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*3,245 shoulder replacements from the Nordic Arthroplasty Register Association*

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# Low arthroplasty survival after treatment for proximal humerus fracture sequelae: 3,245 shoulder replacements from the Nordic Arthroplasty Register Association

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**Background and purpose** — Proximal humerus fractures (PHF) may result in sequelae indicating arthroplasty. We report cumulative survival rates and reasons for revision after arthroplasty for proximal humerus fracture sequelae (PHFS).

**Patients and methods** — Data were derived from the Nordic Arthroplasty Register Association. The Kaplan–Meier method was used to illustrate survival rates. A scaled Schoenfeld residual plot was used to report the risk of revision for men relative to women in patients who were treated with reverse shoulder arthroplasty (RSA). Revision was defined as removal or exchange of any component or the addition of a glenoid component.

**Results** — 30,190 primary arthroplasties were reported from 2004 to 2016, of which 3,245 were for PHFS. The estimated 1-, 5-, and 10-year cumulative survival rates (95% CI) were 96% (95–97), 90% (89–92), and 86% (83–88) for stemmed hemiarthroplasty and 94% (92–95), 89% (87–91), and 86% (82–90) for RSA with a median time to revision of 18 months (IQR 9–44) and 3 months (IQR 0–17). The risk of revision for men relative to women in patients who were treated with RSA was 3.2 (1.9–5.1) 0–1 year after surgery and 1.9 (0.9–4.1) 1–8 years after surgery. The estimated 1-, 5-, and 10-year cumulative survival rates (95% CI) were 94% (92–96), 88% (85–90), and 80% (75–86) for men and 95% (94–96), 86% (84–89), and 81% (77–84) for young patients.

**Interpretation** — Shoulder arthroplasty for PHFS was associated with lower survival rates, compared with previously published results of shoulder arthroplasty for acute PHF. The low arthroplasty survival rates for men and young patients especially are worrying.

Both non-surgical and surgical treatments of proximal humerus fractures (PHF) are associated with risk of nonunion, malunion, or avascular necrosis and secondary osteoarthritis of the glenohumeral joint. These complications may later clinically manifest as proximal humerus fractures sequelae (PHFS) with pain, stiffness, and decreased range of motion (Mansat and Bonnevialle 2015, Boileau 2016).

There is not yet consensus on the optimal treatment of PHFS (Kilic et al. 2010, Alentorn-Geli et al. 2014, Jacobson et al. 2014, Raiss et al. 2014). Stemmed hemiarthroplasty (SHA) came into common usage in the treatment of acute PHF and PHFS in the 1990s, but during the last decade reverse shoulder arthroplasty (RSA) has become increasingly popular (Wand et al. 2012). By using the RSA design, shoulder stability and function can be improved even with a compromised rotator cuff (Namdari et al. 2013, Nikola et al. 2015).

The majority of previous studies of shoulder arthroplasty for PHFS have focused on pain, range of motion, and functional outcome scores (Boileau et al. 2006, Murray et al. 2011, Moineau et al. 2012, Alentorn-Geli et al. 2014, Raiss et al. 2014, Nikola et al. 2015, Hattrup et al. 2016, Raiss et al. 2016, Raiss et al. 2017). Only a few case series have reported revision rates (Boileau et al. 2001, Mansat and Bonnevialle 2015).

We report cumulative survival rates and reasons for revision after shoulder arthroplasty for PHFS.

## Patients and methods

Data were derived from the Nordic Arthroplasty Register Association (NARA), which is a collaboration between the


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national shoulder arthroplasty registries in Sweden, Denmark, Norway, and Finland (Rasmussen et al. 2016). The Finnish data were not included in the present study because of incomplete format. The completeness of the shoulder registries is above 90% in Denmark and Norway and above 80% in Sweden for both primary and revision arthroplasties (Rasmussen et al. 2016). From January 2004 to December 2016 NARA contains data from Sweden, Denmark and Norway on 30,190 shoulder arthroplasties. 9,137 arthroplasties were used for acute PHF, 3,245 for PHFS, 1,976 for inflammatory arthritis, 3,324 for rotator cuff problems, and 11,647 for osteoarthritis. In 861 arthroplasties, the diagnosis was recorded as "Others" or was missing.

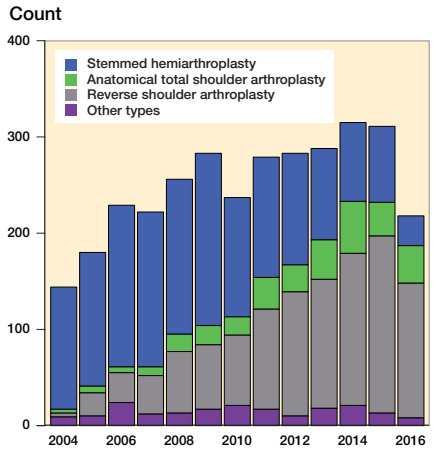



Figure 1. Number of stemmed hemiarthroplasties, anatomical total shoulder arthroplasties, reverse shoulder arthroplasties and other types including stemless, resurfacing, and metaphyseal fixed implant arthroplasties.

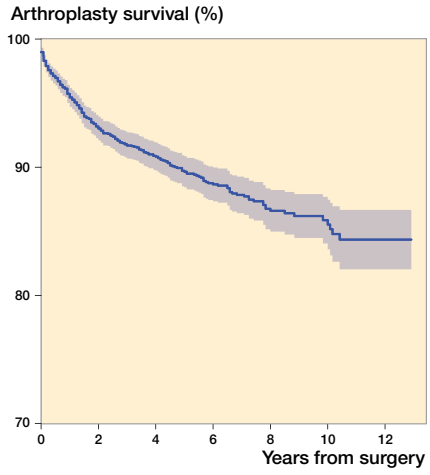



Figure 2. Cumulative survival for all types of arthroplasties from 2004 to 2016 with 95% CI and numbers at risk.

PHFS is defined by NARA as fractures reported as nonunion, malunion, fracture with previous osteosynthesis, or a healed fracture reported together with osteoarthritis or humeral head necrosis. The NARA data set includes patient-related data (nationality, age, sex, and diagnosis), operative data (date, arthroplasty type, and brand), and revision data (date, reason for revision, and new arthroplasty brand).

Type of shoulder arthroplasty is reported as stemmed hemiarthroplasty, anatomical total shoulder arthroplasty, reverse shoulder arthroplasty, resurfacing hemiarthroplasty, resurfacing, total shoulder arthroplasty, stemless hemiarthroplasty, or stemless total shoulder arthroplasty. Information on stem length and fixation technique is not included in the dataset. In the comparison of arthroplasty types, we included only stemmed hemiarthroplasty and reverse shoulder arthroplasty. The other arthroplasty types were not included because of few cases.

Revision of an arthroplasty was defined as removal or exchange of any components or the addition of a glenoid component. If more than 1 reason for revision had been reported to the individual registries, the following hierarchy of reasons for revision was used, so only 1 reason for revision was registered in the common data set: Infection; Periprosthetic fracture; Luxation and instability; Loosening; Rotator cuff problem; and "Other reasons," which include glenoid wear, malposition of the arthroplasty, and pain with no other reasons reported (Rasmussen et al. 2016). In all the Nordic countries each person is identified by a unique civil registration number given at birth. The civil registration number was used in the national registries to accurately link the revision procedure to the primary arthroplasty and to check for death and emigration in the national population registries. The end of follow-up was the date of revision, date of death or December 31, 2016.

### *Statistics*

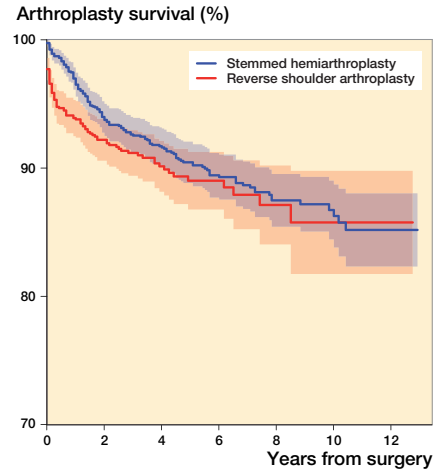
Descriptive statistics were used to report demographic data, follow-up time, time to revision, and reasons for revision. We used the Kaplan–Meier method to illustrate the unadjusted survival rates with 95% confidence interval (CI). Due to violation of the proportional hazards assumption, a scaled Schoenfeld residual plot was used to report the risk of revision for men relative to women in patients who were treated with RSA. The estimated risk of revision was calculated for 2 separate intervals to fulfill the proportional hazard assumption. The comparison was adjusted for age and period of surgery. Although it violates the assumption of independence, patients with bilateral shoulder arthroplasty procedures were included in the survival analysis as if they were independent. The level of statistical significance was set at $p < 0.05$ and all tests were 2-tailed. The analyses were performed using SPSS version 22.0 (IBM Corp, Armonk, NY, USA).

### *Ethics, funding, and potential conflicts of interest.*

Ethics committee approval was not required. No funding was received for this study. No competing interests are declared.

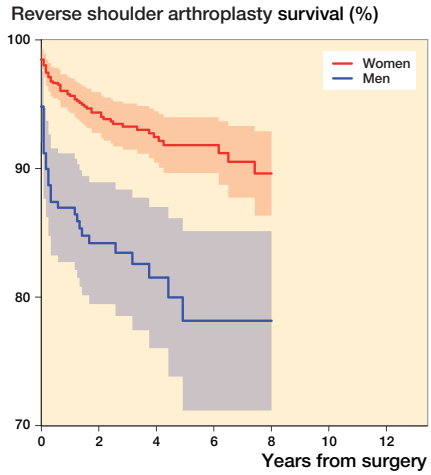
## Results

The annual number of arthroplasties and especially the number of RSAs increased during the study period (Figure 1). Mean age was 69 years (SD 12). Median follow-up time was 45 months (IQR 20–81). There were 306 (9.4%) revisions of all types of arthroplasty with a 12-year cumulative survival rate of 84% (Figure 2). Median time to revision was 15 months (IQR 3 to 33). Overall, the most common reasons for revision were Luxation and instability (3.2%), "Other reasons"




| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RSA | 1,152 | 829 | 595 | 393 | 247 | 153 | 92 | 46 | 19 | 6 | 0 |
| SHA | 1,587 | 1,357 | 1,147 | 946 | 755 | 591 | 423 | 268 | 158 | 71 | 5 |

Figure 3. Cumulative survival for stemmed hemiarthroplasty and reverse shoulder arthroplasty from 2004 to 2016 with 95% CI and numbers at risk.




| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Men | 250 | 181 | 146 | 118 | 92 | 66 | 45 | 32 | 18 | 11 | 6 |
| Women | 902 | 769 | 623 | 502 | 393 | 315 | 235 | 178 | 136 | 105 | 80 |

Figure 4. Cumulative survival for women and men treated with RSA with 95% CI and numbers at risk.

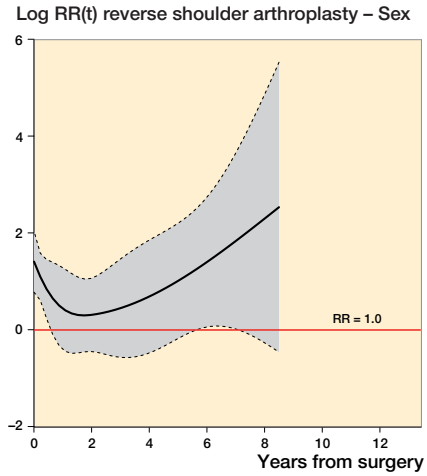



Figure 5. Risk of any revision (solid black line) with 95% CI (dashed lines) for men relative to women treated with RSA adjusted for age and period of surgery. The horizontal red line indicates no difference in risk of revision (RR = 1). The RR estimates are divided into 2 intervals to fulfill the proportional hazard assumption: 0–1 year: RR = 3,2 (1.9–5.1) and 1–8 years: RR = 1.9 (0.9–4.1).

**Reasons for revision for all types of arthroplasties (All), stemless, resurfacing, and metaphyseal fixed implant arthroplasties (Other types), stemmed hemiarthroplasty (SHA), and reverse shoulder arthroplasty (RSA). Values are number (n), percentage of primary arthroplasties in parentheses, and percentage (%) of revisions**

| Reason | All n (%) | % | Other types n (%) | % | SHA n (%) | % | RSA n (%) | % |
|---|---|---|---|---|---|---|---|---|
| Infection | 53 (1.6) | 17 | 6 (1.2) | 12 | 25 (1.6) | 16 | 22 (1.9) | 22 |
| Periprosthetic fracture | 13 (0.4) | 4 | 3 (0.6) | 6 | 7 (0.4) | 5 | 3 (0.3) | 3 |
| Luxation and instability | 105 (3.2) | 34 | 10 (2.0) | 20 | 39 (2.5) | 26 | 56 (4.9) | 54 |
| Loosening | 21 (0.6) | 7 | 8 (1.6) | 16 | 4 (0.3) | 3 | 9 (0.8) | 9 |
| Rotator cuff problems | 35 (1.1) | 11 | 9 (1.8) | 18 | 25 (1.6) | 16 | 1 (0.1) | 1 |
| Other reasons [a] | 65 (2.0) | 21 | 11 (2.2) | 22 | 41 (2.6) | 27 | 13 (1.1) | 13 |
| Missing | 14 (0.4) | 5 | 3 (0.6) | 6 | 11 (0.7) | 7 | 0 (0) | 0 |
| Total | 306 (9.4) | 100 | 50 (9.9) | 100 | 152 (9.6) | 100 | 104 (9.0) | 100 |

[a] includes glenoid wear, malposition of the arthroplasty, and pain with no other reasons reported.

(including glenoid wear) (2.0%) and Infection (1.6%) (Table). 889 (27%) patients died within the study period.

### *Type of arthroplasty*

There were 1,587 SHAs and 1,152 RSAs. 502 arthroplasties were categorized as "Others" and for 4 arthroplasties the arthroplasty type was missing. 152 (9.6%) SHAs and 104 (9.0%) RSAs were revised. The median time to revision was 18 months (IQR 9–44) for SHA and 3 months (IQR 0–17) for RSA. The most common reason for revision was Luxation and instability for RSA and "Other reasons" (including glenoid wear) for SHA (Table). The estimated 1-, 5-, and 10-year cumulative survival rates (95% CI) were 96% (95–97), 90% (89–92), and 86% (83–88) for stemmed hemiarthroplasty and 94% (92–95), 89% (87–91) and 86% (82–90), for reverse shoulder arthroplasty (Figure 3).

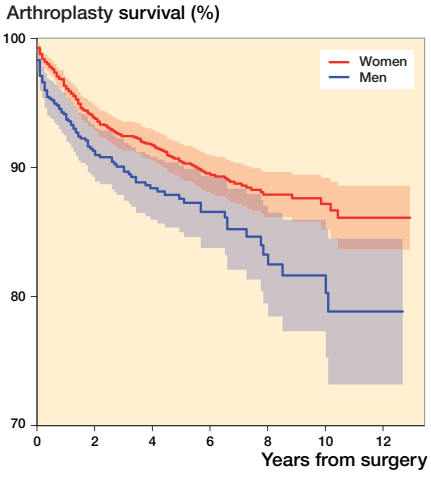
250 men and 902 women were treated with RSA during the study period. The estimated cumulative survival rates (95% CI) for these patients at 1 and 5 years were 87% (83–91), and 78% (71–85) for men and 96% (94–97) and 92% (90–94) for women (Figure 4). The risk of revision for men relative to women in patients who were treated with RSA was 3.2 (1.9–5.1) 0–1 year after surgery and 1.9 (0.9–4.1) 1–8 years after surgery (Figure 5).

### *Sex*

2,422 (75%) of the study population were women. 97 (12%) men and 209 (9%) women were revised. The estimated 1-, 5-, and 10-year cumulative survival rates (95% CI) were 94% (92–96), 88% (85–90), and 80% (75–86) for men and 96% (95–97), 90% (89–92), and 87% (85–89) for women (Figure 6).

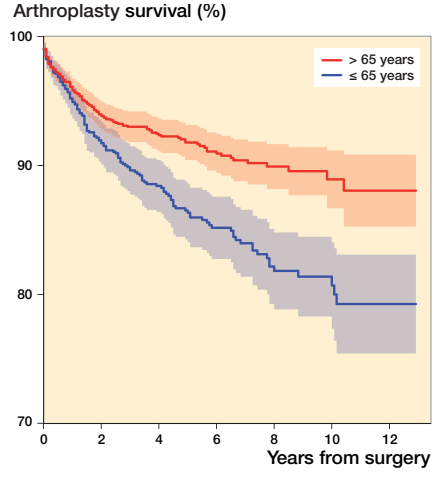
### *Age*

2,061 (63%) of the study population were older than 65 years at the time of surgery. A total of 152 (13%) patients at the age of 65 years or younger and 154 (7.5%) patients older than 65 years were revised. The estimated 1-, 5-, and 10-year cumulative survival rates (95% CI) were 95% (94–96), 86% (84–89), and 81% (77–84) for young patients and 96% (95–97), 92%



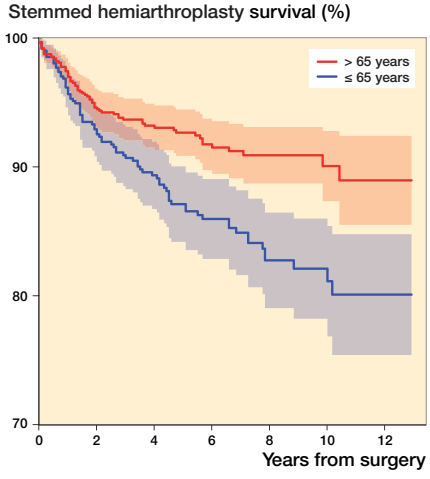

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Men | 823 | 629 | 501 | 380 | 272 | 198 | 126 | 84 | 45 | 21 | 0 |
| Women | 2,422 | 1,969 | 1,517 | 1,197 | 913 | 683 | 480 | 284 | 160 | 67 | 5 |

Figure 6. Cumulative survival for women and men from 2004 to 2016 with 95% CI and numbers at risk.




| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ≤ 65 | 1,184 | 962 | 777 | 616 | 467 | 368 | 267 | 168 | 99 | 46 | 2 |
| > 65 | 2,061 | 1,636 | 1,295 | 961 | 718 | 413 | 339 | 200 | 106 | 42 | 3 |

Figure 7. Cumulative survival for patients who were 65 years or younger and older than 65 years from 2004 to 2016 with 95% CI and numbers at risk.




| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ≤ 65 | 621 | 531 | 447 | 384 | 308 | 251 | 190 | 118 | 73 | 36 | 2 |
| > 65 | 966 | 826 | 700 | 562 | 447 | 340 | 233 | 150 | 85 | 35 | 3 |

Figure 8. Cumulative survival for patients who were 65 years or younger and older than 65 years treated with SHA from 2004 to 2016 with 95% CI and numbers at risk.

(90–93), and 89% (86–91) for older patients (Figure 7). In particular, young patients treated with SHA had a low arthroplasty survival rate (Figure 8).

## Discussion

We found that the 12-year cumulative survival rate after PHFS was 85% for SHA and 86% for RSA. This is clearly lower than survival rates found for acute PHF (Brorson et al. 2017). A plausible explanation may be that it is more difficult, with more surgical trauma added, to insert an arthroplasty when the indication is PHFS relative to acute PHF. Furthermore, patients with PHFS often have a long history of pain and poor range of motion prior to the operation, which may induce a subsequent insufficiency and stiffness of both rotator cuff muscles and tendons. This might influence the choice of implant as well as the postoperative outcome to an unknown extent. Finally, some patients are treated for PHFS because of failed osteosynthesis. This may increase the risk of revision because of periprosthetic joint infection relative to acute PHF. As the threshold for revision is expected to be high, the low survival rate for PHFS compared with acute PHF is noteworthy.

5% of RSAs were revised because of luxation and instability, which can be caused by difficulties placing the arthroplasty at the right height with the right tension when the natural anatomy cannot be used as a guidance.

The literature is not unanimous in its reports on complication rates and revision rates regarding RSA and SHA for PHFS. A study (Alentorn-Geli et al. 2014) comparing 12 patients treated with SHA and 20 patients treated with RSA for PHFS found no complications that required revision, but SHA demonstrated a higher number of complications compared with RSA. Another study (Kilic et al. 2010) comparing 19 patients treated with RSA and 36 patients treated with an anatomic arthroplasty found a higher revision rate (11%) and complication rate (25%), for RSA compared with anatomic arthroplasty. However, Alentorn-Geli et al. reported only complications that lead to revision, whereas Kilic et al. reported both minor and major complications. Comparison of complications described in the literature is challenging due to different definitions and reporting. Moreover, most studies on PHFS include small retrospective series and thus a high risk of bias.

We found lower arthroplasty survival at 1 year and shorter time to revision for RSA compared with SHA. This is in line with other studies, where the complications associated with RSA appeared early after surgery (Namdari et al. 2013,). Our study confirm that a short follow-up time shows a different complication and revision rate for RSA relative to SHA, compared with what is seen with a long follow-up time (Ferrel et al. 2015). A systematic literature review (Mansat and Bonnevialle 2015) reported the risk of revision to be 3.5–35% after treatment with arthroplasty for PHFS. In this review, the revision rate did not differentiate between RSA and SHA and the wide range in risk of revision illustrates the uncertainty of the results in small case series.

Several studies suggest that SHA and RSA must be differentiated, which is why confounding by indication may influence the comparison of SHA and RSA. SHA is suitable for less severe PHFS without the need for a greater tuberosity osteotomy, whereas RSA is recommended for severe PHFS when

a greater tuberosity osteotomy is needed (Kilic et al. 2010, Raiss et al. 2014, Mansat and Bonnevialle 2015). A higher complication and revision rate for RSA can be expected if the arthroplasty is used for the most severe cases (Kilic et al. 2010, Raiss et al. 2014). However, a revision after failed RSA can be more challenging than after hemiarthroplasty and some surgeons may hesitate to revise an RSA despite a poor functional outcome. This would lead to an underestimation of failures of RSA overall and relative to hemiarthroplasty (Namdari et al. 2013, Brorson et al. 2017).

There may be different indications for both primary and revision arthroplasty not only among countries but also among regions, hospitals, surgeons, and maybe also for the same surgeon from time to time. This may also be the reason for the different revision rates reported by single-center studies.

Our study has limitations. Information on the fracture, such as morphology, initial fracture treatment, type of sequelae, and migration of the greater tuberosity as well as patient-related factors such as smoking, obesity, and comorbidity were not included in the dataset. Also, the level of surgical experience may influence the choice of arthroplasty, and subsequently the revision rates (Murray et al. 2011). The completeness of the shoulder registries must also be addressed. It is not known whether the number of non-registered patients differs from the patients who were registered. Finally, it is important to be aware that an unknown number of failures are never revised and that some revisions can lead to a good functional outcome. Therefore, they cannot be considered as failures in a later follow-up. Thus, the reported survival rates may not reflect the functional outcome for the patients. Inclusion of patient-reported outcome could have added valuable information, but this was not possible due to the lack of comparable reporting of patient-reported outcomes in the Nordic countries. 27% of the patients died during the study period which, of course, precludes the occurrence of a subsequent revision. This introduces competing risk to the Kaplan–Meier method and the Cox proportional hazard regression model, which, in theory, would overestimate the revision rates. Nevertheless, the Kaplan–Meier method and the Cox proportional hazard regression model is believed to give adequate estimates of the revision risk (Ranstam et al. 2011, Ranstam and Robertsson 2017, Sayers et al. 2018).

In summary, shoulder arthroplasty for PHFS was associated with a lower survival rate, especially for men and younger patients, compared with previously published results of shoulder arthroplasty for acute PHF. The low arthroplasty survival rates especially for men treated with RSA and young patients treated with SHA are worrying. These results are pertinent when deciding on the treatment of PHFS. The low survival rate also indicates that it is important to be critical in the choice of treatment when it comes to initial fracture management, to avoid increased risk with joint replacement as treatment of PHFS.

All authors took part in conception and design of study and in interpretation of the results. AMF, RH, BS, SLJ, and JVR prepared data from the national registries. JVR, AMF, DU, and SR performed the statistical analysis. DU, SR, IM, VA, and JVR participated in the preparation of the manuscript. DU and SR incorporated input from all the other authors and were responsible for writing the manuscript.

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Alentorn-Geli E, Guirro P, Santana F, Torrens C. Treatment of fracture sequelae of the proximal humerus: comparison of hemiarthroplasty and reversed total shoulder arthroplasty. Arch Orthop Trauma Surg 2014; 134(11): 1545-50.

Boileau P. Complications and revision of reverse total shoulder arthroplasty. Orthop Traumatol Surg Res 2016; 102: 33-43.

Boileau P, Trojani C, Walch G, Krishnan S G, Romeo A, Sinnerton R. Shoulder arthroplasty for the treatment of the sequelae of fractures of the proximal humerus. J Shoulder Elbow Surg 2001; 10(4): 299-308.

Boileau P, Chuinard C, Le Huec J C, Walch G, Trojani C. Proximal humerus fracture sequelae: impact of a new radiographic classification on arthroplasty. Clin Orthop Relat Res 2006; (442): 121-30.

Brorson S, Salomonsson B, Jensen S L, Fenstad A M, Demir Y, Rasmussen J V. Revision after shoulder replacement for acute fracture of the proximal humerus. Acta Orthop 2017; 88(4): 446-50.

Ferrel J R, Trinth T Q, Fischer R A. Reverse total shoulder arthroplasty versus hemiarthroplasty for proximal humeral fractures: a systematic review. J Orthop Trauma 2015; 29(1): 60-8.

Hattrup S J, Waldrop R, Sanchez-Sotelo J. Reverse total shoulder arthroplasty for posttraumatic sequelae. J Orthop Trauma 2016; 30(2): 41-7.

Jacobson A, Duquin T R, Sanchez-Sotelo J, Schleck C D, Sperling J W, Cofield R H. Anatomic shoulder arthroplasty for treatment of proximal humerus malunions. J Shoulder Elbow Surg 2014; 23(8): 1232-9.

Kilic M, Berth A, Blatter G, Fuhrmann U, Gebhardt K, Rott O, Zenz P, Irlenbusch U. Anatomic and reverse shoulder protheses in fracture sequelae of the humeral head. Acta Orthop Traumatol Turc 2010; 44(6): 417-25.

Mansat P, Bonnevialle N. Treatment of fracture sequelae of the proximal humerus: anatomical vs reverse shoulder prosthesis. Int Orthop 2015; 39(2): 349-54.

Moineau G, McClelland W B, Trojani C, Rumian A, Walch G, Boileau P. Prognostic factors and limitations of anatomic shoulder arthroplasty for the treatment of posttraumatic cephalic collapse or necrosis (type-1 proximal humeral fracture sequelae). J Bone Joint Surg Am 2012; 94(23): 2186-94.

Murray I R, Amin A K, White T O, Robinson C M. Proximal humeral fractures: current concepts in classification, treatment and outcomes. J Bone Joint Surg Br 2011; 93(1): 1-11.

Namdari S, Horneff J G, Baldwin K. Comparison of hemiarthroplasty and reverse arthroplasty for treatment of proximal humeral fractures. J Bone Joint Surg 2013; 95(18): 1701-8.

Nikola C, Klobucar H, Medancic N. Reverse shoulder arthroplasty in acute fractures provides better results than in revision procedures for fracture sequelae. Int Orthop 2015; 39(2): 343-8.

Raiss P, Edwards T B, Silva M R, Bruckner T, Loew M, Walch G. Reverse shoulder arthroplasty for the treatment of nonunions of the surgical neck of the proximal part of the humerus (type-3 fracture sequelae). J Bone Joint Surg 2014; 96(24): 2070-6.

Raiss P, Edwards T B, Collin P, Bruckner T, Zeifang F, Loew M, Boileau P, Walch G. Reverse shoulder arthroplasty for malunions of the proximal part of the humerus (type-4 fracture sequelae). J Bone Joint S 2016; 98(11): 893-9.

Raiss P, Edwards T B, Bruckner T, Loew M, Zeifang F, Walch G. Reverse arthroplasty for patients with chronic locked dislocation of the shoulder (type 2 fracture sequela). J Shoulder Elbow Surg 2017; 26(2): 279-87.

Ranstam J, Kärrholm J, Pulkkinen P, Mäkelä K, Espehaug B, Pedersen A B, Mehnert F, Furnes O; NARA study group. Statistical analysis of arthroplasty data, II: Guidelines. Acta Orthop 2011; 82(3): 258-67.

Ranstam J, Robertsson O. The Cox model is better than the Fine and Gray model when estimating relative revision risks from arthroplasty register data. Acta Orthop 2017; 3674: 1-3.

Rasmussen J V, Brorson S, Hallan G, Dale H, Äärimaa V, Mokka J, Jensen S, Fenstad A M, Salomonsson B. Is it feasible to merge data from national shoulder registries? A new collaboration within the Nordic Arthroplasty Register Association. J Shoulder Elbow Surg 2016; 25(12): 369-377.

Sayers A, Evans J T, Whitehouse MR, Blom AW. Are competing risks models appropriate to describe implant failure? Acta Orthop 2018; 89(3): 256-8.

Wand R J, Dear K E, Biqsby E, Wand J S. A review of shoulder replacement surgery. J Perioper Pract 2012; 22(11): 354-9.