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ORIGINAL PAPER

The Impact of the SARS-CoV-2 Pandemic on Bone Marrow Transplants in Brazil

Sacha Krolow e Silva[1,*], Jéssica Manami Seki[2], Helena Angelica Blume[3], Matheus Vinícius Henrique[4], Marcela Silva Fructos[5], Maria Eduarda Meirelles Marchese[5], Júlia de Azambuja Vaniel[6], Thais Matos Silva[6], Ketlin Laufer Schuh[7], Luanna Carla Brandão Pereira[8], Julia Stela Xavier Paim[9], Eduarda Correa Freitas[10], Sandra Maria Gonçalves Vieira[2,10]

1. Universidade Federal do Rio Grande do Sul – Programa de Pós-Graduação em Ciências – Departamento de Bioquímica – Porto Alegre (RS) – Brazil.
2. Universidade Federal do Rio Grande do Sul – Faculdade de Medicina – Departamento de Medicina – Porto Alegre (RS) – Brazil.
3. Universidade Federal do Rio Grande do Sul – Faculdade de Medicina – Departamento de Nutrição – Porto Alegre (RS) – Brazil.
4. Universidade do Vale do Rio dos Sinos – Escola de Saúde – Curso de Medicina – São Leopoldo (RS) – Brazil.
5. Pontifícia Universidade Católica do Rio Grande do Sul – Escola de Medicina – Porto Alegre (RS) – Brazil.
6. Universidade Federal do Rio Grande do Sul – Faculdade de Farmácia – Departamento de Análises – Porto Alegre (RS) – Brazil.
7. Universidade Federal do Rio Grande do Sul – Escola de Enfermagem e de Saúde Coletiva – Faculdade de Enfermagem – Porto Alegre (RS) – Brazil.
8. Universidade Potiguar – Faculdade de Enfermagem – Natal (RN) – Brazil.
9. Universidade Federal do Rio Grande do Sul – Instituto de Ciências Básicas da Saúde – Faculdade de Biomedicina – Porto Alegre (RS) – Brazil.
10. Hospital de Clínicas de Porto Alegre – Porto Alegre (RS) – Brazil.

*Corresponding author: krolowsacha@gmail.com

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ABSTRACT

Introduction: Bone marrow transplantation (BMT) is an established therapy for the treatment of various health conditions. In Brazil, procedures are registered by the Brazilian Association of Organ Transplants (ABTO) and the Hospital Information System of the National Health System (SIH/SUS). The COVID-19 pandemic has forced health systems to adapt to the increased risk of death. **Objectives:** To evaluate the landscape of BMT in Brazil from 2018 to 2024, comparing the pre-pandemic, pandemic, and post-pandemic periods in terms of frequency, type of transplant, registration, and regional distribution. **Methods:** A retrospective descriptive study using data on BMTs performed from January 2018 to June 2024, from the databases of the SIH/SUS and the ABTO, which were subsequently analyzed in an R environment. **Results:** A total of 21,164 BMTs were recorded by ABTO (61% autologous) and 5,841 by SIH/SUS (predominantly allogeneic). A reduction in procedures was observed during the pandemic, followed by a recovery in the post-pandemic period in both databases (ABTO: +32.6% vs. pandemic period; SIH/SUS: +29.1%). ABTO maintained a predominance of autologous transplants (≈ 58-61%), while SIH/SUS showed a consistent predominance of allogeneic transplants (≈ 73-75%), mainly from related donors. There was a strong regional concentration in the Southeast, especially in São Paulo, followed by the South, Northeast, Midwest, and North. The analyses did not show statistically significant differences between regions but showed a post-pandemic growth trend. Regional heterogeneity was observed in terms of the type of transplant and marked inequality in the distribution of transplant centers, with a worse center/patient ratio in the North and Midwest regions. Despite the numerical differences, the databases showed convergent temporal and regional patterns. **Conclusion:** From 2018 to 2024, BMT procedures in Brazil were significantly impacted by the pandemic, with subsequent recovery in both databases. The findings highlight structural inequalities in access to transplantation and reinforce the need for greater integration and standardization of information systems, as well as the expansion of infrastructure in less-served regions.

Descriptors: Bone Marrow Transplantation; Health Equity; Access to Health Services; Epidemiology.

O Impacto da Pandemia do Vírus SARS-CoV-2 *nos Transplantes de Medula Óssea no Brasil*

RESUMO

Introdução: O transplante de medula óssea (TMO) é uma terapia consolidada para o tratamento de diversas condições de saúde. No Brasil, os procedimentos são registrados pela Associação Brasileira de Transplantes de Órgãos (ABTO) e pelo Sistema de Informações Hospitalares do Sistema Único de Saúde (SIH/SUS). A pandemia por COVID-19 fez com que os sistemas de saúde tivessem que se adaptar ao aumento da incidência do risco de morte. **Objetivos:** Avaliar o panorama dos TMO no Brasil no período de 2018 a 2024, comparando os períodos pré-pandêmico, pandêmico e pós-pandêmico quanto à frequência, tipo de transplante, registro e distribuição regional. **Métodos:** Estudo descritivo retrospectivo que utilizou dados sobre os TMO realizados no período de janeiro de 2018 a junho de 2024 a partir das bases de dados do SIH/SUS e da ABTO, que foram posteriormente analisados em ambiente R. **Resultados:** Foram registrados 21.164 TMO pela ABTO (61% autólogos) e 5.841 pelo SIH/SUS (predomínio de alogênicos). Observou-se redução dos procedimentos durante a pandemia, seguida de recuperação no período pós-pandêmico em ambas as bases (ABTO: +32,6% *vs*. período pandêmico; SIH/SUS: +29,1%). A ABTO manteve predominância de transplantes autólogos (≈ 58-61%), enquanto o SIH/SUS apresentou predomínio consistente de alogênicos (≈ 73-75%), principalmente de doadores aparentados. Houve forte concentração regional no Sudeste, especialmente em São Paulo, seguida pelas Regiões Sul, Nordeste, Centro-Oeste e Norte. As análises não demonstraram diferenças estatisticamente significativas entre Regiões, mas evidenciaram tendência de crescimento pós-pandêmico. Observaram-se heterogeneidade regional quanto ao tipo de transplante e marcada desigualdade na distribuição de centros transplantadores, com pior relação centro/paciente nas Regiões Norte e Centro-Oeste. Apesar das diferenças numéricas, as bases apresentaram padrões temporais e regionais convergentes. **Conclusão:** No período de 2018 a 2024, os procedimentos de TMO no Brasil sofreram impacto significativo da pandemia, com posterior recuperação em ambas as bases. Os achados evidenciam desigualdades estruturais no acesso ao transplante e reforçam a necessidade de maior integração e padronização dos sistemas de informação, além da expansão da infraestrutura em Regiões menos assistidas.

Descritores: Transplante de Medula Óssea; Equidade em Saúde; Acesso aos Serviços de Saúde; Epidemiologia.

INTRODUCTION

Bone marrow transplantation (BMT) is a widely recognized therapeutic strategy in the management of various hematological diseases, some solid tumors, bone marrow failure syndromes, hemoglobinopathies, and genetic disorders of metabolism and immunity[1-9]. Hematopoietic stem cells (HSCTs) used in bone marrow transplantation (BMT) can be obtained from peripheral blood, umbilical cord blood, or directly from bone marrow. They can come from the patient themselves (autologous transplant), processed and reinfused after treatment, or from a compatible donor (allogeneic transplant), that is, a family member (related) or a registered volunteer (unrelated) in the Brazilian Registry of Voluntary Bone Marrow Donors (*Registro Brasileiro de Doadores Voluntários de Medula Óssea -REDOME*)[2].

In Latin America, only 15 of the 28 countries have consolidated transplant programs, reflecting large regional disparities[10]. The frequency of bone marrow transplants is influenced by multiple factors, including inequalities in access to specialized healthcare centers, reliance on public funding for procedures performed in private hospitals, a shortage of qualified professionals, and inadequate infrastructure. These challenges result in a transplant rate approximately eight times lower than that observed in the United States and the European Union[10,11], highlighting the need for specific strategies to strengthen the capacity and sustainability of Latin American programs.

The COVID-19 pandemic has significantly impacted bone marrow transplant programs worldwide. Several countries have adopted contingency measures, such as expanding the use of haploidentical transplants[12], in addition to clinical and logistical adaptations in accordance with the recommendations of the European Society for Blood and Marrow Transplantation[13]. Globally, the Worldwide Network for Blood & Marrow Transplantation reported the implementation of emergency protocols, including systematic testing for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), universal graft cryopreservation, donor prioritization, and the incorporation of telemedicine for follow-up[14,15]. Despite these strategies, many centers faced delays, cancellations, and reduced donation rates, requiring intensive fundraising campaigns and the reallocation of resources[16].

In the Brazilian context, the literature on the impact of the COVID-19 pandemic on transplant programs remains scarce and fragmented across the pre-, intra-, and post-pandemic periods, limiting a clear understanding of the national dynamics of BMT. Regarding BMT, the main reports include an increased risk of serious infections among candidates and recipients, as well as logistical difficulties in obtaining hematopoietic stem cells (HSCTs) from allogeneic donors registered in REDOME, due to mobility restrictions imposed during the pandemic[17]. Given this scenario, the present study aims to evaluate the bone marrow transplant (BMT) landscape in Brazil from 2018 to 2024, encompassing the pre-pandemic, pandemic, and post-pandemic periods, with an emphasis on analyzing numerical variations, regional distribution, and technical and operational challenges that influence the performance of Brazilian transplant centers (TCs).

METHODS

Study design

This descriptive, retrospective study aimed to evaluate the landscape of bone marrow transplantation (BMT) in Brazil during the pre-pandemic, pandemic, and post-pandemic periods of COVID-19. The analysis encompassed procedures recorded from January 2018 to June 2024, comparing three defined time intervals: pre-pandemic period – January 2018 to March 2020; pandemic period – April 2020 to March 2022; and post-pandemic period – April 2022 to June 2024[18].

Data sources

The data were obtained from the records of the Brazilian Association of Organ Transplants (Associação Brasileira de Transplantes de Órgãos - ABTO)[19], from the Hospital Information System of the Unified Health System (Sistema de Informações Hospitalares do Sistema Único de Saúde - SIH/SUS) – accessed via the TabNet/DataSUS tool[20] and the REDOME[21]. Information regarding bone marrow transplants (BMTs) performed in the country between January 2018 and June 2024 was included. This study analyzed only BMTs, since the ABTO database does not distinguish between the different types of hematopoietic stem cell transplantation (HSCT) procedures, grouping them under the general category of "BMT". The decision was made not to use data from the Sistema Nacional de Transplantes do Ministério da Saúde (MS)[22], because this system only provides information on an annual basis, without detailing by period, which would limit temporal analysis and comparability across defined intervals.

Comparability between databases

The databases consulted present relevant structural differences. ABTO consolidates data reported directly by the TCs, covering procedures performed in the public and supplementary systems. SIH/SUS, on the other hand, exclusively records procedures financed by the SUS, based on hospital administrative records. These methodological differences imply potential variations related to healthcare coverage, financing, and the timing of data consolidation, and the results should be interpreted in light of these distinctions.

Both databases allowed for temporal stratification compatible with the defined periods (pre-, intra-, and post-pandemic), ensuring uniformity in the comparison between the intervals.

Definitions

BMTs were classified into two main categories: 1) allogeneic – when HSCTs were obtained from a donor different from the recipient, subdivided into related and unrelated; 2) autologous – when HSCs were collected and reinfused into the same patient; 3) funding modality: public, if data only from SIH/SUS, and public and private, for data from ABTO.

Data control and standardization

After extraction, the data underwent internal consistency verification, including checks of totals, category compatibility, and comparisons with official reports from the originating institutions. Transplant categories were harmonized across databases according to each system's original nomenclature. Considering the structural differences between ABTO and SIH/SUS, comparative analyses prioritized temporal trends and proportional distributions, avoiding direct comparisons of absolute values between databases with distinct healthcare coverage. Given the aggregated and non-normal nature of the count data, nonparametric tests were chosen for comparisons between Regions. It is recognized that the temporal structure may introduce dependence between observations from the same Region over the periods, and the results should be interpreted with caution.

Variables analyzed and statistical analysis

The variables evaluated and compared across the three periods included: frequency of BMTs performed, geographic distribution of procedures, type of transplant (autologous or allogeneic), and funding modality (public or private). The data were organized in spreadsheets using Microsoft Excel® and subsequently analyzed in R (R Core Team, version 4.1.1). Descriptive analyses included calculating absolute and relative frequencies, and comparisons between periods were performed at the 5% significance level ($p < 0.05$).

Ethical considerations

This study was approved by the Research Ethics Committee of the Hospital de Clínicas de Porto Alegre (CAAE 90758525.8.0000.5327).

RESULTS

Analyzing the absolute frequencies of BMTs by type (Table 1) in Brazil between the pre-pandemic (January 2018 to March 2020), pandemic (April 2020 to March 2022), and post-pandemic (April 2022 to June 2024) periods, it is observed that ABTO performed a total of 21,164 procedures (12,884 autologous and 8,280 allogeneic), with continuous growth in the total number of transplants: 7,265 in the pre-pandemic period (4,319 autologous and 2,946 allogeneic), 6,816 in the pandemic period (3,987 autologous and 2,829 allogeneic), and 9,037 in the post-pandemic period (5,519 autologous and 3,518 allogeneic). Despite the reduction observed during the pandemic, the post-pandemic period showed a significant recovery, with an increase of approximately 32.6% compared to the pandemic period and 24.4% compared to the pre-pandemic period. The proportional distribution remained relatively stable across the three periods, with a slight predominance of autologous transplants (58%-61%) over allogeneic transplants (39%-42%).

Table 1. Frequency of autologous (auto-HSCT) and allogeneic (allo-HSCT) bone marrow transplants—related (r-alloHSCT) and unrelated (u-alloHSCT)—according to the pre-pandemic, pandemic, and post-pandemic periods in Brazil, 2018–2024: DataSUS and ABTO

Perod	u-alloHSCT DataSUS	r-alloHSCT DataSUS	allo-HSCT DataSUS	auto-HSCT DataSUS	allo-HSCT ABTO	auto-HSCT ABTO
Pre-pandemic	364	829	1,193	429	2,946	4,319
Pandemic	222	723	945	382	2,829	3,987
Post-pandemic	278	1,014	1,292	421	3,518	5,519

Source: Elaborated by the authors based on data retrieved from SIH/SUS, accessed through the TabNet/DataSUS tool and ABTO records.

In contrast, data from SIH/SUS (DataSUS), which only includes procedures performed within the SUS (Brazilian Public Health System), also showed a progressive increase in the total number of transplants, with 5,841 transplants performed throughout the analyzed period: 1,622 in the pre-pandemic period (1,193 allogeneic and 429 autologous), 1,327 in the pandemic period (945 allogeneic and 382 autologous), and 1,713 in the post-pandemic period (1,292 allogeneic and 421 autologous). A decrease is observed during the pandemic period, followed by a recovery in the post-pandemic period, with growth of 29.1% compared to the pandemic period and 5.6% compared to the pre-pandemic period. Furthermore, there is a consistent predominance of allogeneic transplants in the Brazilian Unified Health System (SUS), increasing from 73.55% in the pre-pandemic period to 75.42% in the post-pandemic period. Among allogeneic transplants, the proportion of donors remained highest across all periods (pre-pandemic: 69.49%; pandemic: 76.51%; post-pandemic: 78.48%), while unrelated donors represented a smaller proportion, stable over time.

In the Southeast Region, the state of São Paulo performed significantly more transplants compared to the other states in the Region and the country in all three periods and in both databases (DataSUS: 51.29% in the pre-pandemic period, 52.60% in the pandemic period and 55.63% in the post-pandemic period; ABTO: 48.65% in the pre-pandemic period, 46.14% in the pandemic period and 44.46% in the post-pandemic period). Other states that stood out are Paraná (DataSUS: 10.79% pre-pandemic, 14.62% pandemic, and 12.26% post-pandemic; ABTO: 9.02%, 9.60%, and 9.10%, respectively), in the South Region, and Pernambuco, in the Northeast Region, which also had a significant participation (DataSUS: 6.16% pre-pandemic, 3.69% pandemic, and 5.49% post-pandemic; ABTO: 6.42%, 6.15%, and 6.76%, respectively). In the Midwest Region, Goiás stood out in DataSUS during the pre-pandemic period (0.99%), with no differences compared to the Federal District during the pandemic, which gained prominence in the post-pandemic period (2.04%). However, according to ABTO data, the Federal District was the main representative of the Midwest Region, accounting for 3.69% pre-pandemic, 3.19% during the pandemic, and 4.85% post-pandemic participation in total procedures. In the North Region, the state of Pará registered 0.19% of transplants post-pandemic according to ABTO, although data on procedures is not available in DataSUS23 (Table 2).

Considering the four regions with available data in the ABTO registries, a trend towards regional differences in the total number of transplants was observed, although without statistical significance in the pre-pandemic, pandemic, and post-pandemic periods in the Kruskal-Wallis test [$H(4) = 0.525$; $p = 0.769$]. Spearman's correlation showed a positive temporal trend in all regions ($\rho = 1.00$; $p = 0.333$), reflecting an increase in the total number of transplants in the post-pandemic period. Dunn's post hoc test with Bonferroni correction did not show statistically significant differences in paired comparisons between the regions. Regarding the proportion of autologous and allogeneic transplants, regional heterogeneity was observed. The allogeneic/autologous ratios were 0.28 in the Central-West Region, 0.26 in the Northeast Region, 0.60 in the Southeast Region, and 1.87 in the South Region, indicating a predominance of autologous transplants in the Central-West and Northeast Regions, a more balanced distribution in the Southeast Region, and a predominance of allogeneic transplants in the South Region.

Table 2. Frequency of autologous and allogeneic bone marrow transplants, related and unrelated donors, by region and federative unit, pre-pandemic, pandemic and post-pandemic periods, Brazil, 2018-2024, DataSUS and ABTO.

	Pre-pandemic period						Pandemic Period						Post-pandemic period					
	DataSUS			ABTO			DataSUS			ABTO			DataSUS			ABTO		
Region/state	**Related allogeneic (n = 829)**	**Unrelated allogeneic (n = 364)**	**Total allogeneic (n = 1,193)**	**Autologous (n = 429)**	**Allogeneic (n = 2,946)**	**Autologous (n = 4,319)**	**Related allogen (n = 723)**	**Unrelated allogeneic (n = 222)**	**Total allogeneic (n = 945)**	**Autologous (n = 382)**	**Allogeneic (n = 2,829)**	**Autologous (n = 3,987)**	**Related allogeneic (n = 1,014)**	**Unrelated allogeneic (n = 278)**	**Total allogeneic (n = 1,292)**	**Autologous (n = 421)**	**Allogeneic (n = 3.518)**	**Autologous (n = 5.519)**
Midwest																		
Goiás	7 (0.84)	0 (0.00)	7 (0.59)	9 (2.10)	24 (0.81)	87 (2.01)	1 (0.14)	0 (0.00)	1 (0.11)	0 (0.00)	5 (0.18)	20 (0.50)	3 (0.30)	0 (0.00)	3 (0.23)	2 (0.48)	12 (0.34)	25 (0.45)
Distrito Federal	2 (0.24)	2 (0.55)	4 (0.34)	0 (0.00)	73 (2.48)	207 (4.79)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.26)	47 (1.66)	181 (4.54)	33 (3.25)	0 (0.00)	33 (2.55)	2 (0.48)	107 (3.04)	331 (6.00)
Southeast																		
São Paulo	486 (58.63)	135 (37.09)	621 (52.05)	211 (49.18)	1644 (55.80)	2050 (47.46)	389 (53.81)	94 (42.34)	483 (51.11)	215 (56.28)	1504 (53.16)	1798 (45.10)	562 (55.43)	114 (41.01)	676 (52.33)	277 (65.80)	1818 (51.68)	2200 (39.86)
Rio de Janeiro	36 (4.34)	20 (5.49)	56 (4.69)	25 (5.83)	168 (5.70)	371 (8.59)	48 (6.64)	17 (7.66)	65 (6.88)	27 (7.07)	198 (7.00)	296 (7.24)	59 (5.82)	19 (6.83)	78 (6.04)	42 (9.98)	273 (7.76)	402 (7.28)
Minas Gerais	98 (11.82)	66 (18.13)	164 (13.75)	41 (9.56)	222 (7.54)	493 (11.41)	86 (11.89)	24 (10.81)	110 (11.64)	31 (8.12)	190 (6.72)	488 (12.24)	81 (7.99)	23 (8.27)	104 (8.05)	39 (9.27)	240 (6.82)	611 (11.07)
Paraná	102 (12.30)	72 (19.78)	174 (14.59)	1 (0.23)	363 (12.33)	322 (7.45)	132 (18.26)	60 (27.03)	192 (20.32)	2 (0.52)	347 (12.27)	340 (8.53)	140 (13.81)	65 (23.38)	205 (15.87)	5 (1.19)	382 (10.86)	440 (7.97)
Santa Catarina	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	27 (0.92)	122 (2.82)	1 (0.14)	0 (0.00)	1 (0.11)	0 (0.00)	58 (2.05)	147 (3.69)	9 (0.89)	1 (0.36)	10 (0.77)	0 (0.00)	82 (2.33)	191 (3.46)
Rio Grande do Sul	19 (2.29)	25 (6.87)	44 (3.69)	131 (30.54)	124 (4.21)	324 (7.50)	25 (3.46)	10 (4.50)	35 (3.70)	88 (23.04)	130 (4.59)	380 (9.53)	41 (4.04)	19 (6.83)	60 (4.64)	34 (8.08)	180 (5.12)	485 (8.79)
Northeast																		
Ceará	13 (1.57)	2 (0.55)	15 (1.26)	11 (2.56)	64 (2.17)	183 (4.24)	7 (0.97)	1 (0.45)	8 (0.85)	5 (1.31)	65 (2.30)	155 (3.89)	5 (0.49)	0 (0.00)	5 (0.39)	0 (0.00)	92 (2.61)	179 (3.24)
Pernambuco	60 (7.24)	40 (10.99)	100 (8.38)	0 (0.00)	164 (5.57)	323 (7.48)	33 (4.56)	16 (7.21)	49 (5.19)	0 (0.00)	172 (6.08)	268 (6.72)	63 (6.21)	30 (10.79)	93 (7.20)	1 (0.24)	194 (5.51)	417 (7.56)
Sergipe	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	8 (0.14)
North																		
Pará	NA	NA	NA	NA	NA	NA	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	17 (0.31)

Values presented as absolute numbers (n) and percentages (%). NA = not available. The states of Mato Grosso do Sul, Mato Grosso, Espírito Santo, Maranhão, Piauí, Alagoas, Amazonas, Roraima, Amapá, Tocantins, Rondônia, and Acre were not included because they did not have any data to present, either in the SIH/SUS or in the ABTO records, for the periods analyzed.. Source: Prepared by the authors based on data retrieved from SIH/SUS, accessed through the TabNet/DataSUS tool and ABTO records.

Considering the four regions with available data in SIH/SUS (Central-West, Northeast, Southeast, and South), no statistically significant differences were observed in the total number of transplants between the regions in the pre-pandemic, pandemic, and post-pandemic periods, as indicated by the Kruskal-Wallis test [H(3) = 0.541; $p = 0.763$]. Dunn's post hoc test with Bonferroni correction also did not identify statistically significant differences in paired comparisons between the regions. Spearman's correlation did not demonstrate a significant monotonic association between the number of autologous and allogeneic transplants throughout the analyzed periods ($p > 0.05$). Regarding the proportion of autologous and allogeneic transplants, allogeneic transplants predominated in all regions, with allogeneic/autologous ratios of 3.43 in the Central-West Region, 6.20 in the Northeast Region, 2.60 in the Southeast Region, and 2.76 in the South Region, indicating a greater relative dependence on allogeneic transplants in the Northeast Region.

Despite the quantitative divergence, in which ABTO reports approximately five times more transplants, both databases showed a convergent regional pattern, with a predominance of Southeast > South > Northeast > Midwest > North, with a predominance of allogeneic procedures in all Regions in DataSUS, while ABTO demonstrated a predominance of autologous procedures in the Midwest, Northeast and Southeast Regions, with a higher proportion of allogeneic procedures only in the South Region.

Spearman's correlation between the regional totals across the pre-pandemic, pandemic, and post-pandemic periods showed strong temporal agreement. A perfect positive correlation was observed in the Central-West, Southeast, and South Regions ($\rho = 1.00$; $p = 0.333$), indicating identical temporal behavior. In the Northeast Region, the correlation was moderate and positive ($\rho = 0.50$; $p = 0.667$). The absence of statistical significance is due to the reduced number of time points analyzed, not implying inconsistency between the sources.

Regarding the distribution of unrelated allogeneic TCs by Region, based on REDOME data[21], when compared to the total number of patients on the waiting list for a BMT in the locality, the following is observed: Southeast: 1 TC for every 599.52 patients on the waiting list; South: 1 TC/1,098.75; North: 0 TC/1,436; Northeast: 1 TC/1,565.66; Midwest: 1 TC/1,880 patients. Although the data follow a normal distribution ($p = 0.889$), there is asymmetry in the number of patients per TC across regions (Kruskal-Wallis test, $p = 0.007$), indicating a significant difference in the distribution of TCs between regions.

DISCUSSION

The data collected spanned 78 months, from January 2018 to June 2024, and were standardized in January 2025 to minimize bias introduced by subsequent updates. The choice of the period analyzed, using data from ABTO and DataSUS rather than from the Ministry of Health, was based on the possibility of conducting a more comprehensive temporal analysis, since the end of the Public Health Emergency of National Importance due to COVID-19 in Brazil occurred only in April 2022[18]. Thus, this time frame was considered essential, as extending the analysis to 2024 provides a broader view of post-pandemic trends and contributes to a consistent understanding of the changes that occurred throughout this critical period.

Previous Brazilian studies indicate significant growth in the number of transplants from 2010 to 2019[24]. However, structural differences between ABTO (public and supplementary coverage) and SIH/SUS (exclusively SUS) explain quantitative discrepancies, in addition to reflecting historical regional inequalities, with a concentration of over 60% of transplants in the Southeast Region from 2001 to 2020[25], while the North Region remained without TCs until 2021[23].

Data from ABTO and SIH/SUS follow opposing trends, with DataSUS showing a clear upward trend in allogeneic procedures over the periods, especially with a more balanced division between related and unrelated allogeneic transplants. In contrast, in ABTO, the proportion between allogeneic and autologous transplants remained quite stable, with a slight upward trend in the number of allogeneic procedures. The discrepancies observed likely reflect differences in coverage and registration criteria across the databases, rather than inconsistencies in the data. The differences in the predominance of transplant types by data source should be analyzed with caution, since the data extracted from ABTO includes procedures performed in private institutions or with the participation of health insurance plans, while SIH/SUS deals exclusively with data on BMTs performed in public institutions, based on public funding that may be related to institutional preferences, regional health profiles, or limitations of access to the SUS for certain types of procedures[26].

According to data from the Ministry of Health, in 2024 there were more than 100 TCs authorized by the Ministry of Health, covering 14 states and the five regions of the Brazilian territory, with a greater concentration in the Southeast and South regions[2,21]. The uneven distribution of TCs across regions corroborates the significant differences observed between states in the ratio of bone marrow transplants performed in each federative unit. The higher concentration of TCs in the Southeast Region, particularly in São Paulo, also explains the significantly higher number of transplants in that Region over the years compared to other Brazilian regions and states. Despite performing its first autologous BMT in 2023, the Northern Region still lacks an unrelated allogeneic transplant center listed in the REDOME database. This reinforces the inequality in the distribution of transplant centers across the national territory. Consequently, it can be inferred that gaps in care exist in regions with fewer TCs, leading to a necessary displacement of patients from underserved locations to regions with a higher density of centers[21,24], which generates not only an increase in the costs of care to public coffers, but imposes an additional burden on the patient, who needs to travel to another region in search of adequate treatment[3].

Analysis of donor data in Brazil reveals large regional disparities: the Southeast Region accounts for 44% of the total of more than 5 million registered donors. In comparison, the North Region accounts for only 7%. The difference between these regions exceeds 2 million donors, and the high standard deviation (≈ 834,000) indicates high variability, with the Southeast Region acting as an outlier[21]. In the period from 2017 to 2024, the number of new donor registrations grew until 2019, but has fallen sharply since then, by 75.3% from 2019 to 2024. The total number of registered donors grew from 2012 (3,017,046) to 2024 (5,784,807), with an annual average of 230,647 and a growth rate of 5.9%. The number of transplants, which increased until 2019, fell in 2020 due to the pandemic, recovering in 2023. The regional disparity suggests that factors such as access to information and infrastructure in the Southeast Region, especially in the state of São Paulo, could serve as models for other regions[23,25].

There are some notable differences between the ABTO and DataSUS data. Still, the overall order of the main contributing states remains similar, especially in the Southeast Region, suggesting that regions with a higher volume of transplants tend to have a proportionally similar distribution between the two types of procedures. The COVID-19 pandemic highlighted the health system's vulnerability and fragility in the face of external crises[17,26], impacting, for example, the number of BMTs performed at ABTO. Health system overload, travel restrictions, and the postponement of elective procedures[27] drove this reduction. In addition to this initial impact, the interruption in the registration of new donors was identified as a critical factor in the decrease in BMTs performed. Fortunately, as health systems adopted rigorous protocols and expanded the use of remote monitoring technologies[13,14], as well as introduced vaccines and strengthened transplant teams[14,27], it was possible to increase the number of procedures, as shown in the SIH/SUS data.

Among the limitations of this study, we note a numerical discrepancy between the consulted databases (ABTO and SIH/SUS), resulting from structural methodological differences in healthcare coverage (public sector versus public and supplementary sectors), the primary source of registration, and the criteria for consolidating information. This can lead to information biases, given the absence of individualized linkage between the databases, which prevents the identification of potential overlaps or gaps in registration between the systems and limits the direct comparability of absolute values. The absence of a unified, detailed national database, along with ABTO's generic classification of the term 'BMT' (Bone Marrow Transplantation), which does not distinguish between specific Hematopoietic Stem Cell Transplantation (HSCT) modalities, limits the analysis of specific transplant types within this database. Furthermore, the absence of clinical and sociodemographic variables in the public databases limits the evaluation of factors associated with access, indication, and patient outcomes. The possibility of delayed notification or retrospective updating of administrative data, a phenomenon inherent to secondary health information systems, should also be considered.

CONCLUSION

Between 2018 and 2024, BMT procedures in Brazil showed distinct behaviors across the analyzed databases. Consistent convergence was observed in the overall temporal behavior, with the impact of the pandemic and subsequent reorganization, as well as a high regional concentration of procedures in the Southeast Region, highlighting structural inequalities in the distribution of Transplant Centers and access to treatment, in line with patterns observed in other developing countries. Taken together, the findings indicate that the numerical discrepancies stem predominantly from methodological differences and differences in healthcare coverage across the information systems, rather than from inconsistencies in the underlying epidemiological trend. The robust regional concentration and the influence of structural factors on healthcare dynamics reinforce the need for greater integration, standardization, and transparency among national transplant information systems.

CONFLICT OF INTEREST

Nothing to declare.

AUTHOR'S CONTRIBUTION

Substantive scientific and intellectual contributions to the study: Silva SK, Blume HA; **Conception and design:** Silva SK, Paim JSX; **Data analysis and interpretation:** Silva SK, Blume HA; **Article writing:** Seki JM, Silva SK, Henrique MV, Fructos MS, Marchese MEM, Vaniel JA, Silva TM, Schuh KL, Pereira LCB, Paim JSX; **Critical revision:** Freitas EC, Vieira SMG; **Final approval:** Silva SK.

DATA AVAILABILITY STATEMENT

Data will be available upon request

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DECLARATION OF USE OF ARTIFICIAL INTELIGENCE TOOLS

It was used Deepl for translation of articles.

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