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ORIGINAL PAPER

An 8-step framework for implementing time-driven activity-based costing in healthcare studies

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Abstract

Micro-costing studies still deserving for methods orientation that contribute to achieve a patient-specific resource use level of analysis. Time-driven activity-based costing (TDABC) is often employed by health organizations in micro-costing studies with that objective. However, the literature shows many deviations in the implementation of TDABC, which might compromise the accuracy of the results obtained. One reason for that can be attributed to the non-existence of a step-by-step orientation to conduct cost analytics with the TDABC specific for micro-costing studies in healthcare. This article aimed at exploring the literature and practical cases to propose an eight-step framework to apply TDABC in micro-costing studies for health care organizations. The 8-step TDABC framework is presented and detailed exploring online spreadsheets already coded to demonstrate data structure and math formula building. A list of analyses that can be performed is suggested, including an explanation about the information that each analysis can provide to increase the organization capability to orient decision making. The case study developed show that actual micro-costing of health care processes can be achieved with the 8-step TDABC framework and its use in future researches can contribute to increase the number of studies that achieve high-quality level in cost information, and consequently, in health resource evaluation.

Keywords Micro-costing · Time-driven activity-based costing · Cost analysis · Healthcare costs

JEL Classification I150 · M110

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Abbreviations

BMT bone marrow transplant
EMR electronic medical records
TDABC Time-driven Activity-based Costing
RVU relative value units

Introduction

A current trend in healthcare reimbursement around the world is the shift to a value-based payment model [1, 2]. Value in healthcare has been defined by Porter [3] as outcomes divided by the costs of delivering those outcomes. In this case, considering the high (and increasing) expenses in healthcare as well as the ability to understand, control, and assess actual costs is essential [4–6]. However, the results of a global assessment indicate that the value domain of measuring outcomes and costs requires methods and solutions that allow better performance control [7].

A recent study found that there is a consensus in Europe on how to identify, collect and evaluate costs in health economic studies [8]. The authors discovered that 94–100% of the studies include healthcare service costs; the authors attributed the costs to patient-level services and incorporated a bottom-up microcosting estimation for unit cost. Tan et al. [9] state that bottom-up microcosting is characterized by the identification of patient-specific resource use and hospital-specific unit costs. However, in her study it is suggested that for inpatient stay costs, a division by the number of patients can be used; for indirect costs, a mark-up percentage can be included up to the direct known costs; and for labor costs, a standardized cost per day is utilized. Once these procedures are followed, a researcher's ability to specify the level of patient-specific resource use can decrease.

Such procedures to distribute indirect costs are used by top-down accounting systems, for example in absorption costing, which have been traditionally used in hospital settings. They rely on costs-to-charge ratios and the relative value units (RVUs) are often inaccurate; they also offer little insight into cost composition and provide limited information to support strategies focused on cost optimization [2, 10, 11]. In contrast, Time-driven Activity-based costing (TDABC), proposed by Kaplan and Anderson at the Harvard Business School in 2007 [12], increases direct and indirect cost-data accuracy at the unitary level, identifying the patient-specific resources consumed by means of the real healthcare time consumed by each patient [13, 14].

TDABC was proposed as an improvement to activity-based costing (ABC) [15], because it makes ABC faster and easier to update by transforming all cost drivers into a single cost driver: time without loose data accuracy [16]. When well-designed and applied, TDABC contributes by identifying opportunities to make patient care flow more efficiently, by reducing the resources used in each activity according to real patient demand [17, 18].

Two seminal research studies that used TDABC in healthcare were developed in Mayo Clinic and MD Anderson. The Mayo Clinic applied the method as a pilot project in 2014 and suggested that the highest value of using the method in healthcare is: to improve the healthcare delivery process; to detail costs at a patient level (which is required in a microcosting analysis); and to increase cost-information quality to support value-based payment design [1]. In the MD Anderson case study, Kaplan and Porter started their pilot project at the Neck and Head Center and argued that well-assessed costing unlocks opportunities that contribute to the acceleration of the pace of innovation and value creation [2].

As Porter [4] has already discussed, good quality cost comparisons require cost information from different perspectives and organizations. However, the dissemination of TDABC in healthcare in a large scale requires substantial efforts to collect and organize data, and this is a disadvantage when TDABC ins compared with RVUs systems data [19]. The existence of information technology systems to sustain TDABC for healthcare management and microcosting studies is still a gap that deserves the attention of academics and the software industry [10]. From the academic perspective, the definition of a step-by-step framework to guide software development represents an important contribution to the industry's development and advance.

In a recent systematic review, Keel et al. [20]. identified seven steps that are generally employed by health organizations in applying TDABC; however, the authors noted variations in the implementation of each step, which might have compromised the accuracy of the results obtained. In addition, we identified studies in the literature that use the methodology, but they do not explore the care-flow improvement opportunities using the resources consumed per activity and patient, such as in Martin (2018) [13, 21]. This heterogeneous implementation limits the quality of analysis and complicates comparisons between institutions. We suggest that one reason for these gaps can be the nonexistence of a step-by-step framework to conduct cost analytics using TDABC specific to microcosting studies in healthcare.

Therefore, the purpose of the present study is to propose a step-by-step tutorial to guide and standardize the implementation of TDABC in microcosting studies for healthcare organizations. Departing from the seven steps identified by Keel et al. [20] we developed an eight-step framework to apply TDABC in microcosting studies, with examples from a case study conducted in two Brazilian hospitals.

Microcosting with the 8-step TDABC framework

The present tutorial introduces an 8-step TDABC framework, starting with the definition of the research question, followed by data collection and result analytics. The tutorial summarizes the eight-step sequence for the application of TDABC to microcosting in a framework, which is illustrated in (Fig. 1). After calculation of the total patient costs, a final cost-data analytics step is proposed. This step ensures that cost data can be used to guide the decision-making process by applying the analytics to develop information expressed in charts and tables.

Step 1: Identify the study question or technologies to be assessed

Microcosting studies can be conducted from two main perspectives: healthcare systems (e.g., heart transplant programs)

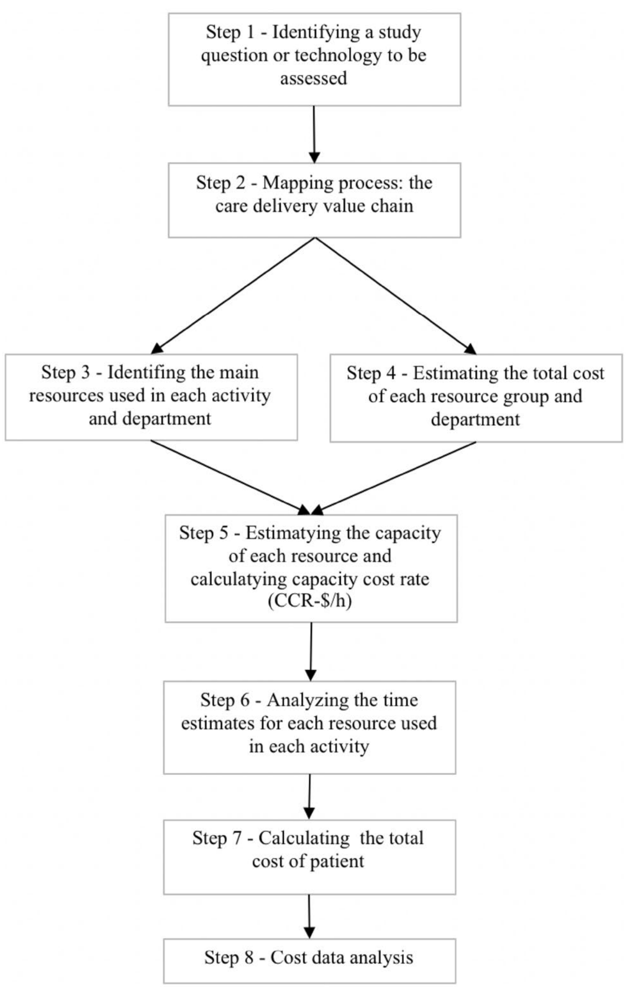


Fig. 1 Eight-step framework for micro-costing with TDABC

or healthcare facilities (e.g., left ventricular assistance device procedure in hospital settings) [22]. When the first one is used, microcosting supports economic evaluations that guide health policies. The second perspective is useful for improving healthcare organizations' capabilities to manage internal resources, add new services, discuss reimbursements, and guide the hospital decision-making process. Knowing which perspective to follow is important, because the first one provides results that are more useful for external users and government decisions, whereas the second is more useful for internal users and hospital decisions.

Step 2: Map the processes: the care-delivery value chain

Data sources for the process map include electronic medical records (EMR), interviews with physicians and nurses, and observations in situ [13, 14, 23]. The use of digital platforms such as Bizagi or Microsoft Visio helps ensure that different participants use the same standardized language to design the chain. This makes it easier for other parties in the process to understand and follow the steps and to create new process maps as needed.

The care-delivery value chain details the clinical pathway, in which a start and an endpoint need to be defined for each patient. The main activities that are part of the treatment flow and routine patient activities are identified [11, 24]. At this phase, researchers may build detailed maps of activities to understand the patient flow; however, to present the final results of a long hospitalization (such as BMT) macro activities or phases are frequently used to facilitate the comprehension and cost comparisons [17, 19, 23]. For example, in a bone marrow transplant (BMT) patient, the period of aplasia is a main activity, whereas a blood count is a routine activity that occurs often in association with many other main activities. This breakdown is important for the subsequent development of cost equations and allocation of resources (Fig. 2).

Step 3: Identify the main resources used in each activity and department

The process map shows all of the resources used by the patient during the care flow. Resources are divided into structure and personnel [20, 25]. Structure represents all of the physical areas in which the patient spends time. Personnel includes all the classes of employees that dedicate their time to the patient.

Step 4: Estimate the total cost of each resource group and department

All cost items associated with each resource group should be estimated by the financial department. For structure costs,

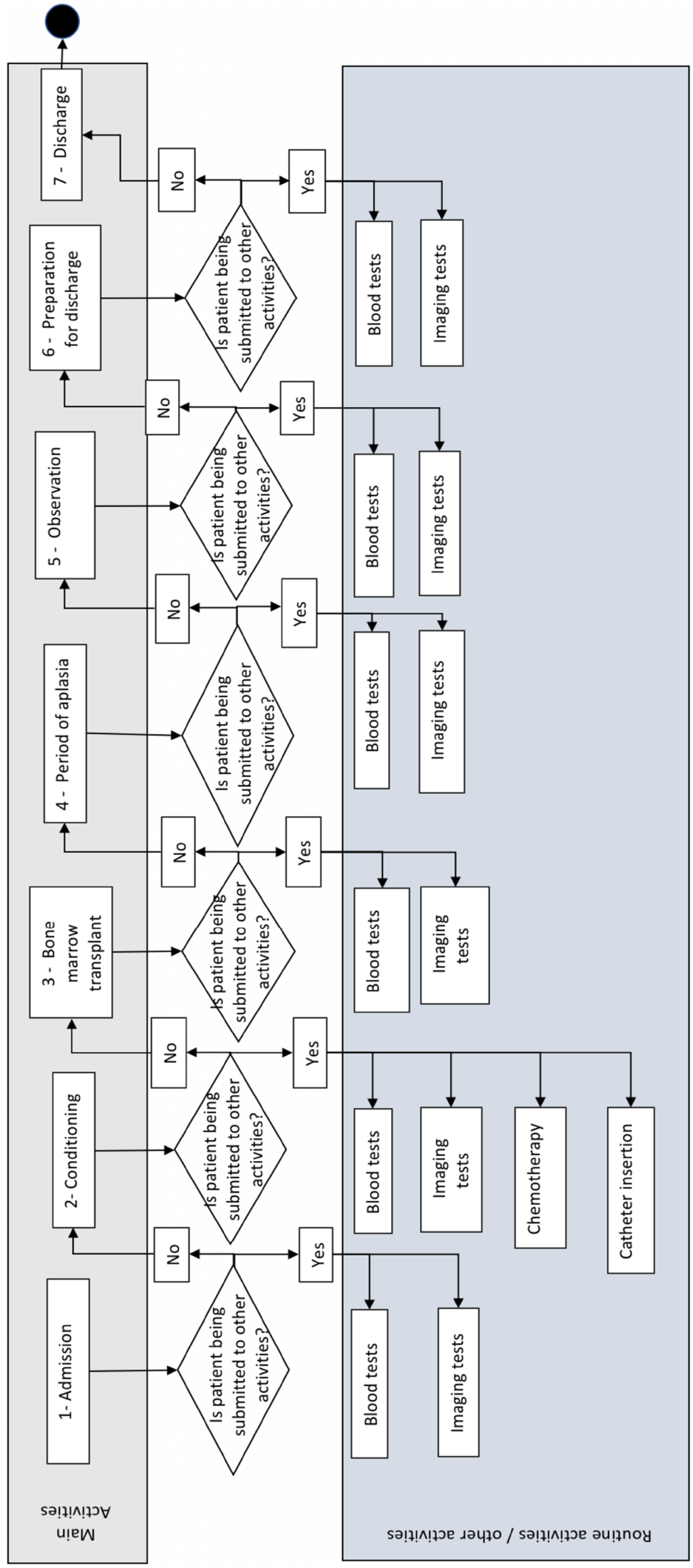


Fig. 2 Bone marrow transplant patient value flow

financial data from at least 12 months back should be used to estimate the average cost of each resource. In countries with more economic instability, inflation adjustments may be incorporated [26]. Usually, hospitals manage costs from a top-down perspective [27]. That means that resources (and therefore costs) are linked to departments, including personnel, depreciation, energy, rent, general materials, prints, third-party contracts, software licenses, taxes, and other more specific resources that are assigned to certain departments. Individual patients can consume resources from more than one department and the TDABC allows to assess this real consume per unit. It is possible because the method uses the patient flow to orient the analysis. [28, 29]. The result is the quantity of all resources consumed by each patient producing a detailed and thorough ledger of patient care.

In addition to the direct departments and resources identified, indirect expenditure sources may be incorporated into the cost information with the aim of including all of the items necessary to patient care [15]. Indirect- cost centers such as human resource management, c-suits, internal logistics, project management, and others may be allocated to all center costs identified during the patient care flow. This distribution may assume parameters that are traditionally used by hospitals, which include real consumption by a department: for example, an inpatient area with 20 beds consumes more management resources than one with 10 beds [12, 30]. This cost is difficult to attribute that is still difficult to attribute to patient-specific consumption; only a complete ABC could solve this issue, but it would make the implementation harder and slower than TDABC.

Once the cost items are determined, the total cost over a given period of time, that is, across the care flow (Fig. 2), is measured for a sample of individual patients. This sample is determined according to the study objectives and premises. For example, the study can include all patients who submitted to treatment in a specific hospital during a period of time (1 year or during the period of study). That means that the average or median cost is estimated based on the average or median calculated for this sample. Due to the right-skewed distribution that is usually present in cost data, the use of least-squares methods such as sample averages and variances, transformations, logarithm, and square roots is sometimes proposed [31]. However, these methods are no substitute for a careful examination of the data using boxplots and histograms. These decisions should be made by investigators or external specialists in the early stages of the estimation process, before overall results are obtained.

Step 5: Estimate the capacity of each resource and calculate capacity cost rate (CCR-$/h)

Capacity cost rate is calculated by dividing the cost of resources by the practical capacity of each personnel resource or structure department. The practical capacity can be calculated using the quantity of structure or personnel that actually perform the work [12], accounting for routine breaks, equipment/facility downtime and other sources of interruption. These expected breaks can be understood as expected idleness. Including the use of capacities when performing the TDABC method allows for an analysis of expected or unexpected idleness and guides actions that lead to better distribution of organizational capacity.

Therefore, in order to calculate the CCR, it is necessary to assess the practical capacity of all involved resources which may include, for example structure, personnel, or technology. Practical capacity should be calculated by taking into consideration the characteristics of each department. For inpatient areas, in which the availability for work depends on the physical structure, the number of beds should be included in the calculation. For the pharmacy department, where the presence of pharmacists is mandatory, employee work hours may be included. Regarding personnel resources, practical capacity is associated with the work hours of each professional category. The data used to calculate the capacity of all departments involved in the patient care flow can be retrieved from hospital productivity reports and employee allocation scales and complemented with interviews of department managers when necessary. These reports also help to identify the expected downtime resulting from machine setup, patient flow, and employee breaks.

Personnel costs per hour are calculated using the salary base of each hospital and the length of time worked per month, along with the expected fringe benefit rates that are associated with each patient by using actual specific-patient consumption, as described in the next step [20].

Step 6: Analyze the time estimates for each resource used in an activity

After the calculation of CCRs, time equations must be designed to identify the unitary specific-patient resource consumption. To identify the actual time during which a patient used different resources, various mechanisms can be utilized. The use of EMR data together with information on hospital systems is highly recommended, because it increases data credibility [10, 13, 32]. Some alternative systems that may contain useful data for use-in-time equations are: department productivity reports, nursing, physician and other professional appointments, machine and equipment reports. When good quality data cannot be retrieved from hospital systems, studies of time and movement, such as chrono-analyses, may be used [20]. These studies may resort to in loco observations to analyze the actual time during which different resources are dedicated to each patient, based on a sample of patients and a period of analysis [33]. Averages and medians may be estimated for each clinical event, providing information on time according to patient complexity. As soon as the times are estimated, the cost equations can be built.

The development of automatized technologies to collect information on healthcare services delivered to patients from EMR represents an opportunity to increase data accuracy in microcosting studies [10]. Technologies, such as robotic process automation and smart apps that allow for the engagement of healthcare professionals can represent an important advance in increasing a health organization's capability to apply TDABC.

Step 7: Calculate the total cost of patient care

Time equations (Eq. 1) are used to calculate the cost per activity and the total cost of each patient [12]:

$$C = \sum \beta_i xCCR_1 + y = \beta_1 xCCR_1 + \beta_2 xCCR_2 + \cdots + \beta_n xCCR_n + y, \quad (1)$$

where (a) C: Total cost of patient treated by the technology; (b) β_i: Time used by each department involved in the process; (c) CCR_i: CCR for each department or resource; (d) i: Number of departments or resources; and (e) y = Other direct costs associated with the process (medications and medical materials).

The development of a matrix can simplify the implementation of all cost equations. Each line represents an activity and each column a resource. The cells are filled with time information and the CCR can be input to simplify the calculation process. The online Appendix A presents an example of matrix that may be built for each individual patient.

After activity cost is determined, other direct costs, such as medication, can be added to determine total cost.

Some studies have calculated total cost by identifying the average time spent by each resource on each activity, using interviews with professionals to identify that time [6, 14, 32]. However, this procedure reflects an indirect measure of microcosting [17]. Helmers and Kaplan have suggested that the greatest accuracy in cost information is achieved if TDABC is performed for each patient in real time to account for the unique costs incurred by each patient [32].

Step 8: Cost-data analytics

In sequence to the cost calculations, analytics data analysis can be performed by exploring visual charts and dashboards. The objective of this microcosting analysis is to detail the highest costs associated with technology implementation and to review the effectiveness of the implementation process. In addition, high-quality cost data may guide decision making by hospital managers and improve an institution's capability to conduct good economic evaluations [9, 34]. Table I shows a list of possible aspects for analysis, their description and value for management. Following these analytics suggestions, the accuracy of data that can be used to support the incorporation of health technology into management decisions increases.

The next section details each step using a practical example of a microcosting study, providing helpful insights from a real practical case study that used the 8-step framework.

Application of the 8-step framework: a case study

Step 1: Identify a study question or technologies to be assessed

The study question in this case study was "what is the actual cost of a bone marrow transplant (BMT)?", a demand by the Brazilian Ministry of Health. This question was explored in the context of a federal program to enhance the quality of the public healthcare system.

Data for BMT assessment were collected from two hospitals (A—public hospital and B—private nonprofit hospital) with active transplant programs. Adult, allogeneic-related patients were selected. The sample for the present analysis included all 12 patients undergoing allogeneic BMT in 2017.

The study was approved by the Institutional Review Board of Hospital Moinhos de Vento of Porto Alegre (approval number 1.910.843) and by the Institutional Review Board of Hospital de Clínicas of Porto Alegre (approval number 2.035.550). Written informed consent was obtained from each participant at the time of enrollment.

Step 2: Map the processes: the care-delivery value chain

Initially, the main activities associated with BMT were identified by examining the literature and through interviews with physicians and clinical staff. Detailed maps of activities which patients are submitted along a BMT hospitalization, such as for example routine professional consults, exams and transportation, were created to orient the EHRs review. These detailed maps were designed per each BMT patient phase (or macro activity) along the hospitalization. With the ambition to turn easier the cost comprehension and comparison BMT, the main activities (clinical pathway phases) were consolidated as the BMT patient value flow (Fig. 2).

Step 3: Identify the main resources used in each activity and department

Using the map, all resources required for each activity were identified through interviews with physicians and analyses of patients' EMR. A matrix was created to associate activities with resources. The online Appendix B used a part of resources identified in the BMT research to express an example of how to structure the matrix to cross activities and resources.

It should be noted that if previous microcosting research on routine activities has already been performed by the hospital, the results can be used for this analysis. For example, if blood tests have been assessed, it is not necessary to measure this cost again; it is possible to input previous results and analyze only the number of repetitions. The creation of a cost database is essential to enable the development of an integrated platform that allows for cost-data sharing among investigators.

Step 4: Estimate the total cost of each resource group and department

Using the resource map, resources classified as structure or personnel had their cost estimated. Hospital cost systems were used to identify direct costs such as depreciation, rents, energy, taxes, and others associated with each department mapped (costs allocated to the unit). The map was also used to distribute indirect costs, such as human resource management, c-suits, internal logistics, project management, and others to direct center costs (management costs absorbed).

This information can be found in the hospital financial systems, so this step can be automated to provide current values as needed. For salaries, the averages by specialties should be calculated using payroll hospital information.

Step 5: Estimate the capacity of each resource and calculate the capacity cost rate (CCR-$/h)

A database combining resource costs, capacities, and CCRs may be built to gather all the information to be used to structure the cost equations. Online Appendix C provides an example of how to build a database of resource costs, capacities, and CCRs.

Step 6: Analyze the time estimates for each resource used in an activity

Time estimates were based on an association between resources and activities. First, all digital information available in EMRs or production reports was used as a data source. For nursing and pharmacy, a chrono-analysis was conducted. A new matrix was built, in which "x" in Appendix B was replaced with the actual times identified, with CCRs for each resource added to simplify the total cost calculation. Having determined CCRs and the actual times for each resource for the different activities, all the information necessary for Eq. 1 was identified or measured. After that, it was possible to determine the costs of patient care and to perform analytics. Appendix D presents a complete matrix for cost assessment.

Steps 7 and 8: Calculate the total cost of patient care and cost analytics

Taking into account all of the analysis suggestions in Table 1, three were selected for this example: resource cost composition, cost per activity or phase, and cost benchmarking.

Resource cost composition

The breakdown of resource costs per patient during the hospital stay is a type of analysis made possible by the use of TDABC for microcosting. It allows for the identification of the most used resources by general patients. It also allows for the determination of the resource consumption differences among patients. Figure 3 shows the cost composition per patient, according to patient length of stay (Patient #11 = 172 days and P9 = 34 days).

Medications and medical materials represented an important resource, especially for the three patients who died (P11, P4, and P7). These patients suffered chronic graft-versus-host disease, a serious and common complication of BMT [35], and required expensive antifungal medications. Nevertheless, a broad variation in the use of medications and medical materials among patients was observed.

Determining the actual time during which each hospital resource was used by individual patients was essential to conduct these analyses. Without a real interpretation of how patients use hospitals, it is not possible to identify different demand patterns for resources that are not clearly listed in hospital bills, such as the individual effort of nurses, physicians, and ward. The contribution of TDABC can be even greater if these resources are stratified at the time when they are used, showing which activity or technology was used more intensely by the patient.

Cost per BMT phase

Exploring the information on how patients used the hospital during the different BMT phases by means of TDABC allowed for the identification of periods when patients became more expensive; this information was compared to the clinical demand recorded for the same periods (Fig. 4).

The cost distribution among activities showed that the phases conditioning, the day of transplantation procedure, and the aplasia periods were more expensive than other phases. During these days, patients were submitted to more physician consults, exams, and chemotherapy, and consumed more medications. The analysis shows that the median of total days for an allogeneic-related BMT was 46 days and

Table 1 Examples of cost analysis

Analysis	Description	Opportunities
Resource cost composition	Use bar charts or pie charts to illustrate the costs representative of each resource in each activity or patient	Identification of resources that are more expensive Identification of periods during which patients demand more human resources and structure. This information contributes to internal allocation studies Identification of a common behavior of similar clinical patients, improving the institutional power to discuss reimbursement Generation of a complete justification rationale for the total cost
Cost per activity or phase	Use bar charts or a timeline chart to plot the cost per activity of all patients	Identification of the most expensive activity to determine opportunities to make the activity more effective Justification of when, in the care flow, the patient uses hospital resources Identification of common behaviors by patients for demand in professionals and structure during the care flow, improving the institutional and clinical capability to identify opportunities to transfer the beginning and end of treatment to home healthcare
Cost benchmarking	Cost comparisons between different institutions	Identification of activities that use less resources in one institution than other Use of box plot charts to identify differences between the accounts in different hospitals Analysis of opportunities to adapt the care flow given what is being done in other institutions. The clinical demands and the quality of treatment may not be affected
Idleness analysis	Activities can have idleness measured in time and monetary metrics, allowing for the development of key performance indicators	Monitoring of objectives, goals and actions per activity, facilitating efficiency control
Statistical association between specific characteristics	Identification of clinical characteristics that can be statistically associated with a cost increase or reduction	Capability to prospect future costs and length of stay as a function of the initial diagnostic Opportunity to discuss reimbursement based on clinical characteristics Hospital capability to create its own short-term budget
Cost expected per patient	Represents the average or median cost per patient using the microcosting database	Calculation of the average or the median cost of a sample of patients Use of the cost information to conduct economic evaluations Identification of standards of care (time or monetary metrics) to better monitor, control, and, consequently, manage the care flow Identification of how the activities along the care flow demand different proportions of resources, guiding the process to allocate professionals

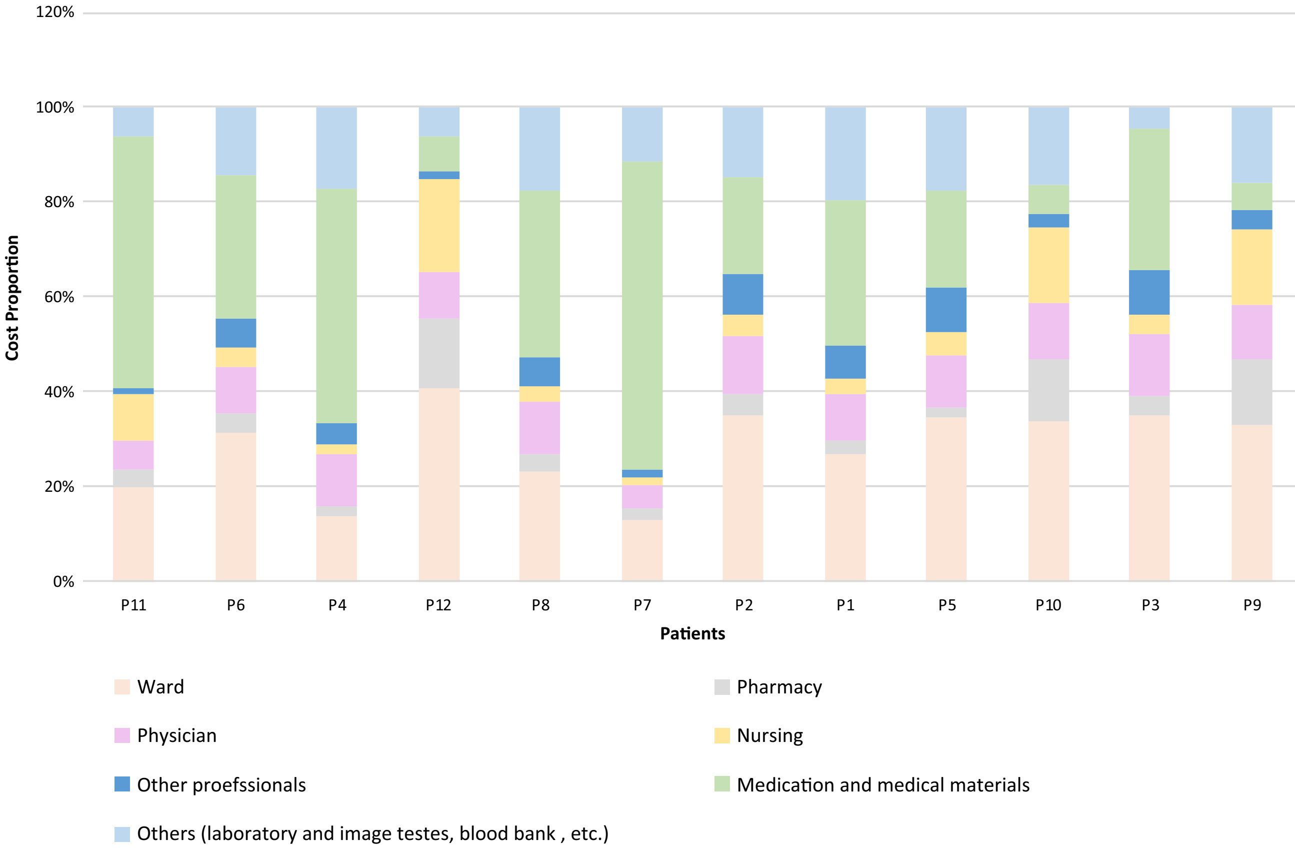


Fig. 3 Resource cost composition

Fig. 4 Cost per BMT phase

that the median of total costs based on activities was USD 77,412.18 (sum product of median days in each phase and cost median per day).

Before applying TDABC, it was not possible to understand exactly when during the treatment patients were using more resources. Controllers could only share the total final cost, after the end of admission. The opportunity to better understand the actual demand for resources enables hospital managers to allocate resources better, improving their ability to address patient requirements with higher quality and with a view to organizational value creation. However, if the objective of the microcosting study is to measure costs for a cost-effectiveness analysis, the average cost may be more representative. In this case, the average cost was USD 155,843.70 and the median of total cost was USD 93,640.99.

The opportunity to assess real data to examine reimbursements deserves further attention. For example, in Brazil, public reimbursement for a BMT transplant is USD 26,708.44; thus, the present analysis shows that this amount does not cover actual costs.

Benchmarking

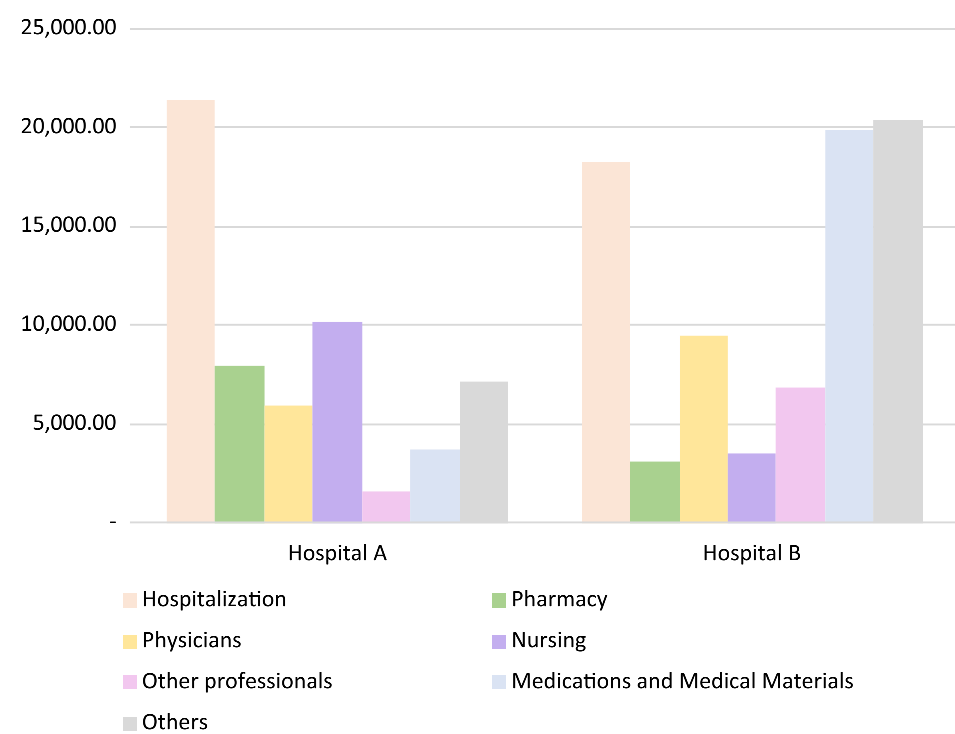
The application of the same cost methodology in two different hospitals (A and B) is useful for a discussion of the differences between organizations regarding the allocation of resources during the value care flow. Patients with similar conditions from both hospitals were compared (Fig. 5). The account "others" includes laboratory and imaging tests, and the blood bank. The costs are expressed in USD.

Analysis in Fig. 5 suggests that hospitalization is the only similar cost item between the hospitals, suggesting similarities in terms of structure costs and capacities of inpatient areas. However, different costs were observed for medications and medical materials, and professionals, nursing, physicians, and pharmacy.

Hospital A buys medications and medical materials through federal bids, in which purchases are always made based on the lowest unit, while the criterion adopted by hospital B was to buy brand-name drugs. Physicians in hospital B are paid per visit and in hospital A they have a fixed salary. The hourly rate is higher in A, but in hospital B patients usually spend 3 h per day with a physician, compared to 1.2 h in hospital A. Physician time increases in both hospitals during the period of aplasia. The behavior of nursing services is the opposite: chrono-analysis showed that in hospital A, nurses and nursing technicians together spend 10 h on average with each patient, compared to 5 h in hospital B.

The two hospitals also differ regarding visitation standards by other professionals, such as physical therapists, dieticians, and dentist. In hospital B these professionals spend 1–2 h per day with each patient as an internal rule; and in the hospital A, one visit occurs every 3 or 4 days. Another difference is that hospital A has a dedicated pharmacist for BMT patients. In hospital B, the BMT unit is supported by pharmaceutical teams that also serve other units. Finally, hospital B outsources the services in the "others" cost item,

Fig. 5 Cost benchmarking: median of total cost per resource in Hospital A vs. Hospital B



which include laboratory tests and blood bank, whereas hospital A performs and supplies these activities in-house.

Healthcare decision-making opportunities using TDABC

TDABC was fundamental for identifying cost information at a detailed and precise level, because it led researchers to identify the actual department and personnel time used by each patient, increasing the level of accuracy of the analysis of specific-patient consumption in the microcosting study. Producing quality information demands an integration of clinicians and financial analysts. In the case study used as an example, hematologists and other clinical professionals supported the cost engineer to correctly identify all the resources demanded during the hospitalization time.

Traditional methods usually do not breakdown cost according to the patient's actual utilization [6]. Those methods usually rely on a top-down perspective, which causes a loss of accuracy [22]: for example, the costs of a given department may be divided by the number of beds, including the cost of nursing, and thus it is not possible to explore the level of complexity and resource demanded by individual patients.

The opportunity to identify individual patient fluctuations in total costs according to clinical condition also represents an important advance and an opportunity for a discussion of reimbursements [20]. Public BMT reimbursement in Brazil is based on fixed pricing for all transplants. However, whereas one patient may profit from this, other more clinically complex cases may sustain financial loss. Before the existence of studies with higher cost accuracy that applied microcosting methods to measure actual costs, it was not possible to show how patients are or are not using different amounts of hospital resources. Studies like the present one show that the fee-for-service system does not contribute to the efficiency of the care flow. In contrast, a pay-for-performance system could use cost information provided by TDABC to support reimbursement decisions [10].

The differences between how hospitals structure the value care flow could only be detected because of the detailed daily analysis that the TDABC demands. This type of analysis prompts hospital managers to search for the best balance among physician, nursing, pharmacy, and other resources to deliver quality healthcare and a positive patient experience. In a preoperative assessment center, researchers applied TDABC to evaluate the value of process improvements performed, achieving a cost reduction of 46% without decreasing healthcare quality [36]. Clinical research to assess actual clinical needs and the best balance among different personnel and structural resources, combined with cost analysis, can better guide value-based decision making in healthcare organizations.

In addition, the utilization of staff or contract personnel, especially physicians, can also be examined. This case study shows that in the hospital where physicians are paid per visit, patients spend more time with this professional than in the hospital with staff physicians. Data produced by TDABC analysis [6, 17] can support pay-for-performance decisions by adding clinical quality metrics to assess the effect of the visits on treatment.

The performance of detailed cost studies allows for the production of data with sufficient accuracy to support health technology decision making and an understanding of how technology costs can fluctuate during treatment. The results of microcosting studies where TDABC is applied help hospital managers better distribute resources (including personnel), if access to data provided by the study is automatized. As soon as information technology systems start to advance to support the use of TDABC in microcosting in healthcare, the organizational capability to guide decisions by value will increase by: cost comparisons by countries, health systems or disease; performance of economic evaluations with higher quality of data; and the capability to develop artificial intelligence to identify standard processes for treatment and cost benchmarking from a global perspective. After the presentation of this 8-step framework, the development of automatized technologies to facilitate service delivery data collection and software based on this 8-step framework can contribute to the acceleration of the innovation processes in the industry and create a solution for the market that can scale TDABC use in healthcare.

Conclusions

This research proposed an innovative step-by-step framework to guide and standardize the implementation of TDABC in microcosting studies for healthcare organizations, challenging the notion that actual costs cannot be measured in healthcare. The 8-step TDABC framework contributes to increasing the number of studies that achieve high-quality level of cost information in health resource evaluation, and by guiding academic research in developing technology information systems to perform TDABC microcosting studies based on standard guidelines. Finally, the 8-step framework allows more healthcare organizations to have access to detailed guidelines on how to better assess and control their costs and processes, leading them toward a value-oriented reimbursement system.

Future researchers can explore the step-by-step framework in order to make more advances in technology innovation, for example, the automatization of data collection in step 4 by smart algorithms based on robotic process automation; the development of a friendly app that would let professionals report their activities per patient, allowing for the creation of an activity time database with real time data collection. The TDABC application with different clinical pathways could provide better comprehensions of how to turn the method application better effective and oriented for decision making.

It is important to highlight that the case study presented was used to simplify the 8 steps to aid comprehension by readers so that the use of BMT cost results as data for economic decision models receives more attention from future researchers. Even though advances in technology that support the use of TDABC in microcosting have been discussed, this research has not advanced in terms of algorithms coding since these advances are required continuously for the scalability of TDABC focused on supporting value-oriented decisions in healthcare.

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Compliance with ethical standards

Conflict of interest None of the authors have any conflict of interests. Supported by the Ministry of Health, Brazil, through PROADI Program, led by Hospital Moinhos de Vento, Porto Alegre, Brazil.

Ethical statement This study has been approved by the Institutional Review Board of Hospital Moinhos de Vento of Porto Alegre (approval number 1.910.843) and by the Institutional Review Board of Hospital de Clínicas of Porto Alegre (approval number 2.035.550). Written informed consent was obtained from each participant at the time of enrollment.

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