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Cost utility analysis of reverse total shoulder arthroplasty

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Abstract

Background—Reverse shoulder arthroplasty provides satisfactory outcomes, but its cost-effectiveness is unproven. We prospectively analyzed outcomes and costs for primary reverse shoulder arthroplasty.

Methods—Thirty serial patients (16 women and 14 men; mean age, 74.1 years [range, 61.1–87.3 years]) with rotator cuff arthropathy had active motion recorded and completed function tests (visual pain analog scale; Simple Shoulder Test; American Shoulder and Elbow Surgeons Shoulder Outcome score; EuroQol; and Short Form-36 Health Survey) preoperatively and postoperatively at 1 and 2 years. Costs included professional fees, operating room and supply costs, and hospital care. Changes were compared by the Wilcoxon signed rank test, and quality-adjusted life-years were calculated preoperatively and postoperatively.

Results—Twenty-seven patients completed the study. Clinical and functional outcomes demonstrated significant improvement ($P < .05$). Significantly improved ($P < .05$) Short Form-36 subgroups included physical functioning, role limitations due to physical health, bodily pain, vitality, and physical composite score. EuroQol dimensions of usual activities and pain/discomfort improved significantly ($P < .05$). Calculations with the SF-6D showed that median QALYs improved from 6.56 preoperatively to 7.43 at 1-year follow-up ($P < .09$) and from 6.56 preoperatively to 7.58 at 2-year follow-up ($P < .003$). The increase in QALYs calculated from the EQ-5D was somewhat greater, changing from 6.21 preoperatively to 7.69 at 1-year follow-up ($P < .0001$) and from 6.13 to 8.10 at 2-year follow-up ($P < .04$). Mean cost was \$21,536. Cost utility at 2 years was \$26,920/quality-adjusted life-year by the Short Form 6 Dimensions and \$16,747/quality-adjusted life-year by the EuroQol.

Conclusion—EuroQol and Short Form-36 results demonstrated modestly cost-effective ($< \$50,000$ /quality-adjusted life-year) improvement for cuff tear arthropathy patients after primary reverse shoulder arthroplasty.

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Level of evidence—Level II, Economic and Decision Analysis.

Keywords

Cost-effectiveness; cost utility; quality-adjusted life-years; reverse shoulder arthroplasty

Allocation of limited resources will undoubtedly be a major point of emphasis as global health care systems move forward during the 21st century. Cost utility analysis is widely viewed as the “gold standard” of cost-effectiveness evaluation, and it is used to assess the value of an intervention in terms of improving both quality and quantity of life.² As a result, cost-effectiveness studies are gaining importance equal to that of clinical studies as payers (public and private) determine how to efficiently allocate a finite amount of health care resources. These resources are more likely to be directed toward treatments that have been shown to improve or to lengthen the quality of the patient’s life.

In most orthopedic interventions, increased life expectancy is rarely expected to be a result of treatment. Rather, an improvement in the quality of life of the patient is the anticipated outcome. In this type of analysis, health “gains” are expressed in quality-adjusted life-years (QALYs), which is a standard and internationally accepted measurement of the incremental health effects of an intervention compared with its cost.¹³ The difference in health effects in patients with a wide variation in health states can be corrected with the use of a utility score.¹⁹ Different health-related quality-of-life instruments have been used to derive these utility factors by measuring responses to the physical, mental, and social effects of illness or an intervention by its effects on daily living and personal satisfaction.⁸

The EuroQol (EQ-5D) is one of the more frequently used self-completed instruments, and it measures 5 health states: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. For each of these health states, patients give a response to quantify the level of difficulty that they are experiencing: none, moderate, or severe.⁵ The Short Form-36 Health Survey (SF-36) is another commonly used instrument, and it can be converted to utilities by use of a Short Form 6 Dimension (SF-6D) algorithm.^{3,4} The SF-6D consists of 6 different health states: physical function, role limitations, social function, pain, mental health, and vitality. For the EQ-5D, the score ranges from 0 (death) to 1 (perfect health); for the SF-6D, the score ranges from 0.29 (lowest score in a living person) to 1 (perfect health).¹⁶ Both the SF-36 and the EQ-5D are standard, validated means to translate the scores from their questionnaires into utilities, which can then be used for cost analysis.^{4,6}

Reverse shoulder arthroplasty (RSA) has been shown to provide satisfactory pain relief and return of shoulder function in elderly patients with rotator cuff arthropathy.^{1,7,11,14} Newer implant designs are being introduced, and indications are expanding. RSA has also shown a high complication rate and is expensive relative to other options, such as hemiarthroplasty. However, limited information exists on the cost-effectiveness of this procedure. Therefore, in this report, we prospectively analyze the outcomes and cost-effectiveness of a serial cohort of RSA procedures during a 2-year follow-up period.

Materials and methods

This study was designed to enroll a consecutive series of patients undergoing RSA. All patients had advanced shoulder arthropathy and rotator cuff tearing with pseudoparalysis and pain. Patients undergoing revision surgery were excluded, but prior surgery was not an exclusion criterion. During the design phase of the study, statistical review indicated that a minimum study cohort of 20 patients was necessary to sufficiently power the study. To account for the potential loss of study patients because of the generally older ages of patients undergoing RSA, we set an enrollment target of 30 patients.

On commencement of the study, all eligible patients ($N = 30$) consented to participate. Thus, 30 consecutive patients (16 women and 14 men) were prospectively enrolled. The mean age of the patients was 74.1 years (range, 61.1–87.3 years). All 30 patients received the same type of implant (Trabecular Metal Reverse Shoulder System, Zimmer Inc, Warsaw, IN, USA), and each operation was performed through a deltopectoral approach by 1 surgeon. Of the 30 patients, 9 had a single previous rotator cuff repair, and 2 had multiple prior repairs. Comorbid conditions were common in this patient population (Table I).

In addition to having shoulder radiographs and undergoing a physical examination for active range of motion (forward flexion, abduction, and external rotation with the arm at the side), patients were asked to complete a visual analog pain scale, the American Shoulder and Elbow Surgeons (ASES) Shoulder Outcome score, the Simple Shoulder Test, the EQ-5D, and the SF-36 during their preoperative visit and again at their 1-year and 2-year postoperative follow-up visits. Cost data were similarly gathered prospectively from the hospital cost-accounting database. These included professional fees (surgeon and anesthesia), operating room costs (including implant), and the cost of hospital care (inpatient, laboratory, radiology, pharmacy, therapy, and medical consultation, if needed).

All data were entered into an encrypted, web-based program for managing databases (REDCap Software; Version 4.8.15; Vanderbilt University, Nashville, TN, USA). Data were then exported for analysis to SAS 9.2 (SAS Institute Inc, Cary, NC, USA). Wilcoxon signed rank tests were performed to compare the changes to clinical (active range of motion; visual analog pain scale [VAPS]), functional (ASES; Simple Shoulder Test [SST]), and quality-of-life (EQ-5D; SF-36) outcomes and QALYs between preoperative and 1-year and 2-year follow-up. QALYs were calculated with the utility scores translated from the EQ-5D and the SF-6D from the University of Sheffield (Sheffield, UK [<http://www.shef.ac.uk/scharr/sections/heds/mvh/sf-6d>]) and the standard U.S. life expectancies tables for 2008 from the National Vital Statistics Reports (National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD, USA [http://www.cdc.gov/nchs/data/nvsr/nvsr59/nvsr59_02pdf]) (applying a 3% discount rate for future costs and benefits to reflect their present value). Because this was a nonparametric test, the median values are reported when comparisons are made of the results from baseline to 1-year or 2-year follow-up. A 2-sided test was used to determine statistical significance ($P < .05$).

Results

Twenty-seven patients were available for follow-up at a mean of 2.2 years (range, 2.0–3.3 years). One patient died before the 2-year follow-up from unrelated causes, and 2 patients were lost to follow-up. Clinical and functional outcomes (VAPS, active range of motion, ASES, and SST) demonstrated significant improvement in all measurements (Table II).

SF-36 subgroups that showed significant improvement included physical functioning, role limitations due to physical health, bodily pain, vitality, and the physical composite score at 1-year and 2-year follow-up (all $P < .01$). There was minimal improvement in social functioning, role limitations due to emotional problems, general mental health, and the mental composite score (Table III). Similarly, at the 2-year follow-up, the EQ-5D dimensions of usual activities and pain/discomfort were significantly improved ($P = .002$ and $P = .02$, respectively), whereas mobility, self-care, and anxiety/depression were improved but failed to reach statistical significance. The improvement in the composite score also reached statistical significance ($P = .04$) (Table IV).

The mean length of hospital stay for all 30 patients was 1.9 days (range, 1–7 days). Complications included acromial fractures ($n = 3$ [10%]), which were all treated successfully without surgery; anemia requiring transfusion ($n = 3$ [10%]); urinary retention ($n = 3$ [10%]); pneumonia ($n = 1$ [3%]); and acute tubular necrosis ($n = 1$ [3%]). These last 2 complications were responsible for prolonged hospital stays of 4 and 7 days, respectively. The acromial fractures all occurred after hospitalization and did not add to the total cost of care for RSA.

Calculations with the SF-6D showed that median QALYs improved from 6.56 preoperatively to 7.43 at 1-year follow-up ($P = .09$) and from 6.56 preoperatively to 7.58 at 2-year follow-up ($P = .003$). The increase in QALYs calculated from the EQ-5D was somewhat greater, changing from 6.21 preoperatively to 7.69 at 1-year follow-up ($P < .0001$) and from 6.13 to 8.10 at 2-year follow-up ($P = .04$). At a mean cost of \$21,536 (Table V; implant cost is included in surgical services and is based on a single manufacturer's list price), the cost utility at 2-year follow-up was \$26,920 by the SF-6D and \$16,747 by the EQ-5D.

Discussion

QALY is a commonly used “unit” of cost-effectiveness that measures quantity as well as quality of life. As it is often calculated with a “utility score” from a self-administered, validated questionnaire (such as the SF-36 and the EQ-5D, as in our study), it adjusts for someone's quality of life. Although imperfect, it is beneficial in that it can be used to compare preoperative with postoperative states of health and subsequently to measure the cost-benefit of a surgical treatment. Thus, the incremental cost per QALY gained for that treatment can be compared with that for another treatment for the same or other conditions. For a particular surgical treatment to be accepted as cost-effective, a “threshold” (the amount of money that society is willing to spend to gain 1 year of life) must be determined. These thresholds are value decisions that are evolving and will likely be influenced over

time by payers, patients, health outcomes, risks, and available resources.¹⁷ In the United States, treatments that cost less than \$50,000 per QALY gained are generally considered cost-effective. Other countries, such as Great Britain, are also closely evaluating the use and limits of thresholds to determine the cost-effectiveness of certain treatments as well as the probability of meeting those thresholds.

By necessity, the cost analysis in this study reflects the medical economics in the United States, which may very well be different in another country. However, the study does provide incremental changes in the SF-36, EQ-5D, ASES, and SST scores of patients as well as in their length of stay and other metrics, which should allow surgeons in other countries to adjust the cost-effectiveness to reflect their local reality. This study does show that RSA is cost-effective even in the high-cost environment of the United States, and we suspect it would also then be cost-effective in much of the rest of the world.

Despite the dearth of information on the cost-effectiveness of RSA, this is a particularly important area of interest. RSA frequently has higher implant costs and the indications for RSA are expanding to other conditions, such as acute proximal humeral fractures.⁶ In our study, we prospectively gathered costs and outcome scores for a specific group of patients undergoing RSA. We found significant improvement in QALYs ($P < .05$) at both 1 year and 2 years postoperatively when these were calculated with the EQ-5D, and we also found significant improvement at 2-year follow-up when QALYs were calculated with the SF-6D. Although the QALY improved at 1 year by the SF-6D calculation, it missed statistical significance ($P = .09$). The cost per QALY was modestly higher when it was calculated with the SF-6D (\$26,920/QALY at 2 years) compared with that calculated with the EQ-5D (\$16,747/QALY at 2 years); nevertheless, both demonstrated improvement in QALYs after RSA at a ratio that is generally believed to be modestly cost-effective ($< \$50,000/\text{QALY}$).¹⁷ Interventions with an incremental ratio of $< \$25,000/\text{QALY}$ are generally considered highly cost-effective.¹² Our results were close to or below the threshold as well, again demonstrating the value of RSA. Other authors have similarly reported less favorable results with the SF-6D than with the EQ-5D, which also tends to show a larger gain in utility in patients who start out in a poor disability state before undergoing a surgical procedure.¹⁶

We have identified only 1 other study that examined the cost-effectiveness of RSA. Our data show much more favorable cost-effectiveness than those reported by Coe et al.⁶ However, there are considerable differences in the methodology of the 2 studies. Coe et al used a Markov model to determine cost-effectiveness. In their model, cost was stipulated on the basis of Medicare reimbursement rates augmented by the addition of estimated implant costs. Outcomes and complications were based on assumptions “averaged from the most relevant and robust peer-reviewed articles.” In addition, they examined incremental improvement of RSA over humeral head replacement, whereas we measured improvement in QALYs from preoperative values to 1-year and 2-year postoperative values. Given these discrepancies in analysis, we determined that Coe et al⁶ reported an incremental cost of \$94,118/QALY, using SF-6D for utility scores, in a group of patients similar to ours (cuff tear arthropathy). Their cohort had a similar mean length of follow-up (2.6 years) and total cost (\$21,964) compared with ours (mean follow-up, 2.2 years; mean cost, \$21,536), but their patients were slightly older (mean age, 78.4 vs 74.1 years). None of their RSA patients

had complications, so the mean utility for their group was 0.682, which is essentially identical to the utility score of 0.67 calculated from the SF-6D in our group. The reason that their cost utility is so much greater than ours (\$94,118 vs \$26,920) is likely to be due to the type of statistical model used and the subsequent mathematical approximations based on assumptions of potential future complications and the comparison of 2 different surgical procedures rather than total improvement.

In a comparison of cost data from other implant arthroplasty procedures, Rasanen et al¹⁸ reported a cost utility of €13,995 (\$18,000 USD) for total knee arthroplasty, from the preoperative state to the state at 1 year, using the 15-dimensional health-related quality-of-life survey. SooHoo and Kominski¹⁹ used a software-generated decision model that assumed a 10-year duration of survival after total ankle arthroplasty, resulting in an incremental cost-effectiveness ratio of \$18,419/QALY.

Although a higher complication rate or deterioration of RSA function after 2 years could result in a higher cost/QALY ratio, especially if revision surgery is required, our findings reflect real costs rather than modeled costs for care after RSA. It will be interesting to reevaluate our patients after 5 years and 10 years to determine whether the QALY improvements are truly long lasting. There is reason for concern. Guery et al¹⁰ reported an overall 95% survival rate at 9 years with implant replacement as the end point. for RSA performed for cuff tear arthropathy. However, the survival rate was only 58% at 10 years when an absolute Constant-Murley score of <30 was the end point. In addition, Favard et al⁹ found that although the need for revision of RSA was relatively low at 10 years, Constant-Murley scores and radiographic changes deteriorated over time. On the basis of these findings, they expressed concern about the longevity of the implant, and they cautioned against using it in younger patients. Certainly, depending on the severity of decline in outcomes and concomitant decreases in QALYs, cost-effectiveness could be significantly affected by lower utility scores in addition to the costs of additional treatment, such as revision surgery. Furthermore, in this elderly population, worsening comorbidities and continued functional decline are common. Any prior improvement in the utility scores of patients due to surgery may well be overwhelmed by such declines. An additional limitation of our data is that all of our patients had RSA for rotator cuff arthropathy, which generally yields results superior to those of revision RSA for failed arthroplasty and potentially for other conditions, such as proximal humeral fractures. Therefore, our cost-effectiveness data should not be extrapolated to additional indications for RSA.

Conclusion

Our data show that primary RSA for rotator cuff arthropathy ranges from cost-effective to highly cost-effective. In addition, cost utility analysis shows that RSA compares favorably with other joint replacement procedures. Although current political factors exclude such data from consideration of coverage or reimbursement in the United States, future cost constraints may mandate ranking or favoring of procedures that generate greater health gains for the money available over procedures that generate lesser gains.^{15,16} Our data can help support the value of RSA in primary surgery for patients faced with these decisions.

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Table I

Comorbid conditions in 30 patients undergoing reverse shoulder arthroplasty

Comorbidity	No. of patients (%)
Obesity	22 (73)
Hypertension	21 (70)
Hyperlipidemia	13 (43)
Cardiac disease	8 (27)
Diabetes mellitus	5 (17)
Chronic obstructive pulmonary disease	4 (13)
Rheumatoid arthritis	3 (10)
Cancer	2 (7)
Cerebrovascular accident	1 (3)

Table II

Clinical and functional outcomes of 30 patients undergoing reverse shoulder arthroplasty

Measurement	Preoperative	2-Year postoperative
VAPS	5.8	0.6
Forward flexion	75°	147°
Abduction	65°	140°
External rotation	30°	63°
ASES	34	86
SST	1.3	8.3

ASES, American Shoulder and Elbow Surgeons Shoulder Outcome score; SST, Simple Shoulder Test; VAPS, visual analog pain scale.

Table III

Improvement over time in social, physical, and emotional functioning of 30 patients undergoing reverse shoulder arthroplasty

Variable	Preoperative	1-Year postoperative (<i>P</i> value)	2-Year postoperative (<i>P</i> value)
General health perceptions	67.0	76.0 (.002)	72.0 (.12)
Physical functioning	40.0	60.0 (<.001)	52.5 (.008)
Role limitations from physical health	0.0	25.0 (.007)	37.5 (.006)
Bodily pain	31.5	62.0 (<.001)	57.0 (<.001)
Vitality	40.0	50.0 (.004)	55.0 (.003)
Social functioning	40.0	60.0 (.17)	81.3 (.29)
Role limitations from emotional problems	66.7	100.0 (.82)	100.0 (.91)
Mental health	76.0	76.0 (.81)	84.0 (.46)
Physical composite score	29.7	41.3 (<.001)	39.9 (<.001)
Mental composite score	55.8	53.1 (.37)	56.7 (.80)
SF-6D index (utility) score	0.59	0.66 (.05)	0.66 (.003)

SF-6D, Short Form 6 Dimensions.

Table IV

Improvement over time in mobility, self-care, pain, anxiety, and general health of 30 patients undergoing reverse shoulder arthroplasty

Variable	Preoperative	1-Year postoperative (<i>P</i> value)	2-Year postoperative (<i>P</i> value)
Mobility	1.0	2.0 (1.0)	2.0 (.18)
Self-care	2.0	1.0 (.02)	1.0 (.23)
Usual activities	2.0	1.0 (.01)	1.0 (.002)
Pain	2.0	2.0 (.004)	2.0 (.002)
Anxiety	2.0	1.0 (.02)	1.0 (.18)
General health	2.0	1.0 (.006)	2.0 (.14)
EQ-5D utility score	0.75	0.81 (.001)	0.81 (.04)

EQ-5D, EuroQol.

Table V

Costs associated with reverse shoulder arthroplasty in 30 patients

Service center	Cost distribution, %*
Surgical services (implant cost, operating room, preoperative, recovery)	64.4
Patient care (hospitalization)	4.8
Orthopedic professional fee	23.3
Anesthesia	1.2
Laboratory	1.0
Radiology	0.3
Pharmacy	4.8
Miscellaneous	0.2
Median total cost	\$21,684
Mean total cost	\$21,536

* Values are percentage unless indicated otherwise.