An Integrated Cost Model Based on Real Patient Flow: Exploring Surgical Hospitalization in a Teaching Hospital

Bruno Barbosa Vieira (bruno.vieira@aluno.cefet-rj.br)
Celso Suckow da Fonseca Federal Centre of Technological Education: Centro Federal de Educacao Tecnologica Celso Suckow da Fonseca https://orcid.org/0000-0003-3835-4560

Augusto Cunha Reis
Celso Suckow da Fonseca Federal Centre of Technological Education: Centro Federal de Educacao Tecnologica Celso Suckow da Fonseca

Alan de Paiva Loures
Universidade Federal de Juiz de Fora Hospital Universitario

Eliel Carlos Plácido
Universidade Federal de Juiz de Fora Hospital Universitario

Fernanda Ferreira de Sousa
Universidade Federal de Juiz de Fora Hospital Universitario

Research

Keywords: surgery cost model, surgery cost analysis, surgical hospitalization, health care costing, public teaching hospital

Posted Date: December 31st, 2020

DOI: https://doi.org/10.21203/rs.3.rs-137754/v1

Abstract

Background: Several studies have been carried out with the objective of identifying health costs and developing methods to improve this research, thus contributing to better decision making based on more reliable evidence. However, there are some gaps to be filled to provide such information. This research aims to fill one of these gaps, proposing a cost calculation model for surgical hospitalizations based on real patient flow to determine hospital institutions' costs.

Methods: An empirical-theoretical study was developed. The empirical approach adopted the three-step modeling process to propose a cost model based on patient flow, considering CHEERS guidelines. For the theoretical approach, a systematic literature review using PRISMA recommendation was applied.

Results: The modeling process made it possible to identify the real flow of the surgical patient. This step made it possible to identify cost sources and comprehend that costs incurred by patient occur from admission (preoperative stage) to discharge (postoperative stage). The literature review showed that most studies only address the surgical stage, neglecting the costs of the two stages mentioned. The cost model was developed with a top-down approach allowing a balance between the accuracy of the information and the feasibility of the cost estimate. The proposed model fills two gaps in the literature, the standardization of a cost model and the ability to assess a vast number of different surgery costs in the same hospital.

Conclusions: Flexibility stands out as an important advantage of the proposed model, as its application is possible to encompass elective and urgent surgeries of medium and high complexity performed in public and private hospitals. As a limitation, the hospital should have a HIS and cost system implemented. The proposed cost model can provide important information that can induce better decision making. This becomes more relevant in the health sector, especially public health, which faces the lack of resources and whose positive effects can improve health care.

Background

According to the latest data from the World Health Organization (WHO), in 2017, the health systems of its 194 member countries spent US$ 7.8 trillion, which is equivalent to 10% of global GDP [1]. Despite the significant amount, there are severe shortcomings in providing health care, especially in developing countries [2, 3]. According to Shrime et al [4], these deficits also include surgical care, classified as essential components of health care systems. Between 2015 and 2030 Lancet Commissions estimates 143 million additional surgeries per year are needed in low and middle-income countries to prevent disabilities and save lives, which means a 46% increase over the total of 313 million surgeries undertaken each year [5].

Brazil had the seventh-largest expenditure in the health field in 2017 among WHO member countries, totaling US$ 194 billion, equivalent to 9.5% of its GDP [6]. The Brazilian public health system (SUS) aims to provide the population with universal and equal access to health actions and services [7, 8, 9]. Among

providers, hospitals stand out as the most expensive SUS components [10, 11], with surgical admissions representing the highest amounts spent by the system in these establishments [12].

Several studies have been carried out with the objective of identifying health costs and developing methods to improve this research, thus contributing to better decision making, based on more reliable evidence [13, 14, 15]. In this context, due to the lack of financial resources, the health decision-maker should be supported with the best possible basis, such as systematic analysis and measurement, that is more consistent than simply repeating decisions or take them by instinct. Economic evaluation in health has been applied to provide this basis, and one of its forms, cost analysis, is considered the essential element of all evaluations [16, 17].

The cost analysis includes the measurement of the used amounts of resources and the allocation of unit values or prices to a set of relevant costs, and the perspective or scope, the standard of comparison, and limitations related to the costs that will be excluded must be established [16, 18].

In Brazil, some studies have addressed cost management in the health field, but it is observed that the economic evaluation in health is still incipient, including public and teaching hospitals. One explanation is that many institutions do not even have cost systems in place yet [19, 20, 21, 22]. Such studies seek to reference the costing methods and how to implement these systems. However, they evidence the low existence of cost and results from descriptions.

Within this context, considering the gap observed in studies on health costs, the research question arises about what is the appropriate methodology for determining costs in health care, notably surgical hospitalizations? To answer this question, this research aims to propose a cost calculation model for surgical hospitalization based on real patient flow to determine such costs in hospital institutions.

This article is organized as follows: the second section presents the methodology used in the systematic literature review and modeling process; the third section demonstrates the results of the review and the cost calculation model for surgical hospitalization, and the fifth section presents the research conclusion, as well as limitations and suggestions for future studies.

Methods

This empirical-theoretical study has two main aspects. The main one is empirical, in which the three-step modeling process was used to propose a cost model based on real patient flow. In addition, theoretical support in which a systematic literature review was applied to identify cost models in researches investigating inpatient surgery costs.

Systematic Literature Review

A systematic literature review was carried out following the PRISMA Statement [23]. Scopus and Web of Science (WoS) bases were used due to the relevance of the journals indexed in them, as well as the

capillarity of subjects. The date of the last update of the search results reported below was on March 17, 2020.

The search parameters and the boolean operators used to search for titles, abstracts, and keywords in both bases were composed of the following sets of terms presented in parentheses: (framework OR model OR recommendation) AND ("inpatient cost") AND (surg*). The first set of terms served to delimit works related to models or recommendations, while the second aimed to narrow studies that dealt with the cost of inpatients, and finally, the third one was used to restrict studies that mentioned surgery.

After searching both databases, the filters for document type “article/review” and language “English” was applied. The document filter was intended to include original and literature review articles and to exclude studies not peer-reviewed. Finally, the filters applied resulted in 85 articles in Scopus and 30 in WoS.

From this moment, the application of the four-step flowchart of the PRISMA Statement began, which adopts the definitions of the Cochrane Collaboration to carry out systematic literature reviews [23]. Figure 1 presents the results obtained in each of the flowchart steps, which are detailed in the sequence.

In the identification stage, the Scopus and WoS databases were consulted, according to search parameters and additional filters already presented. After reviewing the titles of the 115 identified reports, 22 duplicates were eliminated, and 93 reports were kept for the later stage. There was no inclusion of reports identified from other sources.

In the screening stage, the title and summary of 93 reports were read to identify whether the research was related to determining surgical hospitalizations costs. In this stage, 30 reports unrelated to the topic were identified and excluded. The reports whose title and summary did not allow the identification of a relationship were kept for evaluation in the next stage.

For the eligibility stage, 63 full articles would be analyzed, however, two papers were not available for download in any of the databases and were excluded; therefore 61 articles remained for a full reading. This stage aims to identify the existence of articles that presented a model for calculating costs of surgical hospitalizations. Additionally, the articles were evaluated seeking to identify which ones presented the methodology under which the presented costs were determined, and whose values were identified by the study itself after the application of this criterion, 13 articles were selected for inclusion.

During this stage another 48 articles were excluded due to the justifications presented in Table 1. It is noteworthy that many studies whose stated objective was to infer surgery costs did not actually carry out costing process, instead of it estimates based on charges made by hospitals and conversion of these values into costs using a conversion rate (e.g. cost-to-charge ratio) were performed.

Table 1 - Justifications for excluding the full texts	
Reason	**Qt.**
Performs an estimate based on the conversion rate available in a database	30
Reports that hospitalization costs were obtained from the institution without presenting a costing method	6
Does not analyze the cost of surgical hospitalization	3
Focus on costs such as clinical treatment, diagnostics and/or outpatient procedures	2
Not available for download	2
Reports that a governmental database was consulted without presenting a costing method	2
Values presented refer to hospital billing data to the health system instead of costs	2
Considers the amounts paid to the hospital instead of their cost	1
Focus on the literature review of cost-effectiveness studies that do not address cost analysis models	1
Values are a combination of costs and fees recorded in electronic medical records	1
Total	**50**

In the inclusion stage, the 13 articles chosen for eligibility were maintained, as each article was related to a study. The results of the quantitative and qualitative synthesis are presented in the results section.

Modeling Process

The process of development of the cost calculation model took place in a public Brazilian teaching hospital that sought to understand the costs of its surgical hospitalization. Concomitant to the teaching function, this hospital provides services exclusively to SUS, being paid by this system according to its production. To carry out this research, it was submitted to the Hospital's Research Ethics Committee and duly approved according to opinion number 4,106,295 at June 2020. From the point of view of the revenue perceived by the hospital, surgical hospitalization has the greatest financial participation, and therefore, the understanding of the cost of the procedures performed is of great relevance.

The three-step modeling process composed of conceptualization, modeling, and solution [24] were followed to achieve the main objective of this research. For the first step, a systematic literature review was used in the theoretical field. In the practical field, documentary research was carried out on the systems used by the hospital. During this step, it was found in the review that when analyzing the way the results of other studies are presented, it was observed that, in general, they address costs only from the stage of surgery within the operating room.

However, for the hospital, the total cost comprises the period from the patient's admission to his discharge, a process called surgical hospitalization, which includes surgery (main stage). Figure 2 demonstrates the stages that make up the patient's flow on surgical hospitalization compared to the approach that contemplates only surgery. This workflow diagram was created with Bizagi Modeler®.

This differentiation is essential because the remuneration perceived by the hospital includes surgical hospitalization. Thus, it is with a focus on the cost of surgical hospitalization that the model proposed in this study was developed.

For the modeling step of building the model, this study considered the applicable guidelines for Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [17]. The scope is restricted to the health sector component, so it is not intended to identify costs of other components from the societal perspective, such as costs of other health sectors and / or the patient/family, due to the focus of the study being on health management hospital (provider) that performs the surgical procedures [4, 18].

As premises for the use of the model, the institution in which the cost study is developed must have a cost management system that organizes them in cost centers compatible with the hospital structure, and also a Hospital Information System (HIS) that allows the identification of the main parameters related to hospitalizations, such as length of stay, number of exams, the distinction between surgical hospitalizations and other types, such as clinical, and pediatric.

The combined approach between micro-costing and absorption costing was adopted, in several studies, also called top-down. The justification for this choice is the search for a balance between the accuracy of the information and the feasibility of the cost estimate [25]. The micro-costing approach is adequate because there are cost components in the model where it is possible to obtain costs directly. Indirect costs were allocated by absorption costing, suitable for institutions that have defined cost centers.

The solution of the operational model, the third step of development, is materialized in the proposal presented in the results section, at the Surgical Hospitalization Cost Model topic.

Results

SYSTEMATIC LITERATURE REVIEW

Table 2 shows the articles included in the study with the presentation of bibliometric data. It should be noted that the selected studies covered the period of publication between 2005 and 2019, revealing that this is a relatively recent topic. It is noteworthy that there was no delimitation in this review, and even so, 85% of the studies were published within the last ten years.

Table 2
Bibliometric data

Year	Author	Reference	Title	Study country	Journal
2005	Scales Jr., C.D., Jones, P.J., Eisenstein, E.L., Preminger, G.M., Albala, D.M.	[26]	Local cost structures and the economics of robot assisted radical prostatectomy	USA	Journal of Urology
2008	Ramiarina, R., Almeida, R.M.V.R., Pereira, W.C.A.	[27]	Hospital costs estimation and prediction as a function of patient and admission characteristics	Brazil	The International Journal of Health Planning and Management
2010	Kohan, E., Hazany, S., Roostaeian, J., Allam, K., Head, C., Wald, S., Vyas, R., Bradley, J.P.	[28]	Economic advantages to a distraction decision tree model for management of neonatal upper airway obstruction	USA	Plastic and Reconstructive Surgery
2011	Handy Jr., J.R., Denniston, K., Grunkemeier, G.L., Wu, Y.X.	[29]	What is the inpatient cost of hospital complications or death after lobectomy or pneumonectomy?	USA	Annals of Thoracic Surgery
2011	Dowsey, M.M., Liew, D., Choong, P.F.M.	[30]	Economic burden of obesity in primary total knee arthroplasty	Australia	Arthritis Care and Research
2012	Kamath, A.S., Sarrazin, M.V., Vander Weg, M.W., Cai, X., Cullen, J., Katz, D.A.	[31]	Hospital costs associated with smoking in veterans undergoing general surgery	USA	Journal of the American College of Surgeons
2013	Kurichi, J.E., Vogel, W.B., Kwong, P.L., Xie, D., Bates, B.E., Stineman, M.G.	[32]	Factors associated with total inpatient costs and length of stay during surgical hospitalization among veterans who underwent lower extremity amputation	USA	American Journal of Physical Medicine and Rehabilitation

Year	Author	Reference	Title	Study country	Journal
2014	McDonald, M.R., Sathiyakumar, V., Apfeld, J.C., Hooe, B., Ehrenfeld, J., Obremskey, W.T., Sethi, M.K.	[33]	Predictive factors of hospital length of stay in patients with operatively treated ankle fractures	USA	Journal of Orthopaedics and Traumatology
2014	McCarthy, I.M., Hostin, R.A., Ames, C.P., Kim, H.J., Smith, J.S., Boachie-Adjei, O., Schwab, F.J., Klineberg, E.O., Shaffrey, C.I., Gupta, M.C., Polly, D.W.	[34]	Total hospital costs of surgical treatment for adult spinal deformity: An extended follow-up study	USA	Spine Journal
2015	Sözmen, K., Pekel, Ö., Yılmaz, T.S., Şahan, C., Ceylan, A., Güler, E., Korkmaz, E., Ünal, B.	[35]	Determinants of inpatient costs of angina pectoris, myocardial infarction, and heart failure in a university hospital setting in Turkey	Turkey	Anadolu Kardiyoloji Dergisi
2016	Vogl, M., Warnecke, G., Haverich, A., Gottlieb, J., Welte, T., Hatz, R., Hunger, M., Leidl, R., Lingner, H., Behr, J., Winter, H., Schramm, R., Zwissler, B., Hagl, C., Strobl, N., Jaeger, C., Preissler, G.	[36]	Lung transplantation in the spotlight: Reasons for high-cost procedures	Germany	Journal of Heart and Lung Transplantation
2018	Menendez, M.E., Lawler, S.M., Shaker, J., Bassoff, N.W., Warner, J.J.P., Jawa, A.	[37]	Time-driven activity-based costing to identify patients incurring high inpatient cost for total shoulder arthroplasty	USA	Journal of Bone and Joint Surgery - American Volume
2019	Monsivais, D; Morales, M; Day, A; Kim, D; Hoh, B; Blackburn, S	[38]	Cost Analysis of Endovascular Coiling and Surgical Clipping for the Treatment of Ruptured Intracranial Aneurysms	USA	World Neurosurgery

Regarding authors, it is observed that there was no repetition in different works. This finding may mean that there is no concentration of studies or a reference center of prominence in addressing the topic.

Among the countries in which studies on the subject were conducted, it is noted that there is a high concentration in the United States, with nine researches, equivalent to 69% of the total. At the same time, Brazil, Australia, Turkey, and Germany had one study done in each country.

Regarding journals, it is observed that the studies were published in different journals; therefore, there is no concentration. Most of the articles analyzed were published in medical journals, normally associated with the specialties whose surgical procedures were related. There is a lack of references with application to a greater variety of methods.

Table 3 shows the results of the qualitative analysis of the content of the articles considering the purpose of this literature review. The most relevant result is that no article has proposed a cost calculation model for surgical hospitalizations, revealing that this is a gap in the literature to address this topic that this research comes to fill.

Following the assessment of each article, they were evaluated to identify which ones presented the methodology under which the costs presented were determined. Only eight studies declared the methodology used. Activity-Based Costing (ABC) was observed twice [29, 30], and unit cost [25], micro allocation [27], bottom-up [28], activity-based micro-costing [34], e Time-Driven Activity-Based Costing (TDABC) [35] were applied once each.

The other five works were maintained in this review because, despite not proposing a model for calculating costs and not declaring the methodology used for the costing process, they detailed in some way how the cost calculation was carried out.

Table 3
Qualitative analysis of the articles included in the study

Author	Reference	Proposed cost calculation model?	Is there a declared costing methodology? Which one?	Objective	Number of different surgical procedures
Scales Jr., C.D., Jones, P.J., Eisenstein, E.L., Preminger, G.M., Albala, D.M.	[26]	No	No	Compare costs between procedures with different techniques	2
Ramiarina, R., Almeida, R.M.V.R., Pereira, W.C.A.	[27]	No	Yes, unit cost	Estimate cost per specialty / clinic and propose a model to analyze the relationship between costs and patient admission characteristics	-
Kohan, E., Hazany, S., Roostaeian, J., Allam, K., Head, C., Wald, S., Vyas, R., Bradley, J.P.	[28]	No	No	Ascertain the economic advantages of an alternative treatment model compared to conventional treatment	2
Handy Jr., J.R., Denniston, K., Grunkemeier, G.L., Wu, Y.X.	[29]	No	Yes, microallocation	Understand the cost of complications in patients who have undergone thoracic surgery	2
Dowsey, M.M., Liew, D., Choong, P.F.M.	[30]	No	Yes, bottom-up	Estimate obesity-related overhead associated with knee arthroplasty	1
Kamath, A.S., Sarrazin, M.V., Vander Weg, M.W., Cai, X., Cullen, J., Katz, D.A.	[31]	No	Yes, Activity Based Cost (ABC)	Compare costs of surgical hospitalizations between smoking and non-smoking patients	-

Author	Reference	Proposed cost calculation model?	Is there a declared costing methodology? Which one?	Objective	Number of different surgical procedures
Kurichi, J.E., Vogel, W.B., Kwong, P.L., Xie, D., Bates, B.E., Stineman, M.G.	[32]	No	Yes, Activity Based Cost (ABC)	Investigate factors associated with cost and length of stay	1
McDonald, M.R., Sathiyakumar, V., Apfeld, J.C., Hooe, B., Ehrenfeld, J., Obremskey, W.T., Sethi, M.K.	[33]	No	No	Relate anesthetic assessment score to length of stay and costs	1
McCarthy, I.M., Hostin, R.A., Ames, C.P., Kim, H.J., Smith, J.S., Boachie-Adjei, O., Schwab, F.J., Klineberg, E.O., Shaffrey, C.I., Gupta, M.C., Polly, D.W.	[34]	No	No	Calculate specific procedure cost	1
Sözmen, K., Pekel, Ö., Yılmaz, T.S., Şahan, C., Ceylan, A., Güler, E., Korkmaz, E., Ünal, B.	[35]	No	Yes, bottom-up	Determine cost impact of factors related to cardiovascular diseases	3
Vogl, M., Warnecke, G., Haverich, A., Gottlieb, J., Welte, T., Hatz, R., Hunger, M., Leidl, R., Lingner, H., Behr, J., Winter, H., Schramm, R., Zwissler, B., Hagl, C., Strobl, N., Jaeger, C., Preissler, G.	[36]	No	Yes, activity based micro-costing	Calculate specific procedure cost	1
Menendez, M.E., Lawler, S.M., Shaker, J., Bassoff, N.W., Warner, J.J.P., Jawa, A.	[37]	No	Yes, Time-Driven Activity Based Costing (TDABC)	Calculate specific procedure cost	1
Monsivais, D; Morales, M; Day, A; Kim, D; Hoh, B; Blackburn, S	[38]	No	No	Compare costs between procedures with different techniques	2

It is also possible to analyze in Table 3 that cost studies are generally applied to a few different surgical procedures. This is due to the complexity of the cost determination process and the methodology used, normally linked to the investigation of the records of each patient.

There were variations in the central objectives of the analyzed studies. However, it is noted that identifying the cost of the procedure was a concern of several researchers. Even so, it is observed that the costing process was carried out differently among the different studies, which can be justified by the absence of a reference model.

In the following paragraphs, highlights and gaps observed in the studies included in this review are presented:

Scales et al [26] used the daily hospitalization cost and the fixed cost per procedure in the operating room. They noted that cost is impacted by the volume of procedures and used the hospital cost centers separated in surgical costs and costs of hospitalization. However, in their study, the cost of personnel was established based on the national reimbursement table used in the United States by the MEDICARE health insurance system, the length of stay, duration of surgery (based on other studies), and the variable operating room cost does not depend on the type of surgery.

Ramiarina et al [27] refer to the cost per day and the average length of stay, using data from the Brazilian Unified Health System (SUS) and use the cost center to infer the cost per specialty (clinic). However, the proposed methodology does not allow assuming the cost of surgical procedures individually, just by specialty or clinic.

Kohan et al [28] perform the calculation for each patient, investigating the bills, and multiplying the length of stay by the average cost of the daily hospital. On the other hand, do not present the methodology applied to identify all costs, mainly indirect. Personnel costs were established based on the national MEDICARE reimbursement table.

Handy et al [29] use a computerized cost calculation system and consider direct and indirect costs. In their study, weights were used in combination with monthly volumes to allocate costs, by type of cost. Personnel costs in their study are not included.

Dowsey et al [30] include in their research the cost of all treatment, including readmissions, extracting data from the hospital system for each patient. Also, they organize the presentation of results by cost category.

Kamath et al [31] and Kurichi et al [32] use a decision support system that applies ABC to determine costs at the level of each patient. For Kamath et al [31] intermediate costs are allocated based on the proportion to the final procedure, and other indirect costs are apportioned by weight, such as the department area where the patient is. However, in their study, they do not specify which surgery is being analyzed. Kurichi et al [32] determined which characteristics would be associated with total hospitalization costs and identify which hospitalization costs and length of stay are highly correlated. Although they do not include

rehabilitation costs, they do not show how indirect costs were allocated, and they do not show whether personnel costs (eg, doctors) were considered.

McDonald et al [33] report that the average cost of hospital stay (treated as a unit cost) was obtained from the hospital's financial service and that the length of stay was multiplied by the unit cost to define total cost, but does not explain how the average total cost per night was calculated.

McCarthy et al. [34] make use of administrative data and separate costs between general hospital costs and costs in the operating room, but do not explain how the total average cost per hospitalization was calculated and do not include the cost of doctors (surgeons and anesthetists) in their calculation.

Sözmen et al. [35] inform that the data per patient were obtained from the hospital's accounting department and use mean and median to present the values of their study. Costs related to administration, food, cleaning, laundry, water, and electricity generally correlated with length of stay were not considered, and these can have a significant share in total costs.

Vogl et al [36] calculate costs per patient based on hospital accounting system data and define cost centers and calculate average costs for each center. However, they do not show which criterion was used to apportion indirect costs.

Menendez et al [37] used the hospital's software to extract information and have elaborated a flow from the care model to the treatment to assist in the costing process. On the other hand, indirect costs were excluded, as exhaustive modeling and analysis would be necessary, and despite declaring the use of TDABC, in their study, the times were not timed but estimated.

Monsivais et al [38] obtained the cost per patient from the hospital's supply database and accounting system and used the average to present cost results. However, they do not present which criterion was used to apportion indirect costs.

As a conclusion of this review, there is no universally accepted model for determining costs of surgical admissions, there is a wide variation in the methodology applied in studies with a similar purpose, and most cost studies covered only one or a few procedures, which demonstrates the difficulty in carrying out such studies, usually dependent on an investigation full of manual data collection procedures, which makes them difficult to repeat.

However, there are characteristics present in the studies included in this review that can be adopted, such as the use of cost centers, measures of central tendency such as average and median, use of computerized systems for data collection, the definition of criteria for apportionments, in particular, to enable the incorporation of indirect costs, and finally, the inclusion of personnel costs.

Surgical Hospitalization Cost Model

The proposed model includes three moments of the perioperative process: preoperative stage, which includes the admission of the patient to the hospital and his admission to the surgical infirmary; operative stage, which includes anesthetic induction, surgery, and anesthetic recovery in the operating room; postoperative hospital stage, with a return to the infirmary or referral to the ICU, until the patient's discharge [39].

The costs related to the preoperative and the postoperative moments are presented as "Hospitalization cost", and those related to the operating room as "Operating room cost". “Personnel costs” are identified separately, as they can be treated independently and thus allow greater comparability between institutions with different hiring models.

Figure 3 presents the model for calculating costs of surgical hospitalizations, which the result is the sum of costs in the operating room, hospitalization and personnel, for each different procedure.

The "Operating room cost" is composed of the sum of the direct unit cost, represented by the median value of the Hospital Medical Supplies and Medicines spent during surgery registered at electronic consumption notes of HIS, and also the indirect cost of the operating rooms of the hospital prorated by the respective number of procedures performed in each of the operating rooms from the hospital.

The “Hospitalization cost” is obtained by adding the daily cost at Inpatient Unit of the Surgical Clinic (UICC) and Intensive Care Unit (ICU), exams performed, and Internal Regulation Center (NIR) costs, prorated based on the average length of stay in the period for each distinct surgical procedure, the proportion of surgical hospitalizations in concerning the total, the proportion of the tests requested for surgical hospitalizations in relation to the total.

The “Personnel cost” is estimated using the same parameters for apportioning the Hospitalization cost, and the frequency of surgical hospitalizations in each operating room is added. Personnel costs are also obtained by absorption in the cost centers but segregated from the Operating room cost and the Hospitalization cost. The reason is that the reference value established in the SUS Table also segregates these values in the form of “professional services”, so it is possible to carry out an independent analysis.

In order to apply the model, the procedures and quantitative of exams performed (frequency) must be identified, as well as the average length of stay at the UICC and ICU, in a given period. Then, the materials and remedies consumed for each different procedure during the surgery must be identified, with the respective values. This step can be performed by reading the information from the consumption notes of materials and medicines filled during the surgery in manual or electronic means at HIS.

Indirect costs were allocated using the absorption costing methodology in which expenses are allocated to cost centers, thus allowing the identification of those relevant to surgical hospitalizations. For the composition of these indirect costs, were accounted the values referring to: Personnel; Hospital Medical Supplies and Medicines used in the infirmary; Patient Removal; Nutrition and Dietetics Service; Clothing; Common Waste Collection; Cleanliness and conservation; Maintenance and Conservation of Real Estate;

Maintenance and Conservation of Machines and Equipment; Reception; Surveillance and / or Security; Water and sewage; Data communication; Electricity; and Telecommunications.

For the model, the desirable cost centers are: Surgical Centers (with the exception of materials and medicines, already included in the consumption notes); infirmary, called UICC; ICU; diagnostic support units, responsible for Exams; and technical-administrative unit for hospitalization and discharge of patients, called Internal Regulation Center (NIR).

Conclusions

The objective of this research was to propose a cost model for surgical hospitalization based on real patient flow. This objective was achieved after conducting an empirical-theoretical study.

The modeling process made it possible to identify the real flow of the surgical patient within a hospital. This step was essential to identify the cost sources and to understand that the cost generated by this occurs from its admission (preoperative stage) to its discharge (postoperative stage). The literature review showed that most studies only address the surgical stage, neglecting the costs of the two stages mentioned, which are contemplated in this research.

The cost model for surgical hospitalization was developed with a top-down cost approach, which combined micro currency and absorption costing. This approach allows a balance between the accuracy of the information and the feasibility of the cost estimate. Thus, the proposed model fills two gaps in the literature, which gives originality to this research. The first gap is filled with the standardization of a model for calculating the costs of surgical hospitalizations. The second gap is that the proposed model is applied to assess a wide number of different surgeries in the same hospital, while most research investigates costs for a limited number of surgeries.

The proposed model is composed of three distinct cost blocks, the "Operating room cost", the "Hospitalization cost" and the "Personnel cost". These blocks allows the hospital manager to observe their costs in greater detail, which also allows comparisons between different hospitals.

Flexibility stands out as an important advantage of the proposed model, as its application is possible for calculating costs in different areas and contexts of hospitalization, encompassing elective and urgent surgeries of medium and high complexity, performed in public hospitals and also in private hospitals.

This model can also be adapted to other types of hospitalization, such as clinical hospitalization, pediatric hospitalization, and obstetric hospitalization. This allows the application in other health establishments that are general or specialized in some of these types of hospitalization, which expands its potential.

As limitations of research, although Scopus and WOS databases comprise an expressive number of scientific publications, the number of databases consulted is a limitation of this study. The parameters and language defined for the search may also have restricted the results. As a limitation of the model, it is

necessary for the hospital to have patient information in a Hospital Information System (HIS) and an implemented cost system.

It is believed that the proposed cost model will provide information with a high degree of accuracy and timeliness, which can induce better decision making. This becomes more relevant in health care, especially public health, which faces the scarcity of resources and whose positive effects can be seen in improving the provision of care to patients and better functioning in the health network.

Declarations

Ethics approval and consent to participate

This research was submitted to the Juiz de Fora Federal University Hospital 's Research Ethics Committee and duly approved according to opinion number 4,106,295 at June 2020.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Authors' contributions

VB and RA conceived the study, designed its method, and analyzed its conclusions. VB did the systematic literature review and modeled patient’s workflow. VB, LA, PE, SF developed cost model. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

References

1. Global spending on. health: a world in transition. Geneva: World Health Organization; 2019. /HGF/HFWorkingPaper/19.4. (WHO/HIS). Licence: CC BY-NC-SA 3.0 IGO.
2. Grimes CE, Henry JA, Maraka J, Mkandawire NC, Cotton M. Cost-effectiveness of surgery in low- and middle-income countries: A systematic review. World J Surg. 2014;38(1):252–63.
3. Chatterjee S, Laxminarayan R. Costs of surgical procedures in Indian hospitals. BMJ Open 2013;3(6).
4. Shrime MG, Dare AJ, Alkire BC, O'Neill K, Meara JG. Catastrophic expenditure to pay for surgery worldwide: A modelling study. Lancet Glob Heal. 2015;3(S2):38–44.
5. Meara JG, Leather AJM, Hagander L, et al. Global Surgery 2030: Evidence and solutions for achieving health, welfare, and economic development. Lancet. 2015;386(9993):569–624.
6. WHO. Global Health Expenditure Database. Available from: https://apps.who.int/nha/database/ViewData/Indicators/en [acessed Abril, 11, 2020].
7. Brazil. Constitution of the Federative Republic of Brazil, 1988. Promulgated on October 5, 1988. Official Gazette [of the Federative Republic of Brazil], Brasília, DF, 05 oct. 1988.
8. Brazil L. No. 8,080, of September 19, 1990. Provides for the conditions for the promotion, protection and recovery of health, the organization and functioning of the corresponding services and provides other measures. 20. Brasília: Official Gazette [of the Federative Republic of Brazil]; sept. 1990.
9. Viacava F, Oliveira RAD de, Carvalho C, de C, Laguardia, Bellido J. JG. SUS: supply, access to and use of health services over the last 30 years. Cien Saude Colet. 2018;23(6):1751–62.
10. Vignochi L, Gonçalo CR, Rojas Lezana AG. How do hospital managers use performance indicators? Revista de Administração de Empresas 54(5): 496–509.
11. La Forgia GM, Couttolenc BF. Hospital Performance in Brazil. Washington: The World Bank; 2008.
12. Conass. To Understand SUS Management - Medium and High Complexity Assistance. 4th ed. Brasília: CONASS; 2011.
13. Arnold M, Griffin S, Ochalek J, Revill P, Walker S. A one stop shop for cost-effectiveness evidence? Recommendations for improving Disease Control Priorities. Cost Eff Resour Alloc. 2019;17(1):1–4.
14. Aboutorabi A, Radinmanesh M, Rezapour A, Afshari M, Taheri G. A comparison of global surgery tariffs and the actual cost of bills at Hazrate Rasoole Akram educational and medical center. Cost Eff Resour Alloc. 2020;18(1):1–10.
15. Nymark L, Vassall A. A comprehensive framework for considering additional unintended consequences in economic evaluation. Cost Eff Resour Alloc. 2020;18(1):1–10.
16. Drummond MF, Sculpher MJ, Torrance GW, et al. Methods for the economic evaluation of health care programmes. Oxford: Oxford University Press; 2005.
17. Husereau D, Drummond M, Petrou S, et al. Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement. Eur J Heal Econ. 2013;14(3):367–72.
18. Graves N, Walker D, Raine R, Hutchings A, Roberts JA. Cost data for individual patients included in clinical studies: No amount of statistical analysis can compensate for inadequate costing methods. Health Econ. 2002;11(8):735–9.

19. Bonacim CAG, Araujo AMP de. Evaluation of the economic and financial performance of health services: the reflexes of operational policies in the hospital sector. Cien Saude Colet. 2011;16(suppl 1):1055–69.
20. Dallora MELV, Forster AC. The Importance of Cost Management in Teaching Hospitals - Theoretical Considerations. Med (Ribeirao Preto Online). 2014;41(2):135.
21. Bonacim CAG, Araujo AMP de. Cost management applied to public university hospitals: the experience of the Hospital das Clínicas of the Ribeirão Preto Medical School of USP. Rev Adm Pública. 2010;44(4):903–31.
22. Leoncine M, Bornia AC, Abbas K. Systematic for calculating costs by medical-hospital procedure. Production. 2012;23(3):595–608.
23. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med 2009;6(7).
24. Martins GDA, Theóphilo CR. Metodologia da investigação cientifica. São Paulo: Atlas; 2009.
25. Gonçalves MAG, Alemão MM. Avaliação econômica em saúde e estudos de custos: uma proposta de alinhamento semântico de conceitos e metodologias. Rev Med Minas Gerais. 2018;28(5):185–96.
26. Scales CD, Jones PJ, Eisenstein EL, Preminger GM, Albala DM. Local cost structures and the economics of robot assisted radical prostatectomy. J Urol. 2005;174(6):2323–9.
27. Ramiarina R, Almeida RM, Pereira WC. Hospital costs estimation and prediction as a function of patient and admission characteristics. Int J Health Plann Manage. 2008;23(4):345–55.
28. Kohan E, Hazany S, Roostaeian J, et al. Economic advantages to a distraction decision tree model for management of neonatal upper airway obstruction. Plast Reconstr Surg. 2010;126(5):1652–64.
29. Handy JR, Denniston K, Grunkemeier GL, Wu YX. What is the inpatient cost of hospital complications or death after lobectomy or pneumonectomy? Ann Thorac Surg. 2011;91(1):234–8.
30. Dowsey MM, Liew D, Choong PFM. Economic burden of obesity in primary total knee arthroplasty. Arthritis Care Res. 2011;63(10):1375–81.
31. Kamath AS, Sarrazin MV, Vander Weg MW, Cai X, Cullen J, Katz DA. Hospital costs associated with smoking in veterans undergoing general surgery. J Am Coll Surg. 2012;214(6):901–8.e1.
32. Kurichi JE, Vogel WB, Kwong PL, Xie D, Bates BE, Stineman MG. Factors associated with total inpatient costs and length of stay during surgical hospitalization among veterans who underwent lower extremity amputation. Am J Phys Med Rehabil 2013;92(3).
33. McDonald MR, Sathiyakumar V, Apfeld JC, et al. Predictive factors of hospital length of stay in patients with operatively treated ankle fractures. J Orthop Traumatol. 2014;15(4):255–8.
34. McCarthy IM, Hostin RA, Ames CP, et al. Total hospital costs of surgical treatment for adult spinal deformity: An extended follow-up study. Spine J. 2014;14(10):2326–33.
35. Sözmen K, Pekel Ö, Yılmaz TS, et al. Determinants of inpatient costs of angina pectoris, myocardial infarction, and heart failure in a university hospital setting in Turkey. Anadolu Kardiyol Derg. 2015;15(4):325–33.

36. Vogl M, Warnecke G, Haverich A, et al. Lung transplantation in the spotlight: Reasons for high-cost procedures. J Hear Lung Transplant. 2016;35(10):1227–36.
37. Menendez ME, Lawler SM, Shaker J, Bassoff NW, Warner JJP, Jawa A. Time-driven activity-based costing to identify patients incurring high inpatient cost for total shoulder arthroplasty. J Bone Jt Surg – Am. 2018;100(23):2050–6.
38. Monsivais D, Morales M, Day A, Kim D, Hoh B, Blackburn S. Cost Analysis of Endovascular Coiling and Surgical Clipping for the Treatment of Ruptured Intracranial Aneurysms. World Neurosurg. 2019;124:e125–30.
39. Davrieux CF, Palermo M, Serra E, et al. Stages and factors of the "perioperative process": Points in common with the aeronautical industry. Arq Bras Cir Dig. 2019;32(1):1–4.

Figures

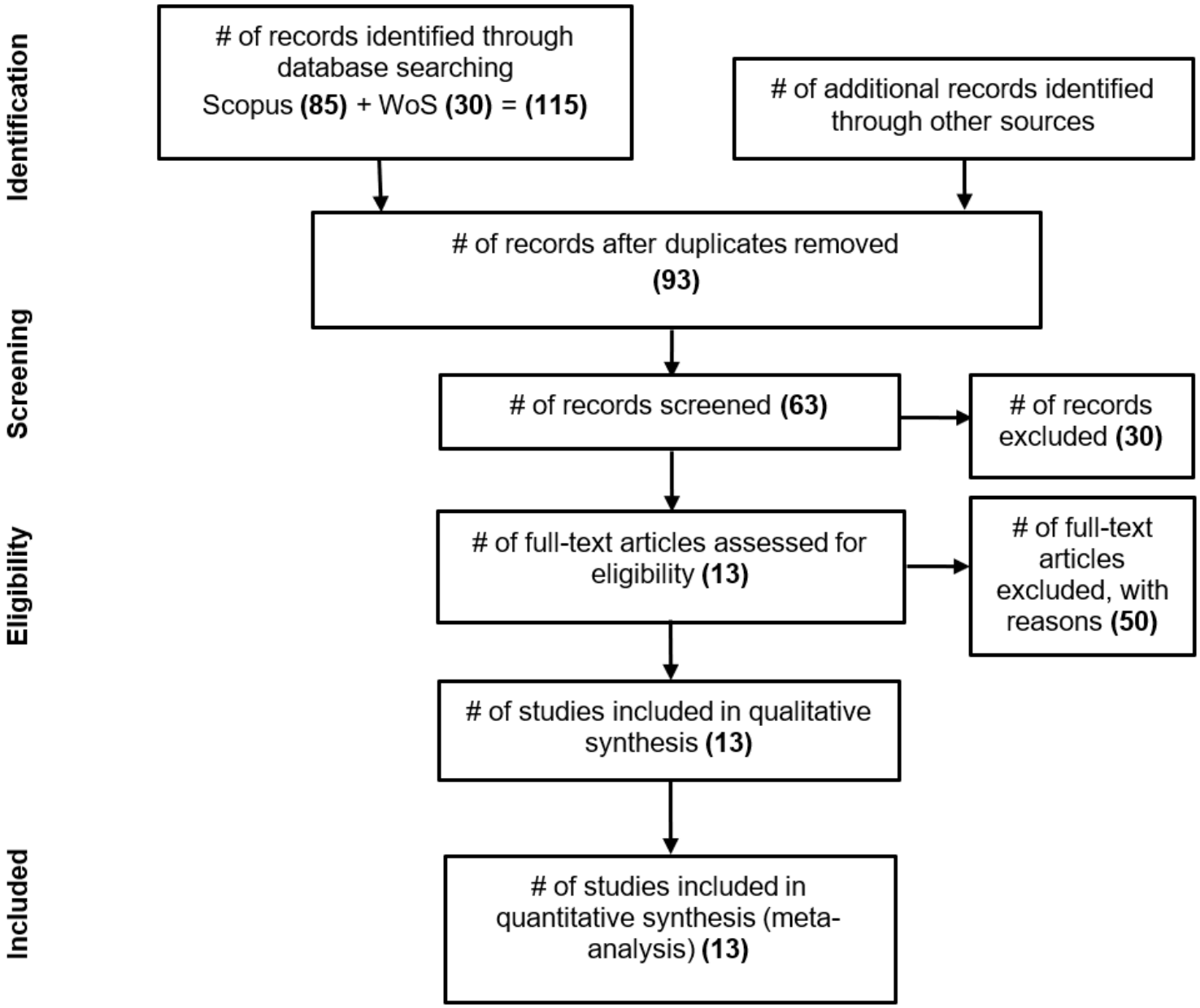

Figure 1

Information flow through the different phases of a systematic review (adapted from the PRISMA Statement, p.3 [23])

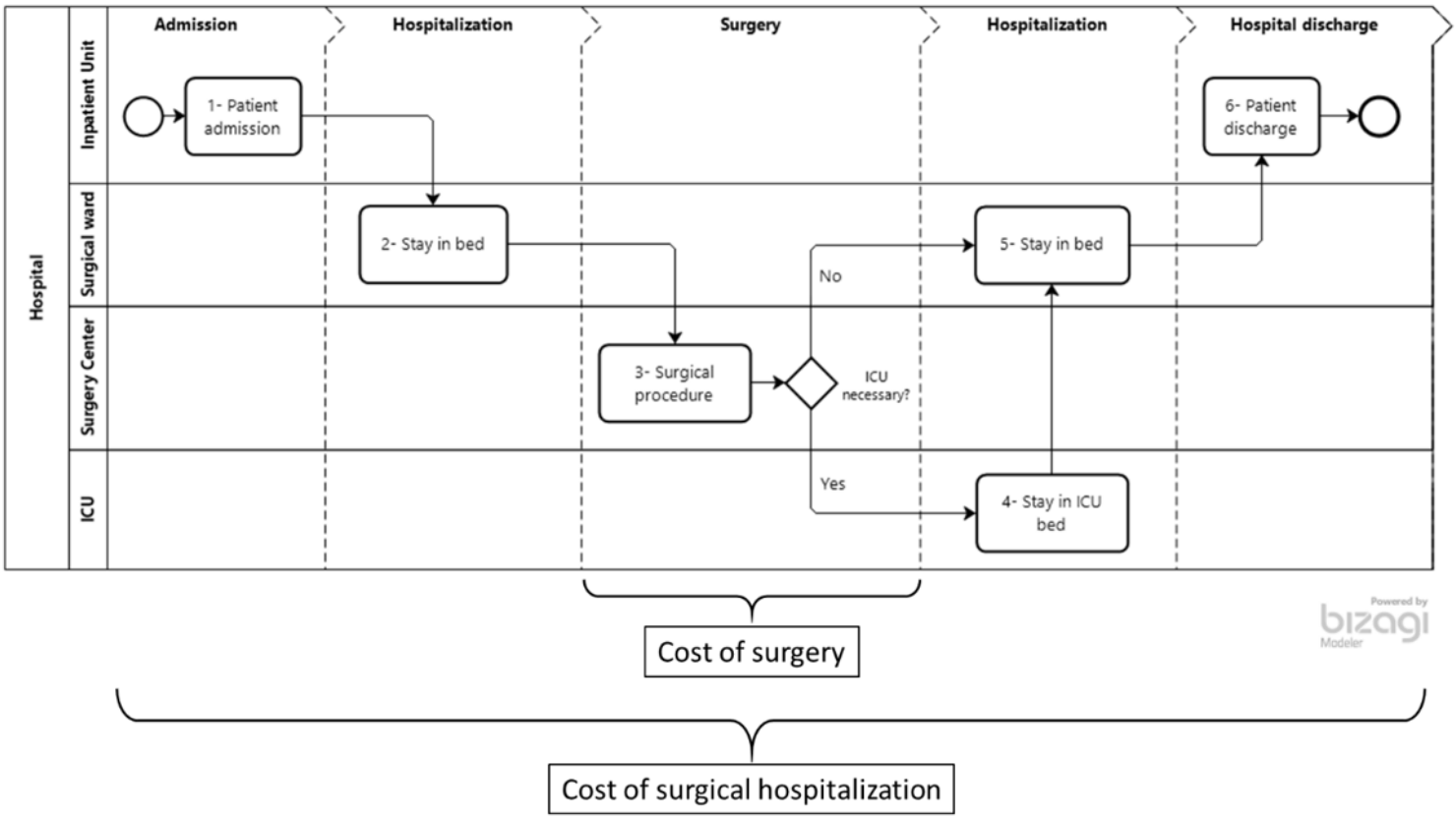

Figure 2

Flow of surgical hospitalization and scope of the study (cost of surgical hospitalization)

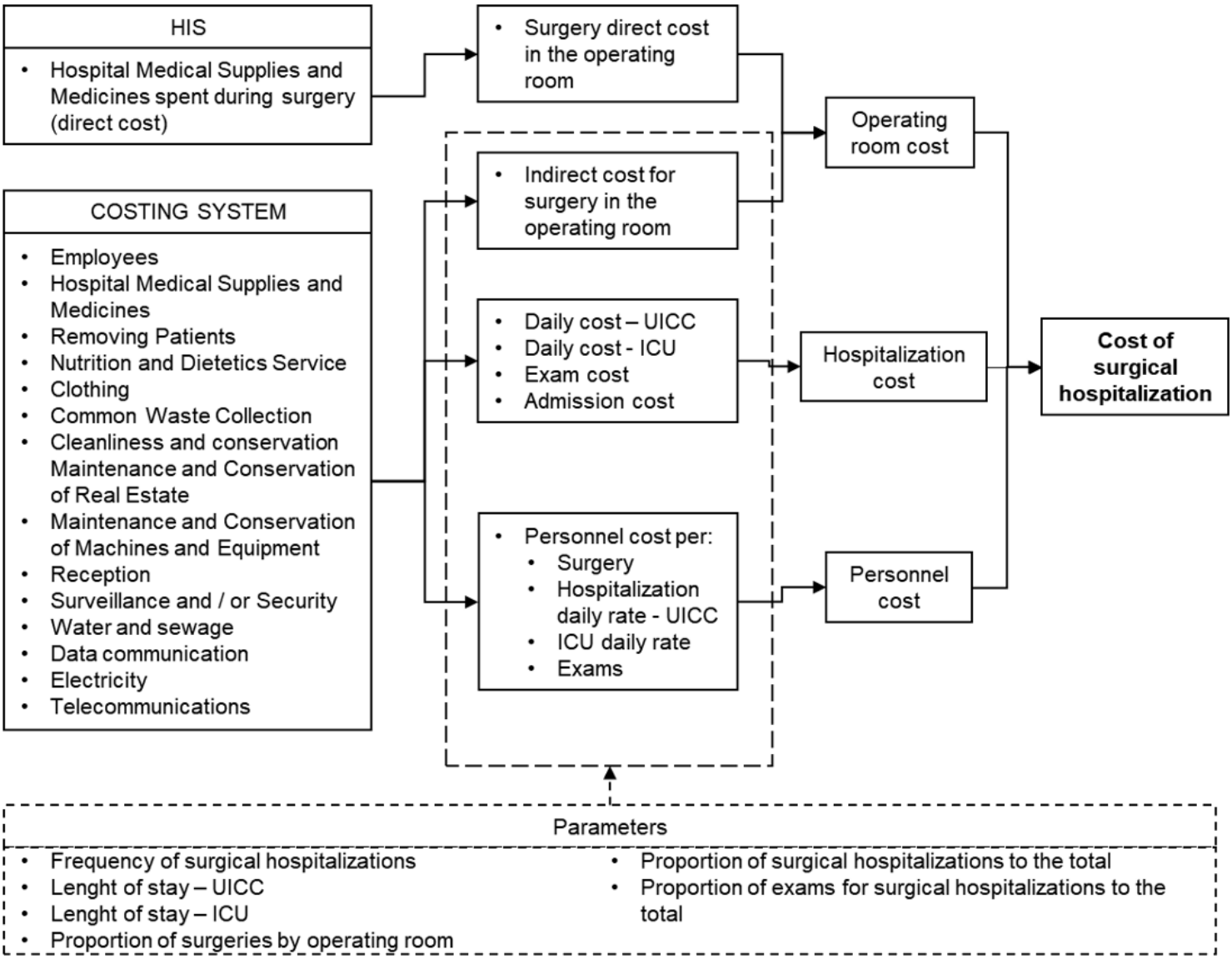

Figure 3

Cost model for surgical hospitalization