The Journal of Arthroplasty 36 (2021) 2674–2679

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Health Policy and Economics

The Cost of Hip and Knee Revision Arthroplasty by Diagnosis-Related Groups: Comparing Time-Driven Activity-Based Costing and Traditional Accounting

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A R T I C L E I N F O

Article history:
Received 19 January 2021
Received in revised form
13 March 2021
Accepted 15 March 2021
Available online 20 March 2021

Keywords::
revision total joint arthroplasty
TDABC
traditional cost accounting
economics
practice management

A B S T R A C T

Background: Traditional hospital cost accounting (TA) has innate disadvantages that limit the ability to meaningfully measure care pathways and quality improvement. Time-driven activity-based costing (TDABC) allows a meticulous account of costs in primary total joint arthroplasty (TJA). However, differences between TA and TDABC have not been examined in revision hip and knee TJA (rTJA). We aimed to compare total costs of rTJA by the diagnosis-related group (DRG), measured by TDABC vs TA.
Methods: Overall costs were calculated for rTJA care cycles by DRG for 2 years of financial data (2018-2019) at our single-specialty orthopedic institution using TA and TDABC. Costs derived from TDABC, based on time and resources used, were compared with costs derived from TA based on historical costs. Proportions of implant and nonimplant costs were measured to total TA costs.
Results: Seven hundred ninety-three rTJAs were included in this study, with TA methodology resulting in higher cost estimates. The total cost per DRG 468, rTJA with no comorbidities or complications (CC), DRG 467, rTJA with CC, and DRG 466, rTJA with major CC, estimated by TDABC was 69%, 67%, and 49% of the estimation by TA, respectively. Implant and nonimplant costs represented different proportions between methodologies.
Conclusion: Considerable differences exist, as TA estimations were 31%-51% higher than TDABC. The true cost is likely a value between the estimations, but TDABC presents granular and patient-specific cost data. TDABC for rTJA provides valuable bottom-up information on cost centers in the care pathway and, with targeted interventions, may lead to a more optimal delivery of value-based health care.

US health care spending continues to rise, now representing 17.9% of the US economy [1]. To offset this trend, the country has made efforts toward value-based health care (VBHC), defined as the health outcomes achieved per dollar spent [2]. To improve health outcomes and lower costs to increase value, participants in the health care system must assess targeted areas for improvement. Accurate measurement of true costs to care for a patient is necessary to achieve meaningful objectives in lowering expenses. Otherwise, evaluating the effect of care pathway interventions is deficient [3].

Medical institutions commonly use traditional hospital cost accounting (TA) or the more modern time-driven activity-based costing (TDABC) to understand hospital expenses [3]. TA may incorporate generalized hospital costs from a big picture perspective, lacking resolution at the patient level. TDABC represents a leaner methodology that can be applied to the individual level,

Conflict of interest statement: Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

Ethical statement: Because this study only included deidentified, Health Insurance Portability and Accountability Act—compliant data, it was exempt from institutional review board approval. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.arth.2021.03.041.
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https://doi.org/10.1016/j.arth.2021.03.041
0883-5403/

given its two requisite parameters of costing: supply and personnel resources consumed by the patient. Another major difference from traditional or prior cost methodologies involves the temporal aspect multiplied to each parameter, hence the time-driven component of TDABC. The cost of the entire care pathway is evaluated through identifying the costs of all supplies and resources used by the patient and the time the patient spent with each resource. This approach allows coverage of multiple operational processes to accurately create models for cost accounting [3].

TDABC has been demonstrated to be a precise cost estimate methodology for primary total joint arthroplasty (TJA) [4–7], but further evidence is limited for revision surgery [8,9]. Revision arthroplasty requires costlier resources than primary arthroplasty [10–12], and the growth of these procedures is expected to grow 137%-601% by 2030 [13,14]. As the United States moves to bundled and alternative payment models promoting VBHC, it is critical for institutions to understand the costs of revision surgery to remain financially viable. Therefore, the aims of this study were to measure and compare the costs associated with revision hip and knee TJA (rTJA) using TA and TDABC.

Methods

Study Design

We retrospectively analyzed two years of financial data from our single-specialty orthopedic institution from January 2018 through May 2020. We calculated the total hospital costs for rTJA episodes of care for DRG 468 (rTJA with no complications or comorbidities (CC)), 467 (rTJA with CC), and 466 (rTJA with major CC) using TA and TDABC methodologies. The mean results of TDABC were compared as a ratio to the TA average values. Implant and nonimplant costs were also compared as ratios of the TA and TDABC total cost. All data are presented as indexed values to protect the internal confidentiality of the proprietary hospital information.

Time-Driven Activity-Based Costing

TDABC is an accounting method developed to improve value [3]. With the help of a third-party, commercial medical cost-analysis database, Avant-garde Health (Boston, MA), we analyzed costs for rTJA episodes of care at our institution using TDABC. This was accomplished through creation of process maps, estimation of the costs of patient-associated resources and services, and summation of all individual processes to determine total hospital costs. Process maps were developed for the preoperative, intraoperative, and postoperative stages. Inpatient costs were accounted from the day of surgery to the day of discharge. Costs were separated into supply, personnel, and equipment categories. Personnel were accounted for by the cost per minute of each employee multiplied by the amount of time spent with the patient. Every staff member has a fee assigned by the mean average salary of the corresponding position (attending surgeon, fellow, anesthesiologist, nurse, etc.). Staff time not spent on patient care is excluded (eg, research, teaching, etc.). Supply costs included implants, medications, and consumable supplies (surgical tools, bandages, dressing materials, etc.) and were determined by the actual price that the hospital purchased at. Major indirect costs were accounted for by including equipment costs for the operating room (OR), postanesthesia care unit (PACU), and inpatient hospital beds [15]. For these three cost centers, annual equipment depreciation, maintenance, and utility and operation costs were summed to determine the total space cost and divided by the number of units available to derive the annual space cost [15]. The annual space cost was divided by the number of minutes available for clinical use and multiplied by the total number of minutes the patient was responsible for using. In addition, to record administrative overhead and other indirect costs, a rate of 19.6% (calculated by a ratio of the annual administrative cost center sum and total institutional cost as allocated by our institutional finance department) was applied to resource costs [5]. Total episode costs were obtained by multiplying the amount of time allotted to a patient for each resource by the cost per minute and then summed across all resources used by the patient to produce an accurate institution-specific cost associated with the delivery of the procedure [15,16].

Process Maps

Comprehensive activity process maps were developed for each stage of care for TJA by the institution's multidisciplinary team of administrators, managers, physicians, nurses, and financial analysts. The institution's service line is consistent among all 20 + surgeons that operate at our orthopedic specialty hospital, so all revisions performed during the study period were included. The process map features important contacts during the episode of care in which the patient encounters and uses a resource, including the activity and performing personnel. The process maps were designed by outlining the phases of care and identifying the quantity of time consumed for the various activities the patient is provided. As variation exists between patient experiences and lengths of time for activities, there are repeatable measures (such as length of stay) and 'to be determined' variables in the process maps. Time stamps from the electronic health record cataloged by staff through the phases of care were used to build timelines for perioperative patient progressions. If no time stamps were available, the duration of time for the discrete steps was estimated by the multidisciplinary team as an average of observed and recorded times. To determine the cost of a staff member, the multidisciplinary team selected the corresponding member fee and derived the cost per minute for each type of personnel. The personnel cost rate was based on a 40-hour per week work schedule for all staff members (including attending physicians to exclude administrative activities), with an exception of a 20-hour per week work schedule for intravenous nurses and nurse assistants. Visiting resident physicians and their salaries are governed by their respective home institutions and were not included in the analysis of hospital costs.

The process maps were used to calculate the total cost of personnel for a patient by multiplying the sequential phases of care mapped by the cost per minute of the personnel performing the activity. An example of the process map for the "surgery" stage of care is provided in Table 1, with the remaining process maps for pre-op before the day of surgery, the pre-op day of surgery, the PACU day of surgery, the inpatient floor day of surgery, and post-op visits listed in the supplementary material. This cost was added to the sum of the supplies consumed (including implants and other therapeutic consumables) and the sum of equipment resources used (including the OR, PACU, and inpatient bed) to calculate the entire episode of care for a single patient. This was performed for every rTJA at our institution to capture granular patient cost data.

The costs of supplies were determined by the actual institution purchase prices for both TDABC and TA. Revision implant costs are a negotiated pricing of the vendor implant cost. The equipment costs for the OR, PACU, and inpatient hospital beds (including utilities, maintenance, and rental depreciation) were accounted for by the capacity cost rate calculation [15]. Administrative overhead, sterile processing, physical plant, and rent not observable in the episode of care pathway were joined at a 19.6% rate on resource costs based on a ratio of indirect to direct costs for the cost centers [5]. The rTJA process maps used for this study were a product of the adjusted primary TJA process maps to account for revision nuances at the

Table 1
An Example Personnel Process Map for rTJA Surgery for the TDABC Methodology.

Day of Surgery—Surgery							
Personnel	Prep Time (Min)	Enter the OR	Exit the OR	After Case (Min)	Probability	CPM ($)	Cost ($)
Anesthesia tech	5	Wheeled into the OR	Wheeled into the OR	5	100%	0.58	TBD
Anesthesiologist	0	Anesthesia start	Incision	1	100%	5.45	TBD
Circulating nurse	10	Wheeled into the OR	Wheeled out of the OR	0	100%	1.47	TBD
Facilitator	38	Wheeled into the OR	Wheeled out of the OR	0	10%	1.47	TBD
Nurse anesthetist (CRNA)	12	Wheeled into the OR	Wheeled out of the OR	0	100%	2.43	TBD
OR nurse/scrub nurse	10	Wheeled into the OR	Wheeled out of the OR	0	50%	1.47	TBD
Orderly	10	Wheeled into the OR	Wheeled out of the OR	10	100%	0.42	TBD
Orthopedic fellow	0	Incision	Closure complete/surgery end	0	100%	0.88	TBD
Orthopedic resident	0	Incision	Closure complete/surgery end	0	50%	0	TBD
Orthopedic surgeon	0	Incision	Closure complete/surgery end	3	100%	6.36	TBD
Physician assistant (PA)	0	Incision	Wheeled out of the OR	0	50%	1.43	TBD
Scrub tech	10	Wheeled into the OR	Wheeled out of the OR	0	50%	0.76	TBD

rTJA, total joint arthroplasty; TDABC, time-driven activity-based costing; OR, operating room; CPM, cost per minute; TBD, to be determined by time stamps.

patient level. The granular process mapping and maintenance were managed by Avant-garde Health (Boston, MA), as contracted by our institution to include the costs, software, and personnel needed.

Traditional Accounting

We collected overall hospital costs for all rTJA cases at our institution during the study period using TA. Costs were obtained via historical cost data from the institutional finance department's internal accounting database, which archives total hospital costs for episodes of care. Costs are divided into categories for room and board, OR, anesthesia, PACU, implants, medical supplies, drugs, OP clinics, pharmacy, laboratory, radiology, nuclear medicine, computed tomography, magnetic resonance imaging, electroencephalogram/electromyography, physical therapy, occupational therapy, cardiology, and other. The average values for all categories were calculated, and each had an internally derived overhead multiplier applied to account for indirect fixed costs. The final overall cost of an rTJA was the aggregate of each cost category, which included indirect, fixed costs for TA.

Supply costs were identical to TDABC as both methods use actual hospital purchasing prices. The internally derived multiplier is created by the hospital chargemaster, sourced from billing and ledger data recorded from confidential, internal margin reports. This multiplier is used to account for the resources costed by the procedure, including indirect and fixed overhead costs mentioned previously.

Statistical Analysis

The raw values were indexed and presented as percentages to protect internal hospital actual dollar amount information. All statistical analyses were performed using SAS v9.4 (SAS Institute, Cary, NC). Because this study only included deidentified, Health Insurance Portability and Accountability Act–compliant data, it was exempt from institutional review board approval. No specific funding was received for this work.

Results

We analyzed the costs using TDABC and TA for 793 revision arthroplasties in this study, with 510 cases for DRG 468, 259 cases for DRG 467, and 24 cases for DRG 466 (Fig. 1). Compared with TDABC, the total costs for TA were 31% higher for DRG 468, 33% higher for DRG 467, and 51% higher for DRG 466 (Fig. 2). The implant costs were 29% of the total TA cost for DRG 468, 27% for DRG 467, and 16% for DRG 466 (Fig. 2).

For DRG 468, nonimplant costs represented 58% of the total cost for TDABC and 71% of the total cost for TA (Fig. 3). For DRG 467, nonimplant costs represented 60% of the total cost for TDABC and 73% of the total cost for TA (Fig. 3). For DRG 466, nonimplant costs represented 67% of total costs for TDABC and 84% of the total cost for TA (Fig. 3).

Discussion

VBHC will continue to gain momentum as the country moves toward limiting excess health care spending. Because of this, it is important to accurately assess and understand hospital costs. Knowing the true costs for service lines allows for precise measurement and planning for the intervention strategy design [3]. TDABC is a systematic methodology that captures granular data on used resources to present authentic hospital costs and represents a more modern, accurate cost accounting methodology for primary TJA [4,5]. Two previous studies showed TDABC costs to comprise 53%-59% of the total cost of traditional hospital accounting methodologies for primary TJA [4,5]. Our study showed the TDABC estimate costs for DRG 466 to be 69%, DRG 467 to be 67%, and DRG 466 to be 49% of TA total hospital costs for revision TJA. Variations in revision procedure costs exist, depending on the CC. For rTJA with and without CCs at our institution, TA overestimates total costs to a lesser extent than the rates reported for primary TJA by Akhavan et al and Palsis et al [4,5]. These studies used various methods, such as a 16.5% multiplier derived by their institution's accounting department or square footage calculations, to account for indirect costs in their TDABC methodologies [4,5]. For our study, we followed the described Kaplan capacity cost rate calculation to determine equipment costs consumed by the patient and used a ratio of indirect costs to total costs derived from our institutional expenses to account for other fixed costs not captured in the pathway [15]. We believe this strategy represents an accurate indirect cost accounting method that resulted in a lower disparity between TDABC and TA estimates.

In cardiac surgery, TDABC was found to derive cost estimates 10% less than traditional cost accounting [17]. In neurosurgery and urology, TDABC has also been used to redesign care pathways after discerning definite costs [18]. In the field of orthopedics, TDABC has been implemented in many recent studies [4,16,19–24]. The purpose of this study was to compare costs using TDABC and TA for rTJA DRG care pathways. For DRG 468 and 467 estimates at our institution, TA costs were ≥31% higher than TDABC costs. TDABC specifically allows measurement of how much capital resources a patient uses, including personnel labor, supplies, and equipment costs. For DRG 466, TDABC estimations were the farthest from TA

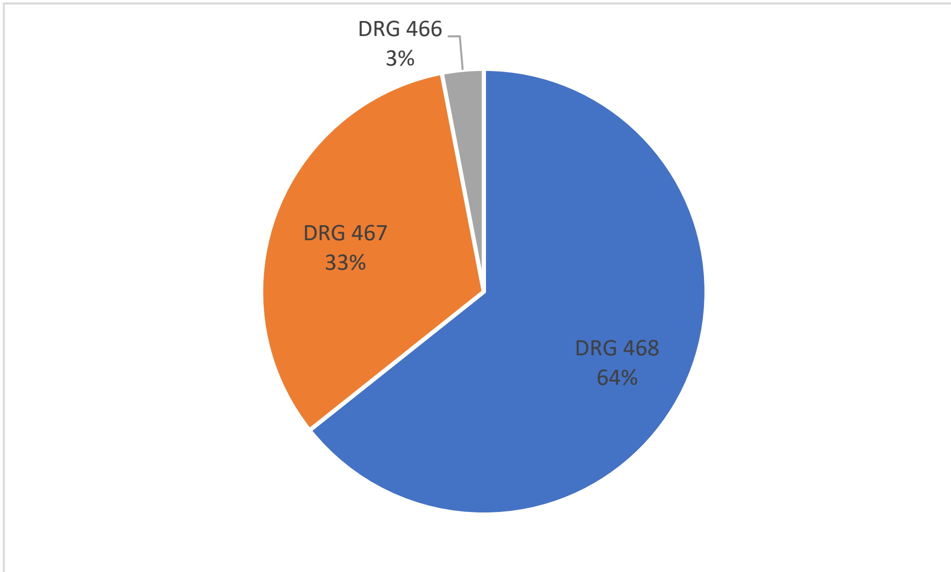

Fig. 1. Distribution of revision total joint arthroplasty for diagnosis-related groups 468, 467, and 466. DRG, diagnosis-related group.

estimations, with 49% of their estimated costs. This could perhaps be due to TA overestimating the resources used for these patients with major CC, TDABC costs more accurately accounting for the costs of the increased length of stay and OR time used to care for this patient group, or both. For these revision procedures with major CC such as an acute myocardial infarction or stroke, it is particularly important for institutions to accurately understand the overall costs associated and considerable resources necessary when treating these patients.

Revision surgery is more complex than primaries and is associated with a poorer prognosis and higher risk of failure [25]. In addition, rTJA involves increased resources and is more time- and cost-intensive than primaries [10–12]. Because of this, rTJA procedures are less profitable for hospitals, often resulting in losses to the hospital which jeopardizes the viability of high-volume rTJA institutions [12,25]. Without accurate cost accounting, hospitals may inadvertently consider rTJA as a much larger negative margin producer than reality. Such a situation could potentially lead to business decisions that limit the number of these procedures and thus limit access for patients. TDABC has been shown to be more accurate than TA in primary TJA [4,5], and now, our study adds further evidence for TDABC to be an accurate methodology for revision procedure cost accounting.

The implant cost has been shown to be a major determinant of the cost for primary TJA, comprising 40%-52% of total hospital costs [16]. The results of our study showed implant costs to be 54%-59% of total costs for rTJA with and without CC when using TDABC, increased for revision procedures compared with primary implants. Previous studies have shown revision implant costs to comprise 28% for knee procedures and 36% for hip procedures of the total hospital cost [26,27]. These lower percentages could be due to these studies excluding more costly revision cases with expensive additional components such as sleeves, cages, augments, plates, and other revision components outside the standard [26,27]. Our study included all-comer revision procedures and lower total hospital costs than those reported in the previous studies, possibly influencing the larger percentages for our study. Depending on the methodology, implants represent a major determinant of overall costs for revision surgery, and future efforts should explore negotiations to decrease revision implant costs.

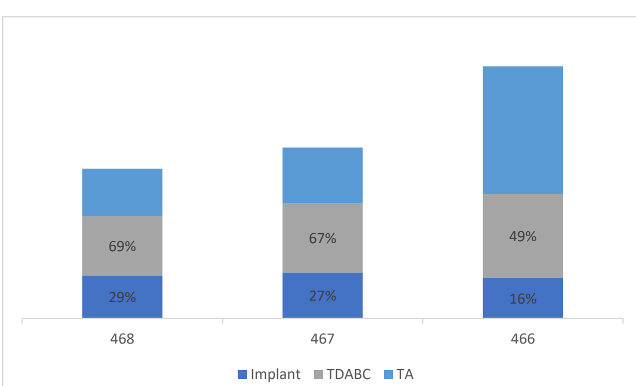

Fig. 2. The graph shows costs derived from TDABC indexed to TA for DRGs 468, 467, and 466. Separately from TDABC costs, implant costs were indexed to the total TA cost. TDABC, time-driven activity-based costing; TA, traditional accounting; DRG, diagnosis-related group.

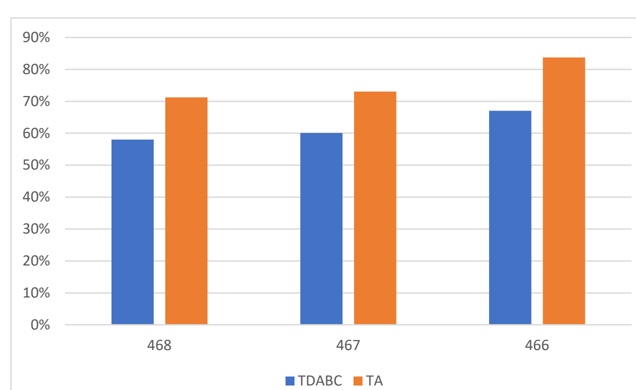

Fig. 3. Nonimplant costs as a percent of the total cost for TDABC and TA for DRGs 468, 467, and 466. TA, traditional accounting; TDABC, time-driven activity-based costing; DRG, diagnosis-related group.

For health systems that want to implement TDABC to estimate institutional costs, there is a time investment needed to create the clinical process maps necessary. Our institution created an original process map after meeting with the multidisciplinary team to describe the phases of care for that service line. Through this effort, areas of potential cost containment are discovered and can be improved through care pathway remodeling. After this initial time investment, recreating the process maps for other service lines was quicker and easier. For this study, we built off the original process map for primary TJA at our institution and adjusted it as necessary for revision subtleties, resulting in a shorter time investment for the process map design. These process maps are housed and updated with the help of our third-party cost-analysis database, which continuously gathers patient-specific time data for the process map variables.

As payment models continue to tie reimbursement with the value of care delivered with respect to the cost and outcomes, institutions and all those involved must have an accurate methodology to determine costs of a major care pathway such as TJA. Surgeons must also understand how their choices of implants and OR time and delivery of care and length of stay targets affect the total costs in the context of the overall margins of the hospital. With TDABC, institutions can keep track and compare surgeons' costs among each other at the patient level, noting any outliers in cost trends (such as a surgeon using a disproportionate amount of antibiotic cement). Determining costs is important for institutions to make decisions on resource allocation and where to focus any interventions of new programs. It is possible that using TA could yield a more negative financial picture than actual because of lumped indirect costs, where TDABC would show a more positive financial margin. Palsis et al showed a negative margin when using TA and a positive margin when using TDABC for primary TJA with an average Medicare reimbursement [5]. With TA costs representing $\geq$31% of total costs for TDABC for DRGs 468 and 467, it is plausible that the cost assessments using TA may not be optimal for resource allocation decisions and institutional developments. For instance, TA could overestimate the costs of a procedure when comparing it with another procedure with the high-level top-down approach that does not account for granular patient-consumed resources.

Although the authors are not able to disclose the difference in costs between the DRGs, we interpret the difference in costs as highlighting the importance of avoiding complications in the revision arthroplasty patient population. Principles of preoperative optimization and coordinated postoperative hospital care remain vitally important in this context as a means of cost containment, in addition to quality. Investment in hospital care could provide positive return on investment if effective in avoiding complications. As our study highlights, the cost between a revision without CC (DRG 468) and the one with major complications and comorbidities (DRG 466) is great in magnitude.

The strengths of this study include a single-institution, large sample size of 793 revision arthroplasties over a two-year period. This is also, to the best of our knowledge, the first study looking at the TDABC vs TA methodology, specifically for rTJA. The present study has several limitations as well. The comparison of TDABC and TA is not an absolute correspondence because of the calculation differences in the major indirect costs of the TA and TDABC methodology in our study. However, we have followed the calculations laid out by Kaplan to incorporate indirect, fixed costs into our TDABC methodology [15]. It is important to understand that the separate methodologies are estimations. TDABC measures patient-consumed resources and does not account for hospital expenses not directly related to patient care, including unused capacity and administrative and general overhead costs for rTJA. Therefore, these indirect costs not captured by equipment costs were estimated using an institutional rate multiplier, which is specific to the expenses of the institution [4,5,23]. This also means that our overhead costs are likely lower in costs because of our relatively older and smaller facilities. Thus, generalizability is a limitation as our single-specialty orthopedic institution has its own unique patient population, operating costs, and care pathways that may differ variably among other health care systems in the United States, such as large tertiary centers. Furthermore, because our orthopedic specialty hospital does not have the facilities to manage all complications (eg dialysis), indicated patients are transferred to our partner multispecialty hospitals for medical management. Our current process maps do not account for these personnel or services, which may underestimate costs for DRG 466. The true cost of a care pathway is most likely a value between the two methodologies, but TDABC ultimately creates a more standardized and granular process for estimating costs that can be used for analysis at the patient level, rather than broadly accounting all institutional operating costs for a care pathway.

Conclusions

For VBHC to be successful, it is critical to understand the precise costs involved with an episode of care. As hospitals are responsible for excessive costs in bundled payment scenarios, determining areas of potential cost containment are important for netting positive margins. TDABC allows this understanding by presenting a more precise picture of expenses for an episode of care, enabling a more optimal construct to design interventions and deliver VBHC. We found TA costs to be higher than estimates from TDABC for rTJA, potentially skewing true comparisons between patients and episodes of care. In contrast to TA consolidating indirect costs, TDABC only allocates expenses to resources used directly by the patient, accounting supplies, personnel, and equipment to provide granular cost data at the patient level. TDABC eliminates the potential for an institution to improperly view a care pathway as a negative producer because of non–patient-specific costs, which has a greater potential when analyzing the costlier revision procedure.

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Appendix

Appendix Table 1
Before Day of Surgery - Pre-Op Day of Surgery.

Before Day of Surgery—Pre-Op Day of Surgery						
Activity	Personnel	Probability	Duration (Mins)	Allocation	CPM ($)	Cost ($)
Initial surgical visit: X-ray	Radiology tech	80%	5	Hospital	0.85	3.40
Initial surgical visit: check-in	Front end supervisor	100%	3	Hospital	0.15	0.45
Initial surgical visit: rooming/prep	Medical assistant	100%	4	Hospital	0.15	0.60
Initial surgical visit: clinical consult	Orthopedic surgeon	100%	20	Hospital	6.36	127.20
Initial surgical visit: scheduling	Front end supervisor	100%	5	Hospital	0.15	0.75
PAT: check-in	Registration clerk	100%	12	Hospital	0.59	7.08
PAT: check-in	Receptionist	100%	2	Hospital	0.52	1.04
PAT: rooming/prep	Patient care tech	100%	5	Hospital	0.5	2.5
PAT: pharmacist consult	Pharmacist	100%	12	Hospital	1.44	17.28
PAT: nursing assessment	Nurse practitioner	100%	60	Hospital	1.55	93
PAT: laboratories	Patient care tech	100%	20	Hospital	0.5	2.5
PAT: anesthesia assessment	Nurse anesthetist (CRNA)	100%	20	Hospital	2.43	48.6
PAT: physical therapy consult	Physical therapist	80%	20	Hospital	1.09	17.44
PAT: case management consult	Case manager	100%	10	Hospital	1.7	17
PAT: imaging	Radiology tech	100%	15	Hospital	0.85	12.75
Presurgical education	OR nurse/scrub nurse	3%	90	Hospital	1.47	3.97
Presurgical education	Physical therapist	1%	30	Hospital	1.09	0.33
Coordination: reviewing patient charts	Registered nurse (RN)	100%	22	Hospital	1.37	30.14
Coordination: reviewing patient charts	Administrative assistant	50%	30	Hospital	0.15	4.5
Coordination: additional patient calls	Registered nurse (RN)	35%	10	Hospital	1.37	4.8
Coordination: additional patient calls	Administrative assistant	15%	10	Hospital	0.15	1.50
Coordination: reviewing patient charts	Hospitalist	50%	12	Hospital	3.02	18.12
Check-in/registration	Registration clerk	100%	12		0.59	7.08
Rooming/prep	Patient care tech	100%	7		0.5	3.0
Nursing assessment	Registered nurse (RN)	100%	45		1.37	61.65
Laboratories drawn	Laboratory tech	100%	4		0.98	3.92
Nursing assessment	OR nurse/scrub nurse	100%	7		1.47	10.29
Anesthesia consult	Anesthesiologist	100%	20		5.45	109.00
CRNA consult	Nurse anesthetist (CRNA)	100%	3		2.43	7.29
Anesthesia nerve block	Anesthesia resident, anesthesiologist, registered nurse (RNA)	100%	7		6.82	47.74
Surgeon consult/site marking	Orthopedic surgeon	100%	10		6.36	63.60
Pt transfer from pre-op to the OR	Anesthesiologist	20%	3		5.45	3.27
Pt transfer from pre-op to the OR	Nurse anesthetist (CRNA)	80%	3		2.43	5.83
Pharmacist order verification	Pharmacist	100%	7		1.44	10.08

Pre-op, preoperative; Mins, minutes; CPM, cost per minute; PAT, preadmission testing; Pt, patient; OR, operating room; CRNA, Certified Registered Nurse Anesthetist.

Appendix Table 2
Day of Surgery - Pre-Op Day of Surgery.

DOS—Pre-Op DOS					
Activity	Personnel	Probability	Duration (Mins)	CPM ($)	Cost ($)
Check-in/registration	Registration clerk	100%	12	0.59	7.08
Rooming/prep	Patient care tech	100%	7	0.5	3.0
Nursing assessment	Registered nurse (RN)	100%	45	1.37	61.65
Laboratories drawn	Laboratory tech	100%	4	0.98	3.92
Nursing assessment	OR nurse/scrub nurse	100%	7	1.47	10.29
Anesthesia consult	Anesthesiologist	100%	20	5.45	109.00
CRNA consult	Nurse anesthetist (CRNA)	100%	3	2.43	7.29
Anesthesia nerve block	Anesthesia resident, anesthesiologist, registered nurse (RNA)	100%	7	6.82	47.74
Surgeon consult/site marking	Orthopedic surgeon	100%	10	6.36	63.60
Pt transfer from pre-op to the OR	Anesthesiologist	20%	3	5.45	3.27
Pt transfer from pre-op to the OR	Nurse anesthetist (CRNA)	80%	3	2.43	5.83
Pharmacist order verification	Pharmacist	100%	7	1.44	10.08

DOS, day of surgery; Pre-op, preoperative; Mins, minutes; CPM, cost per minute; Pt, patient; OR, operating room; CRNA, Certified Registered Nurse Anesthetist.

Appendix Table 3
Day of Surgery - PACU.

Day of Surgery—PACU					
Activity	Personnel	Probability	Duration (Mins)	CPM	Cost
Pt transfer from the OR to the PACU	Circulating nurse, nurse anesthetist (CRNA)	100%	10	3.90	39.00
Documentation	Nurse anesthetist (CRNA)	100%	5	2.43	12.15
The pharmacy reviews/enters the order	Nurse anesthetist (CRNA), pharmacist	100%	2	3.87	7.74
The pharmacy reviews/enters the order	Pharmacist	100%	7	1.44	10.08
The anesthesiologist visits/does assessment	Anesthesiologist	100%	1	5.45	5.45
Pt transfer from the PACU to the floor	Registered nurse (RN), transporter/transportation aide	100%	20	1.80	36.00
Personnel	Ratio			CPM	Cost
Registered nurse (RN)	2:1			1.37	TBD

PACU, postanesthesia care unit; Mins, minutes; CPM, cost per minute; Pt, patient; OR, operating room; CRNA, Certified Registered Nurse Anesthetist.

Appendix Table 4
Day of Surgery - Inpatient Floor.

Day of Surgery—Inpatient Floor							
Activity	Personnel	Probability	Duration (Mins)	Recurrence	Time Period	CPM	Cost
The pharmacy reviews/enters orders	Pharmacist	100%	7	One time activity	Post-op day 1	1.44	10.08
Nurse rounding (for nursing staff not included in the staffing ratio)	Nurse practitioner	50%	10	Once a day	Every day	1.55	7.75
Nurse rounding (for nursing staff not included in the staffing ratio)	Physician assistant (PA)	50%	10	Once a day	Every day	1.43	7.15
The surgeon visits/does assessment	Orthopedic surgeon	100%	3	Once a day	Every day	6.36	19.08
Respiratory care	Respiratory therapist	10%	12	One time activity		1.35	1.62
Insurance authorization	Case manager	35%	1	One time activity		1.70	0.59
Case management	Case manager	100%	10	Once a day	Every day	1.70	17.00
Documentation	Case manager	100%	2	Once a day	Every day	1.70	3.40
Case management round	Case manager, nurse practitioner, physician assistant (PA)	100%	5	Once a day	Every day	4.68	23.40
The patient prepared for discharge	Case manager	100%	5	One time activity		1.70	8.50
Room cleaning	Housekeeping	100%	15	Once a day	Every day	0.42	6.30
Occupational therapy visit	Occupational therapist	100%	45	One time activity	Post-op day 1, Post-op day 2, Post-op day 3 +	1.09	49.05
Physical therapy evaluation	Physical therapist	100%	45	One time activity	Post-op day 0—the day of surgery	1.09	49.05
Physical therapy visit	Physical therapist	100%	30	Once every 12 h	Post-op day 1, Post-op day 2, Post-op day 3 +	1.09	32.70
Final day additional cleaning	Housekeeping	100%	25	One time activity	Post-op day 0—the day of surgery	0.42	10.50
Pain consult	Nurse practitioner	15%	52	One time activity	Post-op day 0—the day of surgery	1.55	12.09
IV placement and management	IV nurse	15%	17	One time activity		1.95	4.97
Personnel	Day ratio	Night ratio	Night starts	Night ends		CPM	Cost
Nurse assistant	8:1	8:1	23:00:00	07:00:00		0.48	TBD
Registered nurse (RN)	4:1	6:1	23:00:00	07:00:00		1.37	TBD

Mins, minutes; CPM, cost per minute; Post-op, postoperative; Pt, patient; OR, operating room; IV, intravenous.

Appendix Table 5
Post-Op Visits.

Post-Op Visits					
Type of Visit	Key Personnel Involved	Probability	Duration (Mins)	CPM	Cost
Post-op visit #1: check-in	Front end supervisor	100%	3	0.15	0.45
Post-op visit #1: X-ray	Radiology tech	100%	5	0.85	4.25
Post-op visit #1: rooming/prep	Medical assistant	100%	5	0.15	0.75
Post-op visit #1: clinical assessment	Orthopedic surgeon	50%	7	6.36	22.26
Post-op visit #1: clinical assessment	Physician assistant (PA)	50%	7	1.43	5.00
Post-op visit #1: check-out/scheduling	Front end supervisor	100%	2	0.00	0.00

Post-op, postoperative; CPM, cost per minute; Mins, minutes.