Primary reverse total shoulder arthroplasty for fractures requires more revisions than for degenerative conditions 1 year after surgery

Spek, Reinier W.A.; Spekenbrink-Spooren, Anneke; Vanhommerig, Joost W.; Jonkman, Nini; Doornberg, Job N.; Jaarsma, Ruurd L.; Jutte, Paul C.; van der Veen, Hugo C.; van Noort, Arthur; van den Bekerom, Michel P.J.

Published in:
Journal of Shoulder and Elbow Surgery

DOI:
10.1016/j.jse.2023.05.013

Publication date:
2023

J Shoulder Elbow Surg (2023) 32, 2508–2518

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Primary reverse total shoulder arthroplasty for fractures requires more revisions than for degenerative conditions 1 year after surgery: an analysis from the Dutch Arthroplasty Register

Reinier W.A. Spek, MD[a,b,c,*], Anneke Spekenbrink-Spooren, MSc[d], Joost W. Vanhommerig, PhD[e], Nini Jonkman, PhD[e], Job N. Doornberg, MD, PhD[b], Ruurd L. Jaarsma, MD, PhD, FRACS[a], Paul C. Jutte, MD, PhD[b], Hugo C. van der Veen, MD, PhD[b], Arthur van Noort, MD, PhD[f,g], Michel P.J. van den Bekerom, MD, PhD[c,h,i]

[a]*Department of Orthopaedic Surgery, Flinders Medical Centre, Flinders University, Adelaide, South Australia, Australia*
[b]*Department of Orthopaedic Surgery, University Medical Centre Groningen, University of Groningen, Groningen, The Netherlands*
[c]*Department of Orthopaedic Surgery, OLVG, Amsterdam, The Netherlands*
[d]*Dutch Arthroplasty Register, 's-Hertogenbosch, The Netherlands*
[e]*Department of Epidemiology, OLVG, Amsterdam, The Netherlands*
[f]*Department of Orthopaedic Surgery, Spaarne Gasthuis, Hoofddorp, The Netherlands*
[g]*Department of Orthopaedic Surgery, Erasmus University Medical Center, Rotterdam, The Netherlands*
[h]*Shoulder and Elbow Expertise Center, Amsterdam, The Netherlands*
[i]*Faculty of Behavioral and Movement Sciences, Department of Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands*

Background: Although reverse total shoulder arthroplasty (RTSA) is considered a viable treatment strategy for proximal humeral fractures, there is an ongoing discussion of how its revision rate compares with indications performed in the elective setting. First, this study evaluated whether RTSA for fractures conveyed a higher revision rate than RTSA for degenerative conditions (osteoarthritis, rotator cuff arthropathy, rotator cuff tear, or rheumatoid arthritis). Second, this study assessed whether there was a difference in patient-reported outcomes between these 2 groups following primary replacement. Finally, the results of conventional stem designs were compared with those of fracture-specific designs within the fracture group.

Materials and methods: This was a retrospective comparative cohort study with registry data from the Netherlands, generated prospectively between 2014 and 2020. Patients (aged $\geq$ 18 years) were included if they underwent primary RTSA for a fracture (<4 weeks after trauma), osteoarthritis, rotator cuff arthropathy, rotator cuff tear, or rheumatoid arthritis, with follow-up until first revision, death, or the end of the study period. The primary outcome was the revision rate. The secondary outcomes were the Oxford Shoulder Score, EuroQol

Institutional review board approval was not required as this study used deidentified data.

*Reprint requests: Reinier W.A. Spek, MD, Department of Orthopaedic Surgery, Flinders Medical Centre, Flinders Dr, Bedford Park, Adelaide, South Australia 5042, Australia.
E-mail address: reinierspek@gmail.com (R.W.A. Spek).

1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2023.05.013

5 Dimensions (EQ-5D) score, numerical rating scale score (pain at rest and during activity), recommendation score, and scores assessing change in daily functioning and change in pain.

Results: This study included 8753 patients in the degenerative condition group (mean age, 74.3 ± 7.2 years) and 2104 patients in the fracture group (mean age, 74.3 ± 7.8 years). RTSA performed for fractures showed an early steep decline in survivorship: Adjusted for time, age, sex, and arthroplasty brand, the revision risk after 1 year was significantly higher in these patients than in those with degenerative conditions (hazard ratio [HR], 2.50; 95% confidence interval, 1.66-3.77). Over time, the HR steadily decreased, with an HR of 0.98 at year 6. Apart from the recommendation score (which was slightly better within the fracture group), there were no clinically relevant differences in the patient-reported outcome measures after 12 months. Patients who received conventional stems (n = 1137) did not have a higher likelihood of undergoing a revision procedure than those who received fracture-specific stems (n = 675) (HR, 1.70; 95% confidence interval, 0.91-3.17).

Conclusion: Patients undergoing primary RTSA for fractures have a substantially higher likelihood of undergoing revision within the first year following the procedure than patients with degenerative conditions preoperatively. Although RTSA is regarded as a reliable and safe treatment option for fractures, surgeons should inform patients accordingly and incorporate this information in decision making when opting for head replacement surgery. There were no differences in patient-reported outcomes between the 2 groups and no differences in revision rates between conventional and fracture-specific stem designs.

Level of evidence: Level III; Retrospective Cohort Comparison Using Large Database; Prognosis Study

Keywords: Reverse total shoulder arthroplasty; fractures; degenerative conditions; revision rate; patient-reported outcome measures; decision-making; conventional versus fracture-specific humeral component

Reverse total shoulder arthroplasty (RTSA) is a well-accepted treatment option for a vast array of debilitating traumatic, degenerative, and autoimmune orthopedic disorders of the shoulder (eg, osteoarthritis and cuff arthropathy). It is unclear, however, whether these different indications also portend different outcomes in the setting of primary arthroplasty.[7,11] One could argue that fractures of the proximal humerus treated with RTSA yield inferior results compared with degenerative conditions because patients with such fractures could present with concomitant vascular injuries, less available bone stock, concomitant tuberosity fractures, and a compromised preoperative workup time to optimize health conditions.[6,7,9] Moreover, an analogy to total hip arthroplasty may exist given that femoral neck fractures are associated with higher complication and readmission rates than hip osteoarthritis.[17,22]

Several studies have compared traumatic vs. nontraumatic indications for RTSA, but each investigation has differed slightly from the other investigations with respect to design, exclusion criteria, and/or outcome.[4,5,8,11,13,14,16] One study compared patients with fractures vs. those with cuff tear arthropathy in a large cohort from a national database and showed that fractures treated with RTSA were associated with more short-term complications and discharges to extended-care facilities.[13] Another study compared fractures with elective indications but revealed no differences in adverse events and functional outcomes at a mean follow-up of >3 years.[5] Although both of these studies provide valuable insights, the applicability of the findings remains limited: The first study lacked long-term outcomes, and the second study included just 1 arthroplasty brand and the procedures were carried out by a small number of surgeons.

More evidence is therefore needed to confirm whether RTSA for fractures yields different outcomes than RTSA for degenerative conditions. Filling this gap in knowledge may allow hospitals to better manage their (financial) resources and may allow surgeons to pinpoint areas for improvement and optimize patient counseling. The first aim of this study was to evaluate whether RTSA for fractures conveyed a higher revision rate than RTSA for degenerative conditions (osteoarthritis, rotator cuff arthropathy, rotator cuff tear, or rheumatoid arthritis). The second aim was to assess whether a difference in patient-reported outcomes was observed between these 2 groups after primary replacement. The third aim was to compare the outcomes (revision rate and patient-reported outcomes) between conventional and fracture-specific humeral component designs in the fracture group.

Materials and methods

Setting and study design

This was a retrospective comparative cohort study using register data from the Netherlands. The Dutch Arthroplasty Register (Landelijke Registratie Orthopedische Interventies [LROI]) is a nationwide collaboration that prospectively collects data and monitors joint replacements. The register was initiated in 2007, and data on primary shoulder arthroplasty procedures and/or revision surgery have been gathered since 2014. Responsiveness increased rapidly, and in 2020, the level of completeness of shoulder arthroplasty registrations reached almost 96%.[3] Deaths are also documented, and mortality data are actively retrieved by Vektis (the Dutch national insurance database for health care, which records deceased citizens).[25] To date, 32 different RTSA brands have been included in the register and the surgical procedures have been performed in 92 private, general, or university hospitals. In 2020, documentation of patient-reported outcome measures (PROMs) following arthroplasty was officially

incorporated in the national guidelines by the Dutch Orthopaedic Association. Shoulder PROMs are collected preoperatively (≤182 days prior to surgery), at 3 months postoperatively (range, 63-110 days), and at 12 months postoperatively (range, 323-407 days), filled out electronically or on paper by patients. Data on surgical procedures are captured by standardized forms (1 form for primary procedures and 1 form for revisions) that are filled out after the procedure by the attending orthopedic surgeon and theater staff.

Population

Patients (aged ≥ 18 years) were included if they underwent primary RTSA for a fracture (RTSA insertion <4 weeks after trauma), osteoarthritis, rotator cuff arthropathy, rotator cuff tear, or rheumatoid arthritis between the start of 2014 and January 1, 2021, with follow-up until first revision, death, or the end of the study period. Patients who underwent RTSA for post-traumatic fracture sequelae or osteonecrosis were excluded. There were no restrictions on length of follow-up and arthroplasty brand. Two groups were compared: acute fractures and degenerative conditions. The former group (fracture cohort) consisted of patients who required RTSA following an acute fracture; the latter group (degenerative condition cohort) comprised patients who underwent RTSA for the treatment of osteoarthritis, rotator cuff arthropathy, rotator cuff tear, and/or rheumatoid arthritis. Within the study period, 10,882 patients underwent primary RTSA, of whom 25 were excluded for various reasons: age < 18 years (n = 4), unknown age (n = 7), incorrectly documented age (n = 3), and missing data on primary arthroplasty (n = 11).

Variables and data collection

The following variables were collected: hospital (anonymized), side, sex, age, RTSA indication, American Society of Anesthesiologists (ASA) score, previous surgery, type of previous surgery (eg, osteosynthesis or rotator cuff repair), Walch classification, body mass index (BMI), smoking status, type of fixation (cemented or cementless), arthroplasty brand, surgical approach, and humeral component design (conventional or fracture-specific design, based on the metaphyseal component in modular RTSAs).

Outcome measures

The primary outcome measure was the revision rate. Revision was defined as a reoperation in which any of the components were removed, exchanged, or adjusted (with or without bone grafting). The secondary outcome measures comprised the following PROMs: Oxford Shoulder Score (OSS), quality of life as measured by the EuroQol 5 Dimensions (EQ-5D) 3-level questionnaire and thermometer, numerical rating scale score (pain at rest and during activity), and recommendation score, as well as an anchor question for change in daily functioning and an anchor question for change in pain. The OSS ranges from 0 to 48 and measures shoulder pain and disability using 12 items; a total score of 48 indicates no symptoms, whereas 0 indicates severe limitations in functional abilities. The EQ-5D index covers 5 dimensions related to patients' quality of life and ranges from −0.329 to 1. The EQ-5D thermometer allows patients to rate their own health on a scale from 0 to 100. For both EQ-5D instruments, a higher score indicates a better outcome. For the numerical rating scale score assessing pain at rest and during activity, patients rate their pain level using a score from 0 to 10, with 10 indicating the worst possible pain and 0 indicating the absence of pain. The recommendation score consists of a single question asking the patient to what extent he or she would recommend a joint replacement to a friend or relative via a 5-point Likert scale (1 indicates strongly advised against joint replacement; 3, neutral; and 5, strongly recommended joint replacement). For the anchor questions (with scores ranging from 1 to 7), patients are asked to compare their pain or functioning in daily life with their preoperative situation; the higher the score, the better the improvement (1 indicates severely deteriorated; 4, unchanged; and 7, strongly improved).

Power analysis

Power calculations were performed using PASS software (NCSS, Kaysville, UT, USA) and were conducted prior to the start of this study. The degenerative condition group was estimated to be 4 times larger than the fracture group. The work of Crespo et al[5] was used as a reference for this power analysis. Calculations were performed accounting for a 10% rate of loss to follow-up. To identify a significant difference on the log-rank test for the survival analysis, 5859 patients were required to be included, comprising one group consisting of ≥4688 patients (137 events) and the other group consisting of 1171 patients (34 events) ($\alpha = .05$, $\beta = .20$).

Statistical analysis

IBM SPSS software (version 27; IBM, Armonk, NY, USA) was used for statistical analysis. Continuous demographic variables were presented as either medians with ranges or means with standard deviations depending on their distribution. Categorical variables were presented as numbers with percentages. To assess survival, a Kaplan-Meier curve was generated with all revisions coded as event (= revision). Additionally, a competing risk analysis was performed to examine the crude incidence of revision where death was a competing risk. A log(−log) plot was used to test the proportional hazards assumption.

Prior to the start of the analyses, 5 potential confounders were identified: age, sex, hospital, ASA score, and arthroplasty brand. Each of these variables, in a stepwise procedure, was added to a multivariable model with revision as the dependent variable and indication (degenerative condition vs. fracture) as the independent variable to determine whether the odds ratio (OR) for indication would change when a variable was added. Significant predictors, as well as variables inducing an OR change > 10%, were deemed confounders and were thus added to the cause-specific Cox regression model.[2] A time-dependent covariate was added to the model to adjust for violation of proportional hazards (if present).[12] Hazard ratios (HRs) were presented with 95% confidence intervals (CIs), and $P < .05$ was considered significant.

To assess differences in the PROMs (secondary outcome) at different time points (preoperatively, 3 months postoperatively, and 12 months postoperatively) between the 2 groups, a linear mixed-effects model for each PROM was carried out (with time and indication as main effects). The endpoint was revision, so

PROMs collected after revision procedures were excluded from analysis. First, the models were run with a random intercept; second, they were run with a random intercept and slope. The best-fitting model was used (based on −2LL), and subsequently, an interaction term of Time × Indication was added to assess differences over time. A standard variance components covariance structure was used for the random factors, and the final model was performed with the restricted maximum likelihood. Because of the overall low PROM response rate, demographic variables were compared between the patients who completed the questionnaires and those who did not.

To determine the minimal clinically important difference (MCID), patients were classified into 3 groups: unchanged (anchor question score of 1-4), changed (anchor question score of 5 or 6), or strongly improved (anchor question score of 7). In line with other studies, our study defined the MCID as the differential between the unchanged group and the changed group, so patients who reported a strong improvement were excluded.[23,24] An independent *t* test was used to compare the mean values of the unchanged and changed groups at 3 months and 1 year postoperatively. Analyses were not stratified for indication.

Results

Demographic characteristics

In this study, 10,857 patients were included, of whom 8753 underwent RTSA for degenerative conditions (predominantly osteoarthritis or cuff arthropathy) and 2104 underwent RTSA for fractures (Table I). The median follow-up period was similar in the 2 groups: 2.23 years (range, 0-7 years) for those with degenerative conditions and 2.25 years (range, 0-7 years) for those with fractures. In the degenerative condition group, the mean age of the patients was 74.3 ± 7.2 years and most of the patients were women (73.9%); in the fracture cohort, the mean age was 74.3 ± 7.8 years and an even greater percentage of patients were women (85.3%). Besides age and BMI, all other parameters (sex, side, ASA score, Walch classification, smoking status, type of fixation, and surgical approach) were significantly different at baseline ($P < .001$) (Table II).

Revision rate

The revision rate in both groups was 3.1%. In the fracture cohort, patients required a reoperation on average at 64 days (range, 1-1555 days) after primary arthroplasty, whereas patients with degenerative conditions underwent revision at a mean of 260 days (range, 1-2402 years) after primary arthroplasty. Among all fracture patients who required revision, the most common reason for reoperation was instability (56.9%) at final follow-up (7 years). Among the patients with degenerative conditions, infection was most frequently reported (38.8%) (Supplementary Tables S1 and S2). The unadjusted Kaplan-Meier curve showed an overall revision rate of 4.3% (95% CI, 3.8-5.0) for degenerative conditions (competing risk, 17.1%; 95% CI, 15.6-18.7) and an overall revision rate of 3.6% (95% CI, 2.8%-4.7%) for fractures (competing risk, 28.2%; 95% CI, 24.5%-32.5%) after 6 years (Table III, Supplementary Table S3). RTSAs performed for fractures showed an early steep decline in survivorship, and the fracture curve intersected the degenerative condition curve at 3.6 years (Fig. 1). Crossover was also seen in the log survival curve; hence, the assumption of proportional hazards was violated. Next, multivariable analysis was performed and revealed age, sex, and brand as confounders. The cause-specific Cox proportional hazards regression analysis was thus controlled for a time-dependent effect of indication and these confounders. The model demonstrated that patients with fractures exhibited a significantly higher likelihood of undergoing revision, particularly in the first year after the primary surgical procedure (HR, 2.50; 95% CI, 1.66-3.77). Over time, the hazards for undergoing revision in the fracture group decreased, with an HR of 0.98 at year 6 (Fig. 1, Table III, Supplementary Table S4).

Table I Distribution of RTSA indications within cohort (N = 10,857)

	n (%)
Osteoarthritis	3957 (36.4)
Cuff arthropathy	3676 (33.9)
Acute fracture	2104 (19.4)
Irreparable cuff tear	808 (7.4)
Rheumatoid arthritis	312 (2.9)

RTSA, reverse total shoulder arthroplasty.

Patient-reported outcome measures

Apart from the recommendation score (measuring to what extent one would recommend joint replacement to a friend or relative) at 12 months in favor of the fracture group, there were no clinically relevant differences at follow-up between the degenerative condition cohort and the fracture cohort with respect to the PROMs. At 1 year postoperatively, the OSS reached 35.7 points in the degenerative condition group and 35.5 points in the fracture group (Table IV, Supplementary Table S5).

Conventional vs. fracture-specific stems

In the acute fracture group, 1137 patients received conventional stem designs (mean age, 74.3 ± 7.8 years) and 675 patients received fracture-specific stem designs (mean age, 74.8 ± 7.6 years), with baseline differences in sex, Walch classification, type of fixation, and surgical approach (Supplementary Tables S6 and S7). Conventional designs yielded 41 revisions (3.6%) whereas fracture-specific

Table II Demographic variables at baseline

	Degenerative condition (n = 8753)	Acute fracture (n = 2104)	*P* value
Age, yr	74.3 ± 7.2	74.3 ± 7.8	.72
Sex			<.001
Female	6468 (73.9)	1794 (85.3)	
Male	2282 (26.1)	310 (14.7)	
Side			<.001
Right	5266 (60.2)	1141 (54.2)	
Left	3487 (39.8)	963 (45.8)	
ASA score			<.001
I	447 (5.1)	112 (5.3)	
II	5305 (60.6)	1143 (54.3)	
III or IV	2916 (33.3)	813 (38.6)	
Walch classification			<.001
A1	3867 (44.2)	987 (46.9)	
A2	2385 (27.2)	72 (3.4)	
B1-B3	1757 (20.1)	50 (2.3)	
C	115 (1.3)	7 (0.3)	
No osteoarthritis	176 (2.0)	791 (37.6)	
BMI	28.2 ± 5.0	28.1 ± 5.6	.76
Smoking status	669 (7.6)	282 (13.4)	<.001
Previous surgery	1462 (16.7)	66 (3.1)	<.001
Fixation			<.001
Cementless	7676 (87.7)	456 (21.7)	
Cemented	1052 (12.0)	1645 (78.3)	
Surgical approach			<.001
Deltopectoral	5406 (61.8)	1417 (67.3)	
Anterosuperior	3180 (36.3)	584 (27.8)	
Other	147 (1.7)	98 (4.7)	
RTSA survivorship, yr	2.23 (0.00-7.00)	2.25 (0.00-7.00)	<.001

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *RTSA*, reverse total shoulder arthroplasty.
Data are presented as mean ± standard deviation, median (range), or number (percentage).

designs yielded 13 revisions (1.9%), with instability as the most common reason for reoperation (Supplementary Table S8). At 4 years after the primary procedure, the revision rate adjusted for age and sex was 3.0% for conventional stems and 1.8% for fracture-specific stems. As shown by a cause-specific Cox regression model, however, conventional designs were not more likely to require a revision procedure (HR, 1.70; 95% CI, 0.91-3.17) (Fig. 2). PROMs were compared via a linear mixed-effects model with a random intercept, and only the score assessing change in daily functioning showed a significant difference (patients with fracture-specific designs scored 4.8 points at 1 year postoperatively, 1.3 points higher than those with conventional stems). All other PROMs did not produce statistically significant differences (Table V).

Discussion

This study analyzed data from the Dutch Arthroplasty Register to assess whether RTSA for fractures conveyed a higher revision rate than RTSA for degenerative conditions and whether one of these indications (fracture or degenerative conditions) portended inferior patient-reported outcomes following primary RTSA. After adjustment for time, age, sex, and brand, we found that patients with fractures were more likely to require a revision procedure at 1 year after the primary procedure, with an HR of 2.5. However, no differences in PROMs could be detected before revision was needed. A subanalysis of the fracture group indicated that conventional stem designs did not produce greater hazards for undergoing revision compared with fracture-specific stems, and apart from a lower perception of daily functioning, there were no differences in all patient-reported outcomes.

Revision rate

Patients with fractures had a higher likelihood of undergoing a revision procedure than patients with degenerative conditions (HR, 2.50) at 1 year after primary RTSA. In a study carried out in 2021, the authors compared fractures vs. elective preoperative conditions (osteoarthritis, rotator cuff arthropathy, irreparable rotator cuff tears, rheumatoid

Table III Cumulative crude revision rates and adjusted HRs according to indication

	Degenerative condition		Fracture		HR	
	Cumulative revision rate (per Kaplan-Meier analysis), %	At risk	Cumulative revision rate (per Kaplan-Meier analysis), %	At risk	Crude	Adjusted
1 yr	2.0 (1.7-2.3)	7223	2.7 (2.1-3.6)	1577	1.69	2.50
2 yr	2.7 (2.4-3.1)	5455	3.2 (2.5-4.1)	1146	1.14	1.74
3 yr	3.2 (2.8-3.6)	3947	3.5 (2.7-4.4)	788	0.91	1.41
4 yr	3.6 (3.2-4.1)	2590	3.5 (2.7-4.4)	499	0.77	1.21
5 yr	4.1 (3.6-4.6)	1519	3.6 (2.8-4.7)	272	0.68	1.08
6 yr	4.3 (3.8-5.0)	623	3.6 (2.8-4.7)	106	0.61	0.98

HR, hazard ratio.
Cumulative revision rate is presented as percentage (95% confidence interval). HRs were adjusted for a time-dependent covariate, age, sex, and brand.

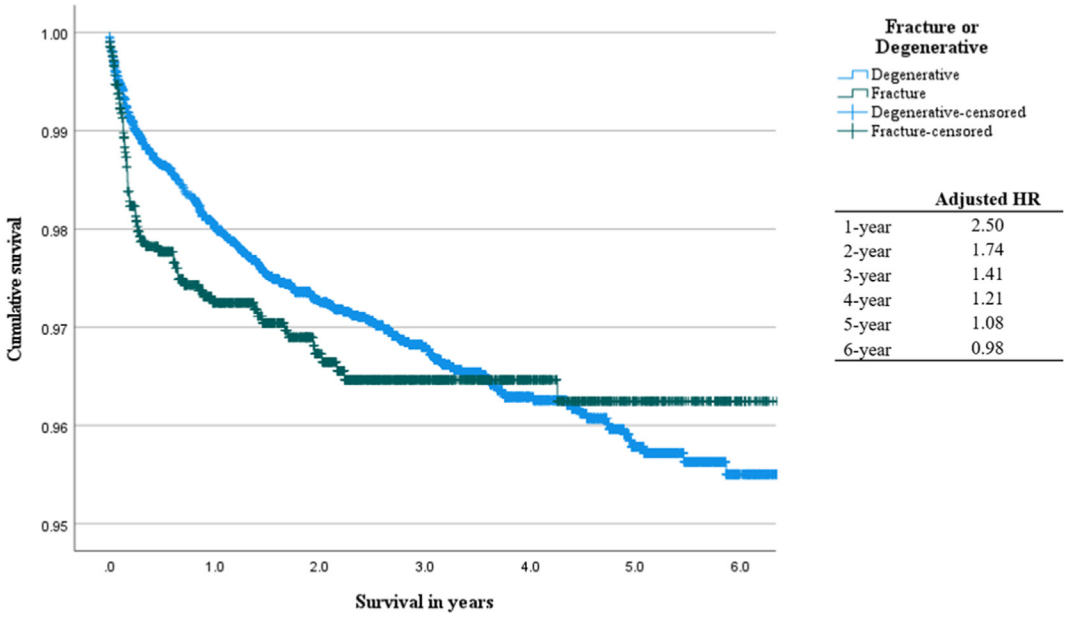

Figure 1 Crude survival curve according to primary indication with hazard ratios (HRs) adjusted for time-dependent covariate, age, sex, and brand.

arthritis, avascular necrosis, and trauma sequelae) and found revision rates of 2.9% in the fracture group and 4.6% in the elective condition group (nonsignificant difference).[5] Their work was very valuable as indicated by the reasonably long follow-up time (50 months for fractures and 46 months for elective procedures) and assessment of various outcome measures (PROMs, range of motion, and intraoperative and postoperative complications).[5] However, a survival analysis was lacking, so the question of whether RTSA for fracture would lead to a higher revision rate remained unanswered; moreover, given that the study only included 108 patients in the fracture group, the results should be interpreted cautiously. A recent systematic review also explored this topic and compared several indications separately (osteoarthritis, rotator cuff arthropathy, irreparable rotator cuff tear, rheumatoid arthritis, fracture, and revision).[11] The mean time to follow-up in the fracture cohort was 36 months, and complications occurred in 11% of patients.[11] What percentage of these complications led to reoperations was not reported, so comparison to our study is not possible.

Patient-reported outcome measures

Aside from a minimal difference in the recommendation score at 12 months postoperatively (degenerative conditions, 2.47; fractures, 3.03; MCID, 0.51), we did not demonstrate any differences regarding the PROMs. A 2020 systematic review compared fractures vs. glenohumeral osteoarthritis and revealed a lower Constant-Murley score (CMS) in the fracture group (CMS of 55) compared with

Table IV Mean PROMs preoperatively and at 3 and 12 months postoperatively for indications of degenerative condition vs. fracture

	Degenerative condition		Fracture		Mixed-effects model	
	Mean (95% CI)	n	Mean (95% CI)	n	β (95% CI)	*P* value
Pain at rest (0 to 10)						
Preoperatively	6.3 (6.1 to 6.4)	1597	6.3 (5.9 to 6.7)	152	−0.2 (−0.8 to 0.3)	.41
3 mo postoperatively	2.2 (2.1 to 2.4)	1009	2.6 (2.0 to 3.2)	81	−0.6 (−1.2 to 0.1)	.08
12 mo postoperatively	1.5 (1.4 to 1.6)	951	1.3 (0.9 to 1.8)	86	0.2 (−0.3 to 0.6)	.52
Pain during activity (0 to 10)						
Preoperatively	7.9 (7.8 to 8.0)	1597	8.2 (7.8 to 8.5)	152	−0.3 (−0.9 to 0.3)	.32
3 mo postoperatively	3.7 (3.5 to 3.8)	1009	4.1 (3.5 to 4.7)	81	−0.4 (−1.0 to 0.3)	.23
12 mo postoperatively	2.4 (2.3 to 2.6)	951	2.5 (1.9 to 3.0)	86	0.0 (−0.5 to 0.5)	.98
EQ-5D index score (−0.329 to 1)						
Preoperatively	0.53 (0.52 to 0.54)	1597	0.34 (0.30 to 0.38)	152	0.20 (0.16 to 0.25)	<.001
3 mo postoperatively	0.71 (0.70 to 0.72)	1009	0.65 (0.60 to 0.69)	81	0.08 (0.03 to 0.12)	.003
12 mo postoperatively	0.74 (0.73 to 0.75)	951	0.75 (0.71 to 0.79)	86	−0.02 (−0.06 to 0.02)	.42
EQ-5D thermometer score (0 to 100)						
Preoperatively	66.4 (65.5 to 67.3)	1597	58.3 (54.7 to 62.0)	152	10.1 (5.0 to 15.3)	<.001
3 mo postoperatively	70.9 (69.6 to 72.2)	1009	69.4 (65.1 to 73.8)	81	4.9 (-0.8 to 10.6)	.09
12 mo postoperatively	72.7 (71.5 to 73.9)	951	74.6 (70.2 to 78.9)	86	−2.3 (−6.8 to 2.1)	.30
Oxford Shoulder Score (0 to 48)						
Preoperatively	17.4 (17.0 to 17.8)	1597	10.4 (8.8 to 12.0)	152	7.3 (5.1 to 9.6)	<.001
3 mo postoperatively	28.7 (28.1 to 29.4)	1009	23.5 (21.1 to 26.0)	81	5.7 (3.1 to 8.2)	<.001
12 mo postoperatively	35.7 (35.0 to 36.3)	951	35.5 (33.3 to 37.7)	86	−0.2 (−2.2 to 1.8)	.87
Recommendation score (1 to 5)						
3 mo postoperatively	2.5 (2.4 to 2.6)	1083	2.8 (2.5 to 3.1)	88	0.0 (−0.3 to 0.3)	.98
12 mo postoperatively	2.4 (2.3 to 2.5)	1027	3.0 (2.6 to 3.3)	92	−0.5 (−0.8 to −0.2)	.002
Change in daily functioning (1 to 7)						
3 mo postoperatively	5.3 (5.3 to 5.4)	1083	3.9 (3.5 to 4.2)	88	−0.2 (−0.5 to 0.2)	.37
12 mo postoperatively	5.7 (5.6 to 5.8)	1027	4.0 (3.6 to 4.3)	92	1.6 (1.3 to 1.9)	<.001
Change in pain (1 to 7)						
3 mo postoperatively	5.8 (5.7 to 5.9)	1083	5.1 (4.8 to 5.5)	88	−0.2 (−0.5 to 0.1)	.30
12 mo postoperatively	6.1 (6.0 to 6.1)	1027	5.3 (5.0 to 5.6)	92	0.8 (0.5 to 1.0)	<.001

PROM, patient-reported outcome measure; *CI*, confidence interval; *EQ-5D*, EuroQol 5 Dimensions.
The β value with corresponding *P* value was derived from linear mixed modeling.

the glenohumeral osteoarthritis group (CMS of 70).[4] This finding may indicate a benefit for elective indications, but because our study also included other entities such as rheumatoid arthritis, it is not surprising that we did not find any differences. The work by Crespo et al[5] revealed—in line with our findings—no differences in the CMS, the Simple Shoulder Test score, the American Shoulder and Elbow Surgeons shoulder score, or pain and disability related to shoulder problems (Shoulder Pain and Disability Index [SPADI]). In their review, Kennedy et al[11] found a high CMS in the glenohumeral osteoarthritis group but a similar CMS across the other preoperative diagnoses (rotator cuff arthropathy, rotator cuff tear, and rheumatoid arthritis); the Simple Shoulder Test score, on the other hand, was similar between the groups. It should be acknowledged that these studies included different PROMs than those in our study; in addition, the study by Crespo et al included avascular necrosis and traumatic sequelae in its elective cohort. Taken together, these findings seem to indicate that glenohumeral osteoarthritis alone may yield higher PROMs than the other indications for RTSA, but when these indications are combined, differences are not demonstrated.

The validity of PROMs in musculoskeletal research remains a topic of ongoing debate. Unsurprisingly, this study did not find differences in PROMs, which could be explained by the myriad factors for which this study did not adjust: the timing of filling out the questionnaires (unpleasant life events at the time of survey completion may introduce bias), low responsiveness, baseline demographic differences, and the fact that some complications requiring reoperations have a rapid onset (eg, periprosthetic fracture and dislocation). The occurrence of such an event after questionnaire completion could have biased the PROMs.

Conventional vs. fracture-specific stems

In a recent systematic review, the authors pooled the outcome measures for non-fracture and fracture-specific stems.[15] They found a higher American Shoulder and

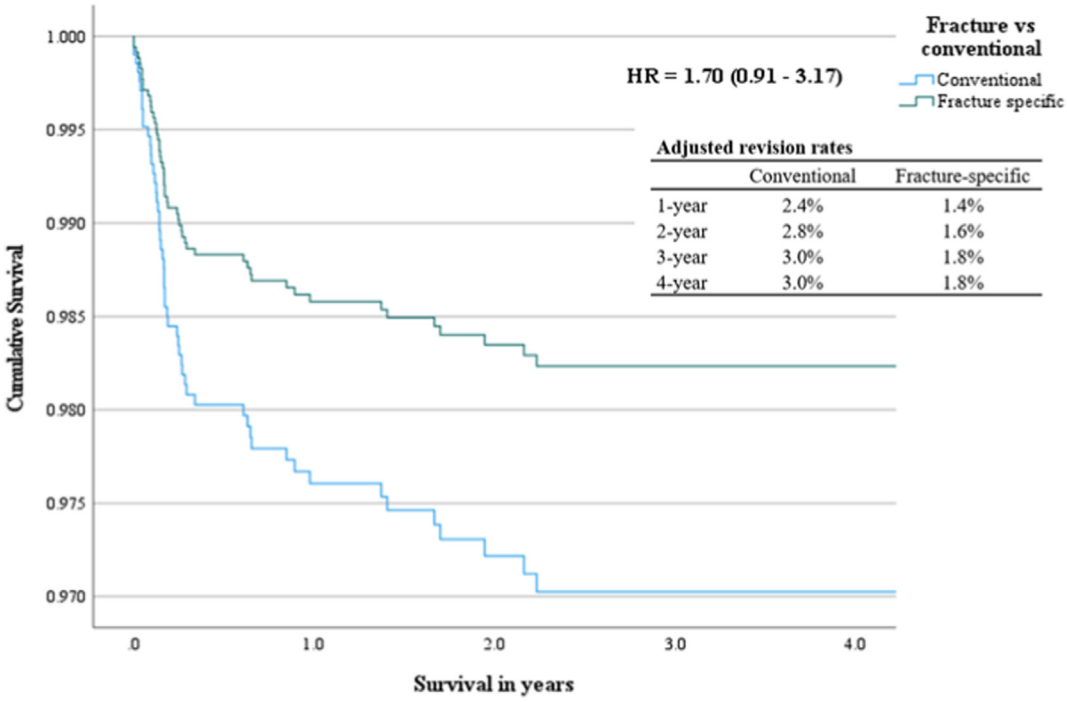

Figure 2 Survival curve adjusted for age and sex displaying conventional vs. fracture-specific humeral designs among patients who underwent arthroplasties for fractures. *HR*, hazard ratio.

Elbow Surgeons score with better forward flexion and external rotation, as well as a higher rate of greater tuberosity healing, in patients who received fracture-specific stems. The heterogeneity of the population is noteworthy, as are the limited sample size (138 conventional designs vs. 192 fracture designs) and the inclusion of both RTSAs and hemiarthroplasties.[15] We acknowledge that our study may have introduced selection bias (as the RTSA design was unknown in 12.2% of cases) and that the absence of tuberosity healing as an outcome is a flaw. Nevertheless, our study did not show any differences regarding revision rate between conventional and fracture-specific stems. It should be underscored that a randomized controlled trial would be the most appropriate next step before guidelines for practice can be changed.

Implications for practice

RTSA for complex proximal humeral fractures in the absence of major comorbidities has become the treatment of choice in active geriatric patients; hence, the number of procedures is likely to increase further in the coming years.[1] In practice, our findings can be used for surgical decision making (RTSA does not come without risks), management of patient expectations (known to influence shoulder arthroplasty outcomes), and the evaluation of expected health care costs and resource utilization by insurance companies and hospitals.[18,19] The outcomes of the various preoperative conditions in the literature should not be synthesized, and although there were no differences in PROMs, this study should spark a discussion on improving RTSA outcomes in the setting of a fracture: How can we reduce the early revision rate owing to instability? Possible explanations are soft-tissue tensioning (eg, subscapularis repair), implant positioning (more challenging in the fracture setting), and tuberosity healing.[10,20] Further investigations are warranted: We advise repeating this work in a few years, allowing for the 10-year outcomes to be evaluated. We also advise incorporating other relevant clinical outcomes such as the earlier discussed complication profiles, range-of-motion evaluation, and radiographic assessment into future study designs.

Strengths and limitations

Revision as the primary endpoint is regarded as a well-defined and accepted outcome measure within the field of arthroplasty, so one can argue that our ability to conduct a time-to-event analysis on this variable is unique and a strength of this study. Other strengths are the high number of patients included, the high volume of participating hospitals (and thus a wide range of different surgeons), the long follow-up time, and the excellent registration rate (in 2020, 96% of all shoulder arthroplasties performed by orthopedic surgeons were registered). Our study's applicability to clinical practice is therefore high.

Some limitations should be considered and fostered while reading our work. First, the completeness of PROMs is unfortunately quite low: Collection of these questionnaires started relatively late as it took time to gain

Table V Subanalysis of PROMs in fracture cohort: conventional vs. fracture-specific humeral component designs

	Conventional design		Fracture-specific design		Mixed-effects model	
	Mean (95% CI)	n	Mean (95% CI)	n	β (95% CI)	*P* value
Pain at rest (0 to 10)						
Preoperatively	6.3 (5.8 to 6.8)	82	6.2 (5.3 to 7.1)	34	−0.7 (−2.2 to 0.7)	.33
3 mo postoperatively	2.7 (1.9 to 3.5)	46	2.2 (1.0 to 3.4)	20	−0.3 (−1.9 to 1.2)	.66
12 mo postoperatively	1.7 (1.1 to 2.3)	45	0.9 (−0.3 to 2.0)	17	0.7 (−0.5 to 2.0)	.25
Pain during activity (0 to 10)						
Preoperatively	8.3 (7.8 to 8.8)	82	7.5 (6.7 to 8.3)	34	−0.9 (−2.4 to 0.7)	.28
3 mo postoperatively	4.4 (3.5 to 5.2)	46	3.1 (2.0 to 4.2)	20	−0.4 (−2.0 to 1.3)	.66
12 mo postoperatively	2.8 (2.0 to 3.5)	45	1.4 (0.3 to 2.4)	17	1.2 (−0.1 to 2.5)	.06
EQ-5D index score (−0.329 to 1)						
Preoperatively	0.32 (0.26 to 0.38)	82	0.42 (0.33 to 0.52)	34	0.01 (−0.11 to 0.14)	.85
3 mo postoperatively	0.63 (0.57 to 0.69)	46	0.70 (0.62 to 0.79)	20	0.00 (−0.14 to 0.13)	.97
12 mo postoperatively	0.73 (0.68 to 0.78)	45	0.81 (0.73 to 0.88)	17	−0.09 (−0.20 to 0.03)	.15
EQ-5D thermometer (0 to 100)						
Preoperatively	59.0 (54.0 to 64.0)	82	63.4 (55.7 to 71.0)	34	0.6 (−11.8 to 13)	.92
3 mo postoperatively	67.8 (61.8 to 73.8)	46	73.3 (65.1 to 81.5)	20	8.4 (−4.4 to 21.1)	.20
12 mo postoperatively	73.1 (67.4 to 78.9)	45	75.1 (65.6 to 84.5)	17	1.9 (−9.5 to 13.3)	.74
Oxford Shoulder Score (0 to 48)						
Preoperatively	10.8 (8.3 to 13.3)	82	10.7 (8.5 to 12.8)	34	5.4 (−1.1 to 11.9)	.10
3 mo postoperatively	24.4 (21.0 to 27.8)	46	25.4 (20.6 to 30.2)	20	2.9 (−4.1 to 9.9)	.41
12 mo postoperatively	33.8 (30.6 to 37.0)	45	37.8 (34.3 to 41.4)	17	−4.6 (−10.1 to 1.0)	.11
Recommendation score (1 to 5)						
3 mo postoperatively	2.9 (2.5 to 3.3)	51	2.6 (2.0 to 3.2)	21	0.0 (−0.6 to 0.7)	.90
12 mo postoperatively	3.5 (3.1 to 4.0)	50	2.9 (2.2 to 3.7)	18	0.5 (−0.3 to 1.2)	.23
Change in daily functioning (1 to 7)						
3 mo postoperatively	3.9 (3.5 to 4.4)	51	3.9 (3.0 to 4.8)	21	1.2 (0.1 to 2.4)	.03
12 mo postoperatively	3.5 (3.0 to 4.0)	50	4.8 (4.2 to 5.5)	18	−1.2 (−2.1 to −0.3)	.008
Change in pain (1 to 7)						
3 mo postoperatively	5.2 (4.8 to 5.7)	51	5.0 (4.3 to 5.8)	21	0.2 (−0.7 to 1.1)	.68
12 mo postoperatively	5.2 (4.8 to 5.7)	50	5.2 (4.5 to 5.8)	18	0.0 (−0.8 to 0.9)	.91

PROM, patient-reported outcome measure; *CI*, confidence interval; *EQ-5D*, EuroQol 5 Dimensions.
The β value with corresponding *P* value was derived from linear mixed modeling.

awareness and incorporate them as standard of care. There were also differences in demographic characteristics between patients with missing PROMs and those with non-missing PROMs: In the degenerative condition group, there were slight differences in age, sex, and ASA score. In the fracture group, statistically significant differences in age and BMI were present (Supplementary Table S9). Second, the study findings are based on the Dutch population, so whether our findings are also valid on a global scale is unknown. Third, there were differences in baseline demographic characteristics with respect to the ASA score and previous surgery, which could have made surgeons decide not to opt for revision procedures in low-demanding older adults, potentially underestimating the revision requirement. The comorbidities of the patients were also unknown and could have influenced the outcomes (number of comorbidities is associated with lower outcomes).[21] Fourth, because of the many participating hospitals and included brands, the subanalysis on design could not be adjusted for these factors. Moreover, mixed-effects modeling on the PROMs was performed without a random slope owing to the limited PROM availability. Fifth, revision was registered only when one of the arthroplasty components was exchanged. Thus, the revision rate in the fracture group was likely underestimated because periprosthetic fractures are sometimes managed with plate fixation only. Finally, confounding may have been introduced because revision surgery depends on multiple factors that are not all included in the register (eg, surgical technique and surgeon's experience).

Conclusion

Patients with fractures are more likely to require revision procedures compared with patients with degenerative conditions when they are treated with RTSA, particularly within the first year after the primary procedure. Although RTSA is regarded as a reliable, quick, and safe

treatment option for fractures, surgeons should inform patients accordingly and incorporate this information in decision making when opting for head replacement surgery. No differences in PROMs were revealed, and fracture-specific stem designs did not yield lower revision rates than conventional stems.

Acknowledgment

We thank the Dutch Arthroplasty Register for providing the data, as well as all the operating theater staff at participating hospitals throughout the Netherlands for collecting the data.

Disclaimers:

Funding: No funding was received to carry out this specific study.
Conflicts of interest: Reinier W.A. Spek has received payments between $10,000 and $100,000 from Prins Bernhard Cultuurfonds (Amsterdam, The Netherlands) and Flinders Foundation (Adelaide, SA, Australia) and payments < $10,000 from Michael van Vloten Foundation (Rotterdam, The Netherlands) and Anna Fonds Nederlands Orthopedisch Research en Educatie Fonds (NOREF) (Mijdrecht, The Netherlands). All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2023.05.013.

References

1. Abdel Khalik H, Humphries B, Zoratti M, Axelrod D, Kruse C, Ristevski B, et al. Reverse total shoulder arthroplasty is the most cost-effective treatment strategy for proximal humerus fractures in older adults: a cost-utility analysis. Clin Orthop Relat Res 2022;480:2013-26. https://doi.org/10.1097/corr.0000000000002219
2. Budtz-Jørgensen E, Keiding N, Grandjean P, Weihe P. Confounder selection in environmental epidemiology: assessment of health effects of prenatal mercury exposure. Ann Epidemiol 2007;17:27-35. https://doi.org/10.1016/j.annepidem.2006.05.007
3. Completeness - LROI Report - Information on orthopaedic prosthesis procedures in The Netherlands. Available at: https://www.lroi-report.nl/data-quality/completeness/. Accessed August 17, 2022
4. Coscia AC, Matar RN, Espinal EE, Shah NS, Grawe BM. Does preoperative diagnosis impact patient outcomes following reverse total shoulder arthroplasty? A systematic review. J Shoulder Elbow Surg 2020;30:1458-70. https://doi.org/10.1016/j.jse.2020.10.003
5. Crespo AM, Luthringer TA, Frost A, Khabie L, Roche C, Zuckerman JD, et al. Does reverse total shoulder arthroplasty for proximal humeral fracture portend poorer outcomes than for elective indications? J Shoulder Elbow Surg 2021;30:40-50. https://doi.org/10.1016/j.jse.2020.03.053
6. Critchley O, McLean A, Page R, Taylor FJ, Graves S, Lorimer M, et al. Reverse total shoulder arthroplasty compared to stemmed hemiarthroplasty for proximal humeral fractures: a registry analysis of 5,946 patients. J Shoulder Elbow Surg 2020;29:2538-47. https://doi.org/10.1016/j.jse.2020.04.005
7. Dillon MT, Prentice HA, Burfeind WE, Chan PH, Navarro RA. The increasing role of reverse total shoulder arthroplasty in the treatment of proximal humerus fractures. Injury 2019;50:676-80. https://doi.org/10.1016/j.injury.2019.01.034
8. Doany ME, Ling K, Jeong R, Nazemi A, Komatsu DE, Wang ED. Comparison of early range of motion in reverse shoulder arthroplasty based on indication: a single center retrospective review. J Shoulder Elb Arthroplast 2022;6:247154922211082. https://doi.org/10.1177/24715492221108283
9. Fraser AN, Bjørdal J, Wagle TM, Karlberg AC, Lien OA, Eilertsen L, et al. Reverse shoulder arthroplasty is superior to plate fixation at 2 years for displaced proximal humeral fractures in the elderly: a multicenter randomized controlled trial. J Bone Joint Surg Am 2020;102:477-85. https://doi.org/10.2106/JBJS.19.01071
10. Jo O, Borbas P, Grubhofer F, Ek ET, Pullen C, Treseder T, et al. Prosthesis designs and tuberosity fixation techniques in reverse total shoulder arthroplasty: influence on tuberosity healing in proximal humerus fractures. J Clin Med 2021;10:4146. https://doi.org/10.3390/JCM10184146
11. Kennedy J, Klifto CS, Ledbetter L, Bullock GS. Reverse total shoulder arthroplasty clinical and patient-reported outcomes and complications stratified by pre-operative diagnosis: a systematic review. J Shoulder Elbow Surg 2020;30:929-41. https://doi.org/10.1016/j.jse.2020.09.028
12. Kuitunen I, Ponkilainen VT, Uimonen MM, Eskelinen A, Reito A. Testing the proportional hazards assumption in cox regression and dealing with possible non-proportionality in total joint arthroplasty research: methodological perspectives and review. BMC Musculoskelet Disord 2021;22:1-7. https://doi.org/10.1186/S12891-021-04379-2/TABLES/2
13. Liu JN, Agarwalla A, Gowd AK, Romeo AA, Forsythe B, Verma NN, et al. Reverse shoulder arthroplasty for proximal humerus fracture: a more complex episode of care than for cuff tear arthropathy. J Shoulder Elbow Surg 2019;28:2139-46. https://doi.org/10.1016/j.jse.2019.03.032
14. Malik AT, Bishop JY, Neviaser AS, Beals CT, Jain N, Khan SN. Shoulder arthroplasty for a fracture is not the same as shoulder arthroplasty for osteoarthritis: implications for a bundled payment model. J Am Acad Orthop Surg 2019;27:927-32. https://doi.org/10.5435/JAAOS-D-18-00268
15. Onggo JR, Nambiar M, Onggo JD, Hau R, Pennington R, Wang KK. Improved functional outcome and tuberosity healing in patients treated with fracture stems than nonfracture stems during shoulder arthroplasty for proximal humeral fracture: a meta-analysis and systematic review. J Shoulder Elbow Surg 2021;30:695-705. https://doi.org/10.1016/J.JSE.2020.09.044
16. Paras T, Raines B, Kohut K, Sabzevari S, Chang YF, Yeung M, et al. Clinical outcomes of reverse total shoulder arthroplasty for elective indications versus acute 3- and 4-part proximal humeral fractures: a systematic review and meta-analysis. J Shoulder Elbow Surg 2022;31:e14-21. https://doi.org/10.1016/j.jse.2021.07.014

17. Qin CD, Helfrich MM, Fitz DW, Hardt KD, Beal MD, Manning DW. The Lawrence D. Dorr surgical techniques & technologies award: differences in postoperative outcomes between total hip arthroplasty for fracture vs osteoarthritis. J Arthroplasty 2017;32:S3-7. https://doi.org/10.1016/j.arth.2017.01.049
18. Rauck RC, Swarup I, Chang B, Dines DM, Warren RF, Gulotta LV, et al. Effect of preoperative patient expectations on outcomes after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2018;27:e323-9. https://doi.org/10.1016/j.jse.2018.05.026
19. Rauck RC, Swarup I, Chang B, Ruzbarsky JJ, Dines DM, Warren RF, et al. Preoperative patient expectations of elective reverse shoulder arthroplasty. J Shoulder Elbow Surg 2019;28:1217-22. https://doi.org/10.1016/j.jse.2018.12.008
20. Reuther F, Petermann M, Stangl R. Reverse shoulder arthroplasty in acute fractures of the proximal humerus: does tuberosity healing Improve clinical outcomes? J Orthop Trauma 2019;33:E46-51. https://doi.org/10.1097/BOT.0000000000001338
21. Rozencwaig R, Van Noort A, Moskal MJ, Smith KL, Sidles JA, Matsen FA. The correlation of comorbidity with function of the shoulder and health status of patients who have glenohumeral degenerative joint disease. J Bone Joint Surg Am 1998;80:1146-53.
22. Schairer WW, Lane JM, Halsey DA, Iorio R, Padgett DE, McLawhorn AS. The Frank Stinchfield award: total hip arthroplasty for femoral neck fracture is not a typical DRG 470: a propensity-matched cohort study. Clin Orthop Relat Res 2017;475:353-60. https://doi.org/10.1007/s11999-016-4868-2
23. Simovitch R, Flurin PH, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the minimal clinically important difference. J Shoulder Elbow Surg 2018;27:298-305. https://doi.org/10.1016/j.jse.2017.09.013
24. Tashjian RZ, Hung M, Keener JD, Bowen RC, McAllister J, Chen W, et al. Determining the minimal clinically important difference for the American Shoulder and Elbow Surgeons score, Simple Shoulder Test, and Visual Analog Scale (VAS) measuring pain after shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:144-8. https://doi.org/10.1016/j.jse.2016.06.007
25. Vektis - business intelligence centrum voor de zorg | Vektis.nl. Available at: https://www.vektis.nl/. Accessed August 17, 2022