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Cost-utility analysis of total shoulder arthroplasty: a prospective health economic study using real-world data

Cécile E. Grobet, MSc[a], Michael C. Glanzmann, MD[b], Klaus Eichler, MD[c], Dominik Rickenbacher, MSc[a], Flurina Meier, MSc[c], Beatrice Brunner, PhD[c], Laurent Audigé, DVM, PhD[a,]*

[a]*Research and Development, Schulthess Klinik, Zürich, Switzerland*
[b]*Shoulder and Elbow Surgery, Schulthess Klinik, Zürich, Switzerland*
[c]*Winterthur Institute of Health Economics, Zürich University of Applied Sciences, Winterthur, Switzerland*

Background: With increasing health care expenditures, knowledge about the benefit and costs of surgical interventions such as total shoulder arthroplasty (TSA) becomes important for orthopedic surgeons, social insurance programs, and health policy decision makers. We examined the impact of TSA on quality of life (QOL), direct medical costs, and productivity losses and evaluated the cost-utility ratio of TSA compared with ongoing nonoperative management using real-world data.
Methods: Patients with shoulder osteoarthritis and/or rotator cuff tear arthropathy indicated for anatomic or reverse TSA were included in this prospective study. QOL (European Quality of Life 5 Dimensions 5-Level questionnaire) and shoulder function (Constant score; Shoulder Pain and Disability Index; short version of the Disabilities of the Arm, Shoulder and Hand questionnaire; and Subjective Shoulder Value) were assessed preoperatively and up to 2 years postoperatively. Health insurance companies provided all-diagnosis direct medical costs for 2018 in Swiss francs (CHF), where 1 CHF was equivalent to US $1.02. Indirect costs were assessed using the Work Productivity and Activity Impairment Questionnaire. Baseline data at recruitment and the total costs of the preoperative year served as a proxy for nonoperative management. The incremental cost-effectiveness ratio (ICER) was calculated as the total costs to gain 1 extra quality-adjusted life-year (QALY) based on both the health care system perspective and societal perspective. The relationship between QOL and shoulder function was assessed by regression analysis.
Results: The mean preoperative utility index for the European Quality of Life 5 Dimensions 5-Level questionnaire of 0.68 for a total of 150 patients (mean age, 71 years; 21% working; 58% women) increased to 0.89 and 0.87 at 1 and 2 years postoperatively, respectively. Mean direct medical costs were 11,771 CHF (preoperatively), 34,176 CHF (1 year postoperatively), and 11,763 CHF (2 years postoperatively). The ICER was 63,299 CHF/QALY (95% confidence interval, 44,391-82,206 CHF/QALY). The mean productivity losses for 29 working patients decreased from 40,574 CHF per patient (preoperatively) to 26,114 CHF at 1 year postoperatively and 10,310 CHF at 2 years postoperatively. When considering these productivity losses, the ICER was 35,549 CHF/QALY (95% confidence interval, 12,076-59,016 CHF/QALY). QOL was significantly associated with shoulder function ($P < .001$).
Conclusion: Using real-world direct medical cost data, we calculated a cost-utility ratio of 63,299 CHF/QALY for TSA in Switzerland, which clearly falls below the often-suggested 100,000-CHF/QALY threshold for acceptable cost-effectiveness. In view of productivity losses, TSA becomes highly cost-effective with an ICER of 35,546 CHF/QALY.

Institutional review board/ethics committee approval was granted by the Cantonal Ethics Committee of Zürich. Approval for the study (no. 2013-0381) was granted on September 30, 2013. This clinical trial was registered with www.ClinicalTrial.gov (identifier NCT01586351).

*Reprint requests: Laurent Audigé, PhD, Research and Development, Schulthess Klinik, Lengghalde 2, CH-8008 Zürich, Switzerland.
E-mail address: laurent.audige@kws.ch (L. Audigé).

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Osteoarthritis (OA) affects approximately 10% of noninstitutionalized adults in the United States, which can result in functional limitation, pain, and poorer quality of life (QOL) for patients and an economic burden on society.[37] Glenohumeral arthritis is initially treated conservatively to improve pain and restore function.[1,3,24] With progressive OA, patients may experience worsening pain and function that result in decreased QOL, and thus, the evaluation of surgical treatment options becomes relevant.[3] Total shoulder arthroplasty (TSA) is known to provide good outcomes in terms of safe and efficient pain relief, as well as improved shoulder function and QOL.[1,3,34]

Owing to the growing aging population and its expectations to stay active, as well as the development of improved implant designs and the technique of reverse TSA with its broader indications, the number of shoulder arthroplasties has increased nearly 10-fold in the past 3 decades.[33,34,36] With this trend, the emerging socioeconomic burden will drive future discussions to consider the proper allocation of limited financial resources. Health economic evaluations are therefore important for orthopedic surgeons, social insurance programs, and health policy decision makers and, in fact, play a role in outcome measure evaluations of surgical interventions.[9] However, very few cost-utility analyses have compared nonoperative management or physiotherapy with shoulder replacement[20,22,26,28]; in all but 1 study that included 30 patients,[28] only hypothetical or modeled data obtained from the literature were used. There is a need for studies using individual real-world data focused on patient-reported outcome measures (PROMs), clinical outcomes, and claims data to assess the relationship between patient benefit and costs measuring the value of health care for society.[5,27]

Although there is no implemented cost-effectiveness threshold for a given health care intervention in Switzerland, a threshold of 100,000 Swiss francs (CHF) per quality-adjusted life-year (QALY) has been recommended for high-income countries.[25] The purpose of this study was to examine the impact of TSA on QOL, direct medical costs, and productivity losses and evaluate the cost-utility ratio of TSA compared with ongoing nonoperative management using real-world data. We hypothesized that QOL would improve until 2 years after surgery, leading to a favorable cost-utility ratio for TSA patients treated at a specialized Swiss orthopedic hospital.

Materials and methods

Design

We performed a prospective health economic study assessing patient benefits and costs associated with TSA compared with nonoperative management using a before-and-after surgery comparison (pre-post design). The follow-up period was 2 years, and we evaluated cost utility from a health care system perspective and a societal perspective. The methodologic details were outlined in a similar study investigating arthroscopic rotator cuff repair.[13] Current standards for performing health economic evaluations and the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist were applied.[9,18]

Patient cohort

Patients were eligible for study inclusion if they were aged ≥ 18 years, received a diagnosis of primary or secondary glenohumeral arthritis and/or rotator cuff tear arthropathy and were indicated for anatomic or reverse TSA, and gave their written informed consent. Patients who underwent revision surgery of a shoulder arthroplasty or had rheumatoid arthritis, acute fractures, or humeral head necrosis were excluded. Eligible patients were consecutively enrolled until there were a total of 150 operated patients who did not drop out before 3 months after surgery.

Operative management and rehabilitation

The surgical procedure was performed according to the standard technique through the deltopectoral interval with patients in the beach-chair position under general anesthesia. For the majority of reverse shoulder arthroplasty patients, the subscapularis was repaired, when feasible, at the end of the intervention. Procedures were carried out or directly supervised by a shoulder surgeon with experience performing >20 TSAs annually. A standard postoperative physiotherapy scheme was applied for the operated shoulder, with active mobilization starting in the first week after the procedure.

Patient-reported and clinical outcomes

The primary outcomes of this study were the change in QOL and costs of TSA. Patients were followed up at 7 time points throughout the study period: at enrollment; at the preoperative time of hospital admission; and at 2 weeks, 3 months, 6 months, 1 year, and 2 years after surgery (Supplementary Fig. S1). To assess QOL, we used the European Quality of Life 5 Dimensions

5-Level questionnaire (EQ-5D-5L).[17] The responses were converted into utilities (ranging from −0.66 [indicating the lowest QOL] to 1 [indicating the highest QOL]) using the EQ-5D-5L value set for Germany.[21] The valid and reliable EQ-5D is the most frequently used instrument to assess health states using utilities and calculate QALYs.[14] Shoulder function was assessed using the Shoulder Pain and Disability Index (SPADI)[31]; the short version of the Disabilities of the Arm, Shoulder and Hand questionnaire (QuickDASH)[2]; and the Subjective Shoulder Value (SSV).[12] Clinical examinations included determination of shoulder range of motion, muscle strength in 90° of abduction, and overall shoulder function as measured by the Constant score (CS),[8] as well as the documentation of postoperative complications.[4]

Cost and productivity data

Direct medical costs and productivity data of TSA patients were collected for 3 periods: (1) the year preoperatively, (2) the first year postoperatively, and (3) the second year postoperatively (Supplementary Fig. S1). A collaboration with the 12 major Swiss health and accident insurance companies was initiated to obtain direct medical cost data of as many included patients as possible. Patients provided information about their health and accident insurance and gave written consent that their insurance provider may provide direct medical inpatient and outpatient cost data extracted from its claims database for this study. Costs included all-diagnosis direct medical costs of all treatments, complications, drugs, and consultations covered by the mandatory health and accident insurance companies across all hospitals and other providers.

Productivity losses due to the shoulder problem were assessed before and after surgery at all 7 follow-up time points using the Work Productivity and Activity Impairment Questionnaire–Specific Health Problem, version 2.0 (WPAI-SHP),[30] which comprises 6 questions about absenteeism (absence from work) and presenteeism (reduced productivity when at work) during the past 7 days. Additional work-related data included (1) the number of hours usually worked during 1 week, (2) whether the level of employment was reduced because of the health problem, (3) the duration of absence from work after surgery, and (4) the current monthly personal income in brackets of 2000 CHF up to ≥16,000 CHF. Costs were provided in CHF with US dollar (USD), Euro (€), and British pound (GBP) equivalents, based on the 2018 conversion rates, of USD 1.02, €0.89, and GBP 0.80, respectively.

Statistical analysis

With a power of 80%, a significance level of .05, a standard deviation [SD] of 0.30, and a maximum 10% loss to follow-up, a sample size of 150 patients was determined from a power analysis aimed to detect a clinically important change of 0.074 in our primary outcome of QOL.[35] All data were entered into a Web-based electronic database using REDCap software (version 9.7.5; Vanderbilt University, Nashville, TN, USA)[16] and exported for analysis into STATA software (version 14.2; StataCorp, College Station, TX, USA). Missing follow-up outcome data were replaced by multiple multivariate chained imputation[32] while considering the following factors: patient age, sex, comorbidities, American Society of Anesthesiologists physical status classification, diagnosis, and prosthesis type. The change in QOL was analyzed using a paired *t* test and reported as the mean with its 95% confidence interval (CI). QALYs were calculated by multiplying utilities over the length of time in which the specific health state was experienced. For the base case—the status nominated in our study to consider a hypothetical situation of nonoperative management—it was assumed that if patients had not undergone surgery, they would have maintained their preoperative health state throughout the follow-up period.

Annual direct medical costs were calculated for each 1-year period. Discount rates were not used because of the short time horizon of 3 years. The incremental cost-effectiveness ratio (ICER) was calculated by dividing the difference in annual costs (postoperative period – preoperative period) by the QALYs gained. The 95% CIs of costs and ICER were calculated using nonparametric bootstrapping.[6] A subgroup analysis was separately performed for working and nonworking patients including productivity losses. Productivity losses for the patient population, which had a labor-type pattern representative of TSA patients in Switzerland, were calculated by multiplying health-related (ie, shoulder-specific) absenteeism and presenteeism[29] with annual earnings.

Changes in all outcome parameters from baseline were analyzed using generalized linear mixed models considering repeated follow-up assessments at multiple time points. The relationship between shoulder function (ie, SPADI, QuickDASH score, SSV, and CS) and QOL was explored with scatter plots and regression analysis with robust standard error estimation.

Sensitivity analysis

One major assumption in the primary analysis of this study was that the QOL index of patients continuing a hypothetical nonoperative management strategy would remain constant over time with constant costs as reported in the preoperative year (base case). This is a rather optimistic scenario, particularly because OA is characterized by the irreversible destruction of articular surfaces and conservative treatment may prolong but not hinder its progression.[24] Nevertheless, some patients may profit from nonoperative management such as physical therapy, intra-articular injections, and oral medication; others may simply accept their shoulder symptoms and adapt to prevent undergoing surgery. Thus, we believe that a stable trajectory of QOL and costs during follow-up for nonoperative management is a fair assumption.

Our sensitivity analysis, in addition to the base case, therefore included 3 scenarios: (1) Simulation of a linear deterioration of 10% in QOL within the nonoperative treatment setting until the 2-year follow-up (Supplementary Fig. S2); (2) hypothetically increased costs of 10% or 20% for the first year after enrollment compared with the documented preoperative costs for intensified nonoperative treatment to maintain initial QOL; and (3) hypothetically decreased costs of 10% or 20% for the first and second years after enrollment compared with the documented preoperative costs owing to acceptance of and adaptation to the shoulder symptoms and reduction in nonoperative treatment.

Results

Patient enrollment and baseline characteristics

Between January 2014 and October 2016, 166 patients were enrolled. One patient received a hemiarthroplasty and 15 patients withdrew consent within 3 months after surgery. Of the 150 included patients, 3 dropped out between the 6-month and 2-year follow-up points and 1 died during the second postoperative year. The follow-up rates were between 96% and 100%. The mean age of the patient cohort was 71 years (SD, 9 years; range, 43-88 years), 44 had undergone previous shoulder surgery (21 rotator cuff repairs, 5 instability operations, 4 humeral osteosynthesis procedures, and 14 other shoulder operations), and the mean inpatient time was 6 days (Table I).

Table I Baseline patient characteristics (N = 150)

	n (%)
Female sex	86 (57)
Comorbidities	89 (59)
ASA physical status classification	
1 (healthy)	11 (7)
2 (mild systemic disease)	86 (57)
3 (severe systemic disease)	52 (35)
4 (severe systemic disease posing constant threat to life)	1 (1)
Duration of symptoms	
<6 mo	24 (16)
6 mo to 1 yr	22 (15)
>1 yr	104 (69)
Working	31 (21)
Workload reduced before TSA	12 (39*)
Nonoperative treatment	
Steroid infiltration	59 (39)
Oral medication	81 (54)
Physical therapy	44 (29)
No treatment	39 (26)
Diagnosis	
RC tear without arthrosis	16 (11)
RC tear with arthrosis	60 (40)
Trauma (fracture)	5 (3)
Primary glenohumeral osteoarthritis	59 (39)
Other secondary osteoarthritis†	10 (7)
Type of prosthesis	
Anatomic	47 (31)
Reverse	103 (69)

ASA, American Society of Anesthesiologists; *TSA*, total shoulder arthroplasty; *RC*, rotator cuff.

* Percentage of 31 working patients.

† Secondary osteoarthritis resulting from shoulder instability (n = 5), calcium pyrophosphate deposition disease (n = 3), or trauma (without fracture) (n = 2).

Patient-reported and clinical outcomes

The mean EQ-5D-5L utility index increased from study enrollment to 2 years by 0.19 (95% CI, 0.15-0.22; $P < .001$) (Fig. 1). The main increase occurred within the first 3 months after surgery. The preoperative QALY value was 0.68 (SD 0.23) whereas the QALY values in the first and second postoperative years were 0.85 (SD, 0.12) and 0.88 (SD, 0.14), respectively; these values were similar to the raw non-imputed data. After 2 years, the incremental QALY gain was 0.18/yr for TSA patients compared with nonoperative management. Preoperative shoulder function according to the SPADI, QuickDASH score, SSV, and CS improved from 38 to 85, from 48 to 20, from 41 to 84, and from 34 to 71, respectively, until 1 year after surgery and remained at this level in the second year after surgery ($P < .001$; Fig. 2, Supplementary Table S1).

Cost-utility analysis

Direct medical cost data were provided by 12 major Swiss insurance companies for 134 patients (89%). The mean direct costs increased from 11,771 CHF in the preoperative year to 34,176 CHF in the first postoperative year and decreased to the preoperative level in the second year after surgery; this resulted in an incremental annual cost of 11,198 CHF for the base-case scenario, which compared TSA patients with nonoperative management, resulting in a constant QOL index and constant costs (Table II). Inpatient costs constituted the large increase observed in the first year after surgery. On the basis of the direct medical costs, the ICER was 63,299 CHF/QALY gained (95% CI, 44,391-82,206 CHF/QALY gained) when comparing TSA with nonoperative management.

Of 31 working patients, 12 had to reduce their work during the preoperative period because of shoulder problems, of whom 6 were on full sick leave. Twenty-eight patients returned to work, on average, 76 days after surgery, with approximately half returning during the first 3 months (Fig. 3). The mean preoperative productivity loss per working patient based on absenteeism and presenteeism was 62%, which decreased to 38% at 6 months and 16% by 2 years after surgery (Fig. 4). Mean productivity losses decreased from 40,574 CHF per working patient in the year before surgery to 10,310 CHF 2 years after surgery (Table II). When considering productivity losses, the ICER decreased to 35,549 CHF/QALY (95% CI, 12,076-59,016 CHF/QALY) for TSA vs. nonoperative management.

Subgroup analysis of the 28 working patients showed that TSA implantation was dominant compared with nonoperative management, with an incremental QALY gain of 0.26/yr and incremental annual cost savings of −13,132 CHF. The corresponding ICER for the nonworking patient group was 73,224 CHF/QALY (95% CI, 46,619-99,828 CHF/QALY).

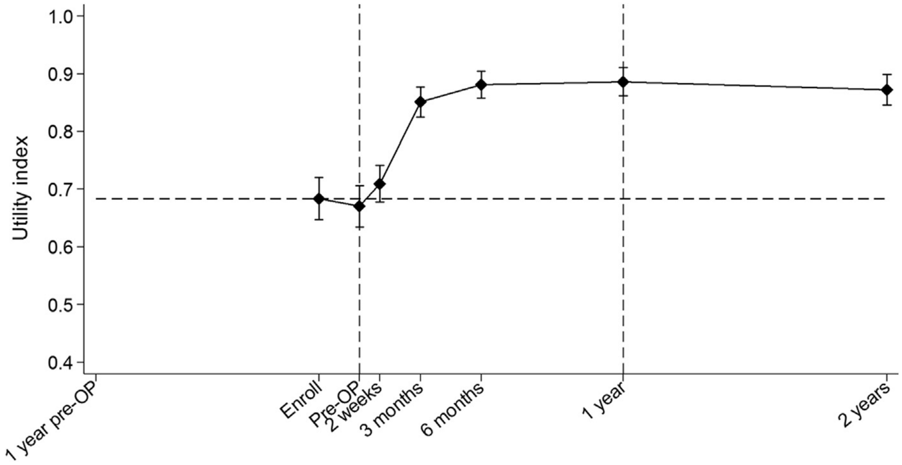

Figure 1 Quality of life (utility index) as measured by European Quality of Life 5 Dimensions 5-Level questionnaire at each follow-up. The *horizontal dashed line* indicates the utility index for nonoperative management, which was assumed to remain unchanged throughout the follow-up period. *Pre-OP*, preoperatively.

The ICERs calculated from the sensitivity analysis ranged from 24,208 to 48,855 CHF/QALY (Table III). For example, while the ICER for the base-case scenario was 35,546 CHF, hypothetically increasing the costs by 10% and 20% lowered the ratios to 32,219 CHF and 28,892 CHF, respectively.

Patient-reported shoulder function according to the SPADI, QuickDASH score, SSV, and CS was significantly associated with the EQ-5D-5L utility index at both the preoperative and the 2-year postoperative time points ($P < .001$), and the coefficient of determination (R^2) at the preoperative time point was 0.33, 0.32, 0.27, and 0.25 for the SPADI, QuickDASH score, SSV, and CS, respectively. The relationship between the EQ-5D-5L utility index and SPADI is shown in Figure 5; similar scatter plots were also achieved for the outcomes of the QuickDASH score, SSV, and CS.

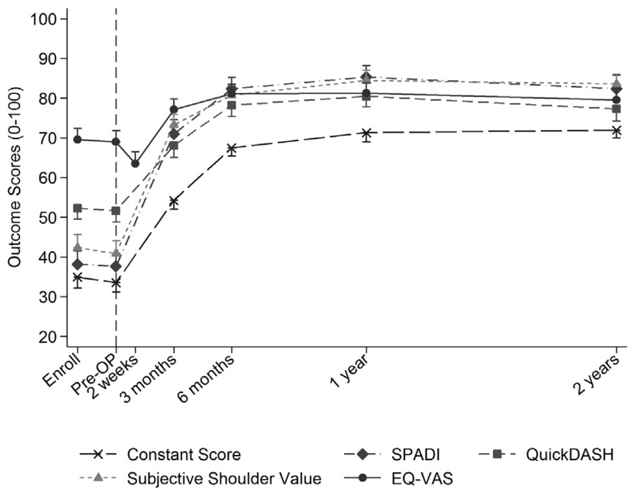

Figure 2 Shoulder function and quality of life over time. Outcome scores ranging from 0 to 100 points are shown at each follow-up time point. The original scale of the short version of the Disabilities of the Arm, Shoulder and Hand questionnaire *(QuickDASH)* score was reversed for presentation purposes. *Pre-OP*, preoperatively; *SPADI*, Shoulder Pain and Disability Index; *EQ-VAS*, EQ-5D General Health Visual Analogue Scale.

Discussion

The most important finding of this cost-utility study using real-world data was that patients undergoing TSA showed a clinically relevant and statistically significant improvement in QOL 3 months after surgery compared with their preoperative state and they maintained this gain in QOL until 2 years after surgery. The cost-utility ratio of TSA was 63,299 CHF/QALY from a health care system perspective (including direct medical costs) and 35,546 CHF/QALY from a societal perspective (including direct medical costs and productivity losses) at the 2-year follow-up compared with nonoperative management. These values are clearly below the often-discussed 100,000-CHF/QALY threshold for high-income countries.[25]

QOL, according to the EQ-5D-5L utility index, improved significantly by 0.19 points, which is well above the minimal important difference of 0.074.[35] The EQ-5D-5L utility index of 0.87 at 2 years after surgery is in accordance with the normative index value of 0.85 for German adults of the same age category.[15] We calculated QALYs in the 2 years after TSA surgery of up to 1.73, yet the same values from previous cost-utility studies using modeled data extended to consider a lifetime horizon ranged from 6.45 to 12.19.[7,20,22,23,26]

Study comparisons are difficult because of the limited number of cost-utility studies available and the diverse methods of data collection and utility calculation. We identified only 1 study reporting primary health economic

Table II QALYs, direct medical costs, and productivity losses

	n	Preoperative year, CHF	First postoperative year, CHF	Second postoperative year, CHF	Incremental QALYs or costs	
					n*	CHF
QALYs	150	0.68 (0.23)	0.85 (0.12)	0.88 (0.14)	150	0.18 (0.20)
Direct medical costs†	134	11,771 (19,883)	34,176 (15,464)	11,763 (15,321)	134	11,198 (17,677)
Inpatient cost data	134	4918 (17,440)	26,470 (12,271)	4833 (10,631)		
Outpatient cost data	134	6853 (5648)	7706 (6236)	6930 (7260)		
Productivity losses‡	29	40,574 (25,603)	26,114 (19,144)	10,310 (17,175)		
Total costs§	134	19,726 (28,485)	38,789 (19,482)	13,241 (16,251)	134	6288 (23,543)
Total costs for working patients§	28	49,096 (32,319)	53,665 (24,498)	18,263 (20,472)	28	−13,132 (28,818)
Total costs for nonworking patients	106	11,968 (21,643)	34,859 (15,869)	11,914 (14,773)	106	11,418 (19,010)

QALY, quality-adjusted life-year; *CHF*, Swiss francs.
Data are presented as mean (standard deviation).
* Patients with complete cost data and corresponding QALYs.
† Data provided by health insurance companies for 134 patients, including all medical costs, as well as those for medical conditions not involving the shoulder.
‡ Only for working patients.
§ Equivalent to sum of direct costs and productivity losses.

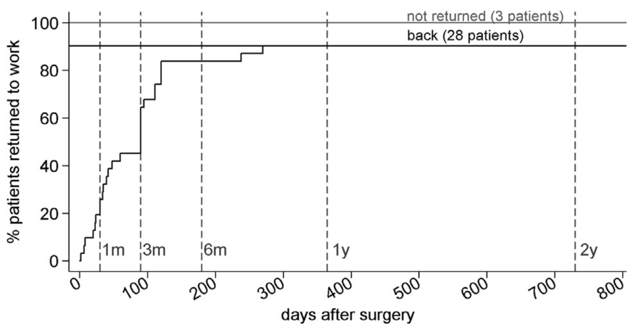

Figure 3 Kaplan-Meier curve showing percentage of patients returning to work after total shoulder arthroplasty. *m*, months; *y*, years.

data, which analyzed 30 patients undergoing reverse shoulder arthroplasty for rotator cuff arthropathy.[28] This work reported a cost-utility ratio of 16,747 USD/QALY at 2 years, but cost data were limited to inpatient costs (including professional fees, operating room and supply costs, and hospital care only); preoperative or additional rehabilitation or outpatient treatment costs were not assessed. Three further studies comparing reverse shoulder arthroplasty vs. nonoperative management calculated ICERs of 8100 USD/QALY,[26] 25,522 USD/QALY,[20] and 37,400 USD/QALY,[22] but these studies used modeling techniques with estimated utility and cost data extracted from the literature and a lifetime horizon, the latter of which impedes any possibility of a direct comparison. Our

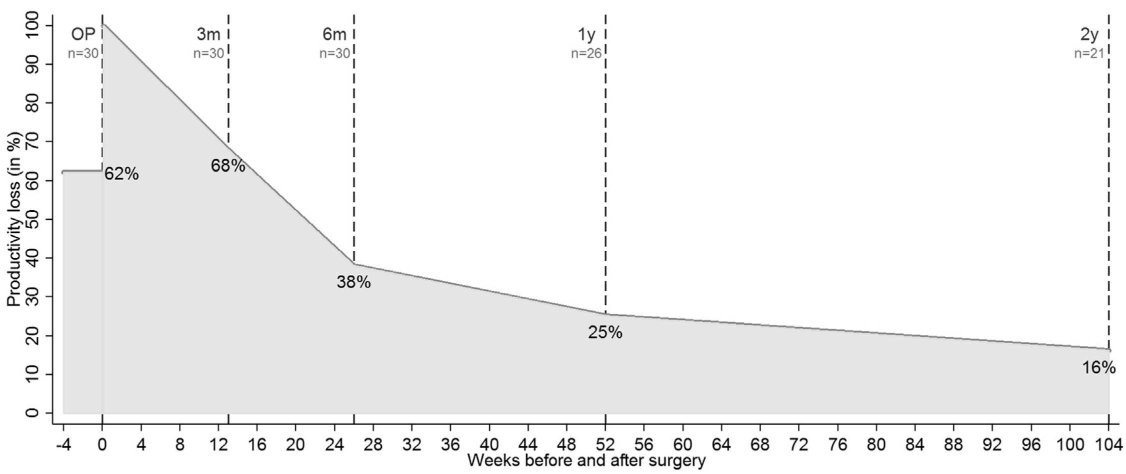

Figure 4 Productivity losses of working patients (n = 30) expressed as percentage of work activity level until 2 years after surgery. The *horizontal line* between −4 and 0 weeks indicates the preoperative period. *OP*, operation; *m*, months; *y*, years.

Table III Sensitivity analysis of ICERs for TSA compared with nonoperative management

Hypothetically lower utility index (compared with preoperative utilities)	ICER of TSA compared with hypothetical nonoperative treatment, mean (95% CI)				
	Unchanged costs, CHF* (base case)	Hypothetically increased costs, CHF* (in first year after enrollment compared with year before enrollment owing to more intensive nonoperative treatment)		Hypothetically decreased costs, CHF* (in first and second years after enrollment compared with year before enrollment owing to reduced nonoperative treatment)	
		10% increased costs	20% increased costs	10% decreased costs	20% decreased costs
Unchanged utility index for nonoperative treatment (base case)	35,546 (12,076-59,016)	32,219 (8414-56,024)	28,892 (4695-53,090)	42,201 (19,219-65,182)	48,855 (26,107-71,602)
10% lower	29,783 (10,483-49,083)	26,996 (7354-46,638)	24,208 (4184-44,232)	35,359 (16,614-54,103)	40,934 (22,563-59,305)

ICER, incremental cost-effectiveness ratio; *TSA*, total shoulder arthroplasty; *CHF*, Swiss francs.
ICERs are presented in CHF with 95% CIs.
* Costs include direct medical costs plus productivity losses.

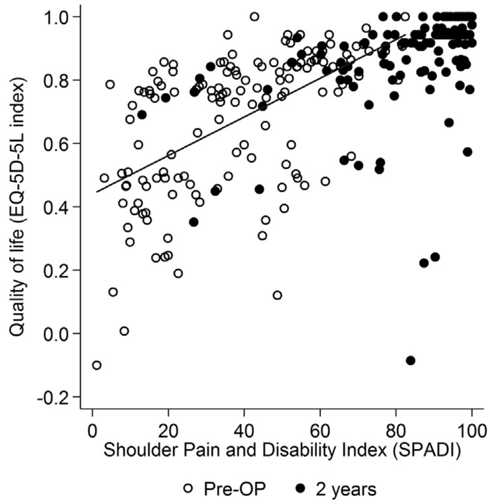

Figure 5 Scatter plot showing association between quality of life (according to European Quality of Life 5 Dimensions 5-Level questionnaire *[EQ-5D-5L]* index) and shoulder function (according to Shoulder Pain and Disability Index *[SPADI]*) over time. Each *open* and *closed* data point represents 1 patient in the preoperative period *(Pre-OP)* and 2 years after surgery, respectively. The *regression line* indicates the association between the EQ-5D-5L utility index and SPADI at the preoperative time point.

ICER only considers 2 years of follow-up. However, the treatment effect of TSA is expected to last far longer, up to 20 years,[11] at least for a proportion of patients. Further investigation is required to assess whether a more favorable ICER and even cost savings would be achieved for TSA over a long-term follow-up extending beyond 2 years. Our results nevertheless show that TSA is already cost-effective 2 years after implantation.

Owing to a mean age higher than retirement age, only 21% of our patient collective worked. For these 31 patients, the productivity losses were high, which highlights the socioeconomic importance of OA and the importance of considering productivity losses. In the cost-effectiveness subgroup analysis, TSA implantation was dominant over nonoperative management for working patients, that is, QALYs were gained and costs were saved, because postoperatively, productivity losses quickly decreased below the preoperative level. The ICER for nonworking patients was higher but still below the often-discussed 100,000-CHF/QALY threshold for high-income countries.[25] The majority of our working patients returned to work, on average 76 days after surgery; this observation is consistent with the mean time to return to work ranging from 1.4 to 4.0 months reported in a recent systematic review.[34] In contrast, our return-to-work rate was higher than the 63%-65% rates of returning to work described by Thon et al.[34] The reasons for this difference may be attributed to a number of factors including our patients who may have been employed in positions requiring less labor-intensive work, differences in working conditions abroad (ie, most of the studies included in the review were conducted in the United States), and longer follow-up time points (eg, some patients were retired by the 5-year postoperative assessment).

The correlations between the EQ-5D and the various PROMs, although weak, were highly significant. Jain et al[19] recently found similar results and concluded that PROMs and QOL scores are not interchangeable; they suggested that studies analyzing the cost-effectiveness and value of shoulder arthroplasty should incorporate both shoulder and upper-extremity PROMs and QOL scores.

Our study has several limitations. First, we did not implement randomization between nonoperative management and TSA to ensure that both treatment options would be applied to similar patients. Patients consulting with our specialty and tertiary referral hospital mainly seek further options because of failed nonoperative management. Any randomization process involving both procedures was, in fact, considered unethical and impossible to implement. A pre-post design was considered the most feasible approach in this clinical setting and has been successfully applied in other health economic studies.[10,13] Second, a strong assumption of this study was that the QOL index would remain constant over time without surgery. Some patients may benefit from additional nonoperative procedures such as physical therapy, intra-articular injections, and oral medication, at least during the initial years of treatment. For other patients, QOL will continue to decrease because of advancing OA and its negative impact on general or mental health and daily living conditions. Therefore, we assumed that a constant QOL index would most realistically represent the population average. With the sensitivity analyses, alternative scenarios were considered. Third, only all-diagnosis direct medical costs including costs of other health-related conditions (eg, comorbidities) were available. The impact of non-TSA costs on incremental costs, however, should be limited because of the pre-post study design, which compares each patient with himself or herself such that patients act as their own controls. In addition, any costs owing to possible surgical side effects are captured in our calculation. Another limitation of this study is the limited follow-up period. With a longer follow-up, changes in the implant and shoulder status that lead to reoperation including revision surgery, as well as changes in daily living conditions, are to be expected. Cost-effectiveness will be affected by any decline in subjective outcome parameters and by any increase in costs associated with additional interventions.

Conclusion

Using real-world direct medical cost data, we calculated a cost-utility ratio of 63,299 CHF/QALY for TSA in Switzerland, which clearly falls below the often-suggested 100,000-CHF/QALY threshold for acceptable cost-effectiveness. In view of productivity losses, TSA becomes highly cost-effective with an ICER of 35,546 CHF/QALY.

Disclaimers

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Supplementary data

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References

1. American Academy of Orthopaedic Surgeons. Management of glenohumeral joint osteoarthritis. Evidence-based clinical practice guideline. 2020. Available at: https://www.aaos.org/gjocpg. Accessed on April 28, 2021.
2. Angst F, Goldhahn J, Drerup S, Flury M, Schwyzer HK, Simmen BR. How sharp is the short QuickDASH? A refined content and validity analysis of the short form of the disabilities of the shoulder, arm and hand questionnaire in the strata of symptoms and function and specific joint conditions. Qual Life Res 2009;18:1043-51. https://doi.org/10.1007/s11136-009-9529-4
3. Ansok CB, Muh SJ. Optimal management of glenohumeral osteoarthritis. Orthop Res Rev 2018;10:9-18. https://doi.org/10.2147/ORR.S134732
4. Audigé L, Goldhahn S, Daigl M, Goldhahn J, Blauth M, Hanson B. How to document and report orthopedic complications in clinical studies? A proposal for standardization. Arch Orthop Trauma Surg 2014;134:269-75. https://doi.org/10.1007/s00402-011-1384-4

5. Ayers DC, Bozic KJ. The importance of outcome measurement in orthopaedics. Clin Orthop Relat Res 2013;471:3409-11. https://doi.org/10.1007/s11999-013-3224-z
6. Briggs AH, Wonderling DE, Mooney CZ. Pulling cost-effectiveness analysis up by its bootstraps: a non-parametric approach to confidence interval estimation. Health Econ 1997;6:327-40.
7. Coe MP, Greiwe RM, Joshi R, Snyder BM, Simpson L, Tosteson AN, et al. The cost-effectiveness of reverse total shoulder arthroplasty compared with hemiarthroplasty for rotator cuff tear arthropathy. J Shoulder Elbow Surg 2012;21:1278-88. https://doi.org/10.1016/j.jse.2011.10.010
8. Constant CR, Gerber C, Emery RJ, Sojbjerg JO, Gohlke F, Boileau P. A review of the Constant score: modifications and guidelines for its use. J Shoulder Elbow Surg 2008;17:355-61. https://doi.org/10.1016/j.jse.2007.06.022
9. Drummond MF, Sculpher MJ, Torrance GW, O'Brien BJ, Stoddart GL. Methods for the economic evaluation of health care programmes. 3rd ed. Oxford: Oxford University Press; 2005.
10. Eichler K, Krass A, Fendl A, Thuring N, Brugger U. Vernetzte Betreuung bei Patienten mit Herzinsuffizienz in der Schweiz: Eine Kostenstudie [Integrated care for patients with heart failure in Switzerland: a cost analysis]. Praxis (Bern 1994) 2009;98:809-15. [in German]. https://doi.org/10.1024/1661-8157.98.15.809
11. Ernstbrunner L, Andronic O, Grubhofer F, Camenzind RS, Wieser K, Gerber C. Long-term results of reverse total shoulder arthroplasty for rotator cuff dysfunction: a systematic review of longitudinal outcomes. J Shoulder Elbow Surg 2019;28:774-81. https://doi.org/10.1016/j.jse.2018.10.005
12. Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. J Shoulder Elbow Surg 2007;16:717-21. https://doi.org/10.1016/j.jse.2007.02.123
13. Grobet C, Audigé L, Eichler K, Meier F, Brunner B, Wieser S, et al. Cost-utility analysis of arthroscopic rotator cuff repair: a prospective health economic study using real-world data. Arthrosc Sports Med Rehabil 2020;2:e193-205. https://doi.org/10.1016/j.asmr.2020.02.001
14. Grobet C, Marks M, Tecklenburg L, Audigé L. Application and measurement properties of EQ-5D to measure quality of life in patients with upper extremity orthopaedic disorders: a systematic literature review. Arch Orthop Trauma Surg 2018;138:953-61. https://doi.org/10.1007/s00402-018-2933-x
15. Grochtdreis T, Dams J, Konig HH, Konnopka A. Health-related quality of life measured with the EQ-5D-5L: estimation of normative index values based on a representative German population sample and value set. Eur J Health Econ 2019;20:933-44. https://doi.org/10.1007/s10198-019-01054-1
16. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 2009;42:377-81. https://doi.org/10.1016/j.jbi.2008.08.010
17. Herdman M, Gudex C, Lloyd A, Janssen M, Kind P, Parkin D, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). Qual Life Res 2011;20:1727-36. https://doi.org/10.1007/s11136-011-9903-x
18. Husereau D, Drummond M, Petrou S, Carswell C, Moher D, Greenberg D, et al. Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement. BMJ 2013;346:f1049. https://doi.org/10.1136/bmj.f1049
19. Jain SS, DeFroda SF, Paxton ES, Green A. Patient-reported outcome measures and health-related quality-of-life scores of patients undergoing anatomic total shoulder arthroplasty. J Bone Joint Surg Am 2019;101:1593-600. https://doi.org/10.2106/JBJS.19.00017
20. Kang JR, Sin AT, Cheung EV. Treatment of massive irreparable rotator cuff tears: a cost-effectiveness analysis. Orthopedics 2017;40:e65-76. https://doi.org/10.3928/01477447-20160926-06
21. Ludwig K, Graf von der Schulenburg JM, Greiner W. German value set for the EQ-5D-5L. Pharmacoeconomics 2018;36:663-74. https://doi.org/10.1007/s40273-018-0615-8
22. Makhni EC, Swart E, Steinhaus ME, Mather RC III, Levine WN, Bach BR Jr, et al. Cost-effectiveness of reverse total shoulder arthroplasty versus arthroscopic rotator cuff repair for symptomatic large and massive rotator cuff tears. Arthroscopy 2016;32:1771-80. https://doi.org/10.1016/j.arthro.2016.01.063
23. Mather RC III, Watters TS, Orlando LA, Bolognesi MP, Moorman CT III. Cost effectiveness analysis of hemiarthroplasty and total shoulder arthroplasty. J Shoulder Elbow Surg 2010;19:325-34. https://doi.org/10.1016/j.jse.2009.11.057
24. Menge TJ, Boykin RE, Byram IR, Bushnell BD. A comprehensive approach to glenohumeral arthritis. South Med J 2014;107:567-73. https://doi.org/10.14423/SMJ.0000000000000166
25. Neumann PJ, Cohen JT, Weinstein MC. Updating cost-effectiveness—the curious resilience of the $50,000-per-QALY threshold. N Engl J Med 2014;371:796-7. https://doi.org/10.1056/NEJMp1405158
26. Nwachukwu BU, Schairer WW, McCormick F, Dines DM, Craig EV, Gulotta LV. Arthroplasty for the surgical management of complex proximal humerus fractures in the elderly: a cost-utility analysis. J Shoulder Elbow Surg 2016;25:704-13. https://doi.org/10.1016/j.jse.2015.12.022
27. Porter ME. What is value in health care? N Engl J Med 2010;363:2477-81. https://doi.org/10.1056/NEJMp1011024
28. Reilly Associates Health Outcomes Research. Work Productivity and Activity Impairment–Specific Health Problem Questionnaire Version 2.0 (WPAI-SHP). 2002. Available at: http://www.reillyassociates.net/Index.html. Accessed on April 28, 2021.
29. Reilly MC, Zbrozek AS, Dukes EM. The validity and reproducibility of a work productivity and activity impairment instrument. Pharmacoeconomics 1993;4:353-65.
30. Renfree KJ, Hattrup SJ, Chang YH. Cost utility analysis of reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2013;22:1656-61. https://doi.org/10.1016/j.jse.2013.08.002
31. Roach KE, Budiman-Mak E, Songsiridej N, Lertratanakul Y. Development of a shoulder pain and disability index. Arthritis Care Res 1991;4:143-9.
32. Royston P, White I. Multiple imputation by chained equations (MICE): implementation in Stata. J Stat Softw 2011;45. https://doi.org/10.18637/jss.v045.i04
33. Schairer WW, Nwachukwu BU, Lyman S, Craig EV, Gulotta LV. National utilization of reverse total shoulder arthroplasty in the United States. J Shoulder Elbow Surg 2015;24:91-7. https://doi.org/10.1016/j.jse.2014.08.026
34. Thon SG, Seidl AJ, Bravman JT, McCarty EC, Savoie FH III, Frank RM. Advances and update on reverse total shoulder arthroplasty. Curr Rev Musculoskelet Med 2020;13:11-9. https://doi.org/10.1007/s12178-019-09582-2
35. Walters SJ, Brazier JE. Comparison of the minimally important difference for two health state utility measures: EQ-5D and SF-6D. Qual Life Res 2005;14:1523-32. https://doi.org/10.1007/s11136-004-7713-0
36. Westermann RW, Pugely AJ, Martin CT, Gao Y, Wolf BR, Hettrich CM. Reverse shoulder arthroplasty in the united states: a comparison of national volume, patient demographics, complications, and surgical indications. Iowa Orthop J 2015;35:1-7.
37. Zhao X, Shah D, Gandhi K, Wei W, Dwibedi N, Webster L, et al. Clinical, humanistic, and economic burden of osteoarthritis among noninstitutionalized adults in the United States. Osteoarthritis Cartilage 2019;27:1618-26. https://doi.org/10.1016/j.joca.2019.07.002