $\times$ 10^8 TNC/kg) or related UCB (4 to 5 $\times$ 10^7 TNC/kg). Patients under 12 years old without major comorbidities may benefit from conditioning with BuCy, while older patients may undergo FluBu conditioning. Graft-*versus*-host disease (GVHD) prophylaxis should include cyclosporine (starting on D-2) and methotrexate (15 mg/m^2 on D+1 and 10 mg/m^2 on D+3, D+6, and D+11). For UCB, methotrexate should be replaced with another immunosuppressive drug, usually mycophenolate mopetil. Seizure prophylaxis with levetiracetam is preferred while on a calcineurin inhibitor and hypertension control[8].

Monitoring serum busulfan levels is strongly recommended, with a targeted area under the curve of approximately 4.500 mcMol x min/L[9].

Table 2. Conditioning regimen.

	Preferred conditioning regimen
MRD*	Busulfan (dose in Table 3) D-6 to D-3 Fludarabine 30 mg/m^2/d D-7 to D-3 rATG (cumulative dose 4.5–7 mg/kg, according to institutional protocol)
MRD**	Busulfan (dose in Table 3) D-10 to D-7 Cyclophosphamide 50 mg/kg/day D-5 to D-2 rATG (cumulative dose 4.5–7 mg/kg, according to institutional protocol

Source: Elaborated by the authors. *Busulfan should be administered immediately after the fludarabine; **may reverse the order of administering BusulfanCyclophosphamide to CyclophosphamideBusulfan to potentially reduce the risk of sinusoidal obstruction syndrome. It is recommended to have a 48-hour interval between busulfan and cyclophosphamide to lower the risk of veno-occlusive disease; rATG: rabbit anti-thymocyte globulin.

Table 3. Busulfan dose*.

Body weight (kg)	Dose per day	Total dose
< 9	4.0	16.0
9–16	4.8	19.2
16–23	4.4	17.6
23–34	3.8	15.2
> 34	3.2	12.8

Source: Elaborated by the authors. *From the Busilvex Leaflet.

ALTERNATIVES DONORS

Unrelated matched donor

Despite achieving excellent outcomes with HCT–MRD, only 15% of SCD patients have an unaffected family donor. To address this barrier, alternative donors, such as matched unrelated donors (MUD), unrelated UCB, and haploidentical (HAPLO) donors, have increased donor availability for SCD patients lacking an MRD[10].

Historically, the use of MAC and MUD donors was associated with higher toxicity and poorer outcomes compared to MRD transplants. Initial efforts to reduce toxicity with NMA regimens led to high rates of primary and secondary graft failure or rejection. A phase II trial (BMT CTN 0601) using MUD for severe SCD and a RIC regimen of alemtuzumab, fludarabine, and melphalan demonstrated a 75% EFS, but the rates of one-year acute and extensive chronic GVHD were high at 17 and 38%, respectively[11].

The European Society for Blood and Marrow Transplantation (EBMT) reported on 71 patients with SCD who were transplanted with either MRD or MUD, demonstrating that HLA matching was the most significant risk factor for OS. However, even among the MUD, the three-year GVHD relapse-free survival was barely acceptable at 69 ± 9%[12].

More recent approaches have tried to optimize conditioning regimens and GVHD prophylaxis to reduce graft failure while preventing severe GVHD, with some acceptable results[13]. In a registry-based study by the Center for International Blood and Marrow Transplant Research (CIBMTR), 111 patients with SCD received transplants from a MUD. Both MAC and RIC regimens were associated with higher mortality and higher incidence of acute and chronic GVHD, whereas NMA approaches yielded better results. This suggests that inducing immune tolerance, rather than the intensity of the regimen, is the key to improved survival following transplantation for SCD[11].

Unrelated UCB has historically been associated with inferior outcomes. This is attributed to a higher incidence of graft failure, GVHD, and delayed immune reconstitution, resulting in a greater infection vulnerability[14]. Currently, the use of UCB as an unrelated donor source for patients with SCD is not recommended.

HAPLOIDENTICAL DONORS

In recent years, nonmyeloablative conditioning regimens with HLA haploidentical donors and post-HCT cyclophosphamide (PTCy) have made HAPLO-HCT an alternative curative therapy in SCD with almost similar outcomes compared with MSD[15]. Although the initial study conducted by the Johns Hopkins group indicated a high rejection rate of 43%, the authors noted that increasing the total body irradiation (TBI) dose from 200 to 400 cGy was sufficient to achieve better results[16].

The Vanderbilt Global Haploidentical Learning Collaborative (VGC2) has recently led an international initiative to develop HAPLO HCT for SCD by incorporating thiotepa into the Johns Hopkins backbone. This has yielded excellent results in adults, but a higher rejection rate of around 25% in pediatric patients. For this population, VGC2 has strongly recommended suppressing the bone marrow for at least two months before HCT using hydroxyurea and hypertransfusions to maintain hemoglobin levels between 9–10 g/dL, reticulocyte count below 10%, and HbS under 30%. Additionally, the TBI dose should be administered in a single fraction of 400 cGy to patients without access to thiotepa[15]. However, better results have been observed, particularly in the group exposed to thiotepa[15].

Due to these results, the Brazilian group proposed to increase the total pre-HCT Cy and the TBI dose while maintaining thiotepa. This strategy resulted in no graft failures, less toxicity, and excellent OS[17]. Thus, the conditioning regimen suggested in Brazil for HAPLO HCT is illustrated in Table 4.

It is acceptable to use a donor with sickle cell trait, but seeking ABO-compatible donors is essential whenever possible. Another key point is to choose donors who lack donor-specific antibodies (DSA)[18]. If the patient

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Table 4. Haploidentical donors conditioning regimen and graft-*versus*-host disease (GVHD) prophylaxis.

Day	Drug	Dose
-70 to -10	Hydroxyurea	30 mg/kg oral daily or maximum tolerated dose
-9	rATG (D1/3)	0.5 mg/kg IV
-8	rATG (D2/3)	2 mg/kg IV
-7	rATG (D3/3) Thiotepa (D1/1)	2 mg/kg IV 10 mg/kg IV over three hours
-6 and -5	Cyclophosphamide	25 m/kg IV daily
-6 to -2	Fludarabine	30 mg/m^2 IV daily
-1	Total body irradiation in one fraction at the same dose rate (D1/1)	400cGy with gonadal shielding (discontinue any steroids if being used)
0	T-cell-repleted bone marrow	5-8 × 10^6 CD34/kg
+3, +4	Cyclophosphamide (D1 and D2)	50 mg/kg IV daily over 1–2 h (between 60 and 72 hours after marrow infusion) and on D+4, 24 hours after D+3
+5	Sirolimus (anticonvulsant prophylaxis with levetiracetam) Mycophenolate mofetil	Loading dose: 3 mg/m^2 *per os*, not to exceed 6 mg. Maintain a serum level of 5–12 ng/mL 15 mg/kg *per os* three times a day, with maximum daily dose 3 g/day
+35	Discontinue mycophenolate mofetil if chimerism in peripheral blood is complete or when mixed stable and no GVHD	
+365	Progressively taper and discontinue sirolimus if chimerism is complete or stable mixed, and there is no GVHD	

Source: Elaborated by the authors. rATG: rabbit anti-thymocyte globulin.

has DSAs, desensitization may be necessary before the beginning of the conditioning regimen (Table 5). DSAs levels should always be checked and discussed with the HLA team before final donor selection and repeated in 30 days of the conditioning regimen. It is crucial to remember that if desensitization is ineffective, transplantation should be discouraged due to the high risk of rejection and, consequently, a greater risk of mortality. Options available for desensitization include plasmapheresis combined with intravenous gamma globulin, rituximab, daratumumab, bortezomib, and irradiated donor buffy coat[15,19].

Table 5. Desensitization protocol for anti-human leukocyte antigen (HLA) antibodies.

Day of transplant	Regimen	Immunosuppression
-18	Plasmapheresis + IVIG	
-15	Plasmapheresis + IVIG	Mycophenolate mofetil and tacrolimus (from D-18 through D-2)
-13	Plasmapheresis + IVIG	
-11	Plasmapheresis + IVIG	
-1	Plasmapheresis + IVIG	
0	Repeat anti-HLA antibodies	
+1 and +2	Plasmapheresis + IVIG*	

Source: modified from Kassim et al.[15]. IVIG: intravenous gamma globulin; *it will be done if necessary, according to the result of the anti-HLA antibody.

CHIMERISM EVALUATION

Chimerism status in the context of HCT for hemoglobinopathies can be dynamic, with patients exhibiting either complete or mixed donor chimerism[19]. Therefore, monitoring chimerism in this context is fundamentally important. The evaluation should start on D+30 post-HSCT and repeat on D+60, D+90, D+120, D+150, D+180, and D+365 post-HSCT. Whenever possible, split chimerism should be performed.

Bernaudin et al.[20] demonstrated that 44% of patients undergoing MAC transplantation for MRD maintained mixed chimerism one year after HCT, with no effect on graft failure or disease manifestations, unlike HAPLO transplantation, in which mixed chimerism is associated with a higher incidence of graft failure. Managing mixed and unstable chimerism is not well established in the literature. Treatment strategies may include adjustments to immunosuppressive therapy to promote stable chimerism. The mere presence of mixed chimerism does not require intervention (such as donor lymphocyte infusion or a second transplant) in MRD, although this should be considered in the HAPLO context[21].

TRANSFUSIONAL SUPPORT

To reduce the risk of alloimmunization to red cell and HLA antigens before transplant, when indicated, patients should receive transfusions of leukoreduced red cells with ideally extended phenotypic matching. To prevent complications related to sickle cell disease, patients should achieve HbS levels below 30% before starting the conditioning[22]. During transplantation, patients should receive simple transfusions to maintain hemoglobin levels between 9 and 10 g/dL until erythroid engraftment occurs. Due to the risk of central nervous system (CNS) hemorrhage, particularly in individuals with cerebrovascular disease, patients should receive platelet transfusions if their platelet count is < 50,000/μL[5].

TREATMENT OF IRON OVERLOAD

Iron overload in the context of HCT is associated with complications such as engraftment failure, hepatic veno-occlusive disease, and GVHD. Many patients with SCD who are candidates for HCT are on a regular transfusion regimen and develop iron overload[23]. Efforts should be made to adequately chelate iron in these patients before transplantation using simple or combined chelation, aiming to achieve ferritin levels lower than 1,000 ng/mL and ensuring adequate T2* MRI scans of the liver and heart. After red cell engraftment, patients with iron overload should begin phlebotomy or iron chelation therapy as soon as possible[8,23].

LONG-TERM FOLLOW-UP

After HCT, most SCD patients have stable organ function[24]. The Sickle Cell Transplant Advocacy and Research (STAR) Alliance conducted a retrospective registry of 247 SCD patients transplanted between 1993 to 2017 at 13 centers[25]. Graft rejection (10% > one year after HCT) and GVHD (25% of the patients, severe in a third of them) were the main HCT-specific complications. Other significant complications were posterior reversible encephalopathy syndrome (10%), isolated seizures (3%), and stroke (3%, at a median D+47). Careful monitoring of the blood pressure, aggressive management of hypertension, magnesium supplementation, and antiepileptic seizure prophylaxis for the duration of immunosuppression are particularly important to avoid these complications[26].

Organ dysfunctions, defined in the STAR Alliance study, were reported in a significant proportion of patients: 37% pulmonary, 6% cardiac, and 14% had new/worsening CNS status[25]. Splenic function improved after HCT. Excessive iron stores were treated with phlebotomy. Most females had normal luteinizing hormone and follicle-stimulating hormone levels for age, and males had normal testosterone levels, but only one pregnancy was reported in 72 male and female patients of childbearing age. Thirteen patients died at a median of 1.8 year after HCT, seven from GVHD and four from infection.

Very comprehensive long-term follow-up guidelines for sickle cell and thalassemia are available from the Consensus Statement from the Second Pediatric Blood and Marrow Transplant Consortium International Conference on Late Effects after Pediatric HCT and from the HCT in children with hemoglobinopathies, which we endorse in this 2025 consensus update[8,27]. Since pneumococcal sepsis may be a lifelong threat, patients should have their vaccination schedule reinforced and antibody titers checked, as well as they need to be continuously educated to aggressively treat fever and/or infections despite normal leukocyte numbers[26,27].

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CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable.

AUTHORS' CONTRIBUTIONS

Substantive scientific and intellectual contributions to the study: Darrigo Junior LG, Gouveia RV, Kuwahara C, Antunes AA, Sousa AM, Vieira AK, Melgaço AH and Seber A. **Conception and design:** Darrigo Junior LG, Gouveia RV, Kuwahara C, Antunes AA, Sousa AM, Vieira AK, Melgaço AH and Seber A. **Analysis and interpretation of data:** Darrigo Junior LG, Gouveia RV, Kuwahara C, Antunes AA, Sousa AM, Vieira AK, Melgaço AH and Seber A. **Technical procedures:** Darrigo Junior LG, Gouveia RV, Kuwahara C, Antunes AA, Sousa AM, Vieira AK, Melgaço AH and Seber A. **Statistics analysis:** Darrigo Junior LG, Gouveia RV, Kuwahara C, Antunes AA, Sousa AM, Vieira AK, Melgaço AH and Seber A. **Manuscript writing:** Darrigo Junior LG, Gouveia RV, Kuwahara C, Antunes AA, Sousa AM, Vieira AK, Melgaço AH and Seber A. **Final approval:** Darrigo Junior LG.

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REFERENCES

1. Ware RE, De Montalembert M, Tshilolo L, Abboud MR. Sickle cell disease. The Lancet. 2017;390(10091):311–23. https://doi.org/10.1016/S0140-6736(17)30193-9
2. Kato GJ, Piel FB, Reid CD, Gaston MH, Ohene-Frempong K, Krishnamurti L, Smith WR, Panepinto JA, Weatherall DJ, Costa FF, Vichinsky EP. Sickle cell disease. Nat Rev Dis Primer. 2018;4:18010. https://doi.org/10.1038/nrdp.2018.11
3. Cappelli B, Volt F, Tozatto-Maio K, Scigliuolo GM, Ferster A, Dupont S, Simões BP, Al-Seraihy A, Aljurf MD, Almohareb F, Belendez C, Matthes S, Dhedin N, Pondarre C, Dalle JH, Bertrand Y, Vannier JP, Kuentz M, Lutz P, Michel G, Rafii H, Neven B, Zecca M, Bader P, Cavazzana M, Labopin M, Locatelli F, Magnani A, Ruggeri A, Rocha V, Bernaudin F, de La Fuente J, Corbacioglu S, Gluckman E; Eurocord, the Cellular Therapy and Immunobiology Working Party (CTIWP) and the Paediatric Diseases Working Party (PDWP) of the EBMT. Risk factors and outcomes according to age at transplantation with an HLA-identical sibling for sickle cell disease. Haematologica. 2019;104(12):e543–6. https://doi.org/10.3324/haematol.2019.216788
4. Simões BP, Pieroni F, Barros GMN, Machado CL, Cançado RD, Salvino MA, Angulo I, Voltarelli JC. Consenso brasileiro em transplante de células-tronco hematopoéticas: comitê de hemoglobinopatias. Rev Bras Hematol Hemoter. 2010;32(Suppl. 1):46–53. https://doi.org/10.1590/S1516-84842010005000020
5. Stenger EO, Shenoy S, Krishnamurti L. How I treat sickle cell disease with hematopoietic cell transplantation. Blood. 2019;134(25):2249–60. https://doi.org/10.1182/blood.2019000821
6. Limerick E, Abraham A. Across the myeloablative spectrum: hematopoietic cell transplant conditioning regimens for pediatric patients with sickle cell disease. J Clin Med. 2022;11(13):3856. https://doi.org/10.3390/jcm11133856

7. Bernaudin F, Socie G, Kuentz M, Chevret S, Duval M, Bertrand Y, Vannier JP, Yakouben K, Thuret I, Bordigoni P, Fischer A, Lutz P, Stephan JL, Dhedin N, Plouvier E, Margueritte G, Bories D, Verlhac S, Esperou H, Coic L, Vernant JP, Gluckman E; SFGM-TC. Long-term results of related myeloablative stem-cell transplantation to cure sickle cell disease. Blood. 2007;110(7):2749–56. https://doi.org/10.1182/blood-2007-03-079665

8. Darrigo Junior LG, Mello Costa TC, Vieira AK, Albino CD, Navarro Barros GM, Garcia JL, Fortunato LR, Santos FLS, Fonseca G, Guerino-Cunha RL, De Santis GC, Simões BP. Hematopoietic stem cell transplantation in children with hemoglobinopathies: Brazilian Society of Bone Marrow Transplantation Consensus. J Bone Marrow Transplant Cell Ther. 2021;2(4):132. https://doi.org/10.46765/2675-374X.2021v2n4p132

9. McPherson ME, Hutcherson D, Olson E, Haight AE, Horan J, Chiang KY. Safety and efficacy of targeted busulfan therapy in children undergoing myeloablative matched sibling donor BMT for sickle cell disease. Bone Marrow Transplant. 2011;46(1):27–33. https://doi.org/10.1038/bmt.2010.60

10. Gluckman E, Cappelli B, Scigliuolo GM, Fuente JDL, Corbacioglu S. Alternative donor hematopoietic stem cell transplantation for sickle cell disease in Europe. Hematol Oncol Stem Cell Ther. 2020;13(4):181–8. https://doi.org/10.1016/j.hemonc.2019.12.011

11. Eapen M, Kou J, Andreansky M, Bhatia M, Brochstein J, Chaudhury S, Haight AE, Haines H, Jacobsohn D, Jaroscak J, Kasow KA, Krishnamurti L, Levine JE, Leung K, Margolis D, Yu LC, Horowitz MM, Kamani N, Walters MC, Shenoy S. Long-term outcomes after unrelated donor transplantation for severe sickle cell disease on the BMT CTN 0601 trial. Am J Hematol. 2024;99(4):785–8. https://doi.org/10.1002/ajh.27251

12. Gluckman E, Fuente J, Cappelli B, Scigliuolo GM, Volt F, Tozatto-Maio K, Rocha V, Tommaso M, O'Boyle F, Smiers F, Cunha-Riehm CBD, Calore E, Bonanomi S, Graphakos S, Paisiou A, Albert MH, Ruggeri A, Zecca M, Lankester AC, Corbacioglu S; Paediatric Diseases (PDWP) and Inborn Errors Working Parties (IEWP) of the EBMT. The role of HLA matching in unrelated donor hematopoietic stem cell transplantation for sickle cell disease in Europe. Bone Marrow Transplant. 2020;55(10):1946–54. https://doi.org/10.1038/s41409-020-0847-z

13. Rangarajan HG, Abu-Arja R, Pai V, Guilcher GMT, Soni S. Outcomes of unrelated donor stem cell transplantation with post-transplant cyclophosphamide for graft-versus-host disease prophylaxis in patients with severe sickle cell disease. Biol Blood Marrow Transplant. 2018;24(2):413–7. https://doi.org/10.1016/j.bbmt.2017.10.030

14. Ruggeri A, Eapen M, Scaravadou A, Cairo MS, Bhatia M, Kurtzberg J, Wingard JR, Fasth A, Lo Nigro L, Ayas M, Purtill D, Boudjedir K, Chaves W, Walters MC, Wagner J, Gluckman E, Rocha V; Eurocord Registry; Center for International Blood and Marrow Transplant Research; New York Blood Center. Umbilical cord blood transplantation for children with thalassemia and sickle cell disease. Biol Blood Marrow Transplant. 2011;17(9):1375–82. https://doi.org/10.1016/j.bbmt.2011.01.012

15. Kassim AA, de la Fuente J, Nur E, Wilkerson KL, Alahmari AD, Seber A, Bonfim C, Simões BP, Alzahrani M, Eckrich MJ, Horn B, Hanna R, Dhedin N, Rangarajan HG, Gouveia RV, Almohareb F, Aljurf M, Essa M, Alahmari B, Gatwood K, Connelly JA, Dovern E, Rodeghier M, DeBaun MR. An international learning collaborative phase 2 trial for haploidentical bone marrow transplant in sickle cell disease. Blood. 2024;143(25):2654–65. https://doi.org/10.1182/blood.2023023301

16. Bolaños-Meade J, Fuchs EJ, Luznik L, Lanzkron SM, Gamper CJ, Jones RJ, Brodsky RA. HLA-haploidentical bone marrow transplantation with posttransplant cyclophosphamide expands the donor pool for patients with sickle cell disease. Blood. 2012;120(22):4285–91. https://doi.org/10.1182/blood-2012-07-438408

17. Brazilian Society of Bone Marrow Transplantation and Cellular Therapy. Proceedings of XXVIII Annual Meeting of Brazilian Society of Bone Marrow Transplantation and Cellular Therapy. J Bone Marrow Transplant Cell Ther. 2024;5(Suppl. 1). https://doi.org/10.46765/2675-374X.2024v5nSuppl1

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18. Patel DA, Akinsete AM, Connelly JA, Kassim AA. T-cell deplete versus T-cell replete haploidentical hematopoietic stem cell transplantation for sickle cell disease: where are we? Expert Rev Hematol. 2019;12(9):733–52. https://doi.org/10.1080/17474086.2019.1642103

19. Ciurea SO, Al Malki MM, Kongtim P, Zou J, Aung FM, Rondon G, Chen J, Taniguchi M, Otoukesh S, Nademanee A, Forman SJ, Champlin R, Gendzekhadze K, Cao K. Treatment of allosensitized patients receiving allogeneic transplantation. Blood Adv. 2021;5(20):4031–43. https://doi.org/10.1182/bloodadvances.2021004862

20. Bernaudin F, Dalle JH, Bories D, de Latour RP, Robin M, Bertrand Y, Pondarre C, Vannier JP, Neven B, Kuentz M, Maury S, Lutz P, Paillard C, Yakouben K, Thuret I, Galambrun C, Dhedin N, Jubert C, Rohrlich P, Bay JO, Suarez F, Raus N, Vernant JP, Gluckman E, Poirot C, Socié G; Société Française de Greffe de Moelle et de Thérapie Cellulaire. Long-term event-free survival, chimerism, and fertility outcomes in 234 patients with sickle-cell anemia younger than 30 years after myeloablative conditioning and matched-sibling transplantation in France. Haematologica. 2020;105(1):91–101. https://doi.org/10.3324/haematol.2018.213207

21. Abraham A, Hsieh M, Eapen M, Fitzhugh C, Carreras J, Keesler D, Guilcher G, Kamani N, Walters MC, Boelens JJ, Tisdale J, Shenoy S; National Institutes of Health; Center for International Blood and Marrow Transplant Research. Relationship between mixed donor–recipient chimerism and disease recurrence after hematopoietic cell transplantation for sickle cell disease. Biol Blood Marrow Transplant. 2017;23(12):2178–83. https://doi.org/10.1016/j.bbmt.2017.08.038

22. Sharma D, Ogbenna AA, Kassim A, Andrews J. Transfusion support in patients with sickle cell disease. Semin Hematol. 2020;57(2):39–50. https://doi.org/10.1053/j.seminhematol.2020.07.007

23. Angelucci E. How I manage iron overload in the hematopoietic cell transplantation setting. Blood. 2025;145(4):372–82. https://doi.org/10.1182/blood.2023022500

24. Inam Z, Tisdale JF, Leonard A. Outcomes and long-term effects of hematopoietic stem cell transplant in sickle cell disease. Expert Rev Hematol. 2023;16(11):879–903. https://doi.org/10.1080/17474086.2023.2268271

25. Stenger E, Xiang Y, Wetzel M, Gillespie S, Chellapandian D, Shah R, Arnold SD, Bhatia M, Chaudhury S, Eckrich MJ, Kanter J, Kasow KA, Krajewski J, Nickel RS, Ngwube AI, Olson TS, Rangarajan HG, Wobma H, Guilcher GMT, Horan JT, Krishnamurti L, Shenoy S, Abraham A. Long-term organ function after HCT for SCD: a report from the Sickle Cell Transplant Advocacy and Research Alliance. Transplant Cell Ther. 2023;29(1):47.e1–47.e10. https://doi.org/10.1016/j.jtct.2022.10.012

26. Krishnamurti L. Hematopoietic cell transplantation for sickle cell disease: updates and future directions. Hematology. 2021;2021(1):181–9. https://doi.org/10.1182/hematology.2021000251

27. Shenoy S, Gaziev J, Angelucci E, King A, Bhatia M, Smith A, Bresters D, Haight AE, Duncan CN, de la Fuente J, Dietz AC, Baker KS, Pulsipher MA, Walters MC. Late effects screening guidelines after hematopoietic cell transplantation (HCT) for hemoglobinopathy: Consensus Statement from the Second Pediatric Blood and Marrow Transplant Consortium International Conference on Late Effects after Pediatric HCT. Biol Blood Marrow Transplant. 2018;24(7):1313–21. https://doi.org/10.1016/j.bbmt.2018.04.002