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The cost of total hip replacement: a multicentric TDABC comparison in Brazil

O custo da artroplastia de quadril: uma comparação multicêntrica TDABC no Brasil

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Keywords:
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ABSTRACT

Objective: Monitoring costs is critical in searching for a more effective healthcare system. This study aimed to comprehend the care pathway and measure the costs associated with hip replacement surgeries in different hospitals in Brazil. **Methods:** The time-driven activity-based costing method was applied for cost data collection and analyses. Data on 62 patients were retrieved from five public hospitals. A descriptive cost analysis was followed by a comprehensive analysis of the variability in each hospital's care process, leading to suggestions for cost-saving opportunities along with the surgical care pathway. As a final analysis, the cost of surgical treatment was contrasted with the national reimbursement fee. **Results:** The mean cost per patient of the total sample was $5,784 (MIN-MAX $2,525.9-$9,557.8). Pre- and post-surgery hospitalization periods demonstrated the highest variability in length of time and resource consumption among centers. Compared to the national best practice fee, the average cost per inpatient total hip arthroplasty (THA) pathway from all six hospitals was approximately 7x the national reimbursement. **Conclusion:** The application of the TDABC allowed us to identify differences in the surgical care pathway among hospitals, which could be explored in further studies aimed at designing a benchmark surgical pathway. Differences in how the treatment is delivered to patients also justified the high-cost variability among centers.

Palavras-chave:
TDABC, custos em saúde, artroplastia de quadril, ATS, custeio baseado em atividades, tempo microcusteio

RESUMO

Objetivo: O custo do monitoramento é um elemento-chave na busca contínua por um sistema de saúde mais eficaz. O objetivo deste estudo foi compreender a trajetória assistencial e mensurar os custos associados às cirurgias de artroplastia do quadril em diferentes hospitais do Brasil. **Métodos:** O método de custeio baseado em atividades orientado pelo tempo foi aplicado para a coleta e análise de dados de custos. Os dados de 62 pacientes foram recuperados de cinco hospitais públicos. Uma análise descritiva de custos foi seguida por uma análise abrangente da variabilidade no processo de atendimento de cada hospital, levando a sugestões de oportunidades de redução de custos junto com a via de atendimento cirúrgico. Como análise final, o custo do tratamento cirúrgico foi contrastado com o valor de reembolso nacional. **Resultados:** O custo médio por paciente da amostra total foi de $ 5.784 (MIN-MAX $ 2.525,9-$ 9.557,8). Os períodos de internação pré e pós-operatórios demonstraram a maior variabilidade no tempo e no consumo de recursos entre os centros. Em comparação com o reembolso nacional de melhores práticas, o custo médio por cirurgia de prótese de quadril de paciente internado de todos os seis hospitais foi de aproximadamente 7x o reembolso nacional.

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Conclusão: A aplicação do TDABC nos permitiu identificar diferenças na via de atendimento cirúrgico entre hospitais, o que poderia ser explorado em estudos futuros que visem projetar uma via cirúrgica de referência. As diferenças na forma como o tratamento está sendo entregue aos pacientes também contribuíram para justificar a alta variabilidade dos custos entre os centros.

Introduction

Growing healthcare expenditures have placed health systems under pressure to reduce costs and, at the same time, improve the delivered quality of care (Chen *et al.*, 2015). To address this, methods providing better management of healthcare accounting and care processes contribute to redesigning care delivery. In the continuous search to reduce waste in the healthcare system, reimbursement reform is crucial. Alternative reimbursement models have been discussed to address this issue, especially in surgical specialties, such as orthopedics (Robinson *et al.*, 2012; Sabharwal *et al.*, 2016; Palsis *et al.*, 2018; Parikh *et al.*, 2019). However, many stakeholders, hospitals, and physician practices are ill-prepared for bundled payment reimbursement because of a fundamental lack of understanding of patient care expenses (Palsis *et al.*, 2018). Therefore, they continue to rely on top-down estimates or national fees (Sabharwal *et al.*, 2016).

Total hip arthroplasty (THA) is the gold standard for treating advanced hip osteoarthritis (Learmonth *et al.*, 2007). Some studies show that patients' quality of life after surgery improves, allowing them to return to daily activities. The satisfaction of the patient undergoing THA must be greater than 80% in treating severe osteoarthritis.

Implant costs are the most considerable expense associated with hip and knee replacement procedures. The average sale prices of hip and knee implants have increased more than 100% over the past decade, which challenges the proposition of THA reimbursements (Palsis *et al.*, 2018). However, concern has been expressed regarding hospital care variability (Palsis *et al.*, 2018; Etges *et al.*, 2020). Since then, several studies have used time-driven activity-based costing (TDABC) to explore surgical scenarios in which costly materials are used. This method's fundamental advantage is that it transforms cost drivers into time equations representing the time needed to perform a particular activity (Keel *et al.*, 2017).

Such analyses have resulted in the hidden variability of costs in the addressed care process (Etges *et al.*, 2020). It includes redesigning activities during surgery, identifying benchmarks in healthcare when applied across multiple centers, reducing cleaning and setup time between surgeries, reducing the time between patient arrival and the beginning of surgery, and reducing the time spent in the post-anesthesia care unit (French *et al.*, 2013; Etges *et al.*, 2020). Once the care and costs are understood, it becomes easier to find bottlenecks that lead to such variability in hospitals. This study's main objective is to comprehend the care pathway and measure the costs associated with hip replacement surgeries in different hospitals in Brazil.

Methods

Setting

This study integrates a national initiative led by the Program PROADI – Hospital Moinhos de Vento, which has supported advances in health technology assessment research. The participating centers were selected based on their expertise in health technology assessment projects and whether they were members of the Brazilian Hospital Services Company (EBSERH). The study was based on public hospitals' perspectives that provided healthcare services to the public system and was approved by the ethics committees of the participating hospitals (CAAE: 29694720.0.0000.5330).

The sample of patients evaluated included all patients hospitalized for the THA procedure in the Brazilian unified health system (SUS) for two consecutive months in 2019. This research included six publicly funded academic hospitals that are national centers of excellence (A, B, C, D, E, and F) located in six different states in Brazil. All centers received training on data collection, and an Excel spreadsheet database was created to ensure standard data collection quality at the different hospitals.

Time-driven activity-based costing

The micro-costing methodology application involved a sequence of steps proposed by the literature (Keel *et al.*, 2017; da Silva Etges *et al.*, 2019). The study followed the structure: (i) mapping of the THA service process for all hospitals; (ii) identification of the primary resources used throughout the process; (iii) estimation of the total cost of each resource group; (iv) estimation of each resource's capacity and calculation of the unit capacity cost rate (CCR – $/h); (v) analysis of time estimates for each resource used in an activity; (vi) calculation of the total cost of patient care; and (vii) analysis of cost data.

Mapping the care flow with the main activities and identification of primary resources

The sequence of detailed steps considered the care protocols for THA. It was carried out by a multidisciplinary team including orthopedic services professionals and researchers in the field of health technology assessment. After rounds of discussion with the team, the care flow was drawn up manually and documented using a miro.com platform. The care-delivery value chain details the surgical pathway, in which a start and an endpoint need to be defined for each patient. The main activities that are part of the care flow and routine patient activities were identified in the electronic medical records (EMR) and detailed as macro-phases of the procedure: hospital admission, presurgery, surgery, and post-anesthesia recovery (Figure 1) (Chen *et al.*, 2015; Akhavan *et al.*, 2016; Husted *et al.*,

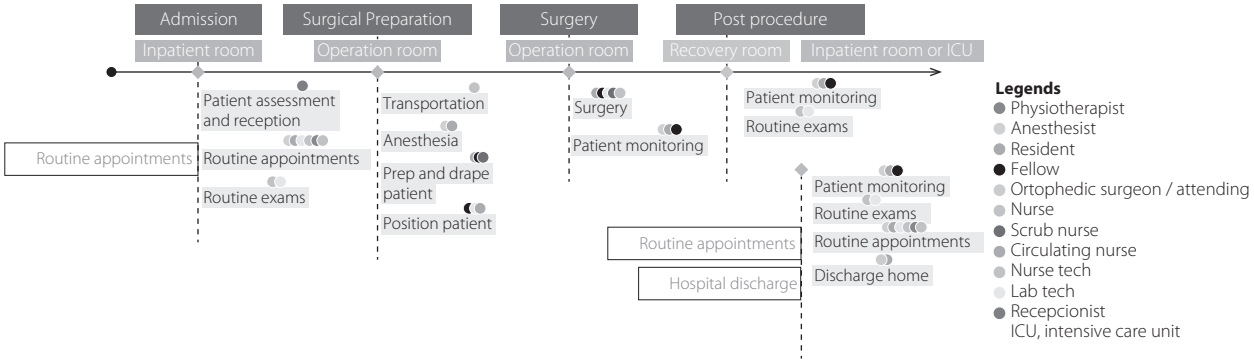

Figure 1. Inpatient pathway

2018). The care flow also shows all the resources used by the patient during the care flow, identified in the second step. Resources were divided into structure and personnel (Chen *et al.*, 2015). The structure represents all the physical areas in which the patient spends time, whereas personnel include all classes of employees that dedicate their time to the patient.

Estimate the total cost of each resource group and calculate the unit capacity cost rate (CCR – $/h)

Regarding the third and fourth steps, resources classified as structure or personnel had estimated costs. Hospital cost systems were used to identify direct costs such as depreciation, rents, energy, taxes, and others associated with each department (expenses allocated to the unit). The averages by specialty should be calculated using payroll hospital information for salaries, and ⁼ all financial information was based on the average monthly expenditure over 12 months from 2019. The actual capacity was calculated considering each department's characteristics, taking into account the number of rooms and workload period to estimate the CCR of each resource. The prices and quantities of materials, prostheses, and medications were collected from invoices and documents containing the acquisition cost of supplies, excluding profit margins, given the participating centers' public nature. Finally, each resource's time estimation was collected through interviews with professionals involved in the care flow and registration in the hospital system.

Cost of patient care and cost data analysis

Sample data were consolidated and analyzed in a Microsoft Excel spreadsheet for Mac 2019. Patient-level cost median, 25th and 75th interquartile interval (IQR), and minimum and maximum values per site were reported descriptively. The TDABC equation, which suggests the sum product of the CCR and the time consumption of each resource, allows us to calculate the median cost per procedure phase, resource, and hospital.

The analyses aimed to identify and explore the variability in each hospital's care process, leading to redesign and cost-saving opportunities. This issue was explored separately from the prosthesis cost due to the interstate differences in supply acquisition of prostheses, price, and brand. Finally, we compared the cost of surgical treatment using a micro-costing methodology contrasted with the national reimbursement fee excluding the prosthesis price to establish the significant determinant costs in the care process (codes from SIGTAP table/SUS: 04.08.04.004-1 – hip arthroplasty (non-conventional; 04.08.04.007-6 – revision arthroplasty or hip reconstruction; 04.08.04.008-4 – total primary arthroplasty, cemented hip; 04.08.04.009-2 – total primary arthroplasty, uncemented/hybrid hip; 04.08.04.005-0 – partial hip arthroplasty; 04.08.06.006-9 – medium resection arthroplasty/large joint).

Cost data were collected in Brazilian currency (*Reais*, in 2019) and converted into international dollars ($) according to the purchasing power parity (PPP) data for 2019 from the Organization for Economic Co-operation and Development.

Results

During this period, 62 patients undergoing elective THA were included in the analysis (hospital A – 16 patients; hospital B – nine patients; hospital C – seven patients; hospital D – five patients; hospital E - 16 patients, and hospital F – nine patients). The median and mean costs per patient of the total sample were $5,784 and $4,950, respectively (IQR 25-75th $4,123-$7,893). The lowest and highest mean cost among the centers was $2,525.9 from hospital A and $9,557.8 from hospital D, respectively. Table 1 shows the population's main characteristics included in the study, the mean cost per surgery, the median length of stay in each hospital, and the hospitals' characteristics regarding the number of beds and monthly surgeries, on average. No patient experienced clinical complications after the procedure.

The median time and CCR for each resource in each phase of the care pathway are shown in Supplementary Table 1. We observed differences in CCR among institutions, which can lead to discrepancies in the total cost of the process that are

not necessarily explained by differences in efficiency in the care process but by the diversity of unit cost per resource among hospitals. These differences can also be explained by regional macroeconomic conditions and by variability in hiring agreements.

Table 2 shows the descriptive median total cost stratified by hospital per care phase, and it also presents the median length of time (in hours) at each care pathway phase per hospital. Hospital D, which has already reported the highest observed cost, also experienced a more extended median

Table 1. Characteristics of patients undergoing elective primary hip arthroplasty

Hospitals	A	B	C	D	E	F
Number of patients	16	9	7	5	16	9
Mean age (SD)	72 (13)	55 (11)	62 (16)	65 (9)	50 (15)	64 (14)
Female (%)	9 (56)	5 (56)	1 (14)	1 (20)	9 (56)	7 (78)
Surgical risk (ASA)+						
1	2 (13)	1 (11)	1 (14)	-	3 (19)	8 (89)
2	11 (69)	6 (67)	4 (57)	4 (80)	12 (75)	1 (11)
3	2 (13)	2 (22)	1 (14)	1 (20)	-	-
NA	1 (6)	-	1 (14)	-	1 (6)	-
Articular disease (%)	8 (50)	9 (100)	5 (71)	3 (60)	13 (81)	6 (67)
Previous trauma (%)	5 (31)	1 (11)	2 (29)	3 (60)	2 (13)	7 (78)
Mean cost (SD)	$ 2,252.9	$ 8,621.1	$ 4,099.8	$ 9,557.8	$ 4,193.7	$ 5,708.2
Median total LOS (days)	5,1	3	4,1	8	2,2	2,2
Number of beds	237	815	198	235	504	300
Mean number of surgeries (monthly)	500	2,192	423	519	750	1,104

+ Rory *et al*., 2019. NI: not informed, there was no register about this variable in hospital system; SD: standard deviation; LOS: length of stay.

Table 2. Median cost and time per phase of THA per hospital

	Hospital	Admission	Pre-procedure	Procedure	Post-anesthesia recovery	Post-procedure recovery	Exams, materials, and medications	Prosthesis	Estimated median cost per patient	Median LOS (days)
Cost per phase ($)	A	$ 71.5	$ 280.6	$ 571.6	$ 130.1	$ 288.5	$ 104.5	$ 1,079.0	$ 2,525.9 (IQR 2.037.8-3.955.9)	-
	B	$ 324.8	$ 367.8	$ 499.1	$ 77.3	$ 865.0	$ 434.7	$ 6,052.4	$ 8,621.1 (IQR 8.229-9.086.5)	-
	C	$ 192.1	$ 278.0	$ 721.6	$ 172.8	$ 811.5	$ 147.1	$ 1,776.7	$ 4,099.8 (IQR 3.802.5-5.609.5)	-
	D	$ 3.291	$ 127.4	$ 1,846.5	$ 225.8	$ 2.195.6	$ 169.0	$ 1,702.1	$ 9,557.8 (IQR 8.207.6-11.577.3)	-
	E	$ 25	$ 100.5	$ 886.1	$ 123.2	$ 780.0	$ 163.6	$ 2,115.1	$ 4,193.7 (IQR 3.613-4.730)	-
	F	$ 475.4	$ 116.7	$ 685.3	$ 276.1	$ 1.134.9	$ 253.1	$ 2,766.8	$ 5,708.2 (IQR 4.051.1-6.745.6)	-
Time per phase ($)	A	8.15	2.23	1.58	2.94	73.68	-	-	-	5.1
	B	20.0	1.00	2.50	4.00	47.00	-	-	-	3.0
	C	22.75	1.75	3.00	5.63	66.75	-	-	-	4.1
	D	91.50	0.50	3.00	1.50	48.00	-	-	-	8
	E	1.92	2.0	2.50	2.46	42.25	-	-	-	2.2
	F	41.58	2.58	2.50	1.58	57.00	-	-	-	2.2

LOS: length of stay.

hospital stay before surgery (admission phase = 91.5 hours). However, this center's sample comprises only five patients, which requires caution when interpreting this result. For instance, it was common for patients to be hospitalized twice, first for exams and the following week for the procedure. The most extended post-surgical hospitalization times were observed at hospitals A (73.6 hours) and C (66.7 hours).

To better understand the cost composition of THA in each center, Figure 2 shows the cost composition of each resource during the inpatient period per hospital. After prosthesis, labor costs such as physicians, fellows, and nursing teams are the most significant portion of THA procedures. It indicates that even with prostheses being a considerable percentage of the THA cost, there is still variability in the care process among hospitals regarding the time and resources involved.

Even though prostheses have a higher impact on the total cost, being nearly 45% of the total cost per patient in most hospitals, there are clear divergences in their interstate acquisition cost. This finding is well illustrated by hospital B, presenting a prosthesis median price three times higher than that of other hospitals, as hospital B only buys an international brand.

Currently, the reimbursement system of the THA by SUS occurs mainly through the AIH of the procedure, according to the SIGTAP table. The median price and length of stay (LOS) among all types of THA ($776) for five days of inpatient therapy were considered for comparison purposes. Figure 3 compares

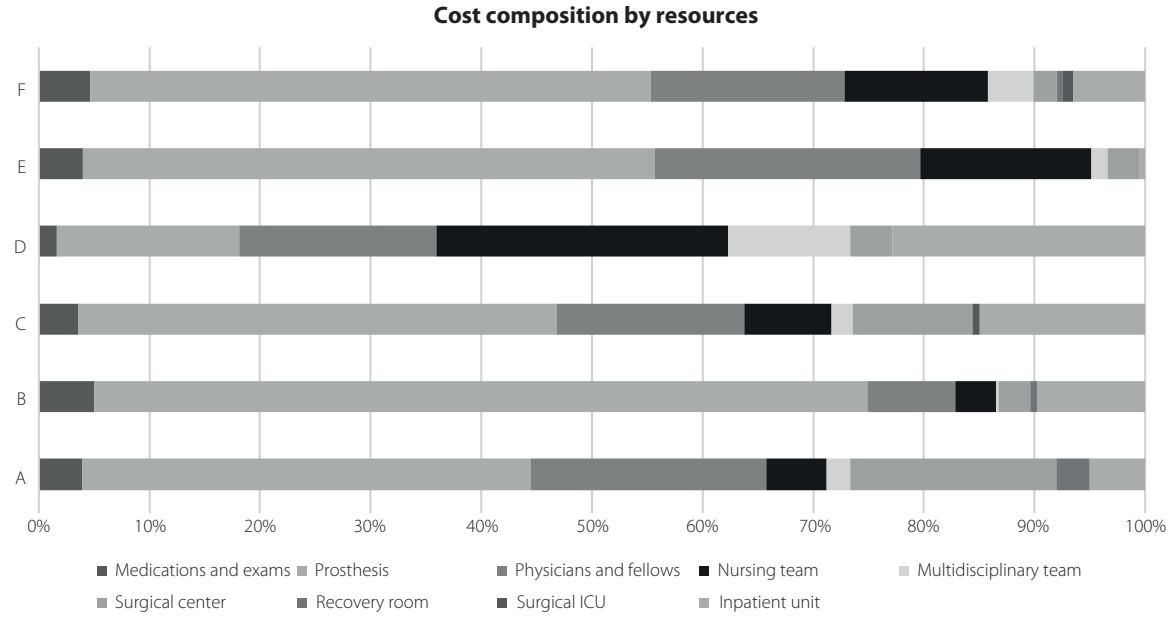

Figure 2. Cost composition by resources

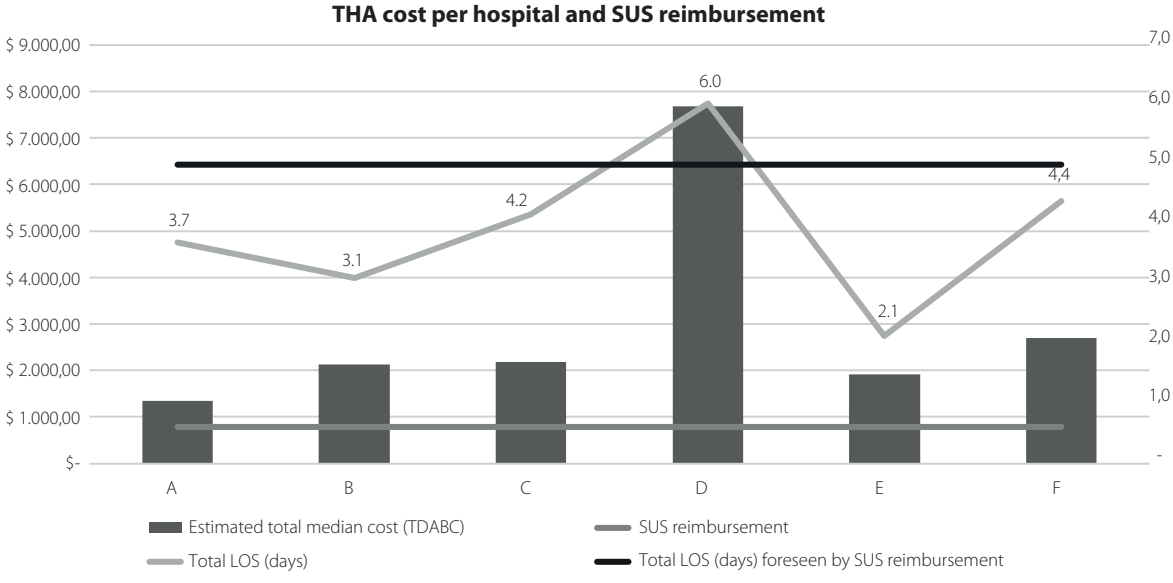

Figure 3. THA cost per hospital and SUS reimbursement

the SUS reimbursement and total cost for each hospital. The current scenario, in which payments are made and encouraged to increase their volume, is a limiting factor for implementing patient-centered health management. The difference among hospitals exploits that the current reimbursement package may financially penalize providers who deal with more complex and high-risk patients. We acknowledge that SIGTAP is not the only reimbursement way for the THA procedure, and it is the majority part of it. There are also other forms of remuneration through AIHs for complications, materials used in rehabilitation, or special procedures. However, the SIGTAP is still the most contributive part and the only one that we can directly attribute to the current payment model of the Brazilian system.

Discussion

Establishing the patient-level cost for a medical condition is an integral part of healthcare strategy improvement so that clinicians, healthcare managers, and policymakers can understand its value (Sabharwal *et al.*, 2016). Using a TDABC methodology through a multicenter study across different Brazilian regions, the total cost of THA among institutions varied from $2,252.9 (hospital A) to $9,557.8 (hospital D). When the prosthesis price is excluded from the analysis and only the care process is included, variability remains among hospitals, especially regarding LOS (in hours) in the hospital admission phase, which consumes more resources. Compared to the national best practice fee, the average cost per inpatient THA pathway from all six hospitals was approximately 7x the national reimbursement (valued at $776 for five inpatient days).

Considering the length of stay on overall cost, it is not surprising that it has also been a favored domain in THA research. Several studies demonstrate how enhanced recovery programs (ERPs) reduce the length of stay without increasing readmission or complication rates (Chen *et al.*, 2015). For instance, in hospital D, it was common for patients to be hospitalized twice, first for exams and the following week for the procedure.

Considering that, based on the existing OrthoChoice bundle for total hip and knee replacement (Porter *et al.*, 2014) and Bundled Payment for Care Improvement (BPCI) (Clair *et al.*, 2016), our data reveal that a similar implementation could also work for the Brazilian unified health system. The referenced bundle includes a preoperative visit, the operation, inpatient care, and a follow-up visit within three months. All physician fees, personnel costs, occupancy costs, drugs, tests, imaging, and other supplies are included. The bundle comprises an expected inpatient stay of six days, including physical therapy, and is not adjusted for shorter or longer hospitalizations. Although outpatient rehabilitation is not covered in the bundle, infection or the need for revision and reoperation are.

Various authors and institutions have used insights from TDABC modeling to improve operational efficiency, reduce waste, enable accurate cost comparisons, and mitigate risk under bundled payments for total joint replacements (Sabharwal *et al.*, 2016).

Learning from best practices can reveal how much time and money can be saved and guide healthcare delivery redesign initiatives. It can stimulate process standardization and innovation, making it more homogeneous and value-oriented (Etges *et al.*, 2020). Once the service costs are transparent for all providers, engaging them in efficiently thinking and acting is easier.

There are a few limitations to consider. The study showed how TDABC allows the assessment of costs along the surgical care pathway but was limited to hospitalization and cost information. Clinical arrival conditions and outcomes were not measured and should be incorporated in an alternative payment model design proposition. We analyzed two months of THA procedures in the hospitals and could not discuss seasonality or cost distributions throughout the year. Because of our limited sample size, the cost results cannot be generalized from a national perspective. Despite the limitations noted above, evidence obtained from real-world data is of paramount importance in raising awareness about disease management and the economic impact of this management. Advanced methods of estimating costs such as TDABC allow us to accurately identify the economic impact of different patient pathways and generate rich information to improve actions in favor of quality assurance of health services. Regarding the variability in the prosthesis acquisition cost, five other brands of prostheses were identified in the sample. We do not have a long-term follow-up of these patients; therefore, we cannot infer the outcomes or health status.

Conclusion

Understanding the surgical care pathway in different institutions is a valuable method to review health care service delivery in a national public system. Our findings suggest that the national reimbursement fee does not cover the cost of delivering surgical treatment. The application of the TDABC allowed us to identify differences in the surgical pathway among hospitals that could be addressed for better resource implementation and reimbursement discussion. Based on the results, we recommend that future studies include more clinical characteristics and follow-up outcomes in economic analyses to introduce a reimbursement policy adjusted for clinical risk, costs, and results.

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Supplementary Table 1. Hospital's characteristics

	A	B	C	D	E	F
Number of beds	237	815	198	235	504	300
Mean number of surgeries (monthly)	500	2,192	423	519	750	1,104

Supplementary Table 2. Cost Capacity Rate, per resource per hospital

	Median Capacity rate per resource					
	A	B	C	D	E	F
Labor						
Physician surgery ($)	$ 87.31	$ 59.96	$ 49.04	$ 63.08	$ 84.31	$ 75.48
Clinical Physician ($)	$ 87.31	$ 59.96	$ 49.04	$ 63.08	$ 84.31	$ 75.48
Fellow physician surgery ($)	$ 6.31	$ 9.50	$ 6.30	$ 5.66	$ 6.30	$ 9.62
Nursing ($)	$ 33.22	$ 17.58	$ 21.08	$ 42.35	$ 52.64	$ 39.36
Nursing Technician ($)	$ 15.24	$ 13.67	$ 9.23	$ 26.26	$ 31.43	$ 20.83
Cleaning Assistant ($)	$ 3.71	$ 5.85	$ 2.98	$ 9.24	$ 2.33	$ 3.67
Administrative Staff	$ 7.11	$ 9.75	$ 3.33	$ 5.86	$ 4.31	$ 4.03
Pharmacist	$ 20.83	$ 9.76	$ 17.87	$ 34.37	$ 39.95	$ 29.03
Physical Therapist ($)	$ 20.29	$ 9.76	$ 14.89	$ 34.53	$ 41.14	$ 34.94
Nutritionist	$ 27.30	$ 9.76	$ 17.87	$ 36.18	$ 28.77	$ 29.75
Psychologist	$ 21.80	$ 9.76	$ 15.14	$ 32.54	$ 36.01	$ 26.22
Non-labor						
Inpatient Unit ($)	$ 1.98	$ 11.74	$ 6.09	$ 15.38	$ 0.55	$ 3.60
Surgical Center ($)	$ 113.80	$ 44.43	$ 74.95	$ 103.26	$ 22.23	$ 21.28
Surgical ICU ($)	$ 23.99	$ 36.48	$ 19.13	$ 23.67	$ 1.71	$ 4.29
Emergency	$ 12.56	$ 5.94	$ 12.01	$ 29.66	$ 1.34	NA
Recovery Room ($)	$ 26.62	$ 17.61	$ 13.95	$ 17.01	$ 1.71	$ 21.28