



Identifying cost-saving opportunities for surgical care via multicenter time-driven activity-based costing (TDABC) analysis as exemplarily shown for cholecystectomy

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Background: This study applied time-driven activity-based costing (TDABC) to accurately assess costs and to demonstrate how it is possible to estimate cost-saving opportunities by exploring the results achieved with the method.

Methods: This is a cohort retrospective and multicenter cost analysis research, which included data from video-assisted cholecystectomy patients from five public-funded hospitals. The TDABC was applied according to recommendations in the literature for data collection and analyses. Descriptive cost analysis was followed by an estimate of the labor cost that could be saved by redesigning the surgical pathway based on the benchmark care cycle identified in the hospitals studied.

Results: The mean cost per patient was Int\$701.61 and median cost was Int\$679 (IQR, Int\$470–\$821), with physician expenditure being the most representative cost variable (35%). The cost-saving analysis suggested that the greatest opportunity for savings was physician time consumed during the surgery: Int\$126

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per patient could be saved by optimizing the physician's involvement in the surgery. When the total labor costs were evaluated, the optimal surgical process estimated for each hospital could save from Int\$18 to Int\$321 per patient (at the most and least efficient of the hospitals, respectively).

Conclusions: By the application of the TDABC, it was demonstrated that the actual care practices to deliver this service varied between the hospitals, resulting in different times and costs for each hospital. These findings suggest that the TDABC method can be used by health managers to redesign surgical pathways, better assess costs and estimate potential cost-saving opportunities to promote value-based strategies in healthcare.

Keywords: Micro-costing; time-driven activity-based costing (TDABC); value-based healthcare; redesign; surgical pathways

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Introduction

Healthcare expenditures have been increasing worldwide without necessarily delivering better healthcare services (1,2). The continuous search for ways to minimize waste in healthcare is one of the main pillars of value-based initiatives around the globe (3). Value is defined by the achieved patient reported outcomes per costs spent to deliver those outcomes (4). For a healthcare system to successfully migrate from fee for service to value based reimbursement requires advances in cost accounting methods, which can provide more accurate data and identify opportunities to make care pathways more efficient (5).

Costs are generated by performing patient care activities, and cost-savings arises from performing particular activities efficiently, allowing to better apply scarce resources to deliver better healthcare service to the population (6). For competitive healthcare value, patient needs must be met without increasing costs, and transparency about outcomes and costs is necessary to engage providers in a culture of value (6). Learning from best practices can reveal how much time and money can be saved and can guide healthcare delivery redesign initiatives. It can incentivize continuous improvement for the healthcare system, making it more homogeneous between centers (7).

Time-driven activity based costing (TDABC) estimates the costs of a given clinical service by combining information about the patient care pathway with the unit cost of each resource used to provide care (8). The TDABC method was proposed as an improvement to activity-based costing since it makes accurate cost analyses easier to update by estimating two parameters: (I) the unit cost of

resource inputs and (II) the time and quantity of resources required to perform a transaction or activity (9). When well-designed, the application of TDABC can optimize resource management on a per-patient basis throughout the entire episode of care (10), helping identify cost-saving opportunities by making healthcare procedures more efficient, competitive, and, consequently, less expensive (11). This method was recently suggested as the gold standard of cost analysis in value-based healthcare initiatives (12).

The application of TDABC to surgical episodes of care has resulted in increased organizational efficiency, including: optimization of operating room scheduling (13); redesigning activities during surgery (14); identifying benchmarks of care when applied across multiple centers (15); reducing cleaning and set up time between surgeries (13); reducing the time between patient arrival and the beginning of surgery, and reducing time spent in the post-anesthesia care unit (5,16). These achievements can be magnified by applying the same method across multiple centers to evaluate healthcare costs and identify cycle of care redesign opportunities (17).

Finding innovative design solutions to identify benchmarks of healthcare service delivery can provide health managers with data to support value-oriented decisions (18). Only through systematic comparison of the entire patient trajectory and risk-adjusted outcomes can managers be confident that the care process is the best alternative (18). As a driver of quality improvement, transparency can be more effective than financial incentives (10), and the combined use of pathway redesign and TDABC methods can achieve a deeper engagement with patients and providers to achieve

more effective and patient-centered pathways.

Considering a public health system, a method that allows managers to compare surgical pathways and identify benchmarks of costs and healthcare service delivery could serve as a guide to cost saving opportunities. This study applied the TDABC method to accurately assess costs and to demonstrate how it is possible to estimate cost-saving opportunities by exploring the results achieved with the method.

Methods

The surgical procedure of video-assisted cholecystectomy was selected to exemplify the TDABC application in a multicenter study. The selection of this condition considered that it is performed in volume in all hospitals, and it was expected do not encounter a high variability between the centers. Video-assisted cholecystectomy data were collected retrospectively and simultaneously from five publicly-funded academic hospitals, which are national centers of excellence (A, B, C, D, and E) located in four different states in Brazil. The participating centers were selected based on their expertise in health technology assessment projects, on whether they were members of the Brazilian Network for Health Technology Assessment (REBRATS), and on their availability and personal capabilities in terms of human resources. The characteristics of the hospitals are described in [Table S1](#).

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was based on a perspective of the public hospitals that provide healthcare service to the public system and was approved by the ethical committee from the Hospital de Clínicas de Porto Alegre, project number CAAE: 71078617010015327. Approval was granted by all ethical committees of participating hospitals and informed consent was not required because we are not collecting or evaluating personal and individual information from patients or professionals.

Data collection

Patients who underwent the video-assisted cholecystectomy between March and October 2018 were included in the study at a maximum of 20 consecutively patients per center. Patients were eligible if they had elective video-assisted cholecystectomy during this period and their billing was approved by the Brazilian Unified Health System (SUS).

All centers received instructions on data collection, and a database was created using REDCap web-based software (Vanderbilt University, Nashville, TN, USA). A multidisciplinary team of researchers was responsible for data collection, developing the methodological framework and analyzing the results.

The team that applied the TDABC method consisted of physicians, industrial engineers and professionals with business backgrounds. All suggested methodological steps were strictly followed ([Figure S1](#)) (19,20) and the checklist suggested in the literature to report TDABC studies was used to guide the article consolidation ([Table S2](#)) (21). By applying TDABC, it was possible to measure the costs of all the resources used to treat a patient's over a complete cycle of care.

Process maps were developed by direct observation of a selected center over a one-week period, followed by validation at the remaining centers. The resulting map was used to identify all resources consumed during the surgery and in each macro-phase procedure: pre-surgery, surgery, and post-anesthesia care unit. The following resource variables were selected for evaluation: personnel, corporate and divisional allocations (structure), and medications and materials related to each phase (pre-procedure, procedure, and post-procedure). A total of 14 surgical pathway cost variables were found ([Figure S2](#)), in addition to materials and medications.

Data collection techniques included medical record reviews, direct observation by the researchers, and interviews with the involved personnel (11). For the time data, units of time were collected from patient's medical records and by the procedure observation by a researcher. In each center, all the patients included have their time registers obtained by a researcher that was observing the activities that each patient was being submitted. Then, the length of time that patients spent in each activity and the respective labor and structural resources consumed in each activity was registered in the database for each patient. In addition, the professionals were asked to report the additional time dedicated to surgical prepare activities, and their answers were computed together with the observed time per patient. The quantity and price of materials, prostheses and medications were collected from invoices and documents containing the acquisition costs of supplies, excluding profit margins.

For calculating the structural and labor capacity cost rates (CCR), different strategies were implemented. Fixed hospital costs, such as energy, third party contracts,

depreciation, system licenses, taxes and general materials used for each patient were estimated per department. Salaries per professional class were considered as labor costs. Indirect departmental costs and overhead, such as administrative costs were not included in this analysis, making the cost information generated a reflex of the direct costs. The not consideration of overhead costs was necessary because of the high variability in level of financial information accessibility in each center.

All financial information was based on the average expenditure incurred per month over a 12-month period. To calculate the labor capacity cost rates (CCR) for each resource, actual capacity was calculated, given the characteristics of each department. For inpatient areas, where workload is proportional to physical space, the number of beds was included in the calculation. For the professionals, monthly work hours and expected fringe benefit rates were considered. The department's capacity was based on hospital productivity reports and employee allocation scales and complemented by interviews with each department's manager.

Statistical analysis

The data were consolidated in a Microsoft® Excel spreadsheet and exported to IBM SPSS® for analysis. The analyses were fragmented in descriptive cost analysis and cost saving estimates by identifying benchmarks of patient care for video-assisted cholecystectomy. Cost data were collected in local currency (2019 BRL) and converted to international dollars according to the 2018 purchasing power parity value (22).

Time and cost databases were created for each variable under analysis. The mean, standard deviation (SD) and standard error (SE) of the patient-level cost per site, followed by the composite cost per site were reported descriptively. The median time and cost per phase were then compared, which allowed connections to be identified between time and cost during the surgical pathway. The TDABC equation, which involves the sum-product of the CCR of each resource and the time consumed by each resource, was applied to the 14 surgical process variables, allowing calculation of the median cost per surgical phase, resource and hospital. The CCR of each resource in the sample of hospitals and the differences in time consumed per resource were used to explain the variation in surgery time and costs.

The analyses were performed to identify the best

surgical pathway and potential cost-saving opportunities in each hospital. First, cost composition was measured by determining the median cost of each resource, broken down into labor and non-labor costs for each phase. By identifying the most representative cost variable, cost-saving opportunities were analyzed graphically, specifically surgical times and CCRs with in each hospital.

To explore the most efficient process, the minimum mean time for each labor resource in the surgical pathway was identified among the hospitals, which resulted in the minimum mean time per labor resource. An optimal surgical-process reference was suggested for each hospital (A', B', C', D', and E'), which multiplied the minimum time for each labor resource by the specific CCR resource. The current labor cost was compared to the optimal potential labor cost, and differences between hospitals represent labor cost-saving opportunities that could be achieved by improving the surgical pathway in each hospital.

Results

During the study period, 100 patients who underwent elective video-assisted cholecystectomy were included (20 patients per hospital). The mean and median costs per patient were Int\$701 and Int\$679, respectively (IQR, Int\$470–\$821). The physician cost was the resource with the highest cost proportion, in average it represented 35% of the cost per patient. *Table 1* shows the costs stratified by hospital.

The median time and CCR for each resource in each phase of the care pathway are shown in *Table 2*. For all the resources, the CCR differed between hospitals, which indicates that even though some hospitals had a most effective care process, its final cost could have been higher than less efficient hospitals. The median cost per patient per hospital, calculated as the sum of median time and CCR for each variable plus medical supplies, is presented in *Table 3*. The highest costs were concentrated during the surgery (*Table 3*), and the greatest variation was in length of time spent in the recovery room after surgery (*Table 2*).

The median cost per patient per hospital varied between Int\$318 (hospital D) and Int\$764 (hospital E). However, the length of time from pre-procedure to post-surgery was similar between these two hospitals (D =3.6 hours; E =3.9 hours).

Labor cost-saving analysis

Breaking down the surgery into macro-activities allowed

Table 1 Cost results for video cholecystectomy in all hospitals

Cost measures/items	Hospitals				
	A	B	C	D	E
Total cost (\$)	15,637	14,581	12,393	7,410	20,032
Mean (\$)	782	729	619	375	1,001
SD	190	134	299	145	496
SE	42	30	67	32	110
Minimum	523	381	312	201	549
Maximum	1,215	984	1,578	766	2,484
Resource componentes					
Assistants*	\$77	\$54	\$69	\$30	\$50
Nursing technicians*	\$25	\$25	\$61	\$11	\$14
Nurses*	\$72	\$26	\$85	\$4	\$90
Physicians*	\$259	\$218	\$246	\$144	\$335
Fellow physicians*	\$26	\$31	\$34	\$33	\$42
Structural*	\$176	\$138	\$85	\$116	\$439
Materials and medication	\$144	\$234	\$38	\$34	\$28

*, the cost information indicates the cost per hour of each resource; SD, standard deviation; SE, standard error.

assessment of the way resources are consumed along the entire surgical pathway. *Figure 1* compares the cost concentration per labor and non-labor resource in each activity of the surgical pathway in each hospital (excluding medical supplies and drugs). This figure demonstrates the impact of the structural CCR of the surgical room, especially in hospital E. The importance of labor cost during surgery is also notable: physicians represented 66%, on average, of the labor costs during the surgery phase. Thus, data on physician labor time and cost during surgery were used to explore cost-saving opportunities, comparing the most (D) and least (E) efficient hospitals (*Table 2*). *Figure 2* shows that hospital E could save Int\$126 by reducing physician time in the surgery phase by conforming to hospital D's parameters.

By identifying the potential economic impact of time-saving opportunities for each labor resource, the cost of a redesigned surgical pathway for each hospital was estimated. *Figure 3* presents the actual mean labor cost per surgical phase and the optimal labor cost estimated for each hospital. The difference between the actual cost and the optimal estimated cost represents the labor cost-saving opportunity per hospital. Hospital E presented the highest cost-saving opportunity (Int\$321), part of which can explained by time

consumed by physicians during surgery. Hospital D had the lowest target labor cost (Int\$207), mostly due to having the lowest physician CCR.

Discussion

This study generated an accurate direct cost information for video-assisted cholecystectomy in Brazil and showed how the TDABC can contribute to guide redesign initiatives aimed at decreasing healthcare waste in surgical pathways.

TDABC is an important method for identifying opportunities to optimize surgical procedures and has been an emerging topic in the health economics literature (15,23,24). It is frequently associated with discussion about migrating from a fee-for-service to a value-based or bundled reimbursement system (25-27). It has been reported that the fee-for-service payment system create barriers to improving the quality of services delivered to patients and to reducing waste. One of these barriers is that the fee-for-service system does not actually value activities that are essential for the delivery of safe and effective health services (1). The present study concentrated on the main phases of a surgical cycle and found that the amount of time consumed by professionals varied according to hospital,

Table 2 Cost capacity rate and median time consumed per resource in each phase

Variables	Hospital A	Hospital B	Hospital C	Hospital D	Hospital E
Cost capacity rate per resource					
Hospital structure pre procedure (\$)	57.75	33.38	10.79	47.60	123.57
Hospital structure procedure (\$)	57.75	33.38	10.79	47.60	123.57
Hospital structure post procedure (\$)	2.14	1.09	10.79	5.78	1.15
Nursing technician pre procedure (\$)	22.97	13.83	16.89	10.14	11.32
Nursing pre procedure (\$)	43.94	32.91	32.08	13.04	33.94
Other professionals surgery (\$)	22.97	13.83	16.89	10.14	11.32
Nursing surgery (\$)	43.94	32.91	32.08	13.04	33.94
Physician surgery (\$)	79.05	73.46	61.10	64.24	65.79
Fellow physician surgery (\$)	6.48	6.48	8.09	8.41	5.99
Cleaners surgery (\$)	9.19	3.80	10.73	8.41	4.89
Nursing technician post procedure (\$)	22.97	13.83	16.89	10.14	11.32
Nursing post procedure (\$)	43.94	32.91	32.08	13.04	33.94
Physician post procedure (\$)	79.05	73.46	61.10	64.24	65.79
Fellow physician post surgery (\$)	6.48	6.48	8.09	8.41	5.99
Median time consumed per resource					
Structure pre procedure (h)	1.30	1.58	2.38	1.08	0.75
Structure procedure (h)	1.42	1.88	1.59	0.89	1.78
Structure post procedure (h)	2.88	7.92	2.64	1.58	1.38
Nursing technician pre procedure (h)	0.08	0.42	0.33	0.33	0.04
Nursing pre procedure (h)	0.13	0.08	0.18	0.08	0.04
Other professionals surgery (h)	2.92	3.79	3.32	1.84	3.67
Nursing surgery (h)	0.50	0.08	1.59	–	1.78
Physician surgery (h)	2.83	2.93	3.18	1.78	3.75
Fellow physician surgery (h)	3.88	3.83	3.76	2.00	4.17
Cleaners surgery (h)	0.27	0.27	0.27	0.67	0.50
Nursing technician post procedure (h)	1.00	1.08	1.13	0.50	0.67
Nursing post procedure (h)	1.00	0.42	0.17	0.25	0.42
Physician post procedure (h)	0.17	0.10	0.07	0.33	0.33
Fellow Physician post Surgery (h)	0.17	0.33	–	0.50	0.33
Surgery cost per resource and phase					
Structure pre procedure (\$)	75.07	52.86	25.63	51.57	92.67
Structure procedure (\$)	81.81	62.59	17.18	42.44	219.33
Structure post procedure (\$)	6.16	8.62	28.51	9.16	1.59
Nursing technician pre procedure (\$)	1.91	5.76	5.63	3.38	0.47

Table 2 (continued)

Table 2 (continued)

Variables	Hospital A	Hospital B	Hospital C	Hospital D	Hospital E
Nursing pre procedure (\$)	5.86	2.74	5.88	0.98	1.41
Other professionals surgery (\$)	66.98	52.44	56.01	18.67	41.52
Nursing surgery (\$)	21.97	2.74	51.06	–	60.24
Physician surgery (\$)	223.97	215.49	194.51	114.56	246.71
Fellow physician surgery (\$)	25.09	24.82	30.40	16.83	24.96
Cleaners surgery (\$)	2.45	1.01	2.86	5.61	2.45
Nursing technician post procedure (\$)	22.97	14.98	19.14	5.07	7.55
Nursing post procedure (\$)	43.94	13.71	5.35	3.26	14.14
Physician post procedure (\$)	13.17	7.35	4.07	21.41	21.93
Fellow physician post surgery (\$)	1.08	2.16	–	4.21	2.00

Table 3 Median cost estimate per patient and hospital

Hospital	Surgery cost per phase				
	Median cost of pre-surgery procedure (\$)	Median cost of surgery procedure (\$)	Median cost of post-procedure (\$)	Median cost of materials and medications (\$)	Median estimated cost per patient (\$)
A	82.85	422.27	87.32	144.39	736.83
B	61.36	359.10	46.82	278.31	745.60
C	37.14	352.02	57.07	37.92	484.16
D	55.92	198.11	43.10	21.54	318.69
E	94.56	595.20	47.20	27.62	764.58

although all of them receive the same public reimbursement based on a fee-for-service system. The full comprehension of the entire care cycle, which can be achieved through the TDABC method, is essential to facilitate patient-centered redesign initiatives and a migration from service to value in the reimbursement system.

The result which demonstrates that part of the differences in costs are explained by the variability on CCR between hospitals, and by the way that resources are consumed by patients throughout the surgical care cycle, highlights how it is valuable to define standards of processes of care to guide surgical procedures in a public health system. It also points out how it is important better understand the costs per hospital, regional and institutional practices before to suggest that one hospital is more or less efficient than other. Although hospital E did not keep patients in the post-anesthesia care unit for long, it had the highest treatment cost due to the high structural cost of the surgical room and greater

physician time during surgery (3.75 hours). On the other hand, hospital B kept patients in the post-anesthesia care unit for a long time but did not have a higher median cost per patient due to its lower structural costs for the surgical room. Hospital D, which had the lowest median cost, completed the surgery quicker than the others and required fewer physician hours to complete the surgery. These differences, which are influenced by organizational culture and regional variations in resource costs, were only identified because of the level of information granularity that the TDABC provides and allows the identification of hospitals which could be assumed as a benchmark to guide cost-saving initiatives.

Porter and Teisberg (6) proposed the concept of value-based health management to ensure the way organizations that are reimbursed cooperates with improving the quality of healthcare services. Allowing healthcare systems to migrate from volume- to patient-centered systems requires methodological advances that enable understanding of

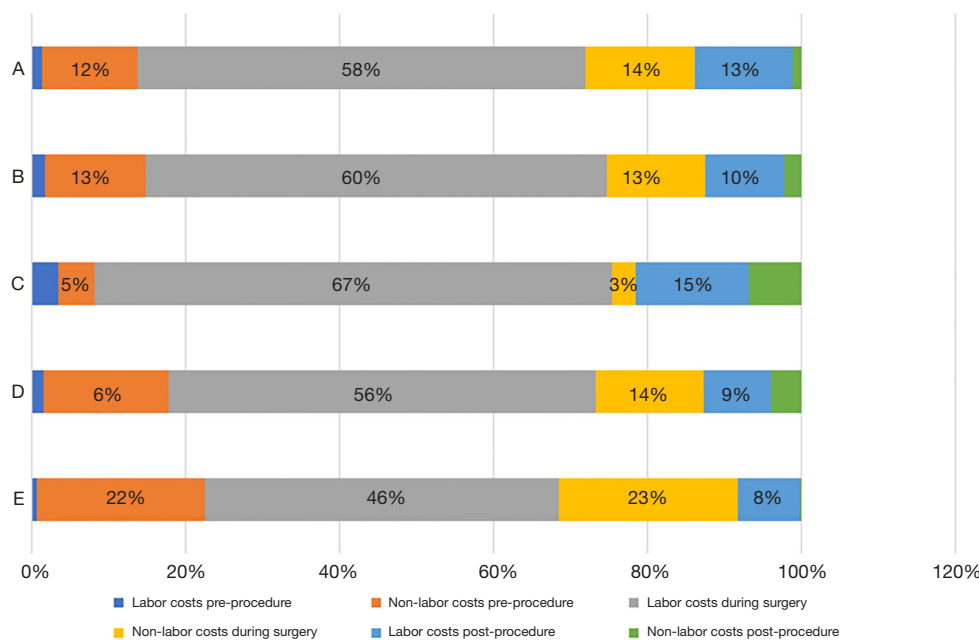


Figure 1 Cost composition per hospital. Labor costs include physicians, nurses, nursing technicians, fellow physicians and cleaners. Non-labor costs include fixed building costs, such as depreciation, energy, general materials.

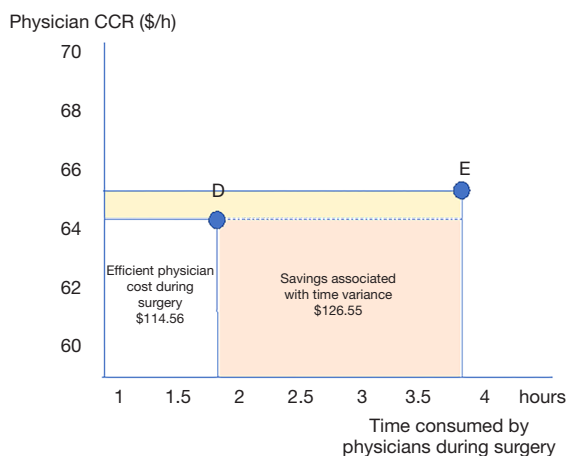


Figure 2 Cost-saving opportunities associated with physician costs during the surgical episode. CCR, cost capacity rate.

patient-specific and individual resource consumption over the course of the care cycle (8).

Motivated by the Enhanced Recovery After Surgery (ERAS) Group recommendations, surgical trajectory redesign efforts have been embraced by health managers (28). Nevertheless, only a few detailed studies have reported

on the economic impact of these recommendations. In a systematic review of cost-effectiveness studies for ERAS programs, we pointed out that the different methods used to evaluate ERAS costs decrease the accuracy of the data and the possibility of using them in future high-quality scientific studies (29). In another systematic review on the economic impact of ERAS implementation, we demonstrated that standard methods for correctly evaluating ERAS costs must be defined to achieve more effective analyses of ERAS programs (30). Given that the TDABC methodology can lead to better understanding of labor and non-labor resource use in surgical pathways, we suggest that future studies use the TDABC to evaluate the economic impact of best practices defined in the ERAS recommendations, which would allow a complete value assessment, i.e. one that includes clinical, process and financial outcomes (29).

Our results suggested that the TDABC can be used to guide the identification of surgical redesign initiatives that could result in cost-savings and waste reduction in healthcare. In addition, by the level of details in the cost information that is achieved, the TDABC method can collaborate for deeper engagement between patients and providers to achieve more effective and patient-centered pathways.

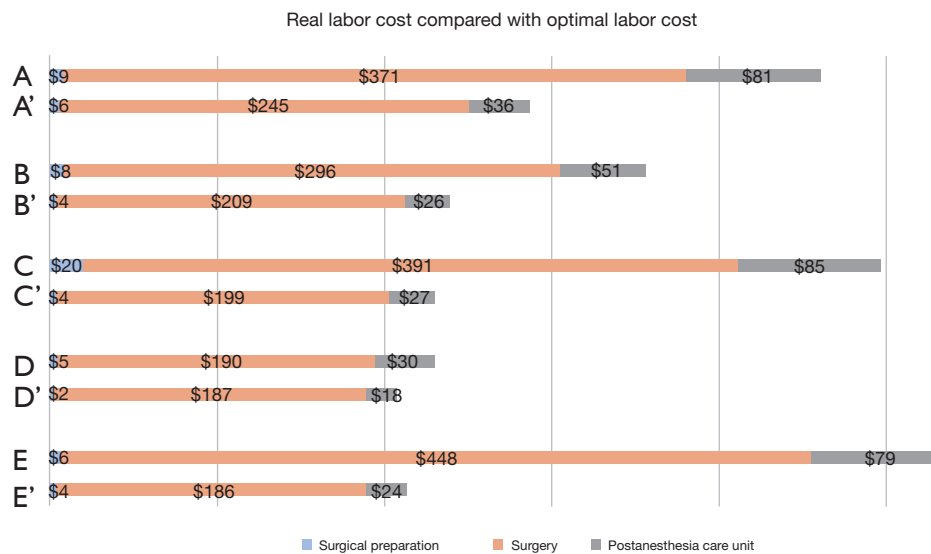


Figure 3 The mean assessed labor cost and the estimated optimal labor cost per hospital. A, B, C, D and E represents the real labor cost calculated for each hospital and A', B', C', D' and E' represents the estimated labor cost for optimal surgical-processes, which are multiplied by the minimum time for each labor resource identified and the specific labor resource cost capacity rate of each hospital.

Limitations

A few limitations should be considered regarding the present study. First, a single surgical procedure was evaluated, and the replication of this methodology to other surgeries and inpatient services is recommended. Second, the study considered only direct costs and not the quality of the service delivered in each hospital, although all patients were discharged and had no complications. Analysis of health outcomes must be added to cost assessment in future studies to ensure a value management approach.

This study included only hospital direct costs, the hospital overhead costs were excluded because of the differences in the financial information accessibility from each center. This variability, in multicenter studies, was identified as a challenge to apply the TDABC with the same level of quality in all centers.

The analyses presented are estimating potential labor cost savings that could be achieved by implementing a redesign initiative. It is strongly recommended in future studies to apply the TDABC to evaluate the results achieved in a surgical redesign project, following the recommendations available on the literature (31) and including the impact of materials and medications. Finally, reducing the time of the video-assisted cholecystectomy would free up the operating room for other procedures, which would further reduce costs, but this opportunity

cost was not investigated.

Conclusions

This is the first multicenter TDABC study conducted in Latin America that has evaluated a high-volume surgical procedure to estimate cost-saving opportunities in health service delivery. It was possible to demonstrate how the results achieved by the application of the TDABC method can be used to identify benchmarks of care that can guide surgical redesign initiatives. Although it is a well-known procedure, the actual care practices varied significantly, which translates into different times and costs for each hospital. These results can be used by managers to inspire innovative solutions for redesigning care processes and reimbursement strategies, better cost assessment, and to support cost-saving opportunities and value-oriented strategies in healthcare.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://jhmhp.amegroupp.com/article/view/10.21037/jhmhp-21-34/coif>). APBDSE and CAP receive payment or grant from Roche, BMS, HMV and HCOR. JADFN receives consulting fees from AMCA. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was based on a perspective of the public hospitals that provide healthcare service to the public system and was approved by the ethical committee from the Hospital de Clínicas de Porto Alegre, project number CAAE: 71078617010015327. Approval was granted by all ethical committees of participating hospitals and informed consent was not required because we are not collecting or evaluating personal and individual information from patients or professionals.

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Table S1 Hospital characteristics

Characteristics	Hospitals				
	A	B	C	D	E
Number of beds	831	1,013	506	915	504
Number of employees	6,061	6,628	3,377	6,032	3,200
Total number of surgeries in 2018	47,546	32,005	17,783	33,109	7,371
Annual budget (\$)	648,116,645	748,129,627	228,645,500	273,813,716	92,029,785

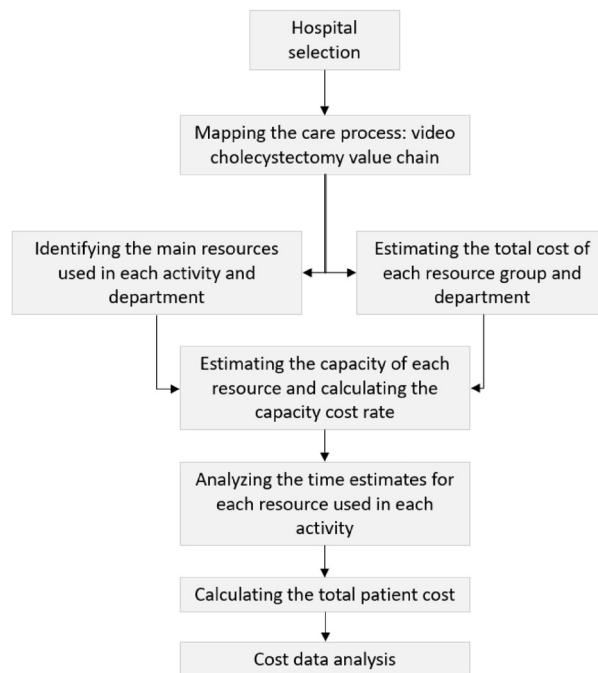


Figure S1 Application of the TDABC. TDABC, time-driven activity-based costing.

Table S2 TDABC checklist

TDABC elements	Classification	Paper section	Article
1.1 It is defined if the results are being explored for general health service management or redesign and value or only to assess costs?	Strongly Suggested, but not mandatory	Introduction	Yes, redesign and value
1.2 Is the clinical pathway, technology or procedure studied justified because of an interest from government, hospital, society or a Health Technology Assessment Analysis?	Mandatory	Introduction	No, but in this case the clinical pathway was used an example to demonstrate how the method can be used to sustain cost-saving estimates. However, the selection of the conditions for that was justified in the methods
1.3 Are study limitations being presented?	Mandatory	Discussion	Yes
1.4 Is the TDABC method selection being justified?	Mandatory	Introduction	Yes, it is the aim of the study to demonstrate how the method can be used to guide redesign initiatives that can result in cost-savings
2.1 Are authors using specific methodologies to design the care pathway?	Mandatory	Methods	Yes, explained in the methods
2.2 Are authors using a multidisciplinary team to apply the TDABC? (Design the process, correctly consider clinical characteristics, correctly evaluate costs)	Mandatory	Methods	Yes
2.3 Are authors reporting activities in the process map on a macro level?	Mandatory	Methods	Yes, <i>Table S2</i>
2.4 Are authors reporting activities in the process map on a micro level?	Strongly Suggested, but not mandatory	Methods	No.
2.5 Is the full process map (or a part of) being presented in a picture or graphic display?	Strongly Suggested, but not mandatory	Results	No
3.1 Is a table or a map being presented to illustrate the association between activities and resources?	Strongly Suggested, but not mandatory	Results	No
3.2 Are the resources that are included in the analysis being defined and justified?	Mandatory	Methods	Yes, all structural and labor
3.3 Are authors reporting observation in-situ approach to better identify resources used in each activity?	Mandatory	Results	Yes.
3.4 Are the authors interviewing the professionals to better identify resources used in each activity?	Mandatory	Results	Yes.
4.1 When using hospital financial database, it is being stated how those data were collected and analyzed?	Mandatory	Methods	Yes.
4.2 Are authors defining the currency and applying discount taxes when it is necessary?	Strongly Suggested, but not mandatory	Methods	Yes, collected in Reais (R\$) and reported in I\$
4.3 When using external financial databases, is there a description of the database and how those data were accessed?	Mandatory	Methods	NA
4.4 When mixed financial databases are being used (for example, salaries from external reference and structural costs from the hospital) is the origin of each data variable being stated?	Mandatory	Methods	NA
4.5 Did the authors explaining how the overhead costs are being considered?	Mandatory	Methods	Yes, it was not included
5.1 Are authors defining if the capacity data used represents the total capacity per resource or it is being considered an expected idleness?	Mandatory	Methods	Yes, it was not being considered an expected idleness
5.2 When authors are considering an expected idleness, it is explained how actual performance data were collected and analyzed?	Mandatory	Methods	NA
6.1 Are authors explaining how time data were collected?	Mandatory	Methods	Yes, observer followed by professionals interviews
6.2 Are authors using interviews with professionals crossed with medical record review to estimate time data?	Strongly Suggested, but not mandatory	Methods	Yes
6.3 When using chronoanalysis, it is being explained how the sample of data was defined?	Mandatory	Methods	No, it is not being used
6.4 Is it being explained if the chronoanalysis used a digital technology to collect real time data, such as mobile app, wearable, drone, etc.?	Strongly Suggested, but not mandatory	Methods	NA
7.1 Is the median or average cost per patient (or per technology) being calculated?	Mandatory	Result and Discussion	Yes
7.2 Are authors presenting the cost per each patient included in the sample? (Chart bar, table, etc.)?	Mandatory	Result and Discussion	Yes
7.3 Is the median or average cost per activity on a macro level being presented?	Mandatory	Result and Discussion	Yes
7.4 Is the median or average cost per activity on a micro level being presented?	Mandatory	Result and Discussion	No
7.5 Is the median or average cost per resource being presented?	Mandatory	Result and Discussion	Yes
7.6 Are authors performing capacity idleness analysis?	Strongly Suggested, but not mandatory	Result and Discussion	No
7.7 Are authors exploring statistical analyses to better understand costs along the process of care?	Strongly Suggested, but not mandatory	Result and Discussion	No
7.8 If the objective was to use the study to support management and value decisions, are authors reporting how value increasing was achieved or if they are planning to achieve it?	Strongly Suggested, but not mandatory	Result and Discussion	Yes, possible cost savings

TDABC, time-driven activity-based costing.

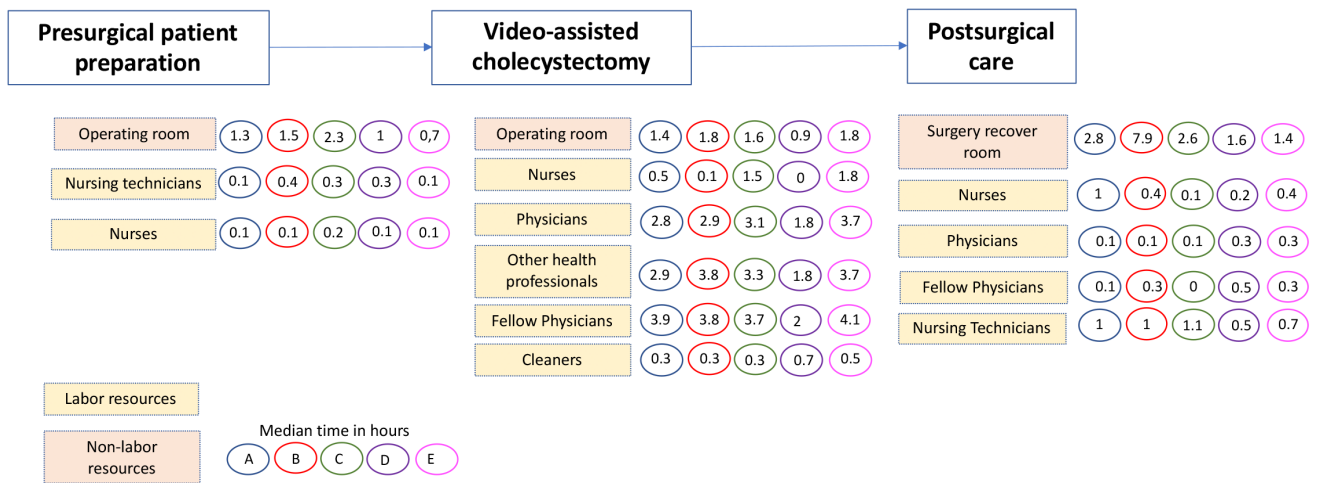


Figure S2 Surgical pathway cost variables. Stratification of the labor and non-labor cost variables along the tree macro phases of the surgical pathway. The colored circles indicate the median time in hours consumed by each resource in each hospital (A-blue, B-red, C-green, D-purple and E-pink).