Chapter 6

The costs of producing a unit of blood in Zimbabwe

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ABSTRACT

Background: There is lack of published data on the costs of blood and blood transfusion in Sub-Saharan Africa. This study aimed to assess the unit costs of producing blood in Zimbabwe using activity-based costing (ABC) method.

Study design and methods: A management accounting approach, based on the ABC, was used to develop a cost model for blood. The production of blood was broken down into recruitment, collection, testing, processing and storage plus distribution. Data for the year 2013 were collected retrospectively from budgets, financial and expenditure reports, databases, interviews with transfusion personnel and managers. All direct and indirect costs, in 2013 US$, were allocated, accordingly, to the activities of blood acquisition.

Results: The total cost of producing safe blood in Zimbabwe for the year 2013 was US$ 8.6 million. Variable costs accounted for 51.2% of the total cost of production. The unit production costs for red blood cells (RBCs) were US$15.94 for recruitment, US$34.62 for collection, US$17.88 for testing, US$11.49 for processing, and US$3.06 for storage plus distribution. The overall cost of production of one unit of whole blood was US$118.42 and red blood cells was US$130.94 constituting 12.4 and 13.7% of the country’s annual GDP per capita.

Conclusions: The high unit cost of producing blood relative to the annual GDP per capita demonstrates that acquiring safe blood is a burden on the health care sector in Zimbabwe. Introducing additional safety measures, such as nucleic acid amplification testing and pathogen reduction technology, although desirable, will further increase this burden.
INTRODUCTION

Blood transfusion is often a lifesaving medical intervention, which is required for many different medical conditions and surgical procedures. In resource-limited countries, blood transfusion is mainly required for complications of pregnancy, anaemia, infectious diseases, and gastrointestinal diseases. Costs relating to the provision of a safe, adequate and accessible blood and blood components supply, for clinical use in transfusions, are increasing at a time when healthcare budgets are constrained. This is particularly remarkable in resource-limited settings where most healthcare spending is foreign-funded. This has necessitated the periodic reassessment of the fees for the provision of blood, to meet costs in procuring equipment, reagents and paying for utilities to meet essential production costs.

Costing blood and blood components is a complex issue as different products have different cost implications. Generally, cost estimations are based on the largest volumes of product that is prepared, that is, the red blood cells (RBCs) or whole blood. The complex nature of the processes and activities existing within a blood service make it more difficult to identify and quantify costs, subsequently resulting in underestimation. The blood service includes various components such as donor education, donor screening, donor selection, donor deferral, blood collection, screening for transfusion-transmissible infections (TTIs), blood typing and cross-matching, blood component processing, storage, and distribution.

Many factors have been identified and described as drivers in the continuous increase in the production costs of blood and blood components. The introduction of advanced technologies to ensure safety from new and emerging infectious agents together with increased donor recruitment and retention costs, have significantly contributed to the rising costs of ensuring a safe and adequate blood supply. Other factors involved include the rising costs of labour, stringent regulatory demands, implementation of quality management systems and need for compliance with internationally recognised standards of ethics and practice. Meeting internationally recognised standards is an expectation of all countries, especially as countries adopt the Resolutions agreed at the annual World Health Assembly Meetings, of the World Health Organisation (WHO). These requirements are subject to periodical increases in operational, administration and overhead expenses, resulting in a rise in the service fees for blood.

The production of blood and its components; and the cost of administering a blood transfusion at the bedside have been evaluated in several studies in developed countries. However, the findings of these studies and resulting cost estimations are not readily transferable to countries in Sub-Sahara Africa (SSA) for a number of reasons. In the first place, almost all developed countries collect blood from voluntary non-remunerated blood donors (VNRBDs), while many countries in SSA continue to rely on direct family donors or family replacement donors, the
latter often is a ‘hidden’ paid donor system. Second, the preparation of blood components is commonly practiced in developed countries, whereas blood in SSA, is generally transfused as whole blood. Third, screening of donated blood in developed countries includes state of the art nucleic acid amplification testing (NAT), which is more sensitive and specific, and costlier, but is a requirement by the national regulatory authorities in developed countries. Furthermore, routine inline leukofiltration, which is not practiced in SSA countries during transfusion, is an additional expense in the developed countries. Implementation of different technologies may result in differences in calculating the production cost of a unit of blood. The cost drivers may be lower in resource-limited countries due to lower labour and infrastructure costs; however, the costs of obtaining equipment, devices and reagents are higher.

Published studies have used different methods for accounting the costs of blood transfusion, which, in some cases may lead to an underestimation of the true costs for the production of blood and blood components. The use of an activity-based costing (ABC) model was considered a better approach for estimating the cost of blood. There is a limited number of published data on the costs and cost drivers for the provision of blood in Sub-Saharan Africa. The aim of this study was to assess the unit costs and cost drivers for the production of blood and blood components at the National Blood Service Zimbabwe (NBSZ), using an ABC model.

MATERIALS AND METHODS

Study setting
The study was carried out at the NBSZ, which has the sole mandate for providing an adequate, accessible and safe blood to all hospitals in the private and public sectors in Zimbabwe. NBSZ is a registered non-profit organization, with a headquarters in Harare and four centres nationwide. In the years 2012 and 2013, NBSZ collected an annual mean of 74,600 units of blood from VNRBDs. NBSZ has centralized screening for TTIs, for every donated unit of blood, including Human Immunodeficiency Virus, hepatitis B virus, hepatitis C virus and syphilis. Every unit is blood grouped and rhesus typed. NBSZ has dedicated computer-based software, e-Delphyn, for active donor data and product management capture in every centre. All blood is collected from screened VNRBDs following internationally recognised guidelines for donor suitability and complying with the Code of Ethics of the International Blood Transfusion Society (ISBT). The blood service in Zimbabwe collects the relatively small volumes of blood at its five sites. In addition, more than 80% of the blood units are collected in many different mobile sites.

Study design
A management accounting approach, based on the ABC method, was used to develop the costing model, from the provider’s perspective. A 9-step process flow model was adopted, as
recommended in the Cost of Blood Consensus Conference report\textsuperscript{18}, which aimed at capturing both direct and indirect cost elements. The analysis focused on the cost elements associated with the blood collection centre and excluded the cost elements which apply to the blood transfusion facilities. Direct blood production activities were identified, which included blood donor recruitment, blood collection, donation testing (screening for TTI’s and blood grouping), component processing, and storage plus distribution. Indirect costs were categorised as follows: finance and administration; coordination; safety, health, environment and quality (SHEQ); planning, information and research (PIR); and general overheads. All direct (both fixed and variable) and indirect costs in US$, for 2013, were allocated accordingly, to the different activities of the blood service. Fixed and variable resources were separately identified, directly allocated to each activity and their individual costs were estimated.

The resources, which could not be identified and allocated to a specific activity, were allocated using two approaches, from which the indirect costs’ estimations were derived. First, interviews were conducted with managers in the respective departments to determine the amount of resources used in support of each of the identified main activities. The ratios provided were used to allocate resources to each activity. Second, where feasible, resources were allocated based on the floor space occupied by each activity or the number of employees in each activity depending on the resource type.

Processing costs were further allocated to the four main blood and components produced at NBSZ, namely, whole blood, RBCs, fresh frozen plasma (FFP) and platelets (PLTs). It was assumed that whole blood would not incur any processing costs. A unit of blood is defined as 420 – 520 ml for whole blood, 220 – 320 ml for RBCs, 200 – 300 ml for fresh frozen plasma (FFP) and 120 – 250 ml for platelets (PLTs). The sum of the direct and indirect costs represents the total production cost of blood and blood components. Costs are presented as direct fixed, direct variable and indirect costs for 2013 in US$. Fixed costs included mainly buildings, utilities, equipment (clinic, laboratory), furniture, vehicles, general, and administrative expenses. Variable costs included staff salaries, supplies (laboratory, clinic, kitchen), and donor incentives. All capital costs were amortized using a standard formula, taking into account the expected remaining life and the estimated discount rate for Zimbabwe during the 2013 calendar year.

Data collection and analysis
Data covering the 2013 calendar year was collected retrospectively from the NBSZ’s budgets, planning documents, ledgers, financial and expenditure reports, databases, and interviews with blood service personnel and managers. Data on the annual interest and inflation rates were obtained from the Reserve Bank of Zimbabwe. Cost data were captured in Microsoft Excel costing work sheets (Microsoft Excel, Microsoft Corp., Redmond, WA) adapted from WHO’s Costing Blood Transfusion Services\textsuperscript{20}.

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The total economic cost for producing blood and the cost for each of the identified main activities was categorized into direct fixed, direct variable and indirect costs. The unit production cost for each activity was calculated by dividing the annual total cost for the activity by the annual total number of units of output (for example number of donors or donations). Summing up the activity unit costs resulted in the overall cost of producing a unit of blood.

Sensitivity analyses
Sensitivity analyses were performed to demonstrate the effect of changing the input parameters on the activity and total unit costs. The influence of parameter uncertainty on the output was assessed by representing input parameters with probability distributions as implemented in @Risk (Palisade Software, Newfield, NY, USA). The real interest rate (estimate of discount rate) was estimated using the Fischer Equation\textsuperscript{21}, by subtracting the inflation rate from the nominal interest rate. The discount rate was used to estimate the equivalent annual cost for buildings and equipment. The discount rate was varied from 0 – 10% (base model input of 7.7%) in the sensitivity analysis, in order to include the rates (3 and 5%) commonly used in literature. NBSZ provided the estimated remaining life for buildings (20 years) and equipment (5 years). Most economic evaluations use 50 years for buildings. In view of this variance the remaining life was varied from 20 – 50 years, in the sensitivity analysis. It was assumed that some of the equipment could last up to ten years; therefore, the remaining life in years was varied from 5 – 10 years. The final variation used the number of units of blood distributed in 2012 as the minimum and the 2013 figure as the maximum.

RESULTS
A total of 70,834 donations visits (including repeat visits) were screened in 2013 and of these, a total of 67,440 visits (95.2%) were accepted for donation. The number of useful units of whole blood collected was 67,422 (99.9%). The total number of components of blood prepared from these donations was 69,242 and the total number of units distributed was 62,303 (90.0%).

The total unit cost estimates of the activity categories used in the model are shown in Table 1. The total unit costs of production were US$118.42 for whole blood, US$130.94 for red blood cells, US$199.46 for fresh frozen plasma and US$76.09 for platelets. These constituted 12.4%, 13.7%, 20.9% and 8.0%, respectively, of the country’s annual GDP per capita (US$953). The total cost of producing blood and blood components in 2013 was US$ 8.6 million. Variable costs accounted for 51.2% of the total cost of production. The major cost components for the overall variable costs were costs for staff salaries (50.8%), laboratory supplies (27.5%) and clinic supplies (15.4%). The activity-based costs for the production of blood and blood components are shown in Figure 1.
The direct unit cost for recruitment was US$ 15.94, representing 13.5% of the total production cost for a unit of whole blood. Advertising/public relations (66.9%) and vehicles (24.9%) were the major direct fixed costs components, while staff salaries were the only contributors to the variable costs for recruitment.

The direct cost of collecting one unit of whole blood was US$ 34.60, contributing 29.3% of the total production cost for a unit of whole blood. The major direct fixed costs contributors for the collection of whole blood were vehicles (46.1%) and buildings and utilities (27.4%). Staff salaries (44.1%) and clinic supplies (41.1%) contributed the most towards the variable costs for donation collection.

The direct cost for donation testing per unit was US$ 17.88, representing 15.1% of the total cost for producing a unit of whole blood. Donation testing included costs of screening for TTIs and blood grouping. Laboratory supplies, mainly reagents for TTI screening and blood grouping contributed 75.7% of the direct variable costs. Building and utilities (59.8%) and laboratory equipment (28.5%) were the most prominent direct fixed costs in donation testing.
<table>
<thead>
<tr>
<th>Activity/ Category</th>
<th>Whole Blood</th>
<th>Red Blood Cells</th>
<th>Fresh Frozen Plasma</th>
<th>Platelets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood donor recruitment and selection</td>
<td>15.94 (15.77 – 16.04)</td>
<td>15.94 (15.77 – 16.04)</td>
<td>11.95 (11.83 – 12.03)</td>
<td>3.98 (3.94 – 4.01)</td>
</tr>
<tr>
<td>Component Processing</td>
<td>-</td>
<td>11.49 (10.12 – 13.06)</td>
<td>41.43 (24.10 – 84.49)</td>
<td>5.62 (5.48 – 5.77)</td>
</tr>
<tr>
<td>Storage and distribution</td>
<td>3.06 (2.69 – 3.80)</td>
<td>3.06 (2.69 – 3.80)</td>
<td>3.06 (2.69 – 3.80)</td>
<td>3.06 (2.69 – 3.80)</td>
</tr>
<tr>
<td>Coordination</td>
<td>6.21 (6.16 – 6.31)</td>
<td>6.31 (6.15 - 6.51)</td>
<td>9.86 (7.84 - 14.69)</td>
<td>6.13 (5.97 - 6.34)</td>
</tr>
<tr>
<td>SHEQ</td>
<td>3.42 (3.38 – 3.51)</td>
<td>3.58 (3.35 - 3.85)</td>
<td>9.28 (6.06 - 17.03)</td>
<td>3.28 (3.06 - 3.56)</td>
</tr>
<tr>
<td>PIR</td>
<td>7.43 (7.34 – 7.58)</td>
<td>7.54 (7.34 - 7.80)</td>
<td>11.79 (19.35 - 17.60)</td>
<td>7.33 (7.12 - 7.60)</td>
</tr>
<tr>
<td>Overheads</td>
<td>16.59 (15.55 – 17.86)</td>
<td>17.06 (16.68 - 18.77)</td>
<td>34.54 (23.74 - 60.72)</td>
<td>16.16 (14.81 - 17.99)</td>
</tr>
<tr>
<td><strong>Total Unit Cost</strong></td>
<td><strong>118.42 (115.25 – 121.89)</strong></td>
<td>130.94 (125.91 - 136.45)</td>
<td><strong>199.46 (158.21 - 298.21)</strong></td>
<td><strong>76.09 (72.19 - 81.39)</strong></td>
</tr>
</tbody>
</table>

Unit costs are given in 2013 US$ with the 95% confidence intervals presented in parenthesis. F & A – Finance and Administration; SHEQ – Safety, Health, Environment and Quality; PIR – Planning, Information and Research; §Whole blood derived
The costs of processing a unit of blood into components were US$ 9.08 for red blood cells, US$ 21.95 for fresh frozen plasma and US$ 5.07 for platelets. Building and utilities (59.0%) and laboratory equipment (26.8%) were the major direct fixed costs contributors for component processing; while staff salaries (59.9%) and laboratory supplies (40.1%) made up most of the direct variable costs.

The direct unit cost for storage and distribution was US$ 3.06, representing 2.6% of the total production cost for a unit of whole blood. Buildings and utilities (65.1%) and vehicles (17.1%) were the major direct fixed cost contributors while staff salaries (76.9%) and laboratory supplies (40.1%) made up most of the direct variable costs.

Indirect costs for producing a unit of whole blood were US$13.27 (11.2% of the total unit cost) for finance and administration, US$6.21 (5.3%) for coordination, US$3.42 (2.9%) for safety, health, environment and quality; US$7.43 (6.3%) for planning and research; and US$16.59 (14.0%) for overhead costs. Indirect costs for the other blood components ranged from US$13.07 – US$19.87 for finance and administration; US$6.12 – 9.31 for coordination; US$3.27 – 8.40 for SHEQ; US$7.31 – 11.30 for PIR and finally US$16.06 – 31.71 for overhead costs.

Figure 2, Figure 3 and Figure 4 show the most influential parameters on the unit activity costs and the total unit cost of blood components obtained in the base case model. Varying the number of fresh frozen plasma units produced had the most influence on the unit cost for processing (38%) and the total unit cost (20%) for fresh frozen plasma. Varying the number of units of blood distributed altered the unit cost for storage and distribution by 8.8%. However, none of the other parameters included in the model individually altered the unit activity costs or the total unit cost of blood by more than 5%, hence the model was considered robust.
Figure 2 | Sensitivity analysis tornado diagram demonstrating the most influential parameters on the unit costs by activity

Figure 4 | Sensitivity analysis spider diagram demonstrating the most influential parameters on the processing and total unit cost of producing FFPs
DISCUSSION

An adequate and safe blood supply is integral to the achievement of the health-related Millennium Development Goals (MDGs) aiming to reduce child mortality, improve maternal health, combat HIV and develop global partnership for development. The presence of whole blood and its components on the WHO’s essential medicines list underscores the important role blood transfusions play in public health. Access to essential medicines is part of the right to the highest attainable standard of health. The overall unit production cost of red blood cells in Zimbabwe for 2013 was US$ 130.94 constituting 13.7% of the country’s GDP per capita. The relatively high cost of a unit of blood may reflect a relevant burden and significantly affect access to blood for transfusion, subsequently hampering efforts towards achievement of MDGs and universal health coverage. This is particularly notable for Zimbabwe where at least 90% of the population does not have health insurance and therefore have to pay out-of-pocket for health care services. Consequently, with a high acquisition cost, patients may fail to procure blood components and forego transfusions or they may go into debt following the purchase. In addition to these costs, blood transfusion is still associated with significant clinical risks. This underscores the need for ensuring appropriate use of this life saving health commodity. This can be achieved through the implementation of patient blood management practices. There is also need for continuous monitoring and evaluation of transfusion practices in the country in order to promote cost-effective and cost-saving practices. All these approaches would require functional hospital transfusion committees to spearhead the evaluation of blood utilization pat-
terns, patient outcomes and associated costs. The unit cost for producing FFP, US $199.46, was significantly high relative to the other components. This was due to the approach used to apportion joint costs associated with component processing. The number of components produced for each component category was used to apportion the joint processing costs. The smaller number of units of FFP currently being produced at NBSZ (approx. 6,000 units/year) in comparison to red blood cells (52,000 units/year) resulted in the higher unit cost. Increasing the number of units produced will result in substantial drop in the unit cost for processing and subsequently the overall unit cost for FFP, as demonstrated in Figure 4. The unit cost of producing PLTs was lower compared to the other components because they were single donor whole blood derived. Pooling the platelets as is normally done to make a single PLT dose for transfusion would result in a significant cost increase.

In its report titled the ‘Status of blood safety in the WHO African region: Report of the 2006 Survey’27, WHO noted the wide variation in the cost of producing one unit of whole blood as reported by the 30 countries that responded to the Global Database on Blood safety (GDBS) questionnaire. When adjusted for 2013 dollars, the reported average cost of producing one unit of whole blood was US$ 73 (range; USD $12– 260). Such wide variations maybe attributed to the fact that blood services in the region have different funding mechanisms, which subsequently translate into different models of transfusion services. Differences in models of collecting blood may include the types of donors (VNRBD, family replacement blood donors [often regarded as a ‘hidden’ paid system of blood donation] and paid blood donors), testing capacities and coverage, and separation of whole blood into components. Some blood services adopted a policy of exclusively recruiting voluntary non-remunerated donors and this is known to be associated with higher costs of blood when compared to family replacement donors28-32. Countries that have implemented component preparation as a routine activity are also likely to have a higher cost of production for a unit of blood due to an increase in resource utilization. The coverage for the screening of blood for TTIs as well as the technologies implemented may also impact greatly on the cost of producing blood. Compared with figures indicated in the WHO report, the unit cost of producing blood in Zimbabwe is on the high side. This is congruent with the organizational structure and risk mitigation policies adopted by the national blood service. The NBSZ has centralized activities such as testing and quality management systems, exclusively recruits VNRBDs, has a 100% screening coverage for TTIs and distributes most of its blood as components. All these structures require a great deal of investment, which subsequently translates into high costs of producing blood. Differences in the methodological approaches taken to account for the total cost of production of blood may also have played a role in the observed variations. The WHO report does not provide information on how countries arrived at the reported figures. Study design issues such as the perspective taken, cost types, cost elements and whether costs reported are financial or economic are key for any in-depth comparisons. This highlights the need for standardized costing methodology in blood services to enable comparability of findings. This
The costs of producing a unit of blood in Zimbabwe is particularly important for countries performing cost recovery systems since underestimating such costs would threaten viability and sustainability of the transfusion services. Previous studies have reported varied estimates of the unit cost of producing blood in SSA. When adjusted for 2013 dollars, the reported estimates were US$ 42 \textsuperscript{33} and US$ 114 \textsuperscript{34} in Malawi, US$ 170 in Namibia\textsuperscript{35}, US$ 125 in Tanzania\textsuperscript{36} and US$ 238 in Uganda\textsuperscript{37}. However, comparing these estimates with each other or with the one in the present study requires caution. The cost perspectives in these studies were different and could, in part, explain the variations in the cost of producing a unit of blood. The two studies from Malawi were performed in hospital-based transfusion services hence the relatively low costs. The study from Tanzania was performed in a hospital running a semi-autonomous blood transfusion service hence much higher costs than studies from Malawi were recorded. In Uganda, where the highest cost was reported, data were collected from a centralized blood transfusion service. These fundamental differences highlight the need for generation of more current cost data on the production of blood for transfusion in SSA.

Several studies in developed countries have estimated and published substantially higher unit costs of producing a unit of blood than our estimate\textsuperscript{3,7,9-11,13,15}. This is quite expected due to the organizational and operational differences that exist between blood transfusion services. Most blood transfusion services in developed countries are well developed and have implemented advanced technologies, for example NAT and pathogen reduction technologies, to improve blood safety. Such advanced blood safety measures have not yet been implemented in Zimbabwe, hence the much lower estimated unit cost compared to estimates reported in developed countries. Most of the studies from the developed countries estimated the costs from a societal perspective\textsuperscript{7,9-11,13}, while this analysis took a provider's perspective, which may in part explain the substantial difference in the cost estimates. The absolute cost of producing a unit of blood observed in this study is lower compared to published estimates. However, it is substantially high relative to the country's GDP per capita. If the cost for a unit of blood in the USA, the Netherlands and South Africa were to be 13.7\% of the GDP per capita, this would translate into absolute costs per unit of US$ 7258, US$ 6959 and US$ 943, respectively. However, the absolute cost in our study would represent 0.2\%, 0.3\% and 1.9\% of the GDP per capita for the USA, the Netherlands and South Africa, respectively. This demonstrates the potential weakness in using the GDP per capita as a reference point for determining affordability. In a failing economy like Zimbabwe's, the GDP per capita is hugely suppressed yet the blood transfusion service still has to rely on imports for most of its equipment and supplies. This results in high costs of production relative to the GDP per capita. Further studies aimed at predicting the impact of the acquisition cost of blood and blood components on the country's medical system may be warranted. These would assess the impact of these costs on the utilization patterns and patient outcomes.
The NBSZ is considering the introduction of NAT in order to enhance the safety of the blood supply. The implementation of NAT will without doubt translate into an increase in the cost of producing blood because it requires dedicated infrastructure, equipment, consumables and technical expertise. The use of excess plasma for fractionation into plasma derivatives may help offset some of the costs associated with the introduction of NAT. However, the true benefits of introducing NAT can only be demonstrated through an economic evaluation or a budget impact analysis.

This study adopted the provider’s perspective in estimating the unit cost of producing blood in Zimbabwe. The societal perspective would have resulted in higher costs than those we estimated, because it would include the costs incurred by the blood donors as they present for blood donation and the opportunity costs of time spent making a donation.

The current study further confirms that providing safe and adequate blood for transfusion is an expensive undertaking. The unit cost of producing blood is likely to increase with the introduction of additional safety measures such as NAT and pathogen reduction technologies. Estimating the ‘true’ cost of producing blood is an enormous task that requires careful consideration of all the activities involved in this complex process. Our estimate may help in raising awareness on the significant costs of producing blood and subsequently encourage all stakeholders to think critically about the appropriate clinical use of blood and blood components.

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**CONFLICT OF INTEREST**

The authors have disclosed no conflicts of interest.
REFERENCES


