

Cost and Cost-Effectiveness of Treating Childhood Cancer at Jimma Medical Center

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Background: More than 70% of childhood cancer patients die in Sub-Saharan African countries due to a lack of access. Additionally establishing a childhood cancer treatment service is perceived as expensive by the decision-makers of LMICs. However, there is a paucity of evidence on the actual cost and cost-effectiveness of this service in LMICs including Ethiopia. This study provides context-relevant evidence to consider childhood cancer treatment in the healthcare priority settings in Ethiopia and other LMICs.

Methods: Newly admitted case files of children for the year 2020/21 were reviewed. The cost was analyzed from the provider's perspective. The effectiveness was calculated using DALY averted based on the 5 years of survival rates, which is estimated from the 1-year survival rate of Kaplan–Meier output. The do-nothing was our comparator, and we assumed no cost (zero cost) will be incurred for the comparator. To account for sensitivity analyses, we varied the discount rate, 5-year survival rate, and life expectancy.

Results: During the study period, 101 children were treated in the unit. The total annual and unit cost to give treatment to childhood cancer patients was estimated at \$279,648 and \$2769, respectively. The highest per-patient annual unit cost of treatment was Hodgkin's lymphoma (\$6252), while Retinoblastoma (\$1520) was the least. The cost per DALY averted was \$193, which is significantly less than Ethiopia's GDP per capita (\$936.3). The results remained very cost-effective in sensitivity analyses.

Conclusion: Childhood cancer treatment is very cost-effective in Ethiopia as per WHO-CHOICE thresholds even in a conservative adjustment of assumptions. Therefore, to enhance and improve children's health, childhood cancer should get a better concern in health priority.

Keywords: unit cost, cost-effectiveness, childhood cancer, Ethiopia

Introduction

In the global priority to control non-communicable, adult cancer has received the highest focus.¹ Additionally, there is a false perception that chronic diseases such as cancer are a disease of adults only and that it does not affect children.² However, the truth is any part of the population and any portion of the body can be affected by cancer.³

Every year approximately 160,000 new cases and 90,000 children die due to cancer.⁴ When measuring the global burden of childhood cancer using disability-adjusted life years (DALYs), its actual number and death are low, but the burden of the disease is higher than any other disease in children and cancer in adults.⁵

Globally 11.5 million DALYs were contributed by childhood cancer, and more than 80% of the disease burden affected LMICs in 2017.⁶ Additionally, due to inaccessibility and not being able to pay for the care more than 70% of childhood cancer patients die of this disease in LMICs.⁷ In Ethiopia, childhood cancer frequency is rising at an alarming state.⁸ As stated by Tikur Anbessa Specialized Hospital clinical record, there were nearly 6000 incidents of childhood cancer per year in Ethiopia.⁹

The perception of establishing childhood cancer treatment is very expensive is among the major reason that hinders LMICs from considering this treatment scheme a national health priority.^{6,10} The policymakers in LMICs often also face difficulty in the allocation of resources due to the absence of credible information on the cost-effectiveness of different healthcare interventions.¹⁰

Furthermore, most of the previous studies in LMICs on cost and cost-effectiveness analysis of childhood cancer treatment have a limitation on their costing methodology and omission of key cost inputs which significantly underestimates total cost.⁶ The other gap of most research in LMICs is that they use top-down and gross costing approaches to conduct cost analysis studies.¹¹

Most importantly, to our knowledge in Ethiopia, no study has demonstrated the establishment of a pediatric oncology service to be a reasonable use of insufficient resources with competing healthcare demands. To address this gap, we undertake a cost and cost-effectiveness analysis of a pediatric cancer treatment unit in Jimma Medical Centre (JMC). Besides, in this study, we tried to include all cost inputs for the analysis to avoid underestimation of total costs, we also conducted the costing analysis by using mixed methods of bottom-up micro-costing and top-down approaches to reach reliable and precise cost estimation.¹¹ Therefore, to determine the total cost of treating childhood cancer in Jimma Medical Centre and to find whether treating childhood cancer in the center is cost-effective or not.

Methods

Study Area and Period

The study was conducted at Jimma Medical Centre (JMC) which is the only teaching and referral hospital in southwest Ethiopia with an 800-bed capacity and a catchment population of over 15 million.¹² It gives services to about 15,000 inpatients, 11,000 emergency cases, and 4500 deliveries per year.¹³

The establishment of cancer treatment centers in five teaching referral hospitals was one national cancer control and treatment strategy.¹⁴ One of these five hospitals is Jimma Medical Center Pediatric Oncology Unit (JMCPOU).⁴ In this unit, there are 22 beds with one oncologist, four residents, and 14 nurses.

Study Population

All children with cancer who were admitted to JMCPOU were the source population, and among these, all patients in the year 2020/21 fiscal year (July 8, 2020, to July 7, 2021, ie, the 2013 Ethiopian Fiscal Year) were included for this study. The cost analysis of this study was conducted from the provider's perspective.

The Study Comparator, Thresholds, and Discount Rate

In the treatment unit, there is no other option to treat cancer in children, therefore we chose no treatment (do nothing) as our comparator to the childhood cancer treatment unit of JMC. Currently, the types of treatment available in JMCPOU are chemotherapy and surgery.

The cost-effectiveness of treatment is interpreted based on the WHO-CHOICE thresholds.¹⁵ We used a 3% discount rate for the effectiveness of the treatment unit based on the WHO-CHOICE recommendation.

Data Collection and Analysis Procedures

Costs

A mixed methodology of bottom-up micro-costing and top-down gross costing approaches was employed to arrive at a reliable and precise cost estimate. After the classification of costs into recurrent costs and capital costs, a detailed conceptual tool was formulated.

All costs were adjusted for the average annual exchange rate of 2020 (\$1:00 USD = 39.4 ETB), for conversion from Ethiopian currency (ETB) into USD to make an easier international comparison.¹⁶

Unit Cost Determination for Each Type of Cancer

To determine unit costs for each type of childhood cancer patient, two different methods were used. The first is to determine the unit cost of personnel, overhead, building, and equipment, we calculated the annual cost for each type of cost. Then, we allocated it to each type of cancer based on the annual proportion of each type of patient stay in the hospital. The second method is to determine the costs of drugs, diagnostics, and the operating room. For this, we collected the utilization of each patient from their respective case files then, we aggregated each type of cancer.

Recurrent Costs

Personnel Costs

To determine unit personnel costs, we identified all medical hospital staff involved in the treatment of childhood cancer patients, including pediatric oncologists, pediatric surgeons, residents, nurses, and pharmacists.

To calculate full-time equivalent medical staff costs using this approach, each medical staff's yearly salaries including fringe benefits were collected. We calculated the staff cost of the non-dedicated medical staff their annual salaries were allocated to the proportion of their time dedicated to the unit.

Chemotherapy and Supportive Care Medications Cost

To allocate the cost of the drug to each type of cancer individual patient utilization was obtained from the pharmacy registry of the oncology treatment unit. This data was started to be collected electronically in the treatment unit for half of the study year using Microsoft Excel.

In this registry, all types of medications prescribed were recorded and whether they had been given to patients or ordered to be bought from outside was recorded. If the drug was not available in the pharmacy there was an NGO that would buy the drugs. And, to avoid the underestimation of the drug costs, we obtained the data on those drugs bought by this NGO from its finance office. The data were available only for six months in our study period. However, because we aimed to determine the annual cost, we multiplied the six-month data by two and the annual cost of drugs was obtained. Unit prices were obtained from the hospital pharmacy department.

Operating Room (OR) Cost

The OR costs associated with pediatric cancer patients were determined by identifying which type of procedure those patients had undergone surgery. Then, the unit cost was obtained from the Liaison office of the hospital.

Diagnostic Cost

It includes laboratory tests, radiology, and pathology. The quantity of each type of diagnostic test was collected from each patient's case file. The collected data were aggregated for each type of cancer patient. The diagnosis test unit costs were obtained from the hospital's main laboratory office of finance.

Overhead Costs

The overhead costs for the treatment unit include administrative personnel, water, electricity, supplies, consumables for a test, transport for blood products, information technology, building, and equipment maintenance. We used a markup method, to obtain the overhead cost of the pediatric oncology unit by assuming the total direct costs of treatment units are the same proportion as the total direct cost of the hospital.

Capital Costs

Equipment Cost and Building Cost

The furniture and other equipment that is specifically used by the centers such as beds, shelves, computers, and refrigerators were identified. The annual value of the building and each piece of equipment were determined by using the annualization method. The replacement value of the equipment was determined by obtaining the market prices of each item at the time of data collection.

To obtain the replacement value of building costs, we obtained the unit cost of constructing a one-meter square of a similar building. Then, to obtain the total current cost of the building, we multiply this cost by the total m² of the childhood cancer treatment unit occupied.

Thirty years of useful life years were used for building 16, and each piece of equipment's useful life years was obtained from the WHO-CHOICE project.¹⁷ The interest rate was obtained from local banks.

For the annual cost of equipment/building costs, we determined the annuity function which was calculated based on each equipment/building life year and interest rate. Annuity functions were obtained from the Drummonds.¹⁸ Finally, the annualized value of each piece of equipment and building was determined.

Outcomes

The effectiveness of the pediatric oncology unit was determined by collecting data on incidence cases of pediatric cancer patients within the study timeframe from the JMCPOU. During treatment, children suffer from a diminished quality of life; for this, we account for the Global Burden of Disease disability weight.¹⁹ In addition, because the average length of therapy varies based on the type of cancer, we used the median years “on therapy”, to obtain the length of disability.

The age of each patient at the time of diagnosis was collected to obtain the median age at the time of diagnosis. We derived potential life lost at the time of death using the Ethiopian population’s life expectancy.²⁰

The other information that was collected was the date of patients who died within one year after the treatment, those who lost to follow-up, and their respective last contact before the loss to follow-up. With this information, we estimated the one-year survival rate of patients using Kaplan–Meier survival analysis. Then, the 5-year overall survival rate was estimated using a study in Chennai, India²¹.

We used this study to estimate our 5-year survival rate because there are no other studies. LMICs that can be related to our study that analyses the 5-year survival rate of all types of cancer. The Chennai, India study reveals that the average 5-year survival of all types of cancer patients is 62% of the 1-year overall survival of pediatric cancer patients.²¹ Therefore, we estimate the 5-year survival rate for our study using this same proportion of 62% 1-year survival rate. All of the above important parameters are listed in Table 1.

To calculate the DALY of pediatric patients if they had not gotten treatment (without intervention), we assumed they will die within one month after they have been diagnosed with cancer in parallel to previous literature.^{24,25} However, we conducted this in sensitivity analysis by varying the patients who will die within months and one year. Finally, the difference between the two DALY scenarios is considered as DALY averted by the JMC pediatric oncology unit.

Table 1 Variables and Sources Included in the Cost-Effectiveness Model

Base Case Variables	Values	Sources
Number of incidents per year	101	JMC pediatric oncology unit data
Discount rate	0.03	WHO-CHOICE ²²
Average Length of disability (in a year)	1	Assumed for the length of therapy
Disability weight during therapy	0.288	GBD ⁵
The life expectancy of the Ethiopian population	58.71	Macro Trends (2020) ²⁰
Ethiopia’s GDP per capita	\$936.30	The World Bank (2020) ²³
Mean age at diagnosis (in a year)	8	Calculated
The proportion of patients with 1-year survival	76.76	Calculated using Kaplan-Meier survival analysis using SPSS
The proportion of patients with 5-year survival	47.59	Assumed; authors’ best estimates using 1-year survival data, and the ratio of 5:1-year survival similar to Swaminathan ²¹
Adjustments for sensitivity analysis Variables		
Disability weight for a treated form of non-Hodgkin’s lymphoma (adjustment for utility)	0.06	GBD. ¹⁹
Discount rate	0 and 0.06	WHO-CHOICE ²²
15% decrease in life expectancy	49.90	Calculated
30% decrease in the 5-year survival rate	41.09	Assumed
20% increase in annual Personnel and overhead costs	-	Assumed

Abbreviations: GBD Global burden of disease, JMC Jimma Medical Centre.

Sensitivity Analysis

In the Sensitivity analysis, the cost parameters we varied to include increasing medical personnel costs by 20%, this is because it is believed certain staff such as doctors are overburdened and work many more hours per week than the contract's working hours. The other cost parameter is the overhead cost, this is because the markup method assumes a linear relationship between direct and indirect costs but children with cancer need special care, so they might use more overhead costs. Therefore, we increased the overhead cost by 20%.

The outcome parameters that were varied in sensitivity analysis include varying all parameter discount rates between extremes of 6% and 0%, the estimated value of five years survival rate, and the life expectancy of childhood cancer survivors. Additionally, to account for long-term morbidity, we applied the GBD disability weight for non-Hodgkin's lymphoma (0.06) across the life course of all types of cancer survivors.

Data Quality Management

Tools were adopted from the literature and modified based on a study of interest.^{10,11,24} The collected data were analyzed using SPSS to estimate the one-year survival rate and Microsoft Excel 2019 for other forms of analysis.

Results

Distribution of the Types of Cancer and Their Costs

During the study period, 101 children with clinically suspected childhood cancer were registered in (JMCPOU) and started treatments. Among these patients, 55 patients were men (Table 2).

Among the patients included in the study, more than one-third (42) patients were acute lymphoblastic leukemia (ALL), and 13 patients were Wilms tumor (WT). These two types of cancers account for more than half of all patients during the study period.

The annual cost to provide treatment to a new pediatric cancer unit in JMC, Jimma, Ethiopia; was estimated to be \$279,648 for the year 2020/21. The highest total cost of all types of cancer was incurred for ALL, and it has a large composition and accounted for more than one-third of overall total costs. The least total cost incurred among major types of cancer treated in the center is RMS patients (Table 2).

On the other hand, among the major cost categories of the pediatric unit, the annual medical personnel cost was the largest single component accounting for 39% of all costs (Table 3), while the least-cost component of the total cost is the operating room cost of 0.1%.

Table 2 Distribution of the Types of Cancer and Their Costs in Different Genders

Type of Cancer Diagnosis	Sex		Percentage of the Patients	Total Annual Cost
	Male	Female		
Acute Lymphoblastic Leukemia (ALL)	23	19	41.6%	\$101,069
Wilms tumor (WT)	5	8	12.8%	\$43,761
Retinoblastoma (RB)	5	4	8.9%	\$30,398
Hodgkin's lymphomas (HL)	6	1	6.9%	\$17,821
Non-Hodgkin's lymphoma (NHL)	4	1	5%	\$13,708
Rhabdomyosarcoma (RMS)	3	2	5%	\$13,676
Osteosarcoma (OS)	2	3	5%	\$10,232
Acute Myeloid Leukaemia (AML)	0	4	4%	\$9235
Other*	7	4	10.9%	\$39,748

Notes: *Neuroblastoma, Hepatoblastoma, Ewing's sarcoma, Burkitt lymphoma, nasopharyngeal cell, Germ cell tumor, and Bladder Mass.

Table 3 The Annual Total Cost of Major Cost Categories in the JMC Pediatric Oncology Unit

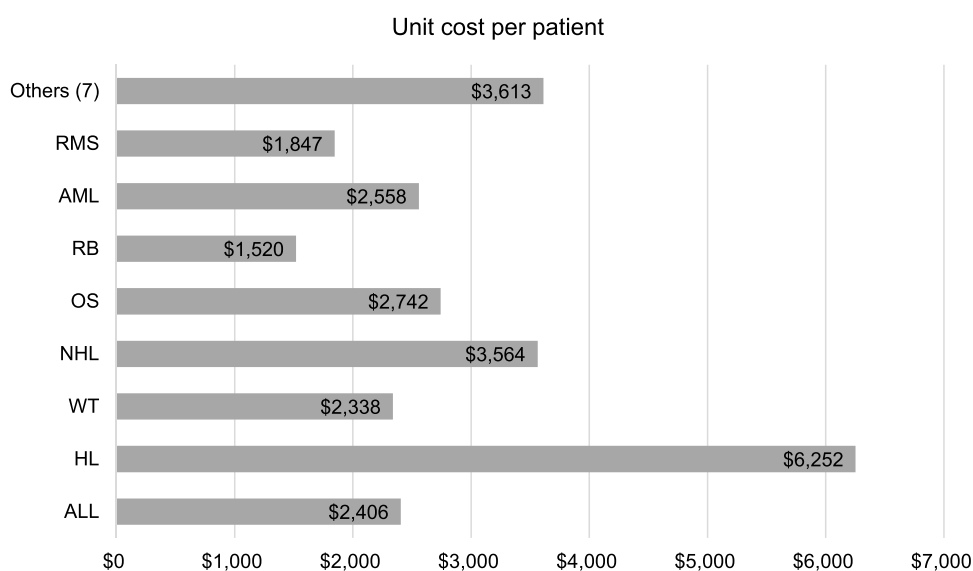
Cost Centers	In USD (\$)	Percentage
Medical personal cost	\$109,305	39%
Total drug cost	\$71,611	26%
Total building cost	\$48,274	17%
Total overhead costs	\$38,609	14%
Total diagnosis test	\$8024	3%
Total equipment cost	\$3489	0.9%
Total OR cost	\$336	0.1%
Total cost per year	\$279,648	100%
The average cost	\$2769	

The Unit Cost of Treating Childhood Cancer

Based on the data from the JMCPOU, the unit cost per newly diagnosed childhood cancer patient was \$2769 (Table 3). Of all types of cancer treated in JMCPOU, the two major types of lymphomas namely Hodgkin's lymphoma and non-Hodgkin's lymphoma accounted for the highest average cost to treat one patient per year (Figure 1).

For the two leukemia (ALL and AML), the unit cost per patient is about equal. The three least average costs per patient are accounted for among the major types of cancer treated in the JMCPOU Wilms tumor, Rhabdomyosarcoma, and Retinoblastoma. Other types of cancer consisting about seven types of cancer, if we distribute the average cost per patient for this type of cancer, it accounts for about \$516 which is less than half of all other types of cancer. Total and average per-patient costs by category are detailed in Annex II.

On the other hand, among cost categories, the cost of personnel is also a significant cost driver for all types of cancer except for ALL, and OS where drug cost is significantly higher than other cost categories. OR and equipment unit cost is the least among all types of childhood cancer. All types of annual average cost categories for each type of cancer are detailed in Annex II.

**Figure 1** The treatment unit cost per patient for each type of cancer.

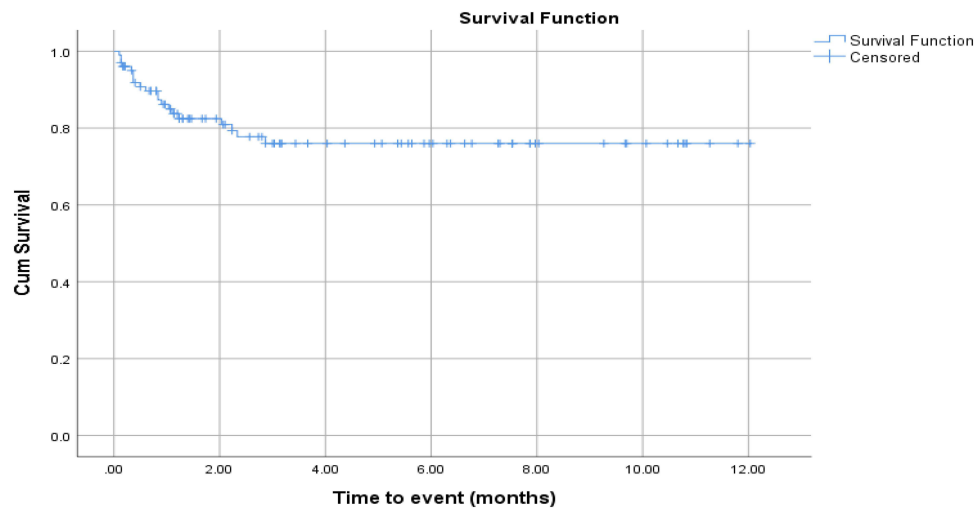


Figure 2 One-year survival curve of childhood cancer patients in Jimma Medical Center pediatric oncology unit.

The Cost-Effectiveness of the JMC Pediatric Oncology Unit

The 5-year survival rate was determined using a 1-year survival rate that was calculated using Kaplan–Meier survival analysis on SPSS. The output of the Kaplan–Meier one-year survival rate was about 75% (Figure 2). Using the Chennai, India²¹ proportion ratio and we estimated the 5-year survival rate which we get 47.6% of the 5-year survival rate.

The parameters used to determine the cost-effectiveness of treating pediatric cancer patients in JMC are listed in Table 1. Using those parameters defined in the base cases (no early mortality and no excess morbidity; 3% discounting). The cost per life saved for a 5-year survival rate was \$5236. The cost per DALY averted in the base case was \$193, which is significantly less than Ethiopia’s per capita income (\$936.3), thus meeting WHO-CHOICE criteria for being considered very cost-effective. These results were sustained after adjusting for 0% discounting levels (\$90). When 6% discounting was tested, operating the cancer unit remained cost-effective (\$324).

Sensitivity Analysis Results

In sensitivity analyses that allowed for deviation from the base cases, however, the resultant costs always remained very cost-effective (ie, below the threshold of 1 time the GDP per capita) (Table 4).

Table 4 One-Way and Multiway Sensitivity Analysis

	Scenarios for Sensitivity				Cost per DALY Averted		
	Reduction in Life Expectancy	Utility Adjustment for Late Effect Morbidity	Reduction In Survival Rate	Increase in the Annual Cost of Personnel and Overhead	3%	0%	6%
The Survival of Patients If They Did not Receive Treatment							
1 month	0%	0.06	0%	0%	\$218	\$102	\$365
1 month	15%	0.06	0%	0%	\$235	\$106	\$409
1 month	30%	0.06	0%	0%	\$262	\$113	\$469
6 month	0%	0.06	30%	0%	\$447	\$182	\$829
1 year	0%	0.06	30%	20%	\$494	\$201	\$916

Discussion

This study is to the best of our knowledge, one of the very few economic evaluations in Sub-Saharan African countries, and no published study analyzes the cost or cost-effectiveness of a childhood cancer treatment unit in Ethiopia. In this study, we tried to find how much is the average cost per year to give care to children with cancer. In addition, we try to answer whether the JMCPOU is cost-effective or not based on the WHO-CHOICE threshold.

Accordingly, this study demonstrates that the program achieved 47.6% of the 5-year survival rate at 2769 USD cost per patient, and \$193 cost per DALY was averted. The study of current analysis indicates that treating childhood cancers in Ethiopia, within highly conservative adjustment of assumptions, remains very cost-effective according to WHO-CHOICE thresholds.

When comparing the current study with similar previous studies, the average cost per childhood cancer patient in JMCPOU for newly diagnosed cancer was generally a bit higher than in other studies reported in Zimbabwe.²⁵ On the other hand, it is significantly lower than other studies reported in LMICs (that range from the highest in Kenya)²⁵ and El Salvador 21 to the medium in Ghana.¹⁰

Our study result shows that the annual cost of treating pediatric cancer patients is \$279,648, which is relatively lower than other study results referred to above except for the Nigerian cases.²⁵ The total cost of pediatric cancer also varies significantly in studies of different countries ranging from the annual total cost of \$229,000 in Nigeria to \$4 million in Kenya and \$5.2 million in El Salvador. The observed variations can originate due to our study did not include indirect costs borne by the families, and instead, our cost analysis is restricted to the provider perspective.

The annual average cost of treating pediatric patients with HL is by far larger (\$6252) than WT patients (\$2338). This result is consistent with the study conducted in two South African hospitals²⁶ related to HL patients. A study conducted in Rwanda, however, is not the case where the range or average costs between the two types of cancer are very close to each other. The methodological difference in our studies could cause such differences in results. Among the differences in our study, the health personnel, overhead, and capital costs are allocated to this type of cancer based on their stay in the hospital.

On the other hand, in our study, the JMCPOU achieved a 76.76% of 1-year survival rate. This result is relatively higher than other related studies conducted in LMIC ranging from 12.5% to 62%.^{10,24,25} The stated difference could be due to the assumptions involved in these studies that considered those lost to follow-up as dead. However, in our estimation of 1-year analysis, we used the Kaplan–Meier estimation of the survival rate.

This study also showed that, when conducting sensitivity analysis by changing the survival rate of patients, the cost-effectiveness of the treatment unit was below the threshold. However, the cost per DALY averted at different discount rates almost doubled. This shows that among different parameters and assumptions used to measure and determine the effectiveness of the treatment unit; the 5-year survival rate of patients has a significant effect on the cost-effectiveness of the treatment center.

The inability to fully consider all cost inputs, such as the cost of blood, are among the limitations of this study. The other limitation is that the hospital unit cost charged for services such as operating theatres (OR), and diagnostic test costs are assumed to include the amortization costs of equipment and personal costs.

The other study limitations worth noting are; first, many annual average costs were derived from the hospital's relevant departments at the time of data collection which may not properly account for fluctuations in service users and inflation rate. Second, when it is compared to the other studies conducted in LMICs, our study that the one-year survival rate is extremely high and this could be due to improper follow-up of patients who stop receiving care or are lost to follow-up but included in the estimation of the one-year survival rate. Thirdly, several assumptions were necessary including the ratio of 5-year to 1-year survival and the markup method assumption to determine the overhead cost. Moreover, the cost-effectiveness among each type of cancer could differ; however, we assume the total cost-effectiveness will represent the individual cost-effectiveness. While the validity of the assumptions is not known, our overall results did not change in sensitivity analyses.

Conclusion

This study demonstrates that an investment of less than \$2769 per patient can save children's lives and safeguard families from the suffering and sorrow of losing a child to cancer. Additionally, the treatment of childhood cancer in a resource-limited setting represents a highly cost-effective intervention by international standards. Therefore, the finding of this study can be used as a piece of evidence to inform policy-makers to strengthen childhood cancer outcomes in Ethiopia and other sub-Saharan African countries.

Ethical Consideration

Ethical clearance was secured by Jimma University Institutional Review Board (IRB). Thereafter, permission was sought from the Head of the Oncology unit, to use the dataset about the study participants for research purposes only. The authors declare that the procedures were followed according to the regulations to the Helsinki Declaration of the World Medical Association.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

All authors have no conflicts of interest to disclose except Dr Diriba Fufa who is a Head of the pediatric oncology unit at Jimma Medical Centre, and also a Chair, at Jimma University, Health Institute Staff Council.

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