Defining the Cost of Arthroscopic Rotator Cuff Repair

A Multicenter, Time-Driven Activity-Based Costing and Cost Optimization Investigation

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Background: Rotator cuff repair (RCR) is a frequently performed outpatient orthopaedic surgery, with substantial financial implications for health-care systems. Time-driven activity-based costing (TDABC) is a method for nuanced cost analysis and is a valuable tool for strategic health-care decision-making. The aim of this study was to apply the TDABC methodology to RCR procedures to identify specific avenues to optimize cost-efficiency within the health-care system in 2 critical areas: (1) the reduction of variability in the episode duration, and (2) the standardization of suture anchor acquisition costs.

Methods: Using a multicenter, retrospective design, this study incorporates data from all patients who underwent an RCR surgical procedure at 1 of 4 academic tertiary health systems across the United States. Data were extracted from Avant-Garde Health's Care Measurement platform and were analyzed utilizing TDABC methodology. Cost analysis was performed using 2 primary metrics: the opportunity costs arising from a possible reduction in episode duration variability, and the potential monetary savings achievable through the standardization of suture anchor costs.

Results: In this study, 921 RCR cases performed at 4 institutions had a mean episode duration cost of $4,094 ± $1,850. There was a significant threefold cost variability between the 10th percentile ($2,282) and the 90th percentile ($6,833) ($p < 0.01$). The mean episode duration was registered at 7.1 hours. The largest variability in the episode duration was time spent in the post-acute care unit and the ward after the surgical procedure. By reducing the episode duration variability, it was estimated that up to 640 care-hours could be saved annually at a single hospital. Likewise, standardizing suture anchor acquisition costs could generate direct savings totaling $217,440 across the hospitals.

Conclusions: This multicenter study offers valuable insights into RCR cost as a function of care pathways and suture anchor cost. It outlines avenues for achieving cost-savings and operational efficiency. These findings can serve as a foundational basis for developing health-economics models.

Level of Evidence: Economic and Decision Analysis Level III. See Instructions for Authors for a complete description of levels of evidence.

In the United States, nearly 5 million patients seek treatment for rotator cuff pathology every year. In 2022, an estimated 1,119,734 primary rotator cuff surgical procedures were performed per year[1], costing nearly $7 billion annually[2]. Rotator cuff repair (RCR) is also among the most cost-variable surgical procedures[3], which inherently makes it an excellent target for both cost analysis and cost-optimization strategies.

Time-driven activity-based costing (TDABC) is a method of microcosting that has been accepted as both more accurate and more transparent than traditional cost accounting. In the field of orthopaedic surgery, TDABC has been utilized to study the cost of surgical procedures[4], clinic consultations[5], and care across different hospital settings. Principally, TDABC allows researchers to accurately identify the cost drivers of an episode duration. However,

*A list of the Avant-Garde Health and Codman Shoulder Society Value-Based Care Group members is provided in a Note at the end of the article.

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TDABC can also be used to highlight optimal resource utilization for increased efficiency or increased capacity[6].

Several studies using TDABC have been published on RCR to date[3,7-9]. Each of the aforementioned studies analyzed the data from a single institution. Although each of the reported cost estimates for RCR is likely accurate for its own institution, they lack external generalizability. Furthermore, a key limitation of reporting on single-institution cost data is the lack of insight into resource efficiency and capacity. Identifying efficiency and capacity opportunities in surgical services is an integral part of an approach to achieving a more sustainable health-care system through cost reduction. Specifically, this can be achieved by reducing the variability in resource consumption. In this regard, TDABC has been considered as the gold-standard method for precisely measuring costs and identifying cost-saving opportunities throughout the care processes[10].

As such, the goal of this study was to utilize a multicenter approach and TDABC methodology to accurately define the cost of RCR with more external generalizability than previously reported, and demonstrate potential cost-optimization opportunities by reducing variability in RCR time-derived costs and implant acquisition costs.

Materials and Methods

This was a multicenter, retrospective study that included all patients undergoing an RCR at 4 U.S. academic tertiary care systems. Hospitals A, B, and C collected data from January 2021 to December 2022, and hospital D collected data from January 2022 to December 2022. Hospitals A, B, and C are located in New England, and hospital D is located in the Mid-Atlantic region. Cases were identified using Current Procedural Technology (CPT) codes for RCR and associated procedures. Patients were excluded if they did not have an RCR or had additional procedures performed beyond those listed above. A complete list of CPT codes identified and included is available in Appendix I.

Data Collection and Analysis

The data for surgical supplies (including implants), medications, time stamps, and personnel costs were extracted from Care Measurement (Avant-Garde Health). Care Measurement provides patient-level electronic health data including demographic characteristics, CPT codes, time stamps throughout the surgical pathway, professional involvement, and supplies and medications utilized, including all acquisition costs. The patient-level data were submitted for validation to look for anomalies, such as inconsistent time stamps and supply prices that were outside of typical ranges. These cases were excluded.

The steps established for the TDABC study were strictly followed and guided the data collection. The patient care pathway map was created and identified resources utilized by patients along the care pathway, assessed the cost of each resource identified, and estimated the capacity of each resource. The capacity cost rate for each resource was calculated. Finally, the cost equations per patient were structured, multiplying the length of time that each resource was utilized by its cost capacity rate, allowing the calculation of the unit costs[2,3]. Appendix II contains a detailed description of how Care Measurement considers the TDABC method in its codes.

The episode duration was defined from patient arrival at the hospital through hospital discharge. The cost analysis focused on direct personnel and direct supply costs, including for medications, implants, and general materials. Indirect and hospital structural costs, such as loss of productivity and hospital fixed costs (depreciation, energy), were excluded. The capacity cost rate, the length of time spent per patient in each phase of the care cycle, and the supply consumption were extracted from Care Measurement, using the real-world data from the period in which each patient was treated. For supply costs, the hospital acquisition cost was considered, excluding profit margins.

Three data analyses were performed to explore the granular cost information achieved with TDABC. The first one described the cost composition in the sample of patients included in the microcosting study. The second one compared the resource consumption between the centers, measuring the variability in the surgical pathway. The third one identified potential cost-saving opportunities achieved by the potential redesign of the care pathways. In all of them, costs were organized in groups according to the resource category: supply, medications, and personnel costs in each phase of the care cycle.

We acknowledge that patient demographic characteristics, surgical complexity, and anesthesia practices vary across centers, potentially influencing the episode duration and cost metrics. To ensure the robustness of our findings, this variability is recognized as a factor in our analysis, underscoring the necessity of contextual interpretation of the data.

Microcosting Descriptive Statistics for RCR Surgery

Descriptive statistics were used to analyze the cost per surgical procedure based on the sample of patients included in the study from each center, followed by a cost composition analysis that allowed for quantification of the proportion of cost justified by supplies and personnel costs in each center. The Mann-Whitney test, a nonparametric statistical test, was used to evaluate differences in total costs between groups. Significance was set at $p < 0.05$.

Care Capacity and Potential Supply Cost-Savings

Care capacity was quantified by identifying the centers where the mean episode duration between patient check-in and post-acute care unit (PACU) discharge was longer than at other centers, and quantifying how many care-hours could be saved by reducing the episode duration variability between the centers. First, the episode duration was broken into phases based on the surgery process map: check-in to anesthesia start, anesthesia start to incision, incision to surgical room check-out, duration in the PACU, and duration in the ward prior to discharge. The mean time duration that patients spent in each phase was measured per hospital, and the mean episode duration from check-in to PACU departure at the center with the shortest episode duration was set as a reference to quantify the number of

TABLE I Sample Description

Hospital	No. of Cases	Age* *(yr)*	Male Sex	CMS†	Length of Time* *(hr)*
A	158	63 ± 10	66%	46%	8.7 ± 4.8
B	610	60 ± 11	64%	31%	6.7 ± 1.4
C	52	52 ± 11	63%	25%	9.1 ± 5.2
D	101	56 ± 10	51%	13%	5.7 ± 0.9
Total	921	60 ± 10	61%	29%	7.1 ± 3.0

*The values are given as the mean and the standard deviation. †U.S. Centers for Medicare & Medicaid Services.

additional care-hours that could be delivered by the other centers based on the potential decreases in episode duration.

Finally, the cost-saving opportunity associated with the variability in implant costs between centers was estimated, focusing on the suture anchors. Suture anchors were selected as the focus of our implant costs as previous studies have shown that implant costs drive overall episode duration costs[3,8,9,11,12]. The suture anchor with the lowest cost utilized at each institution was used to estimate the potential savings achieved, by reviewing implant purchase agreements in the other centers. Potential cost savings were estimated by using the median number of anchors per case utilized across the patient cohort. All of the cost information was collected and presented in U.S. dollars in 2022.

Results

The analyses in this study included 921 patients who underwent RCR at 4 academic, tertiary-care centers. Most of the patients were male (61%), and the mean patient age (and standard deviation) was 60 ± 10 years (Table I). The mean cost per patient was $4,094 ± $1,850. The variability between the 90th percentile ($6,833) and the 10th percentile ($2,282) was 3.0-fold ($p < 0.01$).

The center with the highest volume demonstrated the lowest mean cost (Table II), and most of the cost (56%) was accounted for by the supply cost and usage (number of individual supplies used). The greatest variability between centers was in implant and personnel costs.

Variability in Episode Duration and Implant Cost

The mean length of episode duration of the total surgical cycle was 7.1 hours (Table III). The periods in the PACU and in the ward after the surgical procedure were identified as the ones with the highest variability between the centers. Facility volume was not associated with a shorter episode duration, as the hospital with the third-highest volume had the shortest episode duration (hospital D: 5.7 hours). Table III shows the mean episode duration in hours per surgical phase in each center. Taking the center with the shortest length of time in the PACU to discharge (excluding time in the ward), B, as a reference, it would have been possible to save 43, 120, and 123 PACU care-hours annually in the other 3 centers (Table IV). If the time in the ward is included in the total episode duration and hospital D (in which patients were discharged directly from the PACU) is set as the reference center, it would have been possible to save 178 care-hours at hospital C, 471 care-hours at hospital A, and 640 care-hours as hospital B (Table V).

The implant cost per case was defined as the number of suture anchors utilized multiplied by the cost per implant. Focusing only on the mean suture anchor acquisition costs revealed a variability in price ranging from $578 at hospital D to $1,273 in hospital C (with $768 in hospital A and $826 at hospital B). If all hospitals had been able to acquire the suture anchors at the cost of $578, then it would have been possible to achieve a total savings of $217,440 at the hospitals during the period of analysis, based on the number of cases performed in each hospital and the median number of anchors used per case across the cohort (1) (Table VI).

TABLE II Cost Composition per Patient and Center*

Hospital	No. of Cases	Personnel Cost†	Total Implant Cost†	Medication Cost†	Non-Implant and Non-Medication Cost†	Total Supply Cost†	Total Cost†
A	158	$2,077 ± $647	$1,303 ± $1,505	$116 ± $88	$699 ± $543	$2,064 ± $1,659	$4,141 ± 2,101
B	610	$1,684 ± $346	$1,564 ± $1,395	$43 ± $24	$564 ± $345	$2,171 ± $1,469	$3,855 ± $1,702
C	52	$2,050 ± $494	$1,466 ± $1,743	$41 ± $49	$620 ± $207	$2,127 ± $1,828	$4,178 ± $2,102
D	101	$2,998 ± $535	$1,809 ± $1,400	$62 ± $30	$551 ± $179	$2,423 ± $1,459	$5,421 ± $1,605
Mean		$1,916 ± $604	$1,541 ± $1,440	$58 ± $52	$589 ± $371	$2,178 ± $1,525	$4,094 ± $1,850

*The cost information is expressed on a case level. †The values are given as the mean and the standard deviation.

TABLE III Mean Episode Duration per Surgical Phase and Hospital

Hospital	No. of Cases	Check-in to Anesthesia Start *(hr)*	Anesthesia Start to Incision *(hr)*	Incision to Surgical Room Checkout *(hr)*	PACU *(hr)*	Total, Check-in to PACU Departure *(hr)*	Ward *(hr)*	Total Episode Duration *(hr)*
A	158	2.75*	0.51	1.54	1.30	6.1	2.59*	8.69
B	610	2.35	0.46†	1.43†	1.03†	5.27†	1.49	6.76
C	52	1.96	0.73*	1.94*	3.33*	7.97*	1.16	9.13
D	101	1.07†	0.68	1.71	2.25	5.71	—†	5.71
Mean	—	2.25	0.50	1.5	1.33	5.58	1.48	7.06
Maximum variability	—	1.68	0.27	0.51	2.3	2.69	2.59	3.42

*Highest length of stay observed in the phase of care. †Lowest length of stay observed in the phase of care.

Discussion

In this multicenter, high-powered study, microcosting was applied to accurately identify the cost of RCR and the potential cost savings achievable through reducing variability. We discovered the mean cost for the episode duration for RCR to be $4,094, with high cost variability: a threefold difference was observed between the lowest-cost and highest-cost cases. Notably, the greatest variability was found in the time that patients spent in the PACU and the ward after the surgical procedure, which ranged from a total of 2.25 to >4 hours across the 4 centers. Although surgical time showed less variability (1.43 to 1.94 hours), our analysis highlights the time in the PACU and overall episode duration as critical factors in operational efficiency. Reducing nonoperative components of the episode duration, particularly in the PACU and episode durations, not only reflects an opportunity to streamline patient care but also underscores an avenue for increasing surgical volume. Optimizing these components can alleviate bottlenecks in the surgical care pathway, thereby enhancing the capacity for additional surgical procedures. Despite the inherent limitations posed by operating room availability and labor constraints, this approach to improving operational efficiency presents a strategic pathway to augment surgical throughput. By focusing on these areas for efficiency gains, health-care systems can potentially increase the number of surgical procedures performed, thus leveraging our findings for broader operational improvements without compromising the quality of patient care.

Although our analysis identifies potential efficiencies through episode duration reduction, it may suggest that such reductions are without associated costs. It is important to clarify that our assessment primarily envisioned the potential for additional revenue generation through increased surgical volume facilitated by episode duration reductions. However, we have not delved into the detailed calculation of additional costs that these added surgical procedures might incur—including, but not limited to, direct expenses such as surgical supplies and personnel as well as indirect costs such as increased postoperative care. Additionally, it is essential to state that achieving reductions in episode duration, particularly to levels observed in the most efficient center, would likely incur costs related to process optimization, training, and perhaps even infrastructure adjustments. These investments are critical to realize the efficiency gains noted. They should be factored into any cost-benefit analysis of episode duration reduction strategies, ensuring a comprehensive understanding of both the potential revenue enhancements and the associated costs of operational changes.

Similar to previous work on costs in RCR and other orthopaedic procedures, our study has shown that implant costs are one of the main direct costs driving the total cost for the episode duration[3,8,9,11-17] but also found that there is high market variability in price between centers. There was more than a twofold difference between the center with the lowest cost per anchor and the center with the highest cost per anchor. This discrepancy shows that negotiating implant costs can also influence the total cost of the procedure.

TABLE IV Potential Annual Care-Hours Saved by Reducing the Variability in PACU Time

Hospital	Actual PACU Time *(hr)*	No. of Cases	Target PACU Time *(hr)*	Potential Time Savings *(hr)*	Potential Care-Hours Saved *(hr)*
Reference, B	1.03	610	1.03	—	—
A	1.30	158	1.03	0.27	42.66
C	3.33	52	1.03	2.30	119.60
D	2.25	101	1.03	1.22	123.22

TABLE V Potential Annual Care-Hours Saved by Reducing the Variability in Total Episode Duration Including Time in the Ward

Hospital	Actual Total Episode Duration *(hr)*	No. of Cases	Target Episode Duration *(hr)*	Potential Time Savings *(hr)*	Potential Care-Hours Saved *(hr)*
A	8.69	158	5.71	2.98	470.84
B	6.76	610	5.71	1.05	640.5
C	9.13	52	5.71	3.42	177.84
Reference, D	5.71	101	5.71	—	—

Previous studies utilizing TDABC for RCR analysis, such as those by Bernstein et al.[3], Koolmees et al.[8], and Wise et al.[9], were confined to single institutions, limiting their ability to assess efficiency and cost driver differences across various settings. Bernstein et al. discovered intraoperative costs to be the predominant expense, accounting for 91% of total costs, primarily driven by the use of biologic implants and surgeon preferences. Koolmees et al. reported a mean 90-day episode duration cost of $10,569, with operative costs comprising 76% of this. Meanwhile, Wise et al. found surgical and implant costs to be the major contributors to a mean RCR cost of $5,413 per case, noting a minimal correlation between cost and patient-reported outcomes. Unlike these prior studies, our multicenter analysis uniquely explores the variability in episode duration costs. It identifies postoperative recovery time and suture anchor costs as areas with the highest variability across institutions. This approach not only corroborates the previously noted cost variability but also advances our understanding by pinpointing specific segments within the episode duration and supply chain that offer opportunities for standardization and efficiency improvement.

After recognizing the variability in the episode duration across centers, it is crucial to consider the multifaceted reasons behind such differences. The center exhibiting the shortest episode duration potentially benefitted from specific patient demographic characteristics and surgical and anesthesia practices that are optimized for efficiency. This distinct context raises important questions about the generalizability of these results to other settings with different patient populations and operational protocols. The variability emphasizes the necessity for a tailored approach in applying efficiency improvements, considering the unique characteristics of each health-care facility. Further investigation into the factors influencing the episode duration, such as patient health status, surgical complexity, and anesthesia type, will enhance our understanding of how best to implement such efficiencies across diverse surgical settings.

This study had limitations that warrant consideration. It encompassed 4 academic medical centers, which may have limited the generalizability of our findings across diverse health-care settings. A notable limitation was our inability to differentiate the types of anesthesia used, which could have influenced recovery times. This aspect suggests a valuable direction for future research aimed at elucidating factors that extend postoperative recovery, thereby identifying opportunities for enhancing operational efficiency safely. Furthermore, our analysis did not encompass the evaluation of tear size, patient comorbidities, or other patient-specific factors. Despite these limitations, the breadth of patient data analyzed likely provided a representative overview of the typical patient population undergoing RCR. Additionally, our study did not explore the nuances of surgeon idiosyncrasy and intraoperative decision-making, nor could it directly assess tear characteristics. The potential for cost variation across different care delivery networks remains unexplored. Although our analysis included personnel costs, a detailed examination of labor utilization across centers was beyond our study's scope.

This research offers insights into the variability and potential for efficiency optimization in RCR procedures. However, it does not incorporate postoperative data, including patient-reported outcomes, complications, or failure rates, leaving unanswered questions regarding the real-world value of the proposed cost-saving strategies. Looking forward, there is a critical need for prospective multicenter research that delves into how variables such as anesthesia type, tear size, and labor utilization vary between institutions and their consequent impact on the episode duration and overall episode duration costs. Such studies should also extend to include patient outcomes, providing a comprehensive assessment of whether cost-minimization efforts indeed translate into tangible benefits for patients.

TABLE VI Potential Annual Cost Savings by Reducing the Variability in Suture Anchor Costs

Hospital	No. of Cases	Mean Suture Anchor Cost per Case	Total Suture Anchor Cost per Hospital	Potential Total Cost	Estimated Cost Savings
A	158	$768	$121,344	$91,324	$30,020
B	610	$826	$503,860	$352,580	$151,280
C	52	$1,273	$66,196	$30,056	$36,140
D	101	$578	$58,378	$58,378	—

In conclusion, we utilized microcosting and the TDABC methodology to identify RCR cost in the largest cohort to date. We showed that the episode duration, including variability in postoperative recovery time, was a large driver of cost. The multicenter approach highlights the variability in care delivery for RCR, showing that both optimization of the PACU pathway as well as implant negotiations may significantly reduce episode-of-care costs.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/I287). ■

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