http://dx.doi.org/10.2106/JBJS.L.01495

TABLE E-1 Mean Annual SSI Disability Payments*

Age	Male	Female
18-39	$8816	$9090
40-44	$14,296	$7619
45-49	$16,741	$12,824
50-54	$17,500	$12,824
55-59	$17,566	$9578
60-64	$21,208	$11,052
65-69	$13,896	$9587
70+	$15,667	$8756

*Source: 2011 Current Population Survey. SSI = Supplemental Security Income.

TABLE E-2 CPT Codes, Rate of Occurrence of Concomitant Procedures, and 2013 National Average Medicare Reimbursement*

CPT Code	Description	Rate of Occurrence with Arthroscopic Rotator Cuff Repair (29827)	2013 National Average Medicare Reimbursement
29827	Arthroscopy, shoulder, surgical; with rotator cuff repair	1.000	$1086.35
29826	Arthroscopy, shoulder, surgical; decompression of subacromial space with partial acromioplasty, with coracoacromial ligament (i.e., arch) release, when performed	0.854	$176.58
29824	Arthroscopy, shoulder, surgical; distal claviculectomy including distal articular surface (Mumford procedure)	0.274	$687.95
29823	Arthroscopy, shoulder, surgical; debridement, extensive	0.192	$636.91
29807	Arthroscopy, shoulder, surgical; repair of SLAP lesion	0.010	$1046.21
29828	Arthroscopy, shoulder, surgical; biceps tenodesis	0.076	$934.95
29820	Arthroscopy, shoulder, surgical; synovectomy, partial	0.022	$547.77
29825	Arthroscopy, shoulder, surgical; with lysis and resection of adhesions, with or without manipulation	0.014	$594.38
23430	Tenodesis of long tendon of biceps	0.014	$758.03

*CPT = Current Procedural Terminology, and SLAP = superior labral anterior-posterior

Appendix

The Societal and Economic Value of Rotator Cuff Repair

A. Terms

- Markov decision model. This is a model that simulates a patient's progression through different health states. Each health state has specified transitional probabilities with every other state in the model, and these transitional probabilities are independent of the patient's prior health states.
- Quality-adjusted life year (QALY). This is an outcome measure equal to the expected gains in life expectancy associated with a treatment option, downwardly adjusted for any limitations in quality of life. A year in perfect health is worth 1.0 QALY, and a year of imperfect health is worth some fraction of 1.0 QALY.
- Sensitivity analysis. This is a process in which model results are repeatedly estimated using modified versions of the model. The ranges of values taken by the output provide a measure for how sensitive a finding is to the model's underlying assumptions.
- Robustness. A finding is considered robust if it is not significantly changed by deviations from the model's original design.
- Dominant strategy. A treatment option is considered a dominant strategy if it is both more effective and less costly than an alternative.

B. Framework for Estimating Indirect Costs

Studies documenting the indirect economic implications of treatment for patients with musculoskeletal conditions in the U.S. are extremely limited. We are not aware of any that examine the effects of rotator cuff tear and repair on employment, income, and other economic outcomes. The lack of studies examining the effects of treatment on indirect cost factors stems in large part from the barriers to conducting carefully designed studies that collect longitudinal data, which track patient clinical and economic outcomes over time (before and after treatment).

Our approach for estimating indirect costs was based on the methods and data reported by Dall et al.[1]. Their approach infers the indirect economic benefits of interventions when direct data do not exist by linking data on (1) the effectiveness of musculoskeletal treatment and (2) the impact of functional impairment on economic outcomes. We provide a brief description of this approach below. Additional details are available in Dall et al.[1].

We used data from the National Health Interview Survey (NHIS) to generate regression coefficients that described the statistical relationship between physical functional status and economic outcomes. We applied regression coefficients to surgical outcomes data obtained from a survey of patients treated at a large orthopaedic surgeon group to estimate the effect of surgery on income, missed workdays, and the probability of receiving disability payments (Supplemental Security Income [SSI]). These findings were incorporated into a Markov decision model to estimate total societal savings resulting from rotator cuff repair.

The NHIS, which is used to monitor the health of the U.S. population, is one of the major data collection programs of the National Center for Health Statistics, which is part of the Centers for Disease Control and Prevention. The NHIS covers the civilian noninstitutionalized population residing in the U.S., with an expected NHIS sample size (completed interviews) of approximately 35,000 households each year.

C. Estimating the Relationship Between Functional Limitations and Indirect Costs

The NHIS collects information from a stratified random sample of the U.S. population on physical function, economic factors such as employment status and income, and other patient characteristics[2]. Our analysis combined the 2004 through 2010 NHIS files to increase the sample size, resulting in a sample of 185,829 adults with an age of eighteen years or older living in noninstitutional settings. The NHIS asks respondents:

By yourself, and without using any special equipment, how difficult is it for you to . . .

- Walk a quarter of a mile—about 3 city blocks?
- Walk up 10 steps without resting?
- Sit for about 2 hours?
- Reach up over your head?
- Stand or be on your feet for about 2 hours?
- Stoop, bend, or kneel?
- Lift or carry something as heavy as 10 pounds such as a full bag of groceries?
- Push or pull large objects like a living room chair?

Responses to each question include (1) Not at all difficult, (2) Only a little difficult, (3) Somewhat difficult, (4) Very difficult, and (5) Can't do at all. Our analysis focused only on activity limitations in which the respondent indicated that back pain, bone and/or joint injury, or arthritis contributed to his or her limitations.

http://dx.doi.org/10.2106/JBJS.L.01495

Using regression analysis, we compared the probability of being employed, household income, missed workdays, and the probability of receiving disability payments for adults with activity limitations and the economic outcomes for adults without musculoskeletal system-related activity limitations. Responses to physical functioning questions were decoupled such that for each question and each response (e.g., "only a little difficult," "somewhat difficult," "very difficult," "can't do at all," and "not at all difficult"), a binary variable (1 = yes, and 0 = no) was created. Persons claiming that the physical functioning task was "not at all difficult" were used as the comparison group. We included the following control variables in each model: age (age groups: eighteen to thirty-nine, forty to forty-four, forty-five to forty-nine, fifty to fifty-four, fifty-five to fifty-nine, sixty to sixty-four, sixty-five to sixty-nine, and seventy years and over), sex, highest educational attainment (high school diploma, baccalaureate degree, or postbaccalaureate degree), and occupation (for analysis of household income and missed workdays).

Logistic regression was used for employment and disability payment status models. In the employment model, the dependent variable took on a value of 1 if a survey respondent reported that he or she had a job in the last week. For the disability payment model, the dependent variable took on a value of 1 if a survey respondent reported that he or she was currently receiving SSI. Ordinary least squares regression was used to quantify the impact of activity limitations on household income, and a negative binomial model was used for missed workdays. The models for income and missed workdays included only respondents who reported that they were employed in the last week. Regression results for the functional outcome variables are presented in Dall et al.[1].

D. Data Acquired from Orthopaedic Surgery Group

Predicted values for indirect cost components were obtained by utilizing patient-reported data (n = 73) collected by a large orthopaedic group practice with multiple locations in the Northeast. The survey contained questions concerning an individual's socioeconomic status and functional ability (using the same questions on functional status in the NHIS) prior to surgery and after surgery. Functional questions included the following possible answers: "No difficulty," "Only a little difficult," "Somewhat difficult," "Very Difficult," and "Cannot do." Numerical values of 1 through 5 were assigned to the responses, with "No difficulty" assigned a value of 1 and "Cannot do" assigned a value of 5.

E. Formulas for Indirect Cost Components

Once the average employment probability by age was obtained, we calculated expected income changes from having a rotator cuff repair as follows:

Expected Income = Estimated Income After Surgery × Probability of Being Employed After Surgery – Estimated Income Before Surgery × Probability of Being Employed Before Surgery.

Our change in the value of missed workdays from receiving a rotator cuff repair was calculated as follows:

Expected Value of Missed Workdays = Estimated Income After Surgery × Probability of Being Employed After Surgery × (Missed Workdays After Surgery/240) – Estimated Income Before Surgery × Probability of Being Employed Before Surgery × (Missed Workdays Before Surgery/240).

Our change in disability payments from receiving a rotator cuff repair was calculated as follows:

Expected Disability Payments = Estimated Disability Payment × Probability of Being on Disability After Surgery – Estimated Disability Payment × Probability of Being on Disability Before Surgery.

Disability payments were determined as a function of age and sex, as shown Table E-1, and were taken from the 2011 Current Population Survey.

Additionally, we assumed that workers lost an average of twenty-eight days as a result of the rotator cuff surgery, which is consistent with the Work Loss Data Institute, Official Disability Guidelines[3]. To account for income lost during this period, average predicted incomes by age were multiplied by an individual's probability of being employed.

F. Estimating Direct Medical Costs

The direct costs for operative and nonoperative treatment were estimated by combining the professional and technical components. We used 2013 national average Medicare reimbursement for the foundation of the estimates and applied modifiers based on payer type and facility as mentioned previously.

For nonoperative treatment, we assumed each course of treatment included one non-image-guided injection and six weeks of supervised physical therapy scheduled three times per week. Three physical therapists at the authors' institutions were interviewed for practice patterns regarding nonoperative treatment of rotator cuff tears. We assumed the Current Procedural Terminology (CPT) code 97001 (physical therapy evaluation) would be used once in the treatment course, while 3 units of supervised exercise (97110) and 1 unit of manual therapy (97140) would be coded at each visit.

For rotator cuff repair, we used the CPT code for arthroscopic rotator cuff repair (29827) and the accompanying facility code, Ambulatory Payment Classification group 0042. We analyzed data from the 2009 State Ambulatory Surgery Databases for

Colorado, Florida, Maryland, New York, New Jersey, and Wisconsin to estimate the rate of concomitant procedures performed with rotator cuff repair. We excluded any codes that were used in <1% of the rotator cuff repairs. The list of codes, rates of occurrence, and 2013 national average Medicare reimbursement are shown in Table E-2.

We multiplied the rate of occurrence by the 2013 national average Medicare reimbursement rate and summed across codes to estimate Medicare payments for rotator cuff repair. We also assumed twelve weeks of postoperative physical therapy two times per week. Similarly for treatment of postoperative stiffness, we assumed an arthroscopic capsular release with manipulation under anesthesia. The facility code is the same as rotator cuff repair, while the CPT code is now 29823. The same physical therapy treatment applies. For postoperative infection, we assumed this complication could be treated with intravenous antibiotics and one surgical debridement. To estimate the cost, we used the mean value for surgical site infections recently reported by the Centers for Disease Control and Prevention[4]. We also assumed an additional six weeks of physical therapy directly attributable to the infection.

Reimbursement for the facility and professional fees for each procedure were summed to create the total reimbursement. The costs for nonoperative treatment and surgery for both rotator cuff repair as well as revision procedures were based on the national average Medicare reimbursements for the procedures in 2013 U.S. dollars. Adjustments, as described below, were then made to reflect reimbursement for various payers, including private insurance, Workers' Compensation, and Medicaid. CPT codes were used to estimate the professional costs.

Cost estimates based on Medicare payment rates may underestimate payments made by private insurers and overestimate payments made by Medicaid, self-insured, and uninsured patients. To reconcile these differences, we adjusted our estimates of direct medical costs using payment rates of other insurers (as a percentage of the Medicare rate) and then weighted by the national distribution of payers for treatment of rotator cuff disease. We set the payment rate of Medicaid and self-pay patients as 80% and 50%, respectively, of the Medicare rate. For private insurers, we used the payment rates reported in the literature. Ginsburg, in a 2010 study, estimated that private insurers, on average, paid 139% of the Medicare payment rates for inpatient care nationally in 2008[5]. The same study also noted private insurer payments as a percentage of Medicare rates for outpatient services in selected areas, ranging from 193% in Cleveland to 368% in San Francisco. We used the median of the reported range, which is 280%, to adjust costs of outpatient services. The Medicare Payment Advisory Committee (MedPAC) estimated that the private rate for physician services was, on average, 123% of the Medicare rate across all services and areas in 2003[6]. For all other patients, including those paid by Workers' Compensation, we assumed their rate was the midpoint of the average Medicare and private insurer rates.

G. Place of Service for Rotator Cuff Repair Surgery

Surgery to repair rotator cuff tears may be done in hospital outpatient departments or freestanding ambulatory surgical centers. Because Medicare reimbursement differs between settings, we used a weighted average facility fee paid to hospital outpatient departments and ambulatory surgical centers, where the weights correspond to the frequency of rotator cuff repair surgery in each setting. To develop the weights, we analyzed data from the 2009 State Ambulatory Surgery Databases for Florida, New York, and Wisconsin. Searching on CPT 29827, we found that, of the 29,072 instances recorded in the database, approximately 65% (18,784) occurred in hospital outpatient departments and 35% (10,288) occurred in freestanding ambulatory surgical centers.

H. Use of Expert Opinion

When we lacked evidence to develop assumptions, we relied on consensus input from a panel of five fellowship-trained sports medicine or shoulder and elbow surgeons who regularly performed rotator cuff repairs and would be considered high-volume providers. We openly solicited their opinions on these variables and then compared values using the most common answer as the base value and others for sensitivity analysis.

Only two variables required expert opinion: the rate that retorn rotator cuff repairs become symptomatic and the long-term retear rate of healed rotator cuff repairs. For the former, 5% was a generally agreed upon best estimate. While all experts agreed that evidence was lacking, the best guess was that, in the long term, retears of rotator cuff repairs occur at rates consistent with rotator cuff tears in the general population.

I. Utility Estimates

Utilities, which represent an individual's preferences for specific health outcomes, are derived from the Short Form-12 (SF-12) with use of the SF-6D. SF-12 values were prospectively measured from a cohort of ninety-five patients who received a rotator cuff repair performed by a master surgeon at a major academic medical center. Minimum follow-up was six months. The mean age of this cohort was 55.4 years, and the sex distribution was 61% male and 39% female. All utility values were normally distributed. The mean utility (and standard deviation) for a rotator cuff tear was 0.66 ± 0.11 QALY, and this utility was assigned for symptomatic rotator cuff tears. The mean postoperative utility was 0.74 ± 0.13 QALY, which was used for the health state corresponding to healed rotator cuff repair. The difference between baseline and postoperative utility was significant ($p < 0.001$). Rotator cuff tears responding to nonoperative treatment were assumed to have the same utility as operatively treated patients, but operatively treated patients experienced disutility of surgery of 0.02 QALY because of postoperative pain and inconvenience of recovery. Asymptomatic retears were also assumed to have the utility of a healed rotator cuff.

Disutility

Disutility values represent the short-term negative impact an intervention has on a patient's quality of life. With surgical procedures, this can include pain, immobility, and nonlethal surgical complications in the postoperative and recovery periods. These transient periods of disutility are accounted for as one-time deductions from the health-related quality of life value gained by the patient in the year of the procedure. We calculated a disutility value using the time to recovery and quality of life during recovery.

To calculate the disutility of rotator cuff repair, we assumed that patients would have utility slightly lower than the preoperative state for six weeks and gradually increase utility until they reached their full postoperative utility at three months[7]. This amounts to a total of 0.02 QALY. For infection, we assumed the recovery would be an entire year, with six weeks of that time spent in a state lower than the baseline rotator cuff tear. For stiffness, we assumed an additional six months of recovery compared with an uncomplicated rotator cuff repair.

J. Sensitivity Analysis

Durability of rotator cuff repair outcome

To assess the effects of assumptions related to rotator cuff durability, we ran the model for different durations. We found that rotator cuff repair becomes cost-saving when the benefits from rotator cuff repair persist beyond 3.5 years after the initial surgery. Several authors have reported a durability of rotator repair benefit beyond three years[8-12].

Workdays lost recovering from rotator cuff repair

We recognize that return to work after rotator cuff repair may be different for different occupations. As such, we varied the missed workdays from the baseline average of twenty-eight days (range, zero to 365 days). The threshold value at which rotator cuff repair becomes cost-saving is 153 full days of work missed due to recovery from rotator cuff repair. If a person misses 153 full days or more of work recovering from rotator cuff repair, then nonoperative treatment becomes less costly. If no days are missed, the cost savings from rotator cuff repair increases to $16,855, and if an entire year is missed, nonoperative treatment saves $23,219. Rotator cuff repair remains the cost-effective strategy across the entire range tested. While it is possible that a worker may miss five months of work for rotator cuff repair, this likely represents a very small portion of patients.

Rate of symptom development in a nonhealed (retorn) rotator cuff repair

Since this variable was estimated by expert opinion, we examined it closely with sensitivity analysis. This analysis revealed that if the annual rate of substantial symptom development in a patient who had a nonhealed rotator cuff repair is ≥97%, nonoperative treatment becomes cost-saving. With cost-effectiveness as the outcome, rotator cuff repair remains preferred across the range tested from a 0% rate of symptom development in a nonhealed (retorn) rotator cuff repair to 100%. While this variable is technically sensitive with cost as the outcome, we do not think that the threshold value is realistic as a mean rate, but it may be for some individuals.

Long-term rate of rerupture of a repaired and healed rotator cuff tendon

Since this variable was estimated by expert opinion, we examined it closely with sensitivity analysis. To do so, we applied a relative risk to the rates of rotator cuff tears experienced by the general population. We found this variable to be highly robust. Even at rates 10× population rates, rotator cuff repair was still cost-saving to society. At this rate, rotator cuff repair is $9062 less expensive than nonoperative treatment and confers 0.58 additional QALY over the patient's lifetime.

Facility where rotator cuff repair is performed

The proportion of surgeries that are performed at ambulatory surgical centers or hospital outpatient departments is somewhat uncertain, but is also likely to fluctuate over time. As such, in the sensitivity analysis, we examined both ends of the spectrum, 100% of surgeries performed at an ambulatory surgical center and 100% at a hospital outpatient department. If all surgeries are performed at an ambulatory surgical center, the cost savings with rotator cuff repair increases to $16,918, whereas if all are performed at a hospital outpatient department, the cost savings with rotator cuff repair is $12,078. These numbers demonstrate that, while this variable does influence cost, it is robust in that it does not change the preferred treatment strategy.

Direct cost estimates as a percentage of Medicare

Estimates of direct costs were based on Medicare reimbursement and adjusted to an all-payer population as a percentage of Medicare reimbursement. These estimates, no matter how accurate presently, are subject to change over time. A sensitivity analysis was performed with direct costs as a percentage of Medicare from 50% to 300%. The societal savings at the mean age of fifty-six years ranges from $23,481 when reimbursement is 50% of current Medicare rates to $4506 when reimbursement is 300% of current Medicare rates. At the mean age of fifty-six years at current Medicare rates, the societal savings is $19,686 per patient. The threshold value, with cost as the outcome, at current Medicare rates is an age of 64.5 years, with rotator cuff repair being cost-effective over the age of 64.5 years and cost-saving below that age.

References

1. Dall TM, Gallo P, Koenig L, Gu Q, Ruiz D. Modeling the indirect economic implications of musculoskeletal disorders and treatment. Cost Eff Resour Alloc. 2013 Mar 15;11(1):5.

2. Centers for Disease Control and Prevention, U.S. Department of Health and Human Services. 2004-2010 national health interview survey. Hyattsville, MD: Division of Health Interview Statistics, National Center for Health Statistics; June 2011.http://www.cdc.gov/nchs/nhis/quest_data_related_1997_forward.htm

3. Denniston P, Kennedy C. Official disability guidelines. 17th ed. Encinitas, CA: Work Loss Data Institute; 2012.

4. Scott RD. The direct medical costs of healthcare-associated infections in U.S. hospitals and the benefits of prevention. Atlanta: Division of Healthcare Quality Promotion, National Center for Preparedness, Detection, and Control of Infectious Diseases, Coordinating Center for Infectious Diseases, Centers for Disease Control and Prevention; 2009.

5. Ginsburg PB. Wide variation in hospital and physician payment rates evidence of provider market power. Res Brief. 2010 Nov;(16):1-11.

6. Medicare Payment Advisory Committee. Report to the Congress: Medicare Payment Policy. Washington DC: MedPAC; March 2005.

7. Kang L, Henn RF, Tashjian RZ, Green A. Early outcome of arthroscopic rotator cuff repair: a matched comparison with mini-open rotator cuff repair. Arthroscopy. 2007 Jun;23(6):573-82, 582.e1-2.

8. Denard PJ, Jiwani AZ, Lädermann A, Burkhart SS. Long-term outcome of a consecutive series of subscapularis tendon tears repaired arthroscopically. Arthroscopy. 2012 Nov;28(11):1587-91. Epub 2012 May 24, doi:10.1016/j.arthro.2012.02.031.

9. Kluger R, Bock P, Mittlböck M, Krampla W, Engel A. Long-term survivorship of rotator cuff repairs using ultrasound and magnetic resonance imaging analysis. Am J Sports Med. 2011 Oct;39(10):2071-81. Epub 2011 May 24, doi:10.1177/0363546511406395.

10. Marrero LG, Nelman KR, Nottage WM. Long-term follow-up of arthroscopic rotator cuff repair. Arthroscopy. 2011 Jul;27(7):885-8. Epub 2011 May 28, doi:10.1016/j.arthro.2011.02.019.

11. Millett PJ, Horan MP, Maland KE, Hawkins RJ. Long-term survivorship and outcomes after surgical repair of full-thickness rotator cuff tears. J Shoulder Elbow Surg. 2011 Jun;20(4):591-7. Epub 2011 Mar 12, doi:10.1016/j.jse.2010.11.019.

12. Vastamäki M, Lohman M, Borgmästars N. Rotator cuff integrity correlates with clinical and functional results at a minimum 16 years after open repair. Clin Orthop Relat Res. 2013 Feb;471(2):554-61. Epub 2012 Aug 16, doi:10.1007/s11999-012-2494-1.