Rotator cuff repair: An analysis of utility scores and cost-effectiveness

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More than 75,000 rotator cuff repairs are performed annually, yet cost-effectiveness data are unavailable. This study examines the cost utility of rotator cuff repair by relating surgical costs to increase in quality-adjusted life-years (QALYs). Eighty-seven patients were followed up prospectively for 1 year, during which cost and quality of life data were collected. Patient-based utility measures of quality of life (European Quality-of-Life measure [EuroQoL] and Health Utility Index [HUI]) were administered. Changes in these measures generated net QALYs. Finally, life expectancies were applied to generate a cost-effectiveness ratio, and subsequent 1-way sensitivity analyses varied costs, QALYs, and discount rates to determine which factors drive cost-effectiveness. Total costs averaged $10,605.20. Significant improvements were noted in health-related quality of life postoperatively. The estimated mean lifetime gain in QALYs from surgery was 0.81 by use of the HUI and 3.43 by use of the EuroQoL. This yielded cost-effectiveness ratios of $13,092.84/QALY by use of the HUI and $3,091.90/QALY by use of the EuroQoL. The cost-effectiveness of rotator cuff repair compares favorably with other common interventions in health care and reaches commonly accepted benchmarks for cost-effectiveness. (J Shoulder Elbow Surg 2007;16: 181-187.)

Since publication of the classic works by Codman[10,11] and Neer,[30] rotator cuff repair has become a widely performed orthopaedic procedure, with 75,000 repairs performed annually and numerous reports showing improvements in pain, strength, and motion after cuff repair.[2,3,5,12,17] Although the purpose of rotator cuff repair is improvement in pain and restoration of shoulder function and thereby quality of life, few data exist to analyze the utility of cuff repair.[36] We chose to analyze rotator cuff repair effectiveness prospectively in terms of monetary cost and improvement in patient-reported outcomes.

Assessment of patient-based outcomes, such as quality of life, and assessment of cost-effectiveness after medical intervention have recently gained much attention. Still, these techniques are uncommon in orthopaedics. Most orthopaedic procedures restore function and reduce pain rather than prolong life, yet few studies validating these surgeries have been done. Even so, earlier research has validated outcomes tools and quality-of-life measurements for shoulder problems. Matsen et al[26,27] reported the usefulness of the Short Form 36 (SF-36) general health questionnaire and the Simple Shoulder Test in assessing outcomes for primary glenohumeral osteoarthritis patients. The SF-36 provides a comprehensive profile on patient quality of life and has been extensively validated in orthopaedics.[37] Recently, Chipchase et al[9] reported on impingement patients, using the SF-36. Hollinshead et al[21] developed a unique instrument to measure quality-of-life outcomes for rotator cuff disease (RC-QOL) and the Functional Shoulder Elevation Test (FSET) to describe the quality of life as influenced by shoulder problems. Skutek et al[34] also reported on the usefulness of the Constant score, American Shoulder and Elbow Surgeons (ASES) index, Simple Shoulder Test, and Disabilities of the Arm, Shoulder and Hand (DASH) module in rotator cuff repair outcome analysis. Lastly, McKee and Yoo[28] used the SF-36 to show the effectiveness of

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rotator cuff repair in improving patients' general health status.

These studies enable a proper cost-effectiveness analysis, but we know of no work that has used utility measures, which are necessary for cost-utility analyses, to analyze rotator cuff repair outcomes. In fact, only two economic evaluations of shoulder surgery exist. Both studied shoulder surgery cost but not cost-effectiveness.[1,32] In this era of accountability for health care expenses, data on cost-effectiveness have gained influence in medical decision making. Here, we use cost-utility analysis, a specific type of economic evaluation in which outcomes are measured in quality-adjusted life-years (QALYs)—a composite measure of health outcomes that reflects both quantity and quality of life. In contrast to a cost-effectiveness analysis, where the metric of outcome is measured along only a single unit of effectiveness such as death, a cost-utility analysis results in a broader and richer measure of outcome, as QALYs incorporate individuals' preferences for various health states, as well as the duration of any changes in their health states. Because the cost-benefit ratio can be generated for various interventions, one can compare different types of treatments for the same condition or determine benefits derived from a medical treatment relative to its expense. We hypothesize, therefore, that rotator cuff repair is a cost-effective intervention relative to other commonly performed interventions in health care.

MATERIALS AND METHODS

Patient cohort

This study was part of a prospective investigation of rotator cuff repair outcomes funded by a Prospective Clinical Research Grant from the Orthopaedic Research and Education Foundation (Rosemont, IL) (principal investigator, E.L.F.). Patients with rotator cuff tears who underwent repair by the principal investigator were eligible for the study. Inclusion required (1) rotator cuff tear verified on arthroscopic evaluation, (2) 12 or more months of failed nonsurgical treatment (steroid injection, nonsteroidal anti-inflammatory drugs, physical therapy), (3) age between 40 and 80 years, and (4) ability to communicate effectively with the investigators and be legally competent to give written informed consent. Exclusion criteria included (1) concurrent humeral arthroplasty and (2) primary glenohumeral osteoarthritis, rheumatoid arthritis, fracture, or osteonecrosis. Demographic data were collected, and costs and outcomes were directly measured for 1 year postoperatively. Institutional review board approval was obtained from the host institution, and all subjects gave informed consent.

Costs

Inpatient charges, procedure charges, and physician fees and payments were collected from patient medical records, hospital billing, and administrative databases. A ratio of cost to charge (RCC) methodology was used to generate inpatient costs for all of the charge categories, as well as to estimate outpatient physical therapy costs.[13] Total direct medical costs were calculated by adding all cost data. A 3% discount rate was applied to all costs that accrued during year 1 to value future costs in present-day monetary units. A social perspective was taken, such that the costs of all services associated with providing care to patients, regardless of who bears the costs, were included.[33] The social perspective is most commonly used in economic evaluations, because it ensures that one is appropriately assessing the total costs to the patients, health care providers, and society rather than those costs specifically to the patients alone, who bear only a component of the costs. Costs were categorized and characterized (Table I). Indirect costs, such as lost productivity, are captured in the estimation of QALYs and were not included in this figure.[16] Numerous studies have found low long-term revision rates and good to excellent results in greater than 90% of patients at long-term follow-up for rotator cuff repairs.[2-4,6,14,15,30,38,39] Consequently, we believed that initial-year expenses would capture the majority of costs associated with rotator cuff repair, with few downstream costs.

Table I Hospital and physician costs (RCC method)

Category	Costs ($)	SD ($)
Hospital costs		
Operating room	3,078.02	593.85
Anesthesiology	500.56	156.31
Recovery room	734.59	75.67
Pharmacy	77.15	61.79
Radiographs	196.95	62.25
Pathology	89.54	36.38
Other laboratory	70.78	32.27
Physical therapy	184.83	76.98
Hospital room	1,943.76	1,050.20
Other	51.13	49.95
Total	6,927.30	1,353.96
Physician payments		
Surgeons	2,900.84	1,738.78
Radiologists	8.84	1.01
Anesthesiologists	768.22	495.83
Total	3,677.90	2,071.88
Total costs	10,605.20	2,566.23

Effectiveness

This study is a specific type of economic evaluation termed a cost-utility analysis. Cost-utility analyses are characterized by the fact that the outcome is measured in units of utilities, which incorporate a subjective measure of preference for various health states. Cost-utility analysis requires a validated tool, whereby patients may report their subjective outcomes after interventions. Suitable instruments include the Health Utility Index (HUI), the European Quality of Life measure (EuroQoL), the Quality of Well-Being Scale, and the Years of Healthy Life measure.[39] The HUI has several individual domains. Each domain is further subdivided and assigned a weight.[22] The EuroQoL also contains several individual domains.[23] Both are easily administered and generate a single numeric score allowing for longitudinal comparisons before and after intervention. Each patient's scores were assessed preoperatively and 1 year after surgery via both instruments. In addition, SF-36 scores preoperatively and 1 year after surgery captured broad changes in quality of life. Patient responses to the questionnaire produce 8 independent domains. The scores from these instruments at baseline and 1 year postoperatively were compared via paired-samples *t* tests and deemed significant at $P < .05$.

QALYs

Orthopaedic procedures are best analyzed by use of QALYs because traditional outcome measures such as death or disease onset (eg, stroke and myocardial infarction) do not apply. In the case of rotator cuff repair, QALYs are appropriate because repair results in significant, durable quality-of-life improvements. QALYs are calculated by multiplying the utility, or preference, of the patient during a specific period by the length of time over which the improvement is experienced. The utility is measured between 0 (worst health state) and 1 (perfect health state) and reflects the patient's overall assessment of his or her current health state. For this study, net QALYs gained after surgery were calculated by obtaining the change between preoperative and postoperative HUI and EuroQoL utility scores. This difference was then multiplied by the patient's life expectancy, as obtained from standard life expectancy tables.[29] As mentioned previously, a 3% discount rate was applied to changes in HUI and EuroQoL utility scores in the calculation of QALYs.

Cost-effectiveness

The cost-benefit ratio, or cost of a QALY gained, was determined by dividing the total cost per patient by the net QALYs gained.

Sensitivity analysis

Sensitivity analysis involved changing 1 or more variables and examining the effect on the result of the analysis—a technique widely used in economic evaluations to assess the validity of study conclusions and how they vary with differing underlying assumptions and estimates.[35] Uncertainty about these parameters results in uncertainty about the cost-effectiveness ratios generated in the reference case. Therefore, sensitivity analysis helps determine the impact of changing assumed values on the conclusions generated by the study. In this study, cost-utility ratios were calculated with the use of the reference case assumptions for rotator cuff repair. Then, 1-way analyses varying the costs, QALYs, and discount rates were conducted. Costs and QALYs were varied by the upper and lower bounds of the 95% confidence intervals from our patient data, and discount rates were varied at standard rates of 0% and 5%.[11] A health economist experienced with health care economic statistical analysis (J.G.Z.) performed the data analysis.

Table II Patient characteristics

Variable	N	%	Mean	SD
Sex				
Male	47	54		
Female	40	46		
Age (y)			62.5	9.52
Race/ethnicity				
White	78	90		
Hispanic/Latino	3	3		
Black/African American	5	6		
Other	1	1		
Rotator cuff repair type				
Open	64	74		
Mini-open	23	26		
Length of stay (d)				
Open			2.5	2.2
Mini-open			1.5	1.7
Other			5.9	20.5
Overall			3.1	10.1

RESULTS

Patient profile

We enrolled 87 patients (54% male and 46% female) in this study (Table II). Sex, race, repair type, and length of stay are shown in Table II. The mean age was 62.5 years (SD, 9.52 years; range, 40.4-83.3 years). On the basis of standard life expectancy tables, the mean additional years of life of these patients from the time of surgery was 21.3 years (SD, 8.9 years; range, 8.9-40.7 years).[29]

Costs

Charges consisted of hospital charges and physician fees. Overall hospital charges averaged $10,135.29 (SD, $2,206.39). Physician fees (surgeon, anesthesiologist, and radiologist fees) averaged $8,484.80 (SD, $1,415.78). Total inpatient charges (hospital charges plus physician fees) averaged $18,924.15 (SD, $3,021.97). When the RCC method was applied, with a mean RCC of 0.63, hospital costs averaged $6,927.30 (SD, $1,353.96) and physician payments averaged $3,570.90 (SD, $2,071.88), as summarized in Table I. Total inpatient costs (hospital plus physician payments) averaged $10,605.20 (SD, $2,566.23).

Effectiveness

HUI and EuroQoL scores preoperatively and at 1 year postoperatively are summarized in Table III and Figure 1. The overall HUI baseline score averaged 0.803 (SD, 0.132), and the HUI score at 1 year postoperatively averaged 0.851 (SD, 0.126). Postoperatively, 3 HUI domains improved significantly, including self-care ($t = -2.27$, $P = .026$), pain ($t =$

Table III HUI and EuroQoL domain scores preoperatively and at 1 year postoperatively

Domain	Preoperative		Postoperative		P value
	Mean	SD	Mean	SD	
HUI					
Sensation	0.949	0.029	0.953	0.138	.790
Mobility	0.993	0.027	0.964	0.053	.073
Cognition	0.987	0.025	0.986	0.025	.824
Self-care	0.990	0.026	0.996	0.013	.026
Emotion	0.964	0.053	0.972	0.043	.129
Pain	0.917	0.092	0.959	0.067	.002
Fertility	1.000	0.000	0.998	0.017	.320
Overall	0.803	0.133	0.851	0.126	.025
EuroQoL					
Mobility	1.17	0.379	1.25	0.436	.083
Self-care	1.37	0.538	1.10	0.309	.0001
Usual activities	1.83	0.548	1.44	0.550	<.0001
Pain/discomfort	2.21	0.577	1.74	0.619	<.0001
Anxiety/depression	1.37	0.537	1.21	0.406	.006
General health	2.18	0.531	1.64	0.602	<.0001
Overall	0.563	0.282	0.763	0.249	<.0001

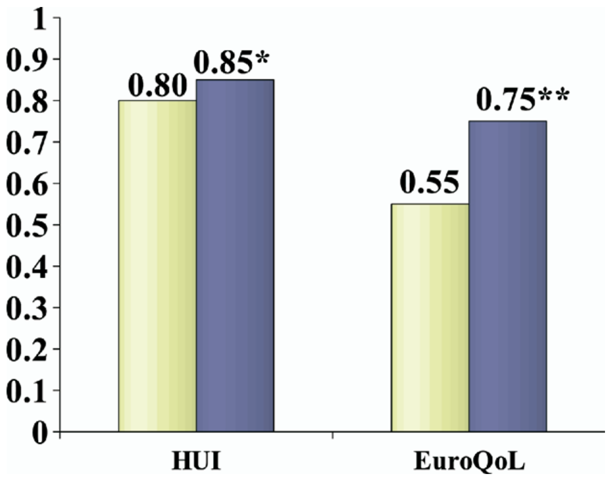

Figure 1 HUI and EuroQoL scores preoperatively (*light gray bars*) and at 1 year postoperatively (*dark gray bars*) (*1 asterisk, P* = .025; *2 asterisks, P* < .0001).

−3.26, *P* = .002), and overall HUI score (*t* = −3.41, *P* = .001). Furthermore, the EuroQoL baseline score averaged 0.552 (SD, 0.302), and the EuroQoL score at 1 year postoperatively averaged 0.752 (SD, 0.258). Postoperatively, 6 EuroQoL domains improved significantly, including self-care (*t* = 4.00, *P* = .0001), usual activities (*t* = 4.82, *P* < .0001), pain/discomfort (*t* = 5.90, *P* < .0001), anxiety/depression (*t* = 2.83, *P* = .006), general health (*t* = 5.70, *P* < .0001), and overall EuroQoL score (*t* = −4.46, *P* = .0001). SF-36 domain scores preoperatively and at 1 year postoperatively are summarized in Table IV. The postoperative scores for physical function (*t* = −2.84, *P* = .005), role limitations due to physical function (*t* = −4.98, *P* < .0001), social function (*t* = −2.70, *P* = .008), and pain (*t* = −7.08, *P* < .0001) improved.

Table IV SF-36 domain scores preoperatively and at 1 year postoperatively

Domain	Preoperative		Postoperative		P value
	Mean	SD	Mean	SD	
Physical function	68.24	23.57	78.09	23.26	<.0001
Role limitations due to physical function	44.81	43.93	74.57	37.51	<.0001
Role limitations due to emotional function	71.62	41.17	78.38	38.00	.215
Energy and fatigue	61.51	20.41	65.33	22.90	.125
Emotional well-being	74.36	17.71	78.05	19.18	.091
Social function	73.70	28.50	83.60	24.86	.003
Pain	44.12	23.16	72.73	25.85	<.0001
General health	72.24	21.37	71.52	21.38	.691

QALYs

By use of the utility instrument scores discounted at 3% per year for each patient's estimated life span, the mean QALYs gained from the surgery were 0.81 (SD, 1.93) for the HUI and 3.43 (SD, 4.16) for the EuroQoL.

Cost-effectiveness

After division of mean cost by QALYs gained, the cost-effectiveness ratio was $13,092.84/QALY by use of HUI scores and $3,091.90/QALY by use of EuroQoL scores.

Sensitivity analysis

Effect of costs. Varying costs by the lower bound of the 95% confidence interval yielded $10,047.68, producing an overall cost-effectiveness ratio of $12,404.54/QALY by use of HUI scores and $2,929.35/QALY by use of EuroQoL scores. Varying costs by the upper bound of the 95% confidence interval yielded a total cost of $11,162.72, producing an overall cost-effectiveness ratio of $13,781.14/QALY by use of HUI scores and $3,254.44/QALY by use of EuroQoL scores.

Effect of QALYs. Varying QALYs by the lower bound of the 95% confidence interval yielded QALYs of 0.34 for the HUI and 2.46 for the EuroQoL, producing cost-effectiveness ratios of $31,191.76/QALY by use of HUI scores and $4,311.05/QALY by use of EuroQoL scores. Varying the QALYs by the upper bound of the 95% confidence interval yielded QALYs of 1.29 for the HUI and 4.39 for the EuroQoL, producing cost-effectiveness ratios of $8,221.09/QALY by use of HUI scores and $2,415.76/QALY by use of EuroQoL scores.

Effect of discount rate. Discount rates on QALYs were applied at rates of 0% and 5%. A 0% rate yielded QALYs of 1.55 for the HUI and 4.78 for the EuroQoL, producing overall cost-effectiveness ratios of $6,842.06/QALY by use of HUI scores and $2,218.66/QALY by use of EuroQoL scores. A 5% discount yielded QALYs of 0.66 for the HUI and 2.84 for the EuroQoL, producing an overall cost-effectiveness ratio of $16,068.48 by use of HUI scores and $3,734.23/QALY by use of EuroQoL scores.

DISCUSSION

Given current trends in health care, medical professionals have become interested in assessing the cost-effectiveness of therapies.[7,8] Sound decision making, however, requires data-driven conclusions. Toward this end, cost-utility analysis takes an intervention's cost combined with patient-based outcomes data to produce ratios that enable comparison between therapies.

Because orthopaedic surgeries, such as rotator cuff repair, restore function and reduce pain but do not increase longevity, quality of life is an excellent measure of outcome. Our data coincide with copious evidence showing that rotator cuff repair significantly improves health-related quality of life.[9,21,26-28,34,37] Using the HUI, we demonstrated that patients had significant improvements in the domains of self-care, pain, and overall score 1 year after surgery. Similarly, the results of the EuroQoL indicate that patients had significant improvements in the domains of self-care, usual activities, pain/discomfort, anxiety/depression, general health, and overall score 1 year after surgery. Lastly, the SF-36 data reveal significant improvements in the domains of physical function, role limitations due to physical function, social function, and pain 1 year after surgery. Common to all of these measures is robust and durable improvement in pain at 1 year postoperatively. This intimates that postoperative relief from pain is extremely important in driving improvements in quality of life obtained from rotator cuff repair.

This report represents the first formal cost-utility analysis of rotator cuff repair. It has the strengths of prospective data collection, the use of 2 different utility measures, and a large sample size. The present data reveal that the largest contributors to overall costs are professional fees, operating room charges, and length-of-stay charges, consistent with prior literature.[18] The actual cost-effectiveness ratios obtained yielded ratios of $13,092.84/QALY and $3,091.90/QALY via the HUI and EuroQoL instruments, respectively. Given that a commonly accepted threshold for cost-effectiveness is $50,000/QALY as outlined by Owens,[31] these data indicate that rotator cuff repair is highly cost-effective, as cost-effectiveness ratios were well below this benchmark. Furthermore, rotator cuff repair compares favorably with other interventions, including total hip replacement ($8,031/QALY),[24] coronary artery bypass graft ($14,300/QALY),[20] medical therapy for hypertension ($23,800/QALY),[25] and hemodialysis ($128,800/QALY).[19] Sensitivity analyses showed that varying costs and discount rates did not appreciably alter the cost-effectiveness of rotator cuff repair. Although varying QALYs did appear to drive cost-effectiveness ratios more than varying costs or discount rates, yielding cost-effectiveness ratios of $31,191.76/QALY by use of HUI scores and $4,311.05/QALY by use of EuroQoL scores, these values still remained below the commonly held threshold for cost-effectiveness, indicating that, relative to other interventions, they are highly cost-effective interventions.

There are limitations to this study. It captured costs for 1 year while applying the QALYs gained at 1 year over the remainder of the patients' estimated life span. This may bias results in favor of the intervention by ignoring downstream costs beyond 1 year. However, previous studies have found low rates of long-term revision and excellent results at 10 or more years of follow-up.[2,4,6,14,15,30,38] Our sense is that most costs occur during the initial postoperative period.

A second limitation is the assumption that QALY data collected at 1 year after surgery persisted throughout the patients' life span without significant change. It is possible that utility scores may further improve or depreciate after 1 year, and a longer follow-up period would have provided more data. However, available literature yields conflicting data. For instance, Galatz et al[14] examined a cohort of 18 patients who underwent rotator cuff repair and found that at 1 year postoperatively, the mean ASES score significantly increased from 48.3 to 84.6, whereas at a minimum of 2 years postoperatively, the mean ASES score deteriorated to 79.9. An investigation at another institution, however, reported results of 33 rotator cuff repair patients and found that more patients had good to excellent results (as assessed by normalized Constant scores), improved activities of daily living, and significant decreases in disability at 10 years than they did at 2 years.[15]

An additional shortcoming of this study, and perhaps of cost-effectiveness analyses in general, is the lack of agreement on universal utility measures. As is evident from this study, the cost-effectiveness ratios were significantly different depending on the instrument used. Although both HUI and EuroQoL values improved postoperatively, the rate of change was much greater with EuroQoL scores. This may indicate that EuroQoL has greater sensitivity in relation to rotator cuff pathology or that there is a ceiling effect in the HUI. A final limitation is that, as a single-surgeon study, there is a degree of homogeneity to the results, which may not represent the average utilities gained or costs accrued for other surgeons performing rotator cuff repair. Future studies need to address these limitations. There is a need for a prospective randomized study on the management of rotator cuff tears that looks at both costs and patient-based outcomes.

To this end, the next step would be to develop a stochastic mathematic model of intervention costs and benefits. This would allow a more continuous representation of long-term functional outcomes, mortality rate, potential revision surgeries, and long-term care costs for more exact estimation of cost-effectiveness ratios. Furthermore, given the potential advantages of arthroscopic repair, which have the possibility to decrease surgical costs dramatically (eg, decreased length of stay),[40] future investigation by our group will seek to determine the cost-effectiveness of arthroscopic repairs in comparison to open techniques.

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