The primary cost drivers of arthroscopic rotator cuff repair surgery: a cost-minimization analysis of 40,618 cases

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Background: An estimated 250,000 rotator cuff repair (RCR) surgical procedures are performed every year in the United States. Although arthroscopic RCR has been shown to be a cost-effective operation, little is known about what specific factors affect the overall cost of surgery. This study examines the primary cost drivers of RCR surgery in the United States.

Methods: Univariate analysis was performed to determine the patient- and surgeon-specific variables for a multiple linear regression model investigating the cost of RCR surgery. The 2014 State Ambulatory Surgery and Services Databases were used, yielding 40,618 cases with Current Procedural Terminology code 29827 ("arthroscopic shoulder rotator cuff repair").

Results: The average cost of RCR surgery was $25,353. Patient-specific cost drivers that were significant under multiple linear regression included black race ($P < .001$), presence of at least 1 comorbidity ($P < .001$), income quartile ($P < .001$), male sex ($P = .012$), and Medicare insurance ($P = .035$). Surgical factors included operative time ($P < .001$), use of regional anesthesia ($P < .001$), quarter of the year (January to March, April to June, July to September, and October to December) ($P < .001$), concomitant subacromial decompression or distal clavicle excision ($P < .001$), and number of suture anchors used ($P < .001$). The largest cost driver was subacromial decompression, adding $4992 when performed alongside the RCR.

Conclusion: There are several patient-specific variables that can affect the cost of RCR surgery. There are also surgeon-controllable factors that significantly increase cost, most notably subacromial decompression, distal clavicle excision, use of regional anesthesia, and number of suture anchors. Surgeons must consider these factors in an effort to minimize cost, particularly as bundled payments become more common.

Level of evidence: Level IV; Economic Analysis

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Keywords: Rotator cuff repair; arthroscopy; subacromial decompression; distal clavicle excision; cost driver; cost minimization; shoulder surgery

Rotator cuff repair (RCR) surgery is a very common orthopedic procedure, with an estimated 250,000 cases in the United States per year.[18] RCR surgery is most often performed arthroscopically, and the incidence is steadily rising, reaching 83.1 patients per 100,000 patient-years

in 2009.[6,8,23] Because of the prevalence of RCR and recent scrutiny of health care spending, there has been much interest in the cost of the procedure. Cost estimates for the procedure have ranged from $6374 to $13,270.[5,18] When compared with nonoperative treatment, it has been shown that RCR surgery is cost-effective, providing a national savings of $3.44 billion per year when accounting for both direct medical costs and lost income.[16]

With the trend toward bundled payments and fixed reimbursements, surgeons performing RCR surgery are incentivized to find ways to reduce costs. This study analyzes both patient and surgical characteristics that contribute to the overall cost of RCR surgery using the State Ambulatory Surgery and Services Databases (SASD), a part of the largest collection of longitudinal health care data in the United States.[13]

Although previous studies have calculated estimates for the cost of specific factors in RCR surgery, little is known about how both patient and surgical factors drive costs on a national basis.[5,18] In this investigation, we evaluated how patient demographic characteristics, income quartile, comorbidities, and insurance provider affect the overall cost of RCR surgery. To estimate the cost of surgery, we used total charges as a proxy. We also analyzed how perioperative decisions about anesthesia type, number of suture anchors, and concomitant subacromial decompression or distal clavicle excision impact cost. Specifically, we hypothesized that the presence of at least 1 comorbidity, longer operative time, and greater use of suture anchors would increase costs.

Methods

Data source

We used the 2014 SASD from 6 states in this study. These databases are part of the Healthcare Cost and Utilization Project, a comprehensive and well-validated data source on health care that is sponsored by the Agency for Healthcare Research and Quality.[14] The SASD contains encounter-level data regarding outpatient procedures performed in freestanding and hospital ambulatory surgery centers. Over 200 data points are collected for every patient encounter. To give a geographically representative sample of the United States, we used the databases from Florida, Kentucky, Iowa, Maryland, Nevada, and New York.

For every case, the SASD contains data about the total charges that were billed. Total billed charges are used to approximate the cost of surgery. Many providers bill various insurers different amounts for the same Current Procedural Terminology (CPT) code according to differing fee schedules. Total charges also do not reflect the true cost to the surgeon and surgical facility but rather the amount they expect to be paid. Despite these limitations, total charges are still useful as a proxy measure of cost. They can show trends in how much surgery centers bill for different concomitant procedures, for patients from different demographic groups, and for patients with differing levels of comorbidity. On a large scale, these trends may be indicative of potential areas of

Table I Univariate analysis of continuous variables for cost of RCR surgery (excluding professional or surgeon fees): single linear regression

Variable	Constant (SE), $	β Coefficient (SE), $	P value
Age	23,152 (445)	37.80 (7.50)	<.001
Time in operating room	14,490 (220)	31.80 (1.70)	<.001
No. of anchors billed	25,099 (97)	787.70 (158.20)	<.001

RCR, rotator cuff repair; *SE*, standard error.

cost savings. Furthermore, using total charges as a proxy for cost was recently validated in a published work.[3]

Data collection

Every encounter that billed for CPT code 29827 ("arthroscopic shoulder rotator cuff repair") was selected. Any cases requiring admission to the hospital after surgery were excluded as inpatient costs would skew the data. We then analyzed variables for both patient and surgical characteristics. Patient characteristic variables included age, sex, race, presence of comorbidities, type of insurance, and income quartile of the patient's ZIP code. Surgical variables included time in the operating room (OR), quarter of the year (January to March, April to June, July to September, and October to December), type of anesthesia, number of suture anchors billed, and concurrent subacromial decompression or distal clavicle excision surgery. We used CPT code 29826 for subacromial decompression and CPT code 29824 for distal clavicle excision. We also used Healthcare Common Procedure Coding System code C1713 ("anchor/screw bone/bone") to determine how many suture anchors were billed. To analyze how our variables affected cost, both univariate analysis and multiple linear regression were performed with total charges as the dependent variable. The total charges reflected the amount billed by the surgery center before any professional or surgeon fees.

Statistical analysis

Univariate analysis was performed first to determine which variables to include in a multiple linear regression (Tables I and II). Single linear regression, independent-samples *t* testing, and 1-way analysis of variance were used where applicable. $P < .05$ was used as the cutoff for statistical significance. These variables were then used in a multiple linear regression, again using $P < .05$ to determine significance. Ninety-five percent confidence intervals for β values were also calculated for the independent predictors (SPSS Statistics, version 21.0; IBM, Armonk, NY, USA).

Results

There were 42,134 cases of RCR in 2014 for the 6 states examined. A total of 40,618 cases were available after those requiring inpatient admission were excluded. The average cost of RCR surgery was $25,353 (standard

Table II Univariate analysis of categorical variables for cost of RCR surgery (excluding professional or surgeon fees) with 1-way ANOVA or independent-samples t testing

Variable	Group	% of patients	Cost (SD), $	P value
Anesthesia type	Only general	80.8	18,468 (13,346)	<.001
	Regional	19.2	20,849 (11,697)	
Quarter in which surgery was performed	Quarter 1 (January to March)	25.8	24,329 (16,135)	<.001
	Quarter 2 (April to June)	24.9	24,942 (16,332)	
	Quarter 3 (July to September)	23.5	25,919 (16,895)	
	Quarter 4 (October to December)	25.8	26,256 (17,522)	
Sex	Male	57	25,778 (17,041)	<.001
	Female	43	24,791 (16,332)	
Chronic conditions	0	35	23,330 (15,496)	<.001
	≥1	65	26,444 (17,286)	
Primary payer	Medicare	34.2	26,373 (16,868)	<.001
	Medicaid	4.9	21,814 (14,511)	
	Private insurance	57.8	25,012 (15,880)	
	Self-pay	3.1	23,452 (21,549)	
Income quartile by ZIP code	First	20.7	28,734 (17,721)	<.001
	Second	28.0	27,144 (17,537)	
	Third	24.7	25,214 (16,494)	
	Fourth	26.6	20,810 (14,147)	
Race	White	77.1	25,573 (16,604)	<.001
	Black	8.3	24,816 (16,511)	
	Hispanic	7.6	27,615 (16,698)	
	Asian	1.0	26,127 (17,737)	
	Native American	0.3	20,391 (12,805)	
	Other	5.7	24,585 (19,757)	
Subacromial decompression	Not performed	18.3	21,554 (14,642)	<.001
	Performed	81.7	26,203 (17,067)	
Distal clavicle excision	Not performed	71.0	24,065 (15,962)	<.001
	Performed	29.0	28,508 (18,148)	

RCR, rotator cuff repair; *ANOVA*, analysis of variance; *SD*, standard deviation.

deviation [SD], $16,747). Cost also varied significantly from state to state. Florida had the highest cost ($33,331; SD, $17,906), and Maryland had the lowest ($8988; SD, $3275). All variables tested under univariate analysis are listed in Tables I and II.

Patient characteristics

Patient age, sex, race, presence of chronic conditions, type of insurance, and income quartile by ZIP code were all significant under univariate analysis. Older age was associated with greater costs, with each year adding $37.80 in expected cost ($P < .001$). In addition, men had an average of $987 more in charges than women ($P < .001$). Regarding race, Hispanic patients had the highest costs ($27,615; SD, $16,698) whereas Native American patients had the lowest ($20,391; SD, $12,805). Having at least 1 chronic medical condition was associated with higher costs ($26,444; SD, $17,286) compared with patients with no baseline comorbidities. Costs also differed based on insurance type. Medicare patients had the highest charges ($26,374; SD, $16,868), whereas Medicaid patients had the lowest ($21,815; SD, $14,511). In addition, costs increased with

each increment of income quartile. Patients in the highest income quartile had $7924 more in charges than patients in the lowest quartile ($P < .001$).

Surgical variables

Time in the OR, quarter of the year in which surgery was performed, type of anesthesia, number of suture anchors billed, and presence of subacromial decompression or distal clavicle excision all had a significant impact on the costs of RCR surgery. Longer time in the OR increased cost, with each minute adding $31.80 ($P < .001$). A stepwise increase in cost was found with quarter of the year, with costs increasing throughout the year. Surgical procedures performed in the fourth quarter were $1927 more expensive than those performed in the first quarter ($P < .001$). When used, regional anesthesia was more expensive ($20,849; SD, $11,697) than general anesthesia alone ($18,468; SD, $13,346). Each suture anchor increased cost by $787 ($P < .001$), and when subacromial decompression and distal clavicle excision were performed, they increased cost by $4649 and $4443, respectively (both $P < .001$).

Table III Multivariate analysis of patient and surgical variables

Variable	β Coefficient, $	95% CI, $	P value
Constant	18,998	17,574 to 20,455	<.001
Subacromial decompression	4992	4180 to 5804	<.001
Regional anesthesia	4424	3614 to 5235	<.001
Distal clavicle excision	3424	2699 to 4150	<.001
Income quartile by ZIP code (first is highest income, fourth is lowest)	−3125	−3414 to −2835	<.001
Race (black)	−2068	−3229 to −906	<.001
Presence of comorbidities	1770	1083 to 2457	<.001
No. of anchors	1249	641 to 1856	<.001
Sex (female)	−812	−1443 to −182	0.012
Discharge quarter	752	480 to 1025	<.001
Insurance (Medicare)	748	52.2 to 1444	0.035
Time in OR (in minutes)	47	42.2 to 52.2	<.001

CI, confidence interval; *OR*, operating room.

Multiple regression

We performed multiple linear regression with all variables that were significant under univariate analysis (Table III). The final model included income quartile ($P < .001$), time in the OR ($P < .001$), subacromial decompression ($P < .001$), distal clavicle excision ($P < .001$), anesthesia type ($P < .001$), presence of chronic conditions ($P < .001$), quarter of discharge ($P < .001$), race ($P < .001$), number of suture anchors billed ($P < .001$), sex ($P = .012$), and insurance ($P = .035$). The factors with the most impact on overall cost were the presence of subacromial decompression and the use of regional anesthesia. These increased cost by $4992 and $4424, respectively. In addition, concomitant distal clavicle excision increased cost by $3424.

Discussion

This study found that both patient and surgical characteristics significantly affected the total cost of arthroscopic RCR surgery. Patient sex, race, presence of comorbidities, type of insurance, and income quartile by ZIP code were all significant under multivariate analysis. Time in the OR, quarter of the year in which surgery was performed, type of anesthesia, number of suture anchors billed, and concomitant subacromial decompression or distal clavicle excision also had a significant effect on cost.

As health care spending continues to grow, it is important for patients and physicians alike to keep cost in mind.

Mather et al[16] performed a cost-effectiveness analysis of RCR surgery and found that surgery provides an increase in quality-adjusted life-years for all ages. They also calculated a mean of $13,771 in societal savings per patient over nonoperative treatment. Although RCR surgery is cost-effective, reducing cost can still be beneficial for both surgeons and patients.

Certain patient characteristics may be out of surgeons' control, but awareness of these cost drivers is still imperative for patient counseling. For example, this study found that the presence of at least 1 medical comorbidity was associated with higher costs. This could be because of a longer operative time, as patients with at least 1 comorbidity were in the OR for 10 minutes longer than patients with no comorbidities ($P < .001$). Although Hispanic ethnicity was not significant under multivariate analysis, the Hispanic group was the group with the highest costs under univariate analysis. A previous study by Bokshan et al[2] similarly found that Hispanic ethnicity was associated with higher readmission rates after anterior cruciate ligament reconstruction surgery, possibly leading to higher costs. More research is warranted to understand why Hispanic patients have higher costs; perhaps this is a result of the need for translation services in some cases. In addition, higher income quartiles were associated with higher surgical costs, even when we controlled for insurance provider in our multiple linear regression. Each stepwise increase in income quartile added $3125 in cost. Several previous studies have found that high-income patients are more likely to undergo mitral valve repair and bariatric surgery, so it is possible that high-income patients seek RCR surgery at higher rates.[12,22] However, it is unclear why there is a disparity in the cost of surgery between income quartiles. It is possible that patients with higher incomes utilize surgical facilities that charge more. Further studies ought to examine this discrepancy in more detail. There was also a large difference in cost between the different states examined in this study. Cases in Florida had $24,343 more in total charges than cases in Maryland ($P < .001$). This may be because of differing fee schedules in different states, as one study found that Medicaid reimbursement rates between states varied greatly for common orthopedic procedures.[4] Private insurers do not publish the allowable amounts in their contracts with different providers, but it is possible they also vary significantly between states.

We identified several factors that surgeons can control to lower costs. Regional anesthesia added $4424 to the surgical cost. Although it has been shown that patients who receive a nerve block for RCR surgery spend less time in the postoperative anesthesia care unit, possibly reducing facility costs, our analysis indicates that regional anesthesia still increases surgical cost.[20] This could be because of the added cost of the medication used in the nerve block as well as the cost of the anesthesia provider. Some surgeons may want their patients to receive a nerve block to help with pain control postoperatively, but this must be weighed

against the additional cost it generates. Performing subacromial decompression or distal clavicle excision also adds cost. This is especially significant as over 80% of patients in our study underwent subacromial decompression, and one study found a 440% rise in the incidence of concomitant subacromial decompression and RCR surgery from 2000 to 2007.[15] The additional cost of these procedures is likely a result of the additional operative time needed to perform them, as time was a significant cost driver in our multivariate analysis. It is also possible that additional supplies needed add cost.

It is important that surgeons be cognizant of their operative times. We found in our multivariate analysis that each minute of time in the OR adds $47. A study comparing RCR operative times at low-, intermediate-, and high-volume centers found significant variation, as high-volume centers averaged 77 minutes whereas intermediate-volume centers averaged 135 minutes.[5] Identifying ways to achieve greater time efficiency in the OR is important for all surgeons considering the high cost of OR time and the large variation in operative time that exists between providers.

As mentioned earlier, the use of suture anchors significantly impacts cost, with each anchor adding $1249 in our model. In terms of cost-effectiveness, Genuario et al[10] found that double-row repair is only a cost-effective option if it requires less than $352 in additional cost for tears larger than 3 cm. Our model thus renders double-row repair not a cost-effective means of treating rotator cuff tears.

The high cost of health care in the United States is evident given that health care spending as a percentage of gross domestic product in the United States is nearly double that of high-income European countries.[19] An RCR study in the United Kingdom found that each minute in the OR added $22 in cost,[17] whereas we found that each minute added $47. Even more significant was the difference in the cost of suture anchors. The UK study found that each anchor cost $141,[17] whereas each anchor added $1249 in cost in our model. Therefore, it is highly possible that the high cost of surgical supplies and OR time adds to the high cost of health care in the United States.

Limitations

This study used a large, geographically diverse sample size to ensure our results are applicable to the United States as a whole. We also created a multiple linear regression model to remove any influence from confounding factors. However, there are several limitations to this study. It is possible that the SASD contains misclassified elements, a risk with any large claims-based database. These databases also do not contain information about the severity of the injury that necessitated RCR surgery, so we were unable to determine how this affected our model. There are also several limitations regarding the billing of the encounter. First, there is a risk of differences in coding and billing practices between

providers. Some surgeons may not bill for each anchor they use separately from CPT code 29827, thus under-representing the number of anchors implanted. Second, we used total charges as a proxy for cost. However, total charges may not reflect the cost of the procedure as it has been shown that hospital charges have been rising faster than costs.[7] Reimbursement also differs from charges as it is dependent on the contract a provider has with an insurer. Despite these limitations, the SASD contains many useful metrics for analyzing cost drivers in RCR surgery and is well validated as a data source for a variety of medical procedures.[1,5,9,11,21] To minimize the effect of differing reimbursement amounts from different insurance providers, we controlled for insurance in our multiple linear regression. The trends identified in this investigation can prove useful for surgeons in their decision making, patient counseling, and efforts to make RCR surgery more cost-effective.

Conclusion

Both patient- and surgeon-specific factors influence the cost of RCR surgery. Patient income quartile, race, sex, insurance provider, and comorbidities were all significant under multiple linear regression. Significant surgical variables included operative time, anesthesia type, quarter of the year, number of suture anchors, and concomitant subacromial decompression or distal clavicle excision. Subacromial decompression was the largest cost driver of RCR surgery, adding $4992. Each suture anchor also added $1249. Providers should be aware of these factors and consider how they can use them to minimize cost.

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The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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