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Reverse total shoulder arthroplasty compared to stemmed hemiarthroplasty for proximal humeral fractures: a registry analysis of 5946 patients

Owain Critchley, MD[a,b,*], Andrew McLean, BPhty (Hons), MBBS (Hons)[c], Richard Page, BMedSci, MBBS, FRACS, FAOrthA[b,d,e], Fraser Taylor, BSc, MBChB, FRACS, FAOrthA[c], Stephen Graves, MBBS, FRACS, FAOrthA, DPhil[f], Michelle Lorimer, BSci (Hons)[g], Yi Peng, MSc[g], Alesha Hatton, BMed Math (Hons)[g], Gregory Bain, MBBS, FRACS, FAOrthA, PhD[a,h]

[a]*Department of Orthopaedics and Trauma Surgery, Flinders University, Adelaide, SA, Australia*
[b]*Department of Orthopaedic Surgery, University Hospital Geelong – Barwon Health, Geelong, VIC, Australia*
[c]*Department of Orthopaedics, Gold Coast University Hospital, Gold Coast, QLD, Australia*
[d]*School of Medicine, Deakin University, Geelong, VIC, Australia*
[e]*Barwon Centre for Orthopaedic Research and Education, Education and Research Center, St John of God Hospital, Geelong, VIC, Australia*
[f]*Australian Orthopaedic Association National Joint Replacement Registry, Adelaide, SA, Australia*
[g]*South Australian Health and Medical Research Institute, Adelaide, SA, Australia*
[h]*Department of Orthopaedics and Trauma, Flinders Medical Center, Adelaide, SA, Australia*

Background: There is an increasing trend toward the use of reverse total shoulder arthroplasty (RTSA) over stemmed hemiarthroplasty (HA) for the management of proximal humeral fractures. There are limited data available comparing the revision rates for RTSA and HA in the setting of a fracture. The aim of this study was to compare the revision rates for RTSA and HA when used for the treatment of a fracture and to analyze the effect of demographics and prosthesis fixation on these revision rates.

Methods: Data obtained from the Australian Orthopaedic Association National Joint Replacement Registry from April 16, 2004, to December 31, 2017, included all procedures for primary diagnosis proximal humeral fracture. The analyses were performed using Kaplan-Meier estimates of survivorship and hazard ratios from Cox proportional hazards models.

Results: Over the study period, there were 3049 (51%) RTSA and 2897 (49%) HA procedures. The cumulative percent revision rate at 9 years was lower for the RTSA than for the HA: 7.0% (95% confidence interval [CI], 4.8-10.1) compared with 11.7% (95% CI, 10.3-13.2). Between 0 and 6 months, the HA had a significantly lower revision rate than the RTSA (hazard ratio, 0.50; 95% CI, 0.34-0.72; $P < .001$). Between 6 month and 3 years, the HA had a significantly higher revision rate. For the RTSA, males have a significantly higher rate of revision compared with females. There is a higher rate of early revision due to instability in younger

The Australian Orthopaedic Association National Joint Replacement Registry is approved by the Australian Federal Government as a federal quality assurance activity under Section 124X of the Australian Federal Health Insurance Act 1973. All investigations were conducted in accordance with the ethical principles of research (The Helsinki Declaration II).

*Reprint requests: Owain Critchley, MD, 11 Aphrasia St, Newtown, VIC 3220, Australia.

E-mail address: owain.critchley@gmail.com (O. Critchley).

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persons (55-64) and males. For both RTSA and HA, cemented prostheses have lower revision rates compared with cementless prostheses.

Conclusions: RTSA has a significantly lower revision rate compared with HA for the treatment of proximal humeral fractures in females. Younger patients (<65) and males are at risk of early revision secondary to instability. In these patient groups, either alternatives to RTSA or further attention to fixation of tuberosities and shoulder rehabilitation may be indicated.

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

Keywords: Proximal humerus fracture; shoulder joint; arthroplasty; joint registry; revision rate; hemiarthroplasty; reverse shoulder arthroplasty

Proximal humeral fractures are common, and the incidence of these fractures is increasing, particularly in older women.[8,10,28,30] They are the third most common fragility fractures, after distal radius and femoral neck fractures, and the mortality at 1 year associated with these fractures is significant.[8] The majority of proximal humeral fractures are minimally displaced and can be managed nonoperatively with immobilization and physiotherapy.[19,20] However, optimal management of more complex 3- and 4-part fractures remains controversial.[4,17,18]

There are a number of treatment options for complex proximal humeral fractures, including nonoperative, open reduction internal fixation, and partial or total (conventional and reverse) joint arthroplasty.[12] Traditionally, where the humeral head requires replacement, elderly patients with osteoporotic bone and/or displaced 3- or 4-part fractures have been treated with stemmed hemiarthroplasty (HA).[25] However, HA in the setting of a fracture has been associated with potentially poor clinical outcomes, particularly if there is malposition or loss of fixation of the tuberosities.[22,29,32] For this reason, reverse total shoulder arthroplasty (RTSA) has gained increasing popularity for fracture management as the functional outcome is less dependent on tuberosity healing and rotator cuff integrity.[7,11,23,26]

There is a growing body of literature comparing the outcomes of HA and RTSA in the treatment of proximal humeral fractures. These studies consistently show that RTSA has comparable or better range of motion and improved patient-reported outcome measures.[2,5-7,9,11,14-16,24,32-36] Despite a potential for improved functional outcomes, there remains uncertainty surrounding the complication, reoperation, and revision rates of both procedures. Some studies have highlighted significantly higher complication rates associated with RTSA when compared with HA, whereas other studies report no difference in complication, reoperation, and revision rates.[6,14,24,31-33,35] Furthermore, previous studies comparing RTSA and HA for proximal humeral fractures from the Nordic and New Zealand Joint Registries have shown no statistical difference between RTSA and HA revision rates up to 5 years.[5,7,34]

The aims of this study were to compare the revision rates of HA and RTSA when used to treat proximal humeral fractures, and to determine the effect of age, gender, and prosthesis fixation on these revision rates. In addition, the reasons for revision of the primary procedure were analyzed.

Materials and methods

This is a large retrospective cohort study of patients who underwent HA or RTSA for the diagnosis of a fracture using data collected by the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR).

The AOANJRR began data collection on September 1, 1999, and was expanded to include shoulder arthroplasty procedures in April 2004 and has documented almost all shoulder arthroplasty procedures throughout Australia since November 2007.

All HA and RTSA procedures reported with the primary diagnosis of a fracture to the AOANJRR between April 16, 2004, and December 31, 2017, were analyzed for revision (exchange of a component). The AOANJRR does not define the acuity of the fracture (humeral or glenoid) or if arthroplasty was for sequelae of fracture. Procedures were grouped according to HA and RTSA. Further analyses based on patient demographic characteristics, prosthesis fixation, and reason for revision were performed. The cumulative percent revision (CPR) rates for HA and RTSA were determined.

Statistical analysis

Statistical analysis was performed using methods used routinely in the analysis of AOANJRR data.[13,27] Survivorship was estimated using the Kaplan-Meier method with 95% confidence intervals (CIs). Age- and sex-adjusted hazard ratios (HRs) calculated from Cox proportional hazards models were used to compare the revision rates between groups. A multivariate model was used to test the interactions between the effects of shoulder class, age, and gender. The assumption of proportional hazards was checked analytically for each model. If the interaction between the predictor and the log of time was statistically significant in the standard Cox model, then a time-varying model was estimated. Time points were selected based on the greatest change in hazard, weighted by a function of events. Time points were iteratively chosen until the assumption of proportionality was met, and HRs were calculated for each selected period. For this study, if no period was specified, then the HR was calculated over the entire follow-up period. All tests were 2-tailed at a 5% level of significance. Statistical analysis was performed using SAS software (version 9.4; SAS Institute, Cary, NC, USA).

Table I Age and gender of primary shoulder arthroplasty (primary diagnosis fracture) for HA and RTSA

Shoulder class	Gender	Number	Percentage	Minimum age	Maximum age	Median age	Mean age	SD
HA	Male	623	21.5	30	93	66	65.7	13.3
	Female	2274	78.5	36	101	74	72.7	10.7
	Total	2897	100.0	30	101	72	71.2	11.6
RTSA	Male	484	15.9	47	94	74	73.3	9.2
	Female	2565	84.1	32	102	76	75.7	8.5
	Total	3049	100.0	32	102	76	75.4	8.7

HA, stemmed hemiarthroplasty; *RTSA*, reverse total shoulder arthroplasty.
The majority of RTSA (84.1%) and HA (78.5%) procedures occurred in females. The median ages for both males and female were higher for RTSA (74 and 76, respectively) than for HA (66 and 74, respectively).

Results

Demographic characteristics

Within the study period, 6097 primary shoulder arthroplasty procedures were identified with the diagnosis of a fracture. This was comprised of 5946 (97.5%) RTSA and HA procedures with the remaining 2.5% predominantly total conventional shoulder replacements. Of the 5946 RTSA and HA procedures performed, 3049 (51%) were RTSA and 2897 (49%) were HA.

Both procedures were most often performed in females (RTSA 84.1%, HA 78.5%). The mean age in the RTSA group was 73.3 years for men and 75.7 years for women. In the HA group, the mean age was 65.7 years for men and 72.7 years for women (Table I).

The number of HA procedures performed decreased annually from 378 in 2008 to 76 in 2017. This represents an 80% decline in the use of HA over the study period. Over the same period, the number of primary RTSA procedures increased annually from 80 to 628, representing an increase of 685% (Fig. 1).

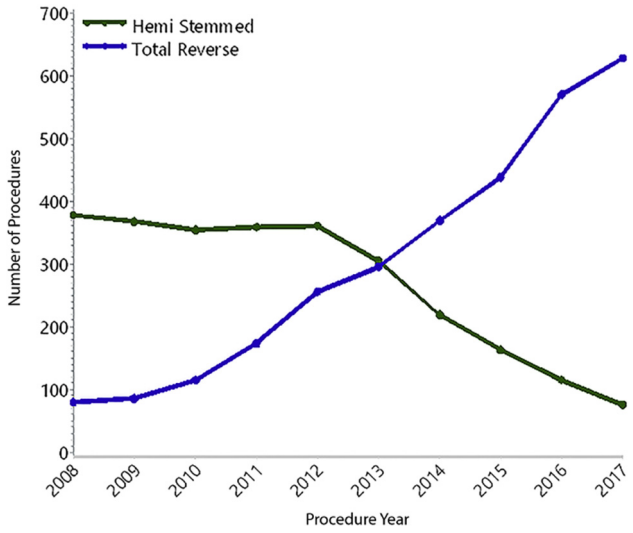

Figure 1 Primary HA and RTSA by year (primary diagnosis fracture). This graph highlights the marked increase in RTSA, and the decline of HA, over the past 10 years for primary diagnosis fracture. *HA*, stemmed hemiarthroplasty; *RTSA*, reverse total shoulder arthroplasty.

Revision rates

Over the study period, a total of 270 (9.3%) primary HA and 111 (3.6%) primary RTSA procedures were revised. The CPR at 9 years was lower for RTSA at 7.0% (95% CI, 4.8-10.1) compared with HA at 11.7% (95% CI, 10.3-13.2) (Table II). In the early postoperative period (0-6 months), RTSA had a higher rate of revision than HA (HR, 0.50; 95% CI, 0.34-0.72; $P < .001$). From 6 months to 3 years, HA had a significantly higher revision rate, with the difference being greatest in the 2.5- to 3-year period (HR, 8.90; 95% CI, 1.19-66.7; $P = .033$). After 3 years, there was no difference in the revision rate (HR, 1.24; 95% CI, 0.63-2.43; $P = .532$) (Fig. 2).

Age

For RTSA, the revision rate decreases with increasing age. Conversely, the revision rates for HA are similar amongst those aged 55-64 and 65-74, but lower in those ≥75 (Fig. 3). The lower revision rate for RTSA after the initial postoperative period was evident in all age groups (55-64, >3 months; 65-74, >6 months; and ≥75, 3 months to 2 years).

The higher rate of early revision of RTSA, compared with HA, was only evident in the 55- to 64-year and ≥75-year age groups. For RTSA, Figure 3, *A*, highlights a higher rate of early postoperative revision in the 55- to 64-year age group when compared with early postoperative revision rates in the 65- to 74-year (Fig. 3, *B*) and ≥75-year (Fig. 3, *C*) age groups.

Gender

There is a gender-related difference in outcomes. RTSA has a higher rate of revision compared with HA for males (HR, 0.63; 95% CI, 0.42-0.96; $P = .031$) and a lower rate of

Table II Yearly cumulative percent revision of primary shoulder arthroplasty by shoulder class (primary diagnosis fracture)

CPR	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr
HA	3.2	6.6	8.7	9.4	10.2	10.6	10.7	11.2	11.7	11.7
	(2.7, 4.0)	(5.7, 7.6)	(7.7, 9.9)	(8.4, 10.6)	(9.1, 11.5)	(9.4, 11.9)	(9.5, 12.0)	(9.9, 12.6)	(10.3, 13.2)	(10.3, 13.2)
RTSA	2.9	3.5	3.8	4.3	4.4	4.9	4.9	7.0	7.0	
	(2.4, 3.6)	(2.9, 4.3)	(3.1, 4.6)	(3.5, 5.3)	(3.6, 5.5)	(3.9, 6.2)	(3.9, 6.2)	(4.8, 10.1)	(4.8, 10.1)	

CPR, cumulative percent revision; *HA*, stemmed hemiarthroplasty; *RTSA*, reverse total shoulder arthroplasty.
RTSA has a lower revision rate at 9 years compared with HA: 7.0% vs. 11.7%.

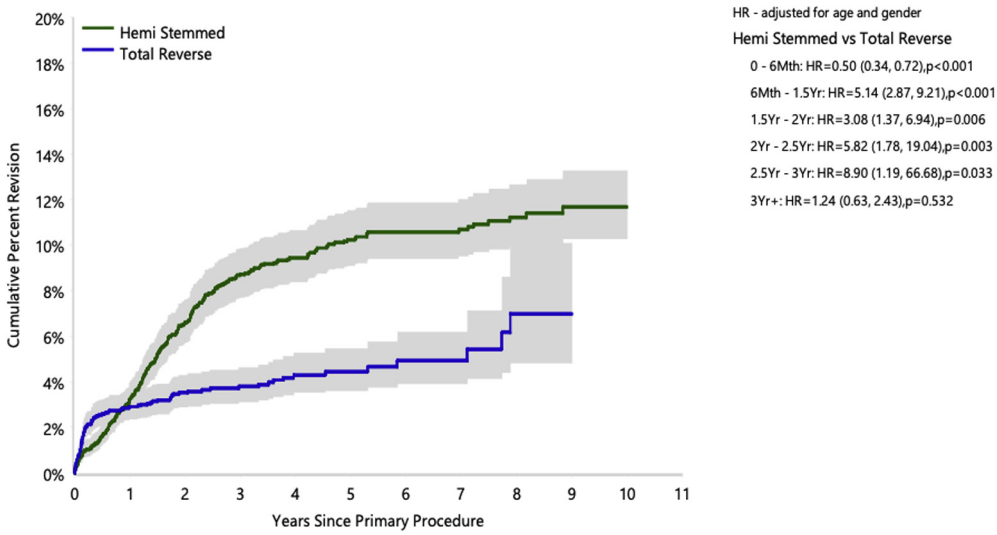

Figure 2 Cumulative percent revision of primary shoulder replacement by shoulder class (primary diagnosis fracture). At 9 years, the cumulative percent revision rate of RTSA is lower than that of stemmed hemiarthroplasty. In the first 6 months, RTSA has a higher rate of revision. *HR*, hazard ratio; *RTSA*, reverse total shoulder arthroplasty.

revision compared with HA for females (HR, 2.24; 95% CI, 1.70-2.94; $P < .001$) (Fig. 4). Males have a higher rate of revision compared with females when RTSA is used (HR, 2.98; 95% CI, 2.02-4.40; $P < .001$). There is no difference between females and males when HA is used (HR, 0.85; 95% CI, 0.63-1.14; $P = .279$) (Fig. 4).

Multivariate analysis

The multivariate model determined that the 3-way interaction between the effects of shoulder class, age, and gender was not significant. Interactions between age and shoulder class and also between gender and age were not significant. However, the interaction between shoulder class and gender was significant, indicating that the benefit of RTSA is gender specific (Table III).

Fixation

Adjusting for gender and age, cemented fixation is associated with a lower rate of revision for both RTSA and HA compared with cementless fixation (Cementless HA vs. Cemented HA: HR, 1.53; 95% CI, 1.20-1.95; $P < .001$ and Cementless RTSA vs. Cemented RTSA: HR, 1.79; 95% CI, 1.23-2.60; $P = .002$) (Fig. 5).

Reason for revision

The most common reasons for revision of RTSA are instability/dislocation (47.7%), infection (17.1%), fracture (16.2%), and loosening (11.7%) (Table IV, Fig. 6).

The most common reasons for revision of HA procedures are rotator cuff insufficiency (26.7%), instability/dislocation (18.9%), infection (10.0%), and pain (10.0%). Revisions for rotator cuff insufficiency and glenoid erosion were unique to HA (Fig. 6). Most revisions for rotator cuff insufficiency occurred between 1 and 3 years after the primary procedure (Fig. 6).

The proportion of primaries revised for fracture, loosening, and infection are lower for RTSA (0.6%, 0.4%, and 0.6%, respectively) compared with HA (0.8%, 0.8%, and 0.9%, respectively). There is no difference in the proportion of primaries revised for instability/dislocation for HA (1.8%) and RTSA (1.7%) (Table IV). However, the

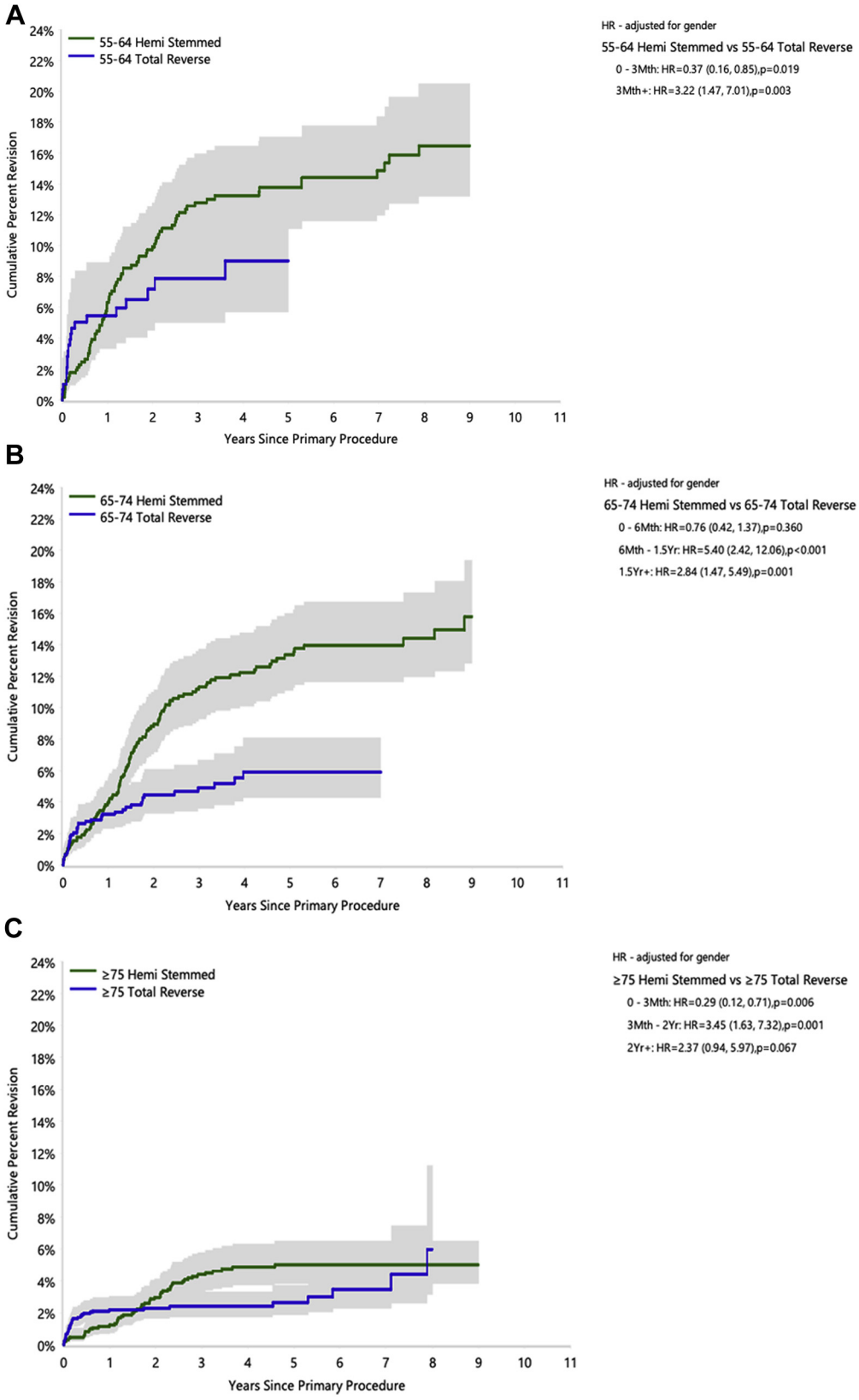

Figure 3 Cumulative percent revision of primary shoulder replacement—age (**A**) 55-64, (**B**) 65-74, and (**C**) ≥75 by shoulder class (primary diagnosis fracture). For the 55-64 and ≥75 age groups, there is no difference in revision rates at 5 and 8 years, respectively. However, there is a higher rate of reverse total shoulder arthroplasty revision in these age groups within the first 3 months. For the 65-74 age group, stemmed hemiarthroplasty has a significantly higher revision rate at 7 years. *HR*, hazard ratio.

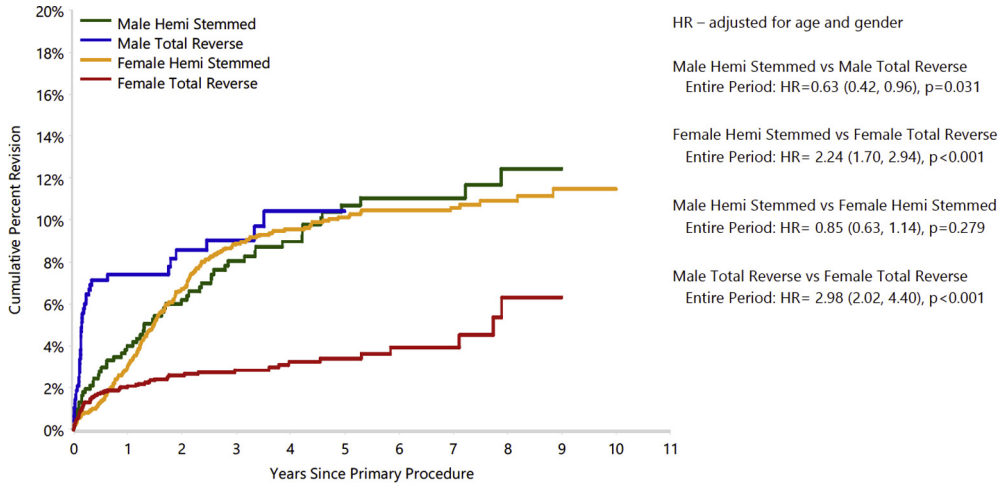

Figure 4 Cumulative percent revision of primary shoulder arthroplasty by gender and shoulder class (primary diagnosis fracture). For males, the RTSA group had a higher rate of revision, whereas the opposite was true for females. The RTSA revision rate for males is 7.4% at 1 year. *HR*, hazard ratio; *RTSA*, reverse total shoulder arthroplasty.

Table III Multivariate model of primary shoulder arthroplasty by age, gender, and shoulder class (primary diagnosis fracture)

Effect	*P* value
Shoulder class	<.0001
Gender	.0011
Age	<.0001
Interaction: gender and shoulder class	<.0001
Interaction: age and shoulder class	.2471
Interaction: gender and age	.7987
Interaction: gender and age and shoulder class	.8868

There is a significant interaction between shoulder class (reverse total shoulder arthroplasty and stemmed hemiarthroplasty) and gender.

majority of RTSA procedures revised for instability/dislocation occur within the first 3 months (Fig. 6).

RTSA revision over time

The rate of revision for instability/dislocation of RTSA procedures has decreased with time. Adjusting for age and gender, at 6 years, the CPR for procedures performed between 2006 and 2010 is 3.6% (95% CI, 2.0%-6.4%) compared with 1.6% for procedures performed between 2011 and 2017 (95% CI, 1.2%-2.2%). The difference is significant for the entire period (Table V and Fig. 7).

Discussion

The use of RTSA for proximal humeral fractures has increased significantly since 2008. To date, there have been few publications comparing the revision rates of RTSA and HA used in the treatment of fractures. This study has demonstrated that, overall, RTSA has a significantly lower revision rate compared with HA for proximal humeral fractures. With regard to demographics, the RTSA revision rate is significantly lower for females and patients aged 65-74.

The New Zealand and Nordic registries reported no significant difference in revision rates when RTSA and HA were compared.[5,7,34] There are a number of potential reasons for the differences in outcome between these registry studies and our study. First, the findings of these registries were based on databases with fewer procedures; in particular, only 218 and 565 RTSA procedures were reported in the New Zealand and Nordic registries, respectively. Secondly, there may be geographical differences in surgeon threshold to revision. Finally, the study periods for the New Zealand and Nordic studies differ from our study. As our results have shown, the number of RTSA procedures has increased significantly in more recent years and the more recent RTSA procedures are less likely to be revised.

Adjusting for gender and age, the use of cemented stem fixation is associated with a lower rate of revision for both HA and RTSA. Previous registry-based studies have not reported on the effect of fixation.[5,7,34] Decreased revision rates seen with cemented fixation are likely related to decreased rates of periprosthetic fractures, improved fixation in osteoporotic bone, and improved ability to control stem rotation and height.

RTSA procedures performed for proximal humeral fractures have a higher rate of revision in the first 3 months compared with those performed for osteoarthritis (HR, 1.82; 95% CI, 1.36-2.44; $P < .001$) in the AOANJRR.[1] After this time, there is no difference in the rate of revision of RTSA performed for fractures compared with osteoarthritis and all other primary diagnoses. Overall,

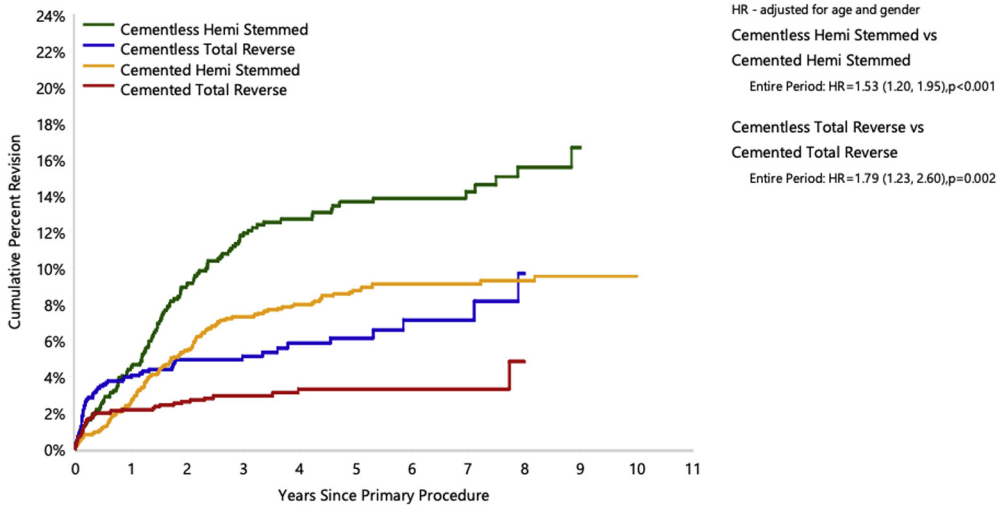

Figure 5 Cumulative percent revision of primary shoulder arthroplasty by shoulder class and humeral fixation (primary diagnosis fracture). For reverse total shoulder arthroplasty and stemmed hemiarthroplasty, cemented fixation was associated with a lower revision rate when compared with uncemented fixation across the entire time period. *HR*, hazard ratio.

Table IV Revision diagnosis of primary shoulder arthroplasty by shoulder class (primary diagnosis fracture)

Revision diagnosis	Stemmed hemiarthroplasty			Reverse total shoulder arthroplasty		
	Number	% Primaries revised	% Revisions	Number	% Primaries revised	% Revisions
Rotator cuff insufficiency	72	2.5	26.7			
Instability/dislocation	51	1.8	18.9	53	1.7	47.7
Infection	27	0.9	10.0	19	0.6	17.1
Pain	27	0.9	10.0	2	0.1	1.8
Fracture	24	0.8	8.9	18	0.6	16.2
Loosening	24	0.8	8.9	13	0.4	11.7
Glenoid erosion	15	0.5	5.6			
Arthrofibrosis	7	0.2	2.6	2	0.1	1.8
Malposition	7	0.2	2.6	1	0.0	0.9
Dissociation	3	0.1	1.1			
Incorrect sizing	2	0.1	0.7			
Lysis	2	0.1	0.7	1	0.0	0.9
Heterotopic bone	1	0.0	0.4			
Implant breakage glenoid				1	0.0	0.9
Rotator cuff arthropathy	1	0.0	0.4			
Other	7	0.2	2.6	1	0.0	0.9
N revision	270	9.3	100.0	111	3.6	100.0
N primary	2897			3049		

HA, stemmed hemiarthroplasty.
A total of 26.7% of HA revisions were due to rotator cuff insufficiency, which was unique to HA. Conversely, 47.7% of reverse total shoulder arthroplasty revisions were due to instability/dislocation.

the use of RTSA for fractures compares favorably with other primary diagnoses. The higher early revision for fractures compared with osteoarthritis may reflect increased instability/dislocation in the setting of inadequate tuberosity repair.

This study has identified a higher early (0-6 month) revision rate for RTSA compared with HA. The reason for this higher early revision rate is predominantly instability/dislocation. This pattern of early revision was most pronounced in males and younger patients (55-64). This may reflect the technical challenges of the procedure to achieve stability and anatomic alignment in the setting of proximal humeral fractures.[3,6,34] Furthermore, as highlighted, the revision rate for instability/dislocation decreased from 2011 to 2017 when compared with procedures performed before 2011, after adjusting for age and gender. This may be a

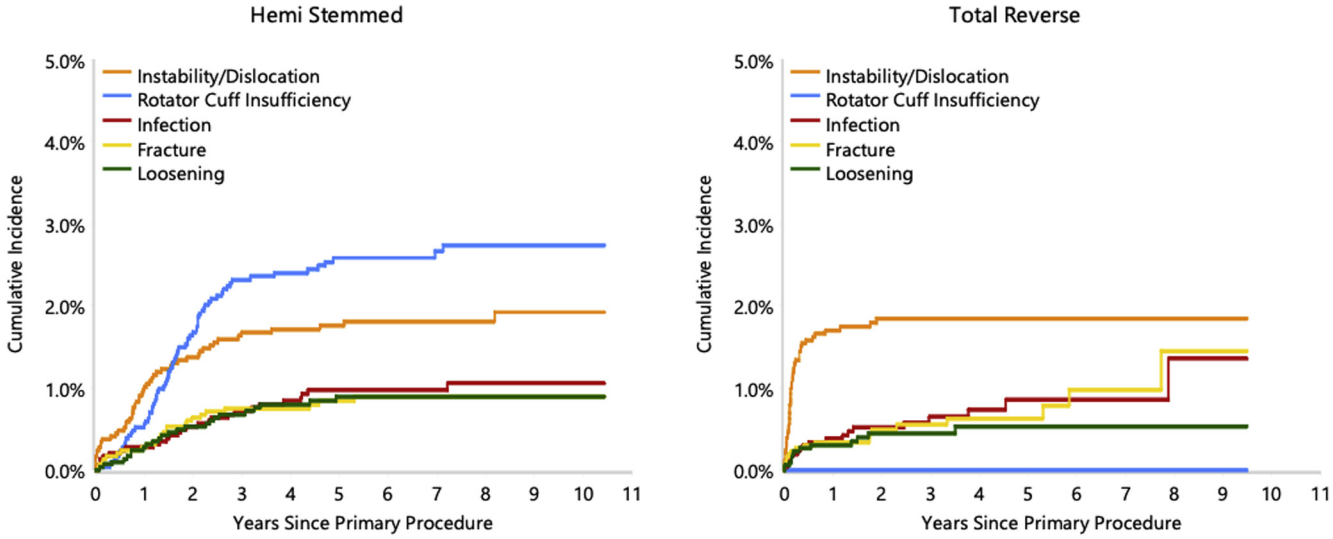

Figure 6 Cumulative incidence revision diagnosis of primary shoulder arthroplasty by shoulder class (primary diagnosis fracture). For stemmed hemiarthroplasty, the most common reasons for revision are rotator cuff insufficiency and instability/dislocation. For RTSA, the most common reason for revision is instability/dislocation. RTSA revisions for instability/dislocation occur in the first 2 years after the primary procedure. *RTSA*, reverse total shoulder arthroplasty.

Table V Yearly cumulative percent revision of primary reverse total shoulder arthroplasty by procedure year (primary diagnosis fracture, revision for instability/dislocation)

CPR	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr
2006-2010	2.9 (1.5, 5.5)	3.6 (2.0, 6.4)	3.6 (2.0, 6.4)	3.6 (2.0, 6.4)	3.6 (2.0, 6.4)	3.6 (2.0, 6.4)	3.6 (2.0, 6.4)	3.6 (2.0, 6.4)	3.6 (2.0, 6.4)
2011-2017	1.6 (1.2, 2.1)	1.6 (1.2, 2.2)	1.6 (1.2, 2.2)	1.6 (1.2, 2.2)	1.6 (1.2, 2.2)	1.6 (1.2, 2.2)			

CPR, cumulative percent revision.

consequence of increasing surgeon experience, changes in surgical technique, optimization of implant selection, and/or improvements in prosthesis design. With regard to the high rate of early revision in males and younger patients (55-64), these patient groups are more prone to higher energy injuries with the potential for more difficult reduction of tuberosities intraoperatively. In addition, these patient groups may be more active in the immediate postoperative period, therefore, placing them at increased early risk of instability/dislocation. Alternative treatment options may be indicated in these patient groups. If RTSA is performed, better attention to better fixation of tuberosities and shoulder rehabilitation may be of benefit. Further detailed analysis of factors predisposing younger persons and males to revision is indicated.

This study has advantages in the reporting of longitudinal data of a large database of similar numbers of HA and RTSA procedures. The number of procedures (particularly RTSA) evaluated in this study is significantly greater than prior registry studies comparing HA and RTSA for fracture. Furthermore, the registry data capture all procedures performed across Australia by a wide spectrum of surgeons in mixed surgical settings. The completeness of the data enhances the external validity of the study.

Despite the advantages listed above, there are also some limitations to this study. First, registries provide information only on patient demographics, diagnosis, prosthesis use, and revision rates; it does not include data on radiographic or functional outcome measures or the complexity of the case. We are unable to determine the severity, type, associated soft tissue injury, and the acuity of the proximal humeral fracture being treated. Also, in patients treated with RTSA, we are unable to determine if the fracture was of the proximal humerus, glenoid, or both. Glenoid fractures are rare and as such likely make up a very small proportion of RTSA.[21] Secondly, we are unable to include data on poorly performing procedures that are not revised. The decision to revise a poorly performing prosthesis is complex and the threshold for revising a poorly performing prosthesis may differ between RTSA and HA. This may be due to a number of factors including

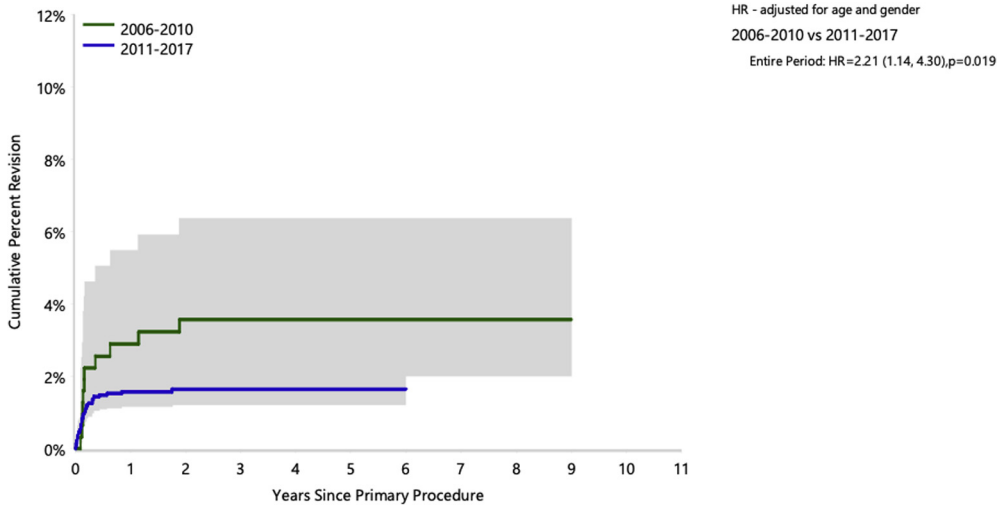

Figure 7 Cumulative percent revision of primary reverse total shoulder arthroplasty by procedure year (primary diagnosis fracture, revision for instability/dislocation). There is a higher rate of revision for instability/dislocation in procedures performed from 2006 to 2010 compared with 2011 to 2017. *HR*, hazard ratio.

surgeon preference, revision options for both HA and RTSA, and the individual patient factors, that is, age, patient wishes, and comorbid status.

Conclusions

To our knowledge, this study reports the largest comparative study of RTSA and HA for the management of proximal humeral fractures. Our findings support the use of RTSA with a cemented humeral component over HA for fractures in female patients. Care should be taken in younger patients (55-64) and males, who are at high risk of early revision, particularly due to instability. Alternative treatment options may be indicated in these patient groups. If RTSA is performed, better attention to fixation of tuberosities and shoulder rehabilitation may be of benefit. Ideally, further prospective trials are required to confirm the functional advantage of RTSA in the fracture setting.

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Disclaimer

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