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HEALTHCARE FINANCING FOR BONE MARROW TRANSPLANTS: A SCOPING REVIEW

Damai Santosa[1]*, Chriswardani Suryawati[2], Ayun Sriatmi[2]
[1]Postgraduate Program of Public Health, Faculty of Public Health, Universitas Diponegoro, Jl. Prof. Jacub Rais, Tembalang, Semarang, Central Java 50275, Indonesia
[2]Department of Health Policy Administration, Faculty of Public Health, Universitas Diponegoro, Jl. Prof. Jacub Rais, Tembalang, Semarang, Central Java 50275, Indonesia
*santosaivha@fk.undip.ac.id

ABSTRACT
Bone marrow transplantation (BMT) is a life-saving procedure for haematological malignancies and other severe blood disorders. It is need resource-intensive treatment with significant financial implications. The cost of BMT varies across different countries and healthcare systems, influenced by factors such as treatment protocols, hospital infrastructure, medication expenses, and post-transplant care. Understanding the financial aspects of BMT is crucial for improving accessibility and ensuring sustainable healthcare service. Objective to analyse the cost of BMT across different regions, identify sources of financing, and explore financial challenges and potential solutions for patients undergoing BMT. A comprehensive literature search was conducted using PubMed, Scopus, and Web of Science databases from 2001 - 2025. MeSH Terms using ((haematology malignancy OR leukaemia OR acute leukaemia OR acute myeloid leukaemia OR acute lymphoblastic leukaemia OR myeloma OR lymphoma OR thalassemia) AND (bone marrow transplantation OR stem cell transplantation OR haematopoetic stem cell transplantation OR hematopoietic stem cell transplantation OR allogeneic transplantation) AND (OR costing OR payer)). Data were extracted on total BMT costs, cost components, sources of financing, and financial challenges associated with the procedure. The analysis followed the Cochrane Handbook for Systematic Reviews of Interventions. Out of 528 initially screened studies, 19 articles met the inclusion criteria. The cost of BMT varied significantly by country, with developed nations reporting higher costs than developing countries. The primary cost components included hospital and treatment expenses, medications, and follow-up care. Financing sources varied across regions, including private health insurance, government-funded healthcare programs, non-profit organisations, fundraising efforts, and out-of-pocket payments. Many patients in low- and middle-income countries face financial barriers due to limited insurance coverage and high out-of-pocket expenses. BMT remains a costly procedure with significant financial challenges, particularly in regions with limited healthcare funding.

Keywords: bone marrow transplant; cost analysis; economic impact; financial burden; healthcare financing; health insurance

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INTRODUCTION

Hematopoietic stem cell transplantation (HSCT) is a crucial worldwide procedure for various haematological malignancies, autoimmune diseases, inherited disorders, and solid tumours. Over 70,000 transplants are conducted annually.(Gratwohl, 2018) The cost of bone marrow transplantation (BMT) significantly impacts low-income countries, where access to this curative procedure is limited due to financial constraints. Research has shown that in middle-income countries, less than 10% of patients need a stem cell transplant, with cost being a significant barrier. BMT can be conducted in low and middle-income countries with reduced costs and similar efficacy, making this therapeutic option more affordable and accessible to a larger population. (Poudyal et al., 2022a),(Faulkner et al., 2021a),(J, 2000).

In an era of health care reform, costs, cost-effectiveness, and charges for health care are increasingly important in the decision to adopt a new therapy. (Castle, Elijah; Kimberly, 2021). Bone marrow transplantation is one of the most expensive cancer treatments, costing an average difference in each country per patient; therefore, many economic studies have focused on the costs of the therapy.

(Broder et al., 2017). According to a 2009 report by the Agency for Healthcare Research and Quality, which analysed data from the Healthcare Cost and Utilization Project, HSCT was among the top ten procedures with the highest rise in hospital expenses. Between 2004 and 2007, the hospital costs associated with HSCT surged by 85%, increasing from $694 million to $1.3 billion. This rise was attributed to both higher hospitalisation rates and escalating costs. However, it is essential to note that these findings are not necessarily applicable to developing countries due to financial constraints.(Faulkner et al., 2021a),(Hashmi et al., 2017). This scoping review aims to analyse the health and economic evidence related to the expenses and costs of BMT procedures in children and young adults, specifically from the viewpoint of healthcare systems, total cost, type of payment, and source of financing.

METHOD

The study was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and AMSTAR (Assessing The Methodological Quality of Systematic Reviews).(Page et al., 2021; Shea et al., 2017)

Search Strategy

Data search and reference were performed from search engines from Google Scholar, PubMed, Embase, Cochrane Library, Scopus, and MeSH Terms using ((haematology malignancy OR leukaemia OR acute leukaemia OR acute myeloid leukaemia OR acute lymphoblastic leukaemia OR myeloma OR lymphoma OR thalassemia) AND (bone marrow transplantation OR stem cell transplantation OR haematopoetic stem cell transplantation OR hematopoietic stem cell transplantation OR allogeneic transplantation) AND (OR costing OR payer))

Eligibility Criteria

A comprehensive literature search was conducted to identify relevant studies, with all search results exported to the Mendeley reference manager for efficient data management. Duplicate records were systematically removed, and the titles and abstracts of the remaining articles were screened based on predefined inclusion and exclusion criteria. Studies were included if they were published in peer-reviewed journals in either English or Indonesian, involved patients who underwent bone marrow transplantation (BMT), and reported costs related to BMT, including hospitalisation, medication, procedural expenses, or overall financial burden. This study excluded studies containing review articles, editorials, letters to the editor, and case reports. It retrieved full-text articles that met the inclusion criteria for further evaluation. Any discrepancies in the screening process were resolved through reviewer discussion to ensure methodological rigour and accuracy in study selection.

Study Selection

The systematic search results were entered into reference management software, and duplicates were removed. Two reviewers independently evaluated the articles based on their titles, abstracts, and full texts to determine whether they met the eligibility criteria. Any discrepancies between the two reviewers were resolved through discussion and agreement. If necessary, a third party was involved in resolving disagreements.

Data Extraction

In this systematic review, data were extracted from the included studies to analyse the financial aspects of bone marrow transplantation (BMT) across different healthcare systems. Information collected included the country where the study was conducted, the total cost of the procedure, payment structures, and the source of financing or payer type. The extraction process followed the guidelines outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* to ensure methodological rigour and consistency.

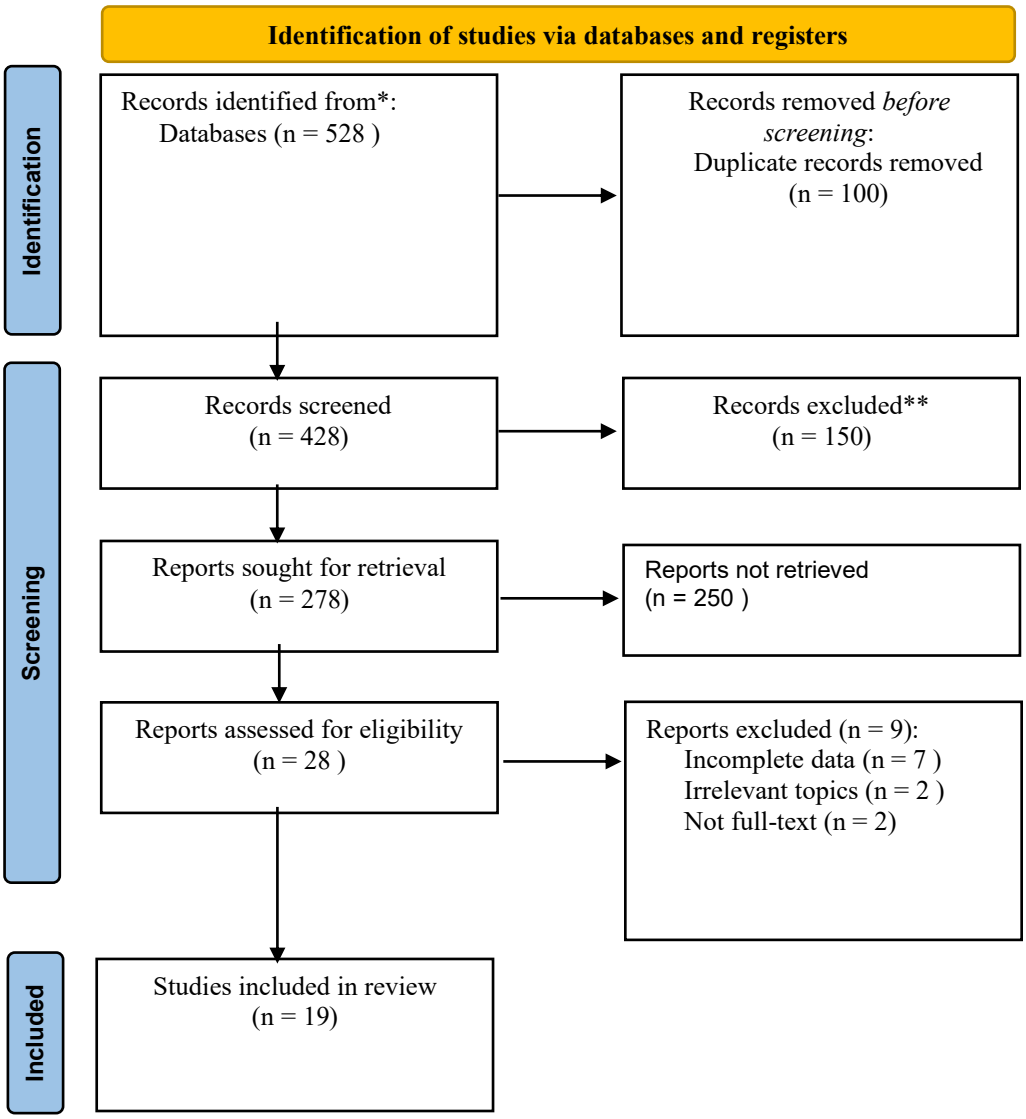

Figure 1. PRISMA flow diagram

Ethical Clearance

This is a systematic review study, so it does not require ethical clearance.

RESULT

Following the PRISMA 2020 guidelines (Figure 1), 528 records were initially screened, and 100 duplicate records were identified and removed, resulting in 428 studies. After applying the inclusion and exclusion criteria, 19 articles were included in this systematic review (Table 1 and Table 2).

Table 1.
HSCT Cost in the world

Country/Transplant Center	Average Cost in USD (median (range))	Description
Multiple centers in USA.(The Cost of Hematopoietic Stem-Cell Transplantation in the United States, 2017)	Allogeneic HSCT with myeloablative regiment: $ 549,208 Allogeneic HSCT with non-myeloablative / reduced-intensity regimen: $432,157 Autologous transplant with myeloablative regimen: $231,259	This data was acquired from commercial Insurance data from Truven Health Market Scan. It represented 1 year cost of 1562 patients that received HSCT between January 1, 2010 and September 23, 2013.
Karolinska University Hospital – Stockholm, Sweden	Allogeneic: €141,493 (about $156953)	This data was from 323 patients receiving allogeneic HSCT from 2003 – 2007. The cost is shown as the mean 1-year cost. The median survival rate in 1 year was 72%.
Multiple Centres in Germany(Mayerhoff et al., 2019)	Allogeneic: €238,333 (about $262,267) Autologous: €107,457 (about $118)410	This data was extracted from one of the German insurance databases that recorded patients receiving transplants from 2010 – 2015.
Children's Hospital of the Pakistan Institute of Medical Science (PIMS)(Faulkner et al., 2011)	$11,513 ($7,518 – $21,176)	This centre is a start-up BMT unit developed and funded by Care2Children (C2C), a non-profit and secular NGO. This newly developed transplant centre is a 2-bed unit. Seven children younger than 10 years old with thalassemia were included in this study. This cost already covered all the procedures, including the follow-up post-BMT cost (median: 17.7 months, range 8.7 – 24.2 months). Of the seven patients admitted, one patient was dead from adverse effects.
South-East Asia Institute for Thalassemia – Jaipur India(Faulkner et al., 2021)	$9,943 ($7,945 - $ 29,813)	These data were collected from three 4-bed unit transplant centres. They covered the cost at 1 year from BMT for children with thalassemia with low-risk features, in good conditions pre-BMT, receiving a matched related graft and GVHD prophylaxis.
People Tree Hospital – Bengaluru India(Faulkner et al., 2021)	$10,741 ($6230 - $40,289)	
CIMS Hospital – Ahmedabad India(Faulkner et al., 2021)	$11,921 ($9382 - $24,102)	
Civil Service Hospital – Kathmandu Nepal(Poudyal et al., 2022)	$5,200 for auto-HSCT $10,200 for MRD-HSCT $13,300 for Haplo-HSCT	This data was collected from a newly developed transplant centre and summarised 66 transplants (30 auto-HSCT, 36 MRD-HSCT, and 12 Haplo-HSCT) in 2016 – 2020. In auto-HSCT, about 87% of patients were alive at median follow-up days (1029, range 130 to 1653 days). In Allo-HSCT, at a median follow-up of 204 days (range 13 – 1130), 75% of patients were alive.
BLK Superspeciality Hospital – New Delhi, India(Sharma et al., 2014)	Autologous: $12,500 ($10,331 - $ 39,367) Allogeneic: $ 17,914 ($10,832 - $ 44,701)	This data was taken from 162 transplant patients (38 autologous and 124 allogeneic) between January 2011 and September 2013 from admission to discharge after engraftment. The highest cost came from pharmacy charges (25.7%)
Dr. Jose E Gonzales University Hospital – Monterrey Mexico	Autologous: $8,528 Allogeneic: $ 12,504	This data was from 50 patients, consisting of 35 adults and 15 children receiving HSCT between January 2010 – February 2011. Thirteen patients (26%) died.
Multiple Centers in Malaysia(Saidon et al., 2020)	Public Hospital: $15,000 Private Hospital: $50,000	This data was described as an estimate of costs from multiple transplant centres in Malaysia.

Table 2.
Source of financing

Country	Source of Financing	Description
United States of America(Gajewski et al., 2004; Narkhede et al., 2022)	1. Private Health Insurance 2. Government Programs (Medicare, Medicaid) 3. Foundations and Non-Profit Organizations 4. Fundraising 5. Personal Source	Private health insurance and government programs are the primary sources of financing. Patients who do not have adequate insurance coverage may rely on foundations, fundraising, or private sources.
Sweden(Fledsberg et al., 2023)	1. Universal Health Coverage 2. Private Insurance 3. Personal Source	Although no specific study mentioned who covered HSCT costs, it was implied that HSCT is covered by universal health coverage (taken from taxes), private insurance, and personal sources.
Germany(Lehne et al., 2016; Nashan et al., 2017)	1. Statutory Health Insurance (SHI) 2. Private Insurance	Around 77% of all the HSCT treatments are covered by the government (SHI), while the other relied on private insurance. The high cost of HSCT is still a burden of SHI, but Germany tried to suppress this burden while maintaining high-quality HSCT.
India(Goel et al., 2022; Kastor & Mohanty, 2018)	1. Government Insurance 2. Private Health Insurance 3. Foundations and Non-Profit Organizations 4. Fundraising 5. Personal Source	Although there are insurances available in India, it is mentioned that no insurance covers less than 20% of Indian people. Some insurance also does not fully cover expensive treatments such as HSCT. This resulted in patients paying higher out-of-pocket costs.
Pakistan(Shamsi et al., 2008)	1. Private Health Insurance 2. Philanthropists, Foundations and Non-Profit Organizations	The government cannot cover the high cost of HSCT in Pakistan; hence, its coverage relies on the private sector or patients' expenses. This leads to low HSCT numbers.
Nepal(Poudyal et al., 2022)	Not mentioned	As Nepal has just developed its first transplant centre, it is not a national program yet, and the program is still in cooperation with the USA.
Malaysia	1. Private Health Insurance 2. Government Insurance Scheme 3. Foundations and Non-Profit Organizations 4. Fundraising 5. Personal Sources	Patients can finance the transplant through private insurance, government insurance schemes, foundations, fundraising, or personal sources.
Mexico	1. Private Health Insurance 2. Government Program 3. Foundations and Non-Profit Organizations 4. Fundraising 5. Personal Source	Patients can use private insurance, private funding, or government programs. After the founding of Seguro Popular in 2004, the government's public health coverage further covered those who did not have formal employment.

Average Cost in Transplant Center

The cost of hematopoietic stem cell transplantation HSCT varies significantly across countries and healthcare systems, influenced by factors such as healthcare infrastructure, insurance coverage, and economic conditions. In the United States, data from commercial insurance records indicate that the average cost of an allogeneic HSCT with a myeloablative regimen is approximately $549,208. In contrast, a reduced-intensity regimen costs around $432,157. Autologous HSCT with a myeloablative regimen is significantly lower, averaging $231,259. Similarly, in Europe, the average cost for allogeneic HSCT at Karolinska University Hospital in Sweden is estimated at €141,493 (approximately $156,953), while in Germany, allogeneic HSCT costs about €238,333 (around $262,267), and autologous HSCT is priced at €107,457 (about $118,410).

In contrast, the cost of HSCT in low- and middle-income countries is considerably lower. At the Children's Hospital of the Pakistan Institute of Medical Science (PIMS), transplant costs range from $7,518 to $21,176, with a median cost of $11,513, while in India, transplant costs vary by centre. The South-East Asia Institute for Thalassemia in Jaipur reports a median cost of $9,943, ranging from $7,945 to $29,813, while People Tree Hospital in Bengaluru and CIMS Hospital in Ahmedabad report median costs of $10,741 and $11,921, respectively. Nepal's Civil Service Hospital provides transplants from $5,200 for autologous HSCT to $13,300 for haploidentical HSCT, reflecting a more affordable approach in a newly developed transplant centre.

Other regions also show significant variation in transplant costs. In Mexico, Dr. Jose E. Gonzales University Hospital reports costs of $8,528 for autologous HSCT and $12,504 for allogeneic HSCT. In Malaysia, public hospitals offer transplants for approximately $15,000, whereas private hospitals charge significantly more, with costs reaching up to $50,000. Additionally, BLK Superspeciality Hospital in India reports autologous HSCT costs ranging from $10,331 to $39,367, with a median cost of $12,500, while allogeneic HSCT ranges from $10,832 to $44,701, with a median cost of $17,914. These variations highlight the financial burden associated with HSCT, emphasising the need for equitable healthcare financing strategies to ensure broader access to this life-saving procedure.

Funding of HSCT in Different Countries

The financing of HSCT varies widely across countries, depending on the structure of their healthcare systems and the availability of financial support mechanisms. In the United States, HSCT is primarily funded through private health insurance and government programs such as Medicare and Medicaid. However, patients who lack sufficient insurance coverage often rely on financial assistance from foundations, non-profit organisations, personal savings, or fundraising efforts to cover the substantial costs associated with the procedure.

In Sweden, where universal health coverage is funded through taxation, HSCT costs are primarily covered by the public healthcare system, supplemented by private insurance and personal contributions when necessary. Similarly, in Germany, approximately 77% of HSCT treatments are financed through the country's Statutory Health Insurance (SHI), while the remaining costs are covered by private insurance. Despite significant government support, the high cost of HSCT continues to burden the healthcare system financially, prompting efforts to balance cost containment with the maintenance of high-quality care.

In contrast, lower- and middle-income countries face more significant challenges in financing HSCT. In India, although government and private health insurance schemes exist, less than 20% of the population is covered, and many insurance plans do not fully cover the high costs of HSCT. As a result, patients often resort to personal savings, fundraising, or support from non-profit organisations. Similarly, Pakistan's government does not provide HSCT coverage, leaving patients dependent on private insurance, philanthropy, or out-of-pocket payments, which significantly limits

access to the procedure. Nepal, having recently established its first transplant centre, has not yet incorporated HSCT into a national healthcare program, and the initiative remains largely dependent on international collaboration, particularly with the United States.

In Malaysia, patients have multiple financing options, including private health insurance, government insurance schemes, and support from non-profit organisations or fundraising campaigns. Similarly, in Mexico, HSCT is funded through private insurance, government healthcare programs, and non-profit organisations' assistance. The introduction of Seguro Popular in 2004 expanded government coverage to individuals without formal employment, improving access to transplantation services for a more significant population segment.

Overall, disparities in HSCT financing highlight the challenges different healthcare systems face in providing equitable access to this life-saving procedure. While high-income countries rely on comprehensive insurance schemes and government funding, patients in low- and middle-income nations often struggle with financial barriers, underscoring the need for improved healthcare policies and international support to ensure broader access to HSCT worldwide.

DISCUSSION

The high cost of treatment in certain regions further restricts access, making affordability a considerable concern. Additionally, living expenses during treatment, including accommodation and transportation, add to the financial burden.21 Alternative solutions such as medical travel, where patients seek treatment in countries with lower BMT costs, and community support initiatives can help mitigate financial challenges. Strengthening financial aid programs, expanding insurance coverage, and increasing support from non-profit organisations can further improve accessibility to life-saving BMT procedures for patients worldwide.20-25. In countries with strong public health systems, such as the UK and Canada, most costs are covered by government programs for eligible citizens. However, additional payment may still be required and can be covered through private insurance, foundations, or private sources. Private health insurance is essential in financing bone marrow transplants in countries such as the United States, India, Singapore, Thailand, and Mexico. Patients who do not have adequate insurance coverage may rely on foundations and non-profit organisations, fundraising, or private sources to cover the costs.(Faulkner et al., 2021b; Jaime-Pérez et al., 2015; Sharma et al., 2014) Fundraising through online campaigns, charity events, or local communities is also an essential source of financing for patients who need additional financial assistance. In addition, some countries, such as Singapore and Mexico, have health savings programs or government insurance schemes that can be used to help finance bone marrow transplant procedures.15-20. For patients with adequate health insurance or access to a public health system, the cost of a bone marrow transplant may be more affordable in their home country. However, for patients who do not have sufficient insurance coverage or live in high-cost countries, seeking options in lower-cost countries such as India, Thailand, or Indonesia may be an alternative worth considering, as long as quality of care is assured.

CONCLUSION

In summary, the expenses and costs of BMT procedures for children and young adults remain a problem in the country, especially from a health and economic perspective. The total cost of the BMT procedure varies between developed and developing countries. The source of payment also varies between countries or regions. To identify the total cost of the BMT procedure, we must calculate all the cost components above based on the cost of each country or region. Further research is needed on the unit cost of BMT for each procedure, both allogenic and autologous. This is very important, especially in developing countries with limited resources in the era of national health insurance because it is very important to consider cost and quality. It is also necessary to create a foundation to help fund donations for BMT procedure.

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