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DOI: https://doi.org/10.1016/j.jse.2023.04.034

Originally published at:
Hochreiter, Bettina; Selman, Farah; Calek, Anna-Katharina; Kriechling, Philipp; Götschi, Tobias; Grubhofer, Florian; Wieser, Karl; Bouaicha, Samy (2023). Why is female gender associated with poorer clinical outcome after reverse total shoulder arthroplasty? Journal of Shoulder and Elbow Surgery, 32(11):2355-2365.
DOI: https://doi.org/10.1016/j.jse.2023.04.034

J Shoulder Elbow Surg (2023) ■, 1–11

JOURNAL OF SHOULDER AND ELBOW SURGERY

www.elsevier.com/locate/ymse

Why is female gender associated with poorer clinical outcomes after reverse total shoulder arthroplasty?

Bettina Hochreiter, MD*, Farah Selman, MD, Anna-Katharina Calek, MD, Philipp Kriechling, MD, Tobias Götschi, MSc, Florian Grubhofer, MD, Karl Wieser, MD, Samy Bouaicha, MD

Department of Orthopedics, Balgrist University Hospital, University of Zurich, Zurich, Switzerland

Introduction: There is a lack of gender-specific research after reverse total shoulder arthroplasty (RTSA). Although previous studies have documented worse outcomes in women, a more thorough understanding of why outcomes may differ is needed. We therefore asked: (1) Are there gender-specific differences in preoperative and postoperative clinical scores, complications, surgery-related parameters, and demographics? (2) Is female gender an independent risk factor for poorer clinical outcomes after RTSA? (3) If so, why is female gender associated with poorer outcomes after RTSA?

Materials and Methods: Between 2005 and 2019, 987 primary RTSAs were performed in our institution. After exclusion criteria were applied, data of 422 female and 271 male patients were analyzed. Clinical outcomes (absolute/relative Constant Score [a/rCS] and Subjective Shoulder Value [SSV]), complications (intra- and/or postoperative fracture, loosening), surgery-related parameters (indication, implant-related characteristics), and demographics (age, gender, body mass index, and number of previous surgeries) were evaluated. Preoperative and postoperative radiographs were analyzed (critical shoulder angle, deltoid-tuberosity index, reverse shoulder angle, lateralization shoulder angle, and distalization shoulder angle).

Results: Preoperative clinical scores (aCS, rCS, SSV, and pain level) and postoperative clinical outcomes (aCS and rCS) were significantly worse in women. However, the improvement between preoperative and postoperative outcomes was significantly higher in female patients for rCS ($P = .037$), internal rotation ($P < .001$), and regarding pain ($P < .001$). Female patients had a significantly higher number of intraoperative and postoperative fractures (24.9% vs. 11.4%, $P < .001$). The proportion of female patients with a deltoid-tuberosity index <1.4 was significantly higher than males ($P = .01$). Female gender was an independent negative predictor for postoperative rCS ($P = .047$, coefficient -0.084) and pain ($P = .017$, coefficient -0.574). In addition to female sex per se being a predictive factor of worse outcomes, females were significantly more likely to meet 2 of the 3 most significant predictive factors: (1) significantly worse preoperative clinical scores and (2) higher rate of intra- and/or postoperative fractures.

Conclusions: Female sex is a very weak, but isolated, negative predictive factor that negatively affects the objective clinical outcome (rCS) after RTSA. However, differences did not reach the minimal clinically important difference, and it is not a predictor for the subjective outcome (SSV). The main reason for the worse outcome in female patients seems to be a combination of higher preoperative disability and higher incidence of fractures. To improve the outcome of women, all measures that contribute to the reduction of perioperative fracture risk should be used.

Approval for this study was obtained from the ethical committee of Balgrist University Hospital (Basec no. KEK-ZH-Nr.2018-01494). All subjects gave informed consent to participate. The study was carried out in accordance with the World Medical Association Declaration of Helsinki.

*Reprint requests: Bettina Hochreiter, MD, Department of Orthopedics, Balgrist University Hospital, University of Zurich, Forchstrasse 340, Zurich CH-8008, Switzerland

E-mail address: bettina.hochreiter@balgrist.ch (B. Hochreiter).

https://doi.org/10.1016/j.jse.2023.04.034

Level of evidence: Level III; Retrospective Cohort Design; Prognosis Study

Keywords: Reverse total shoulder arthroplasty; RTSA; gender; sex; female; women; clinical outcome

A number of studies indicate gender differences in shoulder anatomy.[29,30,33] Morphologic variability in the shoulder influences joint biomechanics and plays an important role in total joint arthroplasty planning and execution. Although it has been shown that differences between female and male anatomy exist, there is a lack of gender-specific research in general but specifically after reverse total shoulder arthroplasty (RTSA).[23] However, an understanding of gender differences in the outcome after RTSA is mandatory to manage patient expectations and thereby improve postoperative satisfaction. Jawa et al[18] showed comparable excellent subjective and objective results for both female and male patients after anatomic total shoulder arthroplasty (TSA), but Wong et al[39] and Friedman et al[12] evaluated gender differences in RTSA and showed better subjective and objective outcome scores in male than in female patients. However, the latter study documented worse preoperative scores in women than men. As postoperative satisfaction correlates with preoperative function,[2,17,40] it is not clear whether gender is an actual cause or merely a surrogate for the extent of preoperative disability. Although the above-mentioned studies solely document that differences in preoperative and postoperative clinical scores between male and female patients might exist, several questions remain,[23] and a more thorough understanding of why the outcome after RTSA may differ between men and women is needed. Therefore, we asked:

(1) Are there gender-specific differences in preoperative and postoperative clinical scores, complications, surgery-related parameters (indication, implant-related characteristics), and demographics?
(2) Is female gender an independent risk factor for a poorer clinical outcome after RTSA?
(3) If so, why is female gender associated with a poorer clinical outcome after RTSA?

Materials and methods

This retrospective cohort study analyzed 987 consecutive primary RTSAs performed in our institution (university hospital) between September 2005 and September 2019. In all cases, the Anatomical Shoulder Inverse/Reverse prosthesis (Zimmer Biomet, Warsaw, IN, USA), an onlay type implant with a neck-shaft angle of 155°, was implanted for irreparable rotator cuff tear, rotator cuff arthropathy, primary arthritis with or without rotator cuff tear, humeral head necrosis, or crystal arthropathy through a deltopectoral approach. Arthroplasties for tumors (n = 2), shoulder instability (n = 33), and proximal humerus fractures as well as for fracture sequelae (n = 74) were excluded. If present, the subscapularis tendon was sharply released from the lesser tuberosity and reattached in a transosseous manner. In general, the humeral stem was inserted using a press-fit technique. Only if a press-fit could not be achieved intraoperatively, the stem was cemented. Postoperatively, the arm was immobilized in a sling for 6 weeks with active-assistive motion throughout this period. Follow-up visits were at 6 weeks, 3 months, 6 months, 12 months, 2 years, 5 years, and every 5 years thereafter. To be included in this study, each patient must have had a preoperative evaluation and a follow-up examination no less than 2 years after surgery. Patients with insufficient follow-up (n = 52), patients who did not want their data to be used for research (n = 11), patients with more than 2 previous shoulder surgeries (n = 46), and patients with additional muscle transfers (n = 76) were excluded. All these exclusion criteria were applied in order to generate comparable groups and to exclude obvious reasons that could lead to a reduced function and outcome. A total of 294 patients were excluded. Eventually, 422 female and 271 male patients were included. Demographics (age, gender, body mass index [BMI], and number of previous surgeries), surgery-related parameters (indication and implant-related characteristics), and complications (intraoperative and/or postoperative fracture and loosening) were evaluated. No distinction was made between intraoperative fractures that had to be surgically addressed and completely undisplaced fractures that were only seen on the postoperative radiographs. We used a clinical outcome score (absolute and relative Constant-Murley Score [aCS and rCS]) and a patient-reported outcome measure (Subjective Shoulder Value [SSV]) to quantify outcomes. The rCS is based on an age- and sex-matched normal population, mainly to avoid overestimating differences in strength measurements (between older and younger patients and between women and men).[19] If relative Constant scores are used, absolute scores should be reported at the same time to allow comparisons with different populations. The pain score was taken from the CS (15-point Likert scale). The minimal clinically relevant difference (MCID) used for determining a clinically relevant change in outcomes was 5.7[31] for the aCS. Preoperative and postoperative clinical assessments were done by one independent examiner who had not operated on the patients (shoulder study nurse). This was done in an institutionally standardized manner using a goniometer with the patient in a sitting position. Active range of motion was video-documented in all patients preoperatively and postoperatively (at all annual follow-up visits).

Preoperatively and postoperatively, standardized radiographs were obtained for all patients. Preoperative radiographs were used to measure the critical shoulder angle (CSA)[26] and the deltoid tuberosity index (DTI) (Fig. 1). The DTI correlates with local bone mineral density (BMD) and is measured on anteroposterior radiographs of the shoulder (ratio between the outer cortical and inner endosteal diameter immediately above the deltoid

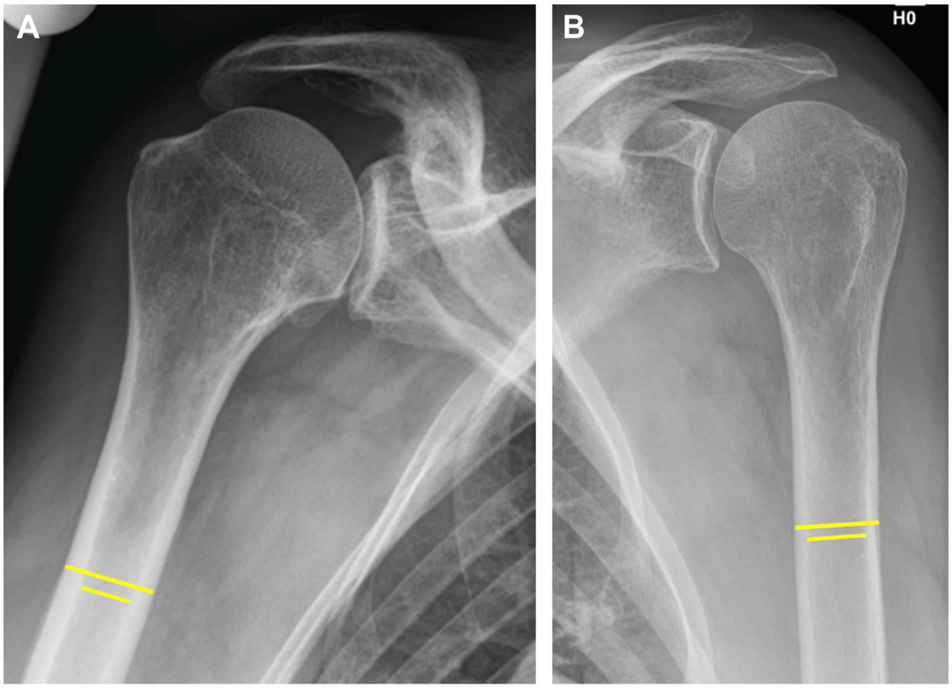

Figure 1 The deltoid tuberosity index (DTI) correlates with local bone mineral density (BMD) and is measured on anteroposterior radiographs of the shoulder (ratio between the outer cortical and inner endosteal diameter immediately above the deltoid tuberosity). Values lower than 1.4 indicate low BMD of the proximal humerus.[35] (**A**) A DTI >1.4 in a 72-year-old male patient. (**B**) A DTI >1.4 in a 63-year-old female patient.

tuberosity). Values lower than 1.4 indicate low BMD of the proximal humerus.[35] For the analysis of parameters regarding implant positioning, we used the first anteroposterior radiograph optimally fulfilling the criteria for standardized radiographs (central beam exactly parallel to the baseplate, the shoulder in internal rotation) that was obtained between 6 weeks and 1 year postoperatively. The inclination of the glenoid baseplate (reverse shoulder angle; Fig. 2, *A*),[6] the lateralization shoulder angle (Fig. 2, *B*), and the distalization shoulder angle (DSA, Fig. 2, *C*)[7] were measured on these radiographs. Radiolucent lines around the glenoid were categorized according to Bogle et al[5] as radiolucent lines around the superior baseplate, inferior baseplate (independent from a notch, if present), central pillar, and around the screws. Radiolucent lines around the humeral shaft were assessed according to Sperling et al[34] (<2 mm or >2 mm in width). A humeral component was considered loose when a lucent line 2 mm or greater in width was present in 3 or more of 8 zones or when tilt or subsidence of the component was identified. Radiographs were assessed by 2 independent orthopedic surgeons who had not operated on the patients.

Statistical analysis

Various outcome variables were not non-normally distributed. Hence, parametric tests and nonparametric tests were used for statistical comparisons between the outcome of males and females depending on distribution. Interval-scaled variables were compared with a Mann-Whitney *U*-test, and categorical outcomes were compared with Fisher exact tests. Linear regressions with a stepwise selection scheme were performed including patient sex and 7 other potentially predictive variables, previously identified in a univariate regression analysis (gender, age, BMI, preoperative rCS, preoperative SSV, DTI, reverse shoulder angle, number of previous shoulder surgeries, and intraoperative and/or postoperative fracture) on various postoperative outcome measures. *P* values below .05 were considered statistically significant. Statistical analysis was conducted with SPSS (version 26.0; IBM, Armonk, NY, USA).

Results

The evaluated parameters and their gender distribution as well as the statistical analyses are presented in Tables I-IV. Male and female patients were comparable regarding age at surgery, affected side, BMI, and follow-up period.

(1) Are there gender-specific differences in preoperative and postoperative clinical scores, complications, surgery-related parameters, and demographics?

Preoperative clinical scores and patient-reported outcome measures (aCS, rCS, SSV, and pain level) as well as postoperative clinical outcomes (aCS and rCS) were significantly worse in women (Table II). However, the difference in aCS did not achieve the MCID of 5.7. Only postoperative internal rotation was significantly better in female patients ($P = .002$). There was no difference in the postoperative subjective outcome (SSV). However, the difference between the preoperative and postoperative

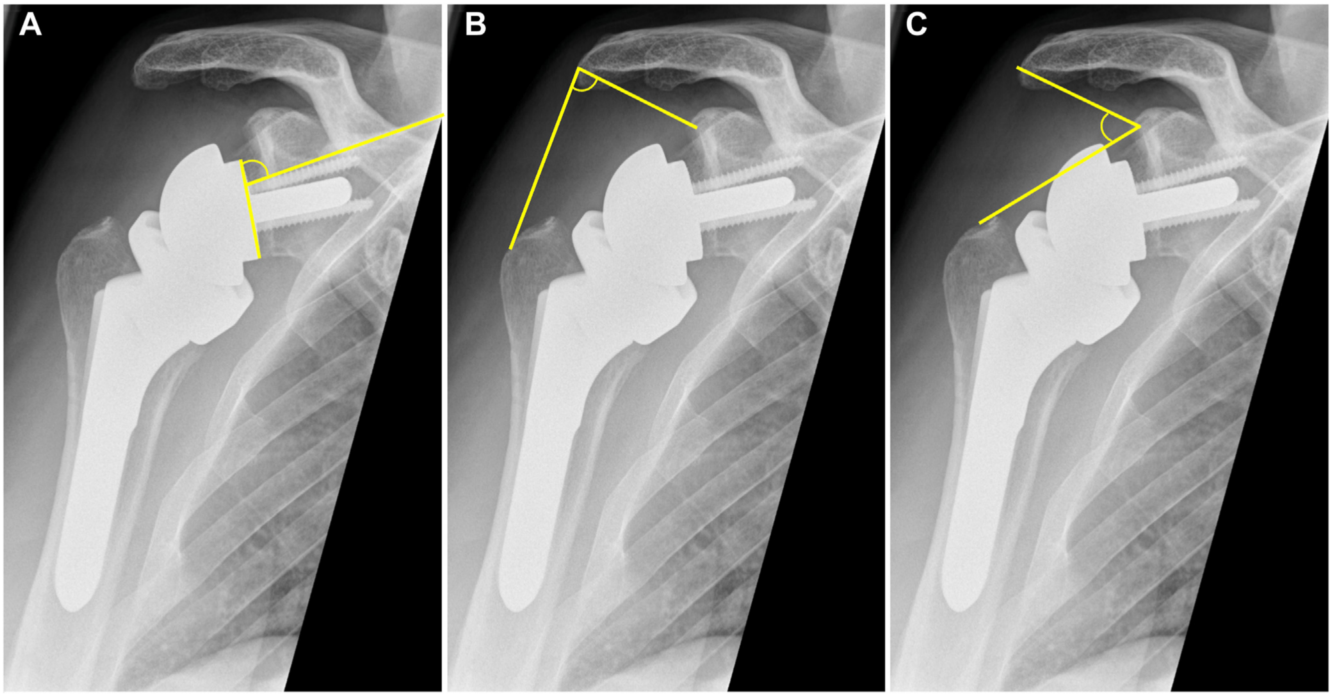

Figure 2 Radiographic measurements. (**A**) The inclination of the glenoid baseplate (reverse shoulder angle),[6] (**B**) the lateralization shoulder angle, and (**C**) the distalization shoulder angle.[7]

outcome and therefore the improvement was significantly higher in female patients for rCS ($P = .037$), internal rotation ($P < .001$), and regarding pain ($P < .001$).

Female patients had a significantly higher number of intraoperative as well as postoperative fractures (26.4% vs. 12.6%, $P < .001$). However, the location of the fracture did not differ between male and female patients. Radiographically, women had a lower DTI ($P < .001$), and the proportion of female patients with a DTI <1.4 (corresponding to local osteopenia) was significantly higher than male patients ($P = .01$).

Female patients had a significantly lower number of prior surgeries before primary RTSA ($P = .005$). For differences in surgery-related parameters and demographics, see Table II.

(2) Is female gender an independent risk factor for a poorer clinical outcome after RTSA?

Female gender was a weak, but independent (negative) predictor for the postoperative rCS ($P = .047$, coefficient −0.084) and postoperative pain ($P = .017$, coefficient −0.574). However, it was not as strong as the other factors that were included in the multivariate analysis, and it was not a predictor for SSV (Table III).

(3) If so, why is female gender associated with a poorer clinical outcome after RTSA?

Forward selection linear regression yielded the preoperative rCS ($P < .001$, coefficient 0.253), the number of previous shoulder surgeries ($P < .001$, coefficient −0.204), and an intraoperative and/or postoperative fracture ($P < .001$, coefficient −0.178) as the main predictive factors for postoperative rCS. For postoperative SSV, an intraoperative and/or postoperative fracture ($P < .001$, coefficient −0.146), the number of previous surgeries ($P < .001$, coefficient −0.233), and the preoperative SSV ($P = .024$, coefficient 0.109) were identified as the main predictive factors. Preoperative rCS was an independent, but not as strong, predictive factor for the postoperative SSV ($P = .042$, coefficient 0.100). The models reached an adjusted R-square of 0.181 and 0.119, respectively. In addition to female sex per se being a predictive factor of a worse outcome, female patients were significantly more likely to meet 2 of the 3 most significant predictive factors.

Already preoperatively, female patients had significantly lower absolute ($P < .001$) and relative CS values ($P < .001$), SSV ($P = .038$), range of motion (regarding flexion [$P = .038$] and internal rotation [$P = .01$]), more pain ($P < .001$), and greater limitation in activities of daily living (ADLs) ($P = .028$).

Furthermore, they suffered an intraoperative and/or postoperative fracture significantly more often. Forward selection logistic regression yielded patient sex to be the most relevant predictor ($P < .001$, coefficient 0.944) for an intraoperative and/or postoperative fracture (Nagelkerke R-square: 0.075). Comparison of patients with and without an intraoperative and/or postoperative fracture showed that aCS, rCS, SSV, daily function (as evaluated in the CS), and

Table I Demographic, surgery/implant associated and radiographic data as well as group comparison

	Female	Male	*P* value[†]
Total (n)	422	271	
Age at surgery (yr)	74.3 (8.2)	69.8 (8.7)	.622
Side (left [l]/right [r])	l: 41, r: 59	l: 40, r: 60	.874
BMI	27 (5.6)	27.8 (4.7)	.721
Previous surgery, n (%)	0: 327 (78)	0: 180 (67.2)	**.005**
	1: 64 (15.3)	1: 66 (24.6)	
	2: 28 (6.7)	2: 22 (8.2)	
FU (mo)	54.3 (31)	57.4 (34.4)	.655
Indication, n (%)			
Irreparable RC tear or insufficiency	139 (33)	113 (41.7)	**.002**
Primary OA + RC tear	130 (30.9)	80 (29.5)	
Primary OA	84 (20)	60 (22)	
Cuff tear arthropathy	52 (12.4)	12 (4.4)	
Crystal arthropathy	4 (1)	1 (0.4)	
Humeral head necrosis	12 (2.9)	4 (1.5)	
Radiographic data			
CSA (°)	35.4 (6.3)	33.5 (5.3)	**.001**
DTI preoperative	1.38 (0.16)	1.43 (0.18)	**.000**
DTI <1.4 (%)	52.6	42.4	**.010**
CSA postoperative (°)	28.7 (7.8)	28.4 (7.2)	.931
RSA postoperative (°)	79.3 (7.8)	79.3 (8.2)	.712
LSA postoperative (°)	81.1 (7.6)	80.5 (6.6)	.069
DSA postoperative (°)	45.1 (11.7)	48.5 (10.3)	**.000**
Implant characteristics			
Glenosphere size (mm; %)	36: 97	36: 51	**.000**
	40: 3	40: 49	
Insert height (mm; %)	0: 55	0: 55	.920
	3: 28	3: 29	
	6: 17	6: 16	
Humeral stem size (mm; %)	7: 10	7: 0.5	**.000**
	9: 28	9: 6	
	10.5: 21	10.5: 7.5	
	12: 31	12: 31	
	14: 10	14: 50	
	16: 0	16: 5	
Humeral stem cemented (%)	40	34	.147
Complications			
Intraoperative or postoperative fracture (%)	111 (26.4)	34 (12.6)	**.000**
Intraoperative fracture (%)	69 (16.4)	23 (8.5)	**.003**
Intraoperative fracture location (%)	Humerus: 67 (97.1)	Humerus: 22 (95.7)	.982
	Acromion: 1 (1.4)	Glenoid: 1 (4.3)	
	Glenoid: 1 (1.4)		
Postoperative fracture (%)	42 (10)	11 (4.1)	**.005**
Postoperative fracture location (%)	Humerus: 27.9	Humerus: 18.2	.783
	Acromion: 55.8	Acromion: 81.8	
	Glenoid: 9.3	Glenoid: 0	
	Spine: 4.7	Spine: 0	
Loosening (%)	20 (4.7)	9 (3.3)	.439
Loosening location (%)	Humerus: 15.8	Humerus: 11.1	.974
	Glenoid: 84.2	Glenoid: 88.9	

BMI, body mass index; *FU*, follow-up; *RC*, rotator cuff; *OA*, osteoarthritis; *CSA*, critical shoulder angle; *DTI*, deltoid-tuberosity index; *RSA*, reverse shoulder angle; *LSA*, lateralization shoulder angle; *DSA*, distalization shoulder angle.
Values in mean, with ± standard deviation in parentheses or exact values if not applicable; significant *P* values are bold.
[†] Fisher exact or Mann-Whitney *U*-test.

Table II Clinical outcome of RTSA and gender comparison

	Female		Male		*P* value*	
	Preoperative	Last FU	Preoperative	Last FU	Preoperative	Last FU
SSV (%)	30.6 (19)	78.4 (21.7)	33.7 (18.1)	79.1 (21.7)	**.038**	.722
aCS (pts)	31.6 (14.7)	63.5 (15.2)	38.0 (15.8)	67.6 (15.9)	**.000**	**.000**
rCS (%)	40.6 (17.8)	77.7 (17.4)	48.0 (18.1)	81.4 (17.7)	**.000**	**.000**
ADLs (pts)	1.2 (1.0)	3.4 (1.0)	1.4 (1.2)	3.5 (1.0)	**.028**	.117
Flexion (°)	84.5 (39.5)	116.5 (27.7)	91.5 (42.6)	121.4 (25.6)	**.038**	**.006**
Abduction (°)	73.9 (36.2)	126.5 (35.2)	80.2 (40.5)	131.2 (33.9)	.083	**.039**
ER (°)	29.9 (24.2)	29.0 (18.7)	32.4 (22.7)	28.3 (17.0)	.204	.855
fIR (pts)	4.2 (2.9)	5.4 (2.7)	4.8 (2.5)	4.8 (2.6)	**.010**	**.002**
Pain level (pts)	5.4 (3.5)	13.4 (2.9)	6.9 (3.7)	13.7 (2.6)	**.000**	.326
Δ SSV (%)	47.8 (26.4)		46.8 (24.3)		.455	
Δ rCS (%)	38.3 (23.0; 53.6)		33.8 (17.9; 51.0)		**.037**	
Δ Flexion (°)	32.4 (49)		30.6 (41)		.550	
Δ Abduction (°)	53 (41.3)		51.5 (44)		.567	
Δ ER (°)	−1 (24.4)		−2 (23.4)		.318	
Δ IR (pts)	2.0 (0; 4)		0 (−2; 2)		**.000**	
Δ Pain level (pts)	9.0 (5; 11)		7.0 (4; 10)		**.000**	

RTSA, reverse total shoulder arthroplasty; *FU*, follow-up; *SSV*, Subjective Shoulder Value; *aCS*, absolute Constant Score; *pts*, points; *rCS*, relative Constant Score; *ADLs*, activities of daily living; *ER*, external rotation; *fIR*, functional internal rotation.

Values in mean, with ± standard deviation in parentheses or median and range in parentheses if not normally distributed; significant *P* values are bold.

* Fisher exact or Mann-Whitney *U*-test.

postoperative function (flexion and abduction) are significantly worse in male and female patients who have sustained a fracture. In addition, in female patients, postoperative external rotation was also limited in the fracture cohort. In 63.6% of all patients, the DTI was ≤1.4; in 63.2% of all patients who sustained a fracture, the DTI was ≤1.4; and in 68% of all female patients who sustained a fracture, the DTI was ≤1.4. However, this was not statistically significant.

Discussion

Several studies have shown gender-specific differences in outcome after various orthopedic procedures, including RTSA.[12,39] However, to date, it has not been evaluated whether the association between gender and outcome is reflective of a true cause-effect relationship or merely a surrogate for worse preoperative scores. Furthermore, none of these studies have analyzed *why* female gender is associated with a poorer outcome. The use of a forward selection linear and logistic regression statistical model evaluating the outcome metric scores and further parameters from 693 patients with 2-year minimum follow-up demonstrates that (1) female gender is associated with a worse preoperative and postoperative clinical score, (2) female gender is a weak but independent predictive factor for the outcome after RTSA, but, more importantly, (3) 2 key predictive factors—the extent of preoperative disability and the occurrence of intraoperative and/or postoperative fractures—are significantly more pronounced and frequent in female patients.

In our study, preoperatively, women were more limited in terms of function and pain than men. Subjective discomfort was also greater. This is in line with the data of Friedman et al[12] and Okoroha et al[27] but contradicts the data of Wong et al.[39] According to our data, women had significantly worse absolute and relative values in the CS both preoperatively and postoperatively, which however did not reach the MCID for the aCS. This is mainly explained by worse flexion and abduction, as other data extracted from the CS, such as ADLs, rotations, and pain levels, did not differ. However, they benefit more than male patients in terms of relative CS, pain, and internal rotation (higher delta between preoperative and postoperative outcome). Consistent with this finding, there was no difference in postoperative subjective outcome (SSV)—female patients were just as satisfied as male patients. This is likely more important for the patient rather than obtaining the highest outcome score possible. One could interpret these data to conclude that women are more tolerant of pain preoperatively and are satisfied with less function postoperatively. This is in agreement with the report from Jawa et al,[18] who were able to show that female patients have lower expectations for postoperative outcomes after TSA. It is also noteworthy that women benefit particularly with regard to internal rotation. This could be due to the increased postoperative exercise as part of specifically female daily activities like closing a bra or hygiene behind the back (toileting), which men can perform in front of the body.

Table III Multivariate (linear and logistic regression) analyses depicting independent risk factors for poor outcomes (rCS and SSV), pain, and intraoperative and/or postoperative fracture after RTSA

	P value	Coefficient
Linear regression		
Significant predictors for postoperative rCS		
Preoperative rCS	.000	.253
Number of previous shoulder surgeries	.000	−.204
Intraoperative and/or postoperative fracture	.000	−.178
Age	.041	.087
Female gender	.047	−.084
Significant predictors for the postoperative subjective shoulder value		
Intraoperative and/or postoperative fracture	.000	−.146
Number of previous shoulder surgeries	.000	−.233
Preoperative SSV	.024	.109
Preoperative rCS	.042	.100
Significant predictors for postoperative pain (as evaluated in the CS—the higher the less pain)		
Number of previous shoulder surgeries	.000	−.883
Preoperative SSV	.008	.017
Age at surgery	.006	.039
Female gender	.017	−.574
Logistic regression		
Significant predictor(s) for postoperative fracture		
Female gender	.017	.879
Significant predictors for intraoperative fracture		
Female gender	.006	.808
Preoperative rCS	.006	−.020
Significant predictors for intraoperative and/or postoperative fracture		
Female gender	.000	.944
Preoperative rCS	.005	.017

rCS, relative Constant Score; *SSV*, Subjective Shoulder Value; *RTSA*, reverse total shoulder arthroplasty.

Female patients had a significantly higher risk of sustaining an intraoperative or postoperative fracture. For this study, intraoperative fractures were not subdivided into fractures that were already seen and addressed intraoperatively and undetected (nondisplaced) fissures that were diagnosed only postoperatively on radiographs. However, a previous study based on our RTSA database (2006-2018) including 782 primary RTSAs[15] showed a rate of fractures that are discovered and addressed intraoperatively of 10% and a rate of fissures that are discovered only postoperatively on radiographs of 5%. We expect the ratio to be similar for the current cohort. In the literature, the rate of intraoperative humeral fractures was reported between 1.5% and 16%.[1,8,13,32] In our study, female patients had significantly lower local BMD as measured by DTI. Notably, the proportion of female patients with a DTI <1.4, corresponding to local osteopenia, was also significantly higher than in men. This is not surprising, given that the prevalence of osteoporosis is significantly higher in women in the overall population.[9] Although the incidence of a fracture could not be statistically correlated with BMD in our study, it was recently shown in a large matched-pair (1:1) analysis of 34,156 patients that patients with osteoporosis have an odds ratio of 1.86 to suffer a periprosthetic fracture after RTSA.[9] A total of 26.2% of all patients scheduled for RTSA in the United States between 2005 and 2014 had osteoporosis.[9] Recently, Levin et al[22] showed a correlation between DTI and intraoperative fracture risk in stemless and stemmed TSA.

In our study, women had significantly fewer prior interventions before primary RTSA. The number of prior procedures is a known risk factor for a poorer outcome and seems to be more relevant for men.[10,16] Women had significantly more cuff tear arthropathies and fewer irreparable rotator cuff tears without osteoarthritis. According to the literature, there is no difference in outcome comparing cuff tear arthropathies and irreparable rotator cuff tears.[36] Regarding radiologic data, women had a significantly higher CSA and lower DSA in our study. Berthold et al[3] investigated several prognostic preoperative and postoperative radiographic factors possibly affecting clinical outcomes in patients after RTSA using a 135° neck-shaft-angle prosthesis design. They found a positive correlation between DSA and active forward elevation (r = 0.299) but no correlation between DSA and other outcome measures as well as no correlation between CSA and outcome measures. However, a high CSA has been shown to be a risk factor for postoperative stress fractures of the acromion and

Table IV Outcome after RTSA divided by gender and presence of an intra- and/or postoperative fracture

Gender	Outcome	No fracture, median (percentile)	Fracture, median (percentile)	*P* value*
Female	aCS	69 (62; 74)	65 (49; 71)	**<.001**
	rCS	84.8 (76.6; 89.5)	79.9 (63; 85.4)	**<.001**
	SSV	90 (70; 95)	80 (52.5; 90)	**.005**
	ADLs	4 (3; 4)	4 (2; 4)	**<.001**
	Pain	15 (13; 15)	15 (15; 13)	.429
	Flexion	125 (110; 135)	120 (80; 130)	**.002**
	Abduction	140 (120; 155)	130 (80; 145)	**.003**
	External rotation	30 (20; 40)	25 (10; 40)	**.029**
	Internal rotation	6 (2; 8)	6 (2; 8)	.391
Male	aCS	73 (65; 78)	66 (39; 76)	**.014**
	rCS	87 (78.1; 93.3)	79.3 (55; 89.5)	**.018**
	SSV	85 (70; 95)	80 (45; 90)	**.022**
	ADLs	4 (4; 4)	4 (2; 4)	**.012**
	Pain	15 (14; 15)	15 (12; 15)	.444
	Flexion	130 (117.5; 140)	115 (70; 130)	**.003**
	Abduction	142.5 (120; 155)	120 (60; 150)	**.007**
	External rotation	30 (20; 40)	30 (15; 40)	.400
	Internal rotation	4 (2; 6)	6 (2; 8)	.758

RTSA, reverse total shoulder arthroplasty; *aCS*, absolute Constant Score; *rCS*, relative Constant Score; *SSV*, Subjective Shoulder Value; *ADLs*, activities of daily living.
Significant *P* values are bold.
* Mann-Whitney *U*-test.

the scapular spine.[20] With regard to implant sizes, the significant differences are not surprising. In our cohort, 97% of female patients received a glenosphere size 36. In a comparison of 38 mm vs. 42 mm glenosphere sizes in 297 patients, Mollon et al[25] have shown that patients who received a 42 mm glenosphere had greater improvements in active forward elevation and active external rotation. Especially female patients who received a 42 mm glenosphere had significantly greater improvements in active forward elevation, active external rotation, and functional scores.[25] This could also explain why women in our series had significantly worse postoperative flexion. Furthermore, the Australian registry data of 28,817 primary RTSAs suggest that, in female patients, a glenosphere size smaller than 38 mm is associated with increased revision rates.[28]

Our study shows that female gender is an independent risk factor for a poorer clinical outcome (rCS, SSV, and pain) after RTSA. However, gender was the least strong predictor of outcome. Our data suggest that the following determinants independently affect the postoperative outcome with a decreasing impact: (1) the extent of preoperative disability, (2) the number of previous surgeries, (3) sustaining an intraoperative or postoperative fracture, (4) age, and (5) gender.

As previously shown,[2,11,17,40] our data again confirmed that the postoperative outcome is predominantly influenced by the preoperative baseline. The combination of higher preoperative disability (as measured by rCS and SSV), higher risk of fracture, and female gender seems to be a reason why female patients have to expect a worse outcome after RTSA. The clinical outcomes of all patients, whether male or female, are worse when a fracture is present. The analysis showed that gender is not a surrogate for BMD in terms of clinical outcomes; DTI was not a significant factor in the regression analyses. However, female patients have a significantly smaller DTI, and low BMD in turn significantly increases fracture risk, which in turn influences the outcome.

This large-scale clinical study of 693 patients has been able to show that patients, regardless of gender, reliably experience clinical improvement after RTSA. An important finding of this study is that subjective satisfaction after RTSA is on average the same in men and women. The 2 groups also do not differ significantly in terms of postoperative pain or limitations in their activities of daily living. The differences in CS seem to be functional in nature. More specifically, they can be explained by worse flexion and abduction. Female gender is an isolated negative predictive factor influencing the objective clinical result. An additional reason for the worse outcome in female patients seems to be a combination of higher preoperative disability and higher rate of intraoperative and postoperative fractures. Therefore, to further improve the outcome of women after RTSA, all measures that contribute to the reduction of perioperative fracture risk should be used as this is a factor that can be influenced by the surgeon in the majority of cases. Risk reduction includes primarily preoperative detection of osteoporosis and, if indicated, treatment in female patients with a DTI <1.4. There is encouraging evidence in both lower limb arthroplasty and spine literature that treating osteoporosis either before or after surgery is beneficial.[4,24]

Another factor to consider is the humeral stem design. In our study, a humeral stem with a 155° neck-shaft angle and an onlay design was used for all patients. Recent studies show that a low neck-shaft angle leads to better functional results[37] and less scapular notching, whereas an onlay design leads to an increased risk of scapular fractures.[14,21,38] This might partly explain our higher rate of acromial fractures. The choice of humeral component (neck-shaft angle, inlay/onlay design) should therefore be carefully considered preoperatively, especially in female "risk" patients. Further known risk factors for postoperative acromial stress fractures, such as a high CSA, or postoperative high lateralization shoulder angle,[20] should be included in preoperative planning and execution as well. Intraoperatively, the surgeon should be aware of the increased fracture risk during exposure and preparation of the humeral shaft. Because only long humeral stems, in which diaphyseal press-fit anchorage plays a major role, were used in this study population, the use of long stems must be reconsidered because of the high incidence of intraoperative fractures. Possibly, the intraoperative fracture incidences would be lower with short-stem prostheses. However, these metaphyseal anchoring short stems had not yet been developed in the time period during which the majority of the study patients underwent surgery in our cohort.

Knowledge of gender differences after RTSA in general and, in particular, knowledge of the higher fracture risk in female patients and the herewith associated poorer outcome may improve the quality of patient education and may help to more accurately manage patient expectations after RTSA.

Limitations

The rCS has been normalized not only for age but also for gender.[19] However, most outcome measures used in orthopedics, including the SSV, American Shoulder and Elbow Surgeons score, or the Simple Shoulder Test, are not validated with respect to gender. Further studies should take into account that men and women might value and perceive pain and loss of function differently. The tests currently used should therefore be evaluated for validity and reliability in this context. This is especially valid for scores evaluating different ADLs (including sports) and related shoulder functions in a "patient-reported" fashion. However, the SSV, which measures purely subjective satisfaction, may not be as susceptible to gender differences in daily activities and demands as, ie, the American Shoulder and Elbow Surgeons score or the Simple Shoulder Test.

Although the indications used in our study are the most common for RTSA, they are heterogeneous despite the exclusion criteria, and it should be noted that our findings related to the differences in gender may not be applicable to other indications for RTSA.

Another limitation of the study is that we could not test whether gender was a surrogate for glenosphere size. As almost 50% of the male cohort received a size 40 glenosphere, it is possible that the better outcome is associated with the larger glenosphere. As only 3 female patients received a size 40 glenosphere, statistical analysis was not possible.

Conclusions

Female sex is a very weak, but isolated, negative predictive factor that negatively affects the objective clinical outcome (CS) after RTSA. However, differences did not reach the MCID, and it is not a predictor for the subjective outcome (SSV). The main reason for the worse outcome in female patients seems to be a combination of higher preoperative disability and higher incidence of fractures. To improve the outcome of women, all measures that contribute to the reduction of perioperative fracture risk should be used.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundation 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.

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