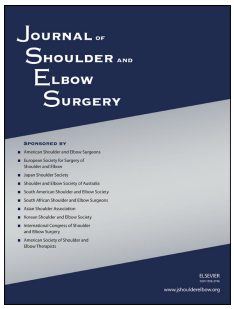

Distal Humeral Hemiarthroplasty compared to Total elbow replacement for distal humeral fractures: a registry analysis of 906 procedures.

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Running Head Title: Hemiarthroplasty or Elbow Replacement for Fracture.

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Distal humeral hemiarthroplasty compared to total elbow replacement for distal humeral fractures: a registry analysis of 906 procedures.

Abstract

Background: Total elbow replacement (TER) is an accepted treatment for complex intra-articular distal humerus fractures in elderly patients. Distal humeral hemiarthroplasty (HA) is also a potential surgical option for unreconstructable fractures and avoids the concerns regarding mechanical wear and functional restrictions associated with TER. In the current literature, there are limited data available to compare the revision rates of HA and TER for the treatment of fracture. We used data from a large national arthroplasty registry to compare the outcome of HA and TER undertaken for fracture/dislocation and to assess the impact of demographics and implant choice on revision rates.

Methods: Data obtained from the Australian Orthopaedic Association National Joint Replacement Registry from May 2, 2005, to December 31, 2021, included all procedures for primary elbow replacement with primary diagnosis of fracture/dislocation. The analyses were performed using Kaplan-Meier estimates of survivorship and hazard ratios from Cox proportional hazards models.

Results: There were 293 primary HA and 631 primary TER procedures included. The cumulative percent revision (CPR) rate at 9 years was 9.7% for HA (95% confidence interval [CI] 6.0, 15.7), and 11.9% (95% CI 8.5, 16.6) for TER. When adjusted for age and gender, there was a significantly higher risk of revision after 3 months for TER compared to HA (HR=2.47 [95% CI 1.22, 5.03], p=0.012). There was no difference in the rate of revision for patients aged <55 years or ≥75 years when HA and TER procedures were compared. In primary TER procedures, loosening was the most common cause of revision (3.6% of

primary TER procedures) and the most common type of revision in primary TER involved revision of the humeral component only (2.6% of TER procedures). TER has a higher rate of 1st revision for loosening compared to HA (HR=4.21(1.29, 13.73); p=0.017). In HA procedures instability (1.7%) was the most common cause for revision. The addition of an ulna component was the most common type of revision (2.4% of all HA procedures).

Conclusion: For the treatment of distal humerus fractures, HA had a lower revision rate than TER after 3 months when adjusted for age and gender. Age <55 or ≥75 years was not a risk factor for revision when HA is compared to TER. Loosening leading to revision is more prevalent in TER and increases with time. In HA, the most common type of revision involved addition of an ulna component with preservation of the humeral component.

Level of Evidence: Level III; Retrospective Cohort Comparison using Large Database; Treatment Study

Keywords: Distal humerus fracture; arthroplasty; hemiarthroplasty; joint registry; elbow arthroplasty; revision rate; elbow joint.

Distal humerus fractures account for 2% – 5% of all fractures and occur in a bimodal age and gender distribution with high energy injuries in younger males and low-energy falls in elderly females with osteoporosis. For displaced and intraarticular fractures, operative management is recommended to restore function. Reconstructive goals are to achieve anatomic reduction of the articular surface with a rigid fixation construct that is durable enough to allow early mobilization. In the setting of poor bone quality, as with osteoporosis or inflammatory arthritis, reconstruction is challenging, particularly with comminution and articular

involvement. Up to twenty-five percent of these fractures in patients over 65 years are not amenable to internal fixation, requiring either intraoperative conversion to arthroplasty, revision surgery for early fixation failure[8 14] or non-operative treatment in favor of the "bag of bones" technique.[6]

Lower rates of revision for TER as an alternative to open reduction and internal fixation (ORIF) in elderly patients with complex distal humerus fractures are well established,[14,24] with acceptable longevity in surviving patients at 10 years.[3,16] However, this is at the cost of several complications, including aseptic loosening, polyethylene wear, osteolysis, infection, ulna nerve irritation and peri-prosthetic fracture.[3,9,14,27] In younger patients with longer life expectancy and higher functional demands, the risk of mechanical failure increases when TER is performed for fracture.[4,7,12,26] Consequently, there has been a growing interest in HA for the treatment of distal humeral trauma in select patients.

The use of HA in distal humerus fractures is well described, with good short- and medium-term results.[13,15,17,19,22,28] HA has been proposed as a reasonable option in older patients who can immediately commence postoperative weight-bearing if reliant on assistive devices for mobilization,[23] as well as younger, active patients who are unwilling to accept activity restrictions associated with TER.[1,21] The absence of an ulna component and linking articulation eliminates a common mode of failure observed in TER related to polyethylene wear and prosthesis loosening. In addition, distal HA preserves the radial and ulna articulations and bone stock which may allow for easier revision arthroplasty if required.

Current published evidence comparing HA and TER for fracture is limited to retrospective studies with small sample sizes. [16,18] Complication rates following HA range between 20% – 60%.[5,19,28] A systematic review in 2022 cited the most common complications being heterotopic ossification, ulna wear, ulna neuropathy and postoperative

stiffness.[17] There are limited reports on the outcome of HA in younger, active patients, with a paucity of longer-term follow-up. Longer term, comparison data are needed to better understand durability of distal humerus HA for the management of distal humeral fractures.

Previous registry-based studies have reported on the use and outcomes of TER for all indications.[7,11,16,20,25] A Swedish Joint Registry study investigated arthroplasty performed only for distal humerus fractures and demonstrated that implant survival rate for fracture was good compared with results from implant survival for any other diagnosis, and that the revision rate for HA was low with no statistically significant difference in survival compared to TER. However, the numbers of HA included in the study were low (87 in total) with only two revisions and no long term data available.[16] The aim of this study was to compare the revision rates of primary HA and primary TER when used to treat distal humerus fractures at a nationwide level by using data from the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR). Secondary aims were to determine the effect of age, gender and prosthesis fixation on revision rates, in addition to the reasons for, and types of revisions for primary procedures.

Materials and Methods

The AOANJRR began data collection on September 1, 1999, was expanded to include elbow arthroplasty procedures in May 2005 and has documented almost all elbow arthroplasty procedures Australia-wide since November 2008.[2] These data are externally validated against patient-level data provided by all Australian state and territory health departments. A sequential, multilevel matching process is used to identify any missing data which are subsequently obtained by follow-up with the relevant hospital. Each month, in addition to internal validation and data quality checks, all primary procedures are linked to any subsequent revision involving the same patient, joint and side. Re-operation other than

Prosthetic revision procedures were not routinely recorded. Data are also matched bi-annually to the Australian National Death Index data to identify patients who have died.

The study period was May 2, 2005 to December 2021. The study population included all primary TER and HA elbow procedures undertaken for fracture/dislocation. Procedures were grouped according to HA and TER, and cumulative percent revision (CPR) were determined. Further analyses based on patient demographic characteristics and reasons for revision and types of revision were performed.

Statistical Analysis

Kaplan-Meier estimates of survivorship were used to report the time to first revision with censoring at the time of death and closure of the dataset at the end of December 2021. The unadjusted cumulative percent revision (CPR), with 95% confidence intervals (CI), were calculated using unadjusted point wise Greenwood estimates. Age- and gender-adjusted hazard ratios (HRs) calculated from Cox proportional hazards models were used to compare the revision rates between groups. 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 time-period. For the current study, if no time-period was specified, the HR was calculated over the entire follow-up period. All tests were two-tailed at 5% significance. Statistical analysis was performed using SAS software version 9.4 (SAS Institute, Inc., Cary, NC, USA).

Results

Demographic characteristics

There were 906 primary elbow arthroplasty procedures with a primary diagnosis of a fracture, of which 293 were HA procedures and 613 were TERs (Table 1). The mean and maximum follow-up between both groups were similar (HA: mean 4.7 years [± 3.7], maximum 15.3 years; TER: mean 4.3 years [± 3.4], maximum 14.4 years). HA was performed in a younger patient population with the mean age in the HA group 68.5 years, compared to 77.5 years in the TER group. Both HA and TER are more commonly performed in female patients (HA 86.3%, TER 83%).

Revision rates

Over the study period, a total of 20 primary HA and 45 primary TER procedures were revised (Table 2). The CPR at 9 years was 9.7% (95% CI 6.0, 15.7) for HA and 11.9% (95% CI 8.5, 16.6) for TER. When adjusted for age and gender, there was a higher rate of revision for TER compared to HA after 3 months (HR=2.47 [95% CI 1.22, 5.03], p=0.012) with no statistical difference prior to this time (Fig 1).

Age

In both the HA and TER groups, the number of procedures performed increased with age (Table 3). However overall, more HA were performed in patients aged < 55 years (n=32, 10.9%) compared to TER (n=15, 2.4%). There was no difference in the rate of revision for patients aged < 55-years (Fig 2) or for patients aged ≥75 years (Fig 3) when HA and TER procedures were compared.

Gender

With the numbers available for both male and female patients, there was no statistically significant difference in the rate of revision between the two elbow replacement groups (Table 4).

Reason for revision

The reason for revision was reported in two ways, as a percentage of primary procedures revised and as a percentage of all revision procedures (Table 5).

In the TER population, loosening accounted for the largest proportion of primary procedure revisions (3.6%), followed by infection (1.5%) and fracture (1.3%). Instability, incorrect sizing, and malposition were the least common causes for TER revisions (0.2%). TER has a significantly higher rate of 1st revision for loosening compared to HA HR=4.21(1.29, 13.73); p=0.017. In the HA group, the largest proportion of primary procedures were revised for instability (1.7%), followed by loosening (1.4%) and infection (1.4%).

In the TER group loosening was the main reason for 48.9% of all revisions (n=22/45). In the TER group a further 20% (n=9/45) of revisions were indicated for infection and 17.8% (n=8/45) were due to fracture. There were no TER procedures revised due to pain or progression of disease. In the HA group the most common reason for revision procedures was instability (25%, n=5/20). Loosening was the second most common indication for revision in HA (20.0%, n=4/20) in addition revision for infection (20.0%, n=4/20). There were no HA procedures revised due to incorrect sizing or malposition and only 5.0% (n=1/20) of all revisions in the HA group were revised due to fracture.

Revision over time

The cumulative incidence of revision by diagnosis between groups is shown (Fig 4). In HA, early revisions are due to fracture, instability, prosthesis dislocation and infection, with loosening becoming the most prevalent cause of revision from 7 years onwards. For TER, early revisions are largely due to fracture and infection, with loosening becoming the most

predominant cause for revision from 3 years onwards. As expected, instability and prosthesis dislocation are uncommon in TER in comparison to HA.

Types of revision

The most common revision of a HA involved the addition of an ulnar component only, n=7. (Table 6). The next most common type of revision involved both the humeral and ulnar components, n=6. There were no cases reported of HA revised to a HA. The most common type of revision of TER involved the humeral component only without need for revision of the ulnar component, n=16. A further 3 cases required revision of the ulnar component in the same procedure. Exchange of the elbow pin (bushing exchange) was required in 7 cases and the ulnar component was revised in isolation in 8 cases. In 4 of the TER revisions, definitive procedures involved an excision arthroplasty with removal of the prosthesis. This compares to 2 elbow HA where all prostheses were removed.

Discussion

Management of unreconstructable distal humerus fractures is challenging and the indications for distal humerus HA are not well defined. Adult distal humerus fractures are relatively rare and the majority of these injuries are suitable for open reduction and internal fixation due to reconstructable intra-articular surfaces[18]. TER and more recently HA are potential treatment options for unreconstructable distal humerus fractures but there are limited numbers of elbow arthroplasty performed which makes comparison trials with sufficient numbers and long-term results difficult to publish. TER is an established treatment option for the arthritic elbow and the annual use of TER for trauma has increased over the past 10 years[25] in contrast to the number of HA which remains largely unchanged. The reasons for this are likely multifactorial; the procedure is technically demanding with concerns around a possible high

complication rate.[28] However, the low numbers are likely also due to the paucity of HA long-term results available and limited number of surgeons trained and willing to perform this relatively rare procedure.

Compared to previous studies, this is the largest comparative study of elbow HA and TER for the management of distal humerus fractures. Our findings are consistent with the results of previous studies suggesting that HA is a suitable management option for unreconstructable distal humerus fractures with comparable revision rates to TER. We expect the findings from this study will contribute to greater use of HA due to the increasing evidence of the outcomes of this treatment option for distal humerus fractures unsuitable for open reduction and internal fixation.

A literature review yielded only two studies that directly compared TER to HA in the fracture setting. Nestorson et al[16] published a joint registry-based study reviewing the use of arthroplasty (HA or TER) as primary treatment for distal humeral fractures. They report HA demonstrated a low revision rate, with 2 revisions performed out of a total of 87 prostheses (2.3%), and 9 adverse events that did not lead to revision surgery (10.3%). This compares with 16 revisions of 317 TER prostheses (5.0%), and 17 adverse events that did not lead to revision surgery (5.4%). The authors did not perform further subgroup comparative analysis of cause and type of revision between HA and TER. Rangarajan et al [18] published a literature review comparing the use of distal humeral HA and TER with a discussion regarding HA indications, contraindications, implant considerations, surgical techniques, complications and outcome data from recent studies. They included 6 studies reporting use of HA and 14 studies using TER in distal humerus fractures treatment with an average follow-up of over 2 years. Their conclusion stated equivalent outcomes for HA and TER at short- and mid-term follow-up, but that distal humeral HA carries a higher overall reoperation rate predominately due to olecranon osteotomy hardware removal.

Two systematic reviews evaluating the outcomes of HA for distal humerus fractures were noted. Kwak et al [13] performed a systematic review of the functional outcomes of hemiarthroplasty for distal humerus fractures. Although functional outcomes for HA were comparable with TER, the overall complication rate remained higher. The most common complication being cartilage wear (39.1%), followed by heterotopic ossification, loosening, neuropathy and stiffness. This review did not include revision rates and and thus is not directly comparable with our series.

Wilfred et al more recently published a systematic review evaluating the outcomes and complications associated with HA in the fracture setting.[28] This included the previous six studies analyzed by Rangarajan, in addition to a further five studies, all of which were classified as level IV evidence. HA demonstrated a reasonable option for fractures not amenable to ORIF as was considered suitable due to fewer weightbearing restrictions. The rate of major complications which required further surgery was 11%, with 7% requiring revision surgery for symptomatic loosening. Our results support the finding that loosening remains a concern with this being the most frequent reason for revision of TER in our series.

In the present study we have found that TER are more likely to be performed in an older population group to HA (77.5 years compared to 68.5 years), with no significant difference in revision rates compared between the HA and TER groups. In the older population, TER was traditionally preferred as it is more constrained compared to HA and there is less concern regarding reconstructing columns and ensuring a balanced and stable soft tissue ligament repair. However, the requirement to preserve distal humeral columns during HA has been questioned with a recent study demonstrating reliable results including stability, range of motion, grip strength and patient-reported outcome measures in HA, irrespective of condylar preservation[10].

Stephens et al[23] explored the role of HA in elderly patients who required assistive devices to mobilize, and where the lifetime weight lifting restriction would limit postoperative mobility and functionality. Nine patients with unreconstructable distal humerus fractures managed with HA were included in the study. The mean age was 71 years, and all patients were living at home independently prior to the injury. Postoperatively the patients were placed in a sling and commenced immediate weight bearing through the HA prosthesis with no mandated physical weight bearing restriction. Patients reported overall preserved functional capabilities, and one patient required revision surgery due to failure of the distal humeral prosthesis. Recent advancements in our knowledge widens the indication for HA in the elderly including those with non-reconstructable columns and those who require immediate postoperative assistive devices to mobilize. Interestingly we did not find a significant difference in revision rates between the HA and TER groups when treating elderly patients (>75 years) which supports the use of HA as a viable option in this age group. We acknowledge that the indications for performing revision procedures in older age groups change and this may have influenced our results.

In our study, the mean age of HA patients was 68.5-years compared with 77.5-years in the TER group. Over the 15-year time period data were collected, a limited number of patients aged < 55 years underwent TER (n=15) compared with HA (n = 32). These low numbers of TER in the younger population are consistent with concerns regarding wear and the longevity of the TER implant. While no significant difference was found in revision rates between HA and TER in the younger population, these results may be due to the low numbers included. Smith et al[21] reported on six patients aged <55-years (mean age 44 years at time of surgery) treated with HA. Satisfactory patient outcomes were reported in all cases with 4 of 6 performing at least one high demand activity (e.g. mountain biking, rock climbing, dirt shoveling, etc). These patients did not require revision surgery specifically for

symptomatic chondral wear. Although rarely indicated, HA for younger patients is well tolerated with a higher level of function compared to TER. However, further comparative studies with larger numbers are required.

While the revision rates between the two groups in this study are comparable, the reason for and type of revision varies. The majority of HA revisions involve the addition of an ulna component (35.0%) while over 60% of TER revisions involve revising the humeral component, the ulna component or both. Particularly in the younger patient, preserving bone stock is critical and revisions involving exchanging components are likely to be associated with more morbidity. Further studies are required to quantify the outcomes of revision surgery between HA and TER, particularly in the younger population.

The advantages of this study include reporting longitudinal data of a large database with number of procedures evaluated in this study significantly larger than any other study comparing TER to HA for fracture. Furthermore, the registry data captures all procedures performed across Australia from a wide spectrum of surgeons from mixed clinical settings. This is particularly valuable considering the relatively low numbers of elbow arthroplasties performed and most published studies evaluate outcomes of a single surgeon. Limitations of this study are those associated with nonrandomized registry - based studies including the potential for coding errors in the database, inherent differences in patient cohort compared and the lack of data reporting on patient-related outcomes, radiographic analysis and potentially underperforming prostheses that are not revised. Also higher failure rates in TER may be related to surgeons preferring to use TER in patients with features making them more likely to experience failure such as poor bone quality, or greater soft tissue injury.

Conclusion

To our knowledge, this is the largest comparative study of elbow HA and TER for the management of distal humeral fractures. HA had a lower revision rate compared with TER after 3 months when adjusted for age and gender. HA may allow a higher level of function and load bearing compared to TER with preservation of bone stock for young active patients. Loosening leading to revision is more prevalent in TER and increases with time, however, this effect is less marked in HA. In HA, the most common type of revision involved addition of an ulna component with preservation of the humeral component. The indications for utilizing HA in the fracture setting are increasing and further prospective trials are recommended to delineate long term functional outcomes in specific patient groups with unreconstructable fractures who may benefit from HA compared to TER.

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Table 1: Summary of Primary Elbow Replacement by Type, Primary Diagnosis Fracture/Dislocation (95% CI)

		HA (n = 293)	TER (n = 613)	TOTAL (n = 906)
Follow-Up Years				
	Mean ± SD	4.7 ± 3.7	4.3 ± 3.4	4.5 ± 3.5
	Median (IQR)	4 (1.5, 7.1)	3.6 (1.6, 6.4)	3.7 (1.6, 6.7)
	Minimum	0	0	0
	Maximum	15.3	14.4	15.3
Age				
	Mean ± SD	68.5 ± 12.9	77.5 ± 9.8	74.6 ± 11.7
	Median (IQR)	68 (61, 78)	78 (72, 84)	76 (68, 83)
Gender				
	Male	40 (13.7%)	104 (17%)	144 (15.9%)
	Female	253 (86.3%)	509 (83%)	762 (84.1%)

Abbreviations: *HA*, hemiarthroplasty, *TER*, total elbow replacement, *SD*, standard deviation, *IQR*, interquartile range.

Table 2: Yearly Cumulative Percent Revision of Primary Elbow Replacement by Type of Primary (95% CI)

CPR	N Revised	N Total	1 Yr	2 Yrs	3 Yrs	4 Yrs
Humeral Hemiarthroplasty	20	293	3.9 (2.2, 6.9)	4.7 (2.8, 8.0)	5.2 (3.1, 8.7)	5.2 (3.1, 8.7)
Total Elbow	45	613	2.6 (1.6, 4.3)	4.5 (3.0, 6.7)	6.2 (4.3, 8.7)	7.7 (5.6, 10.6)

CPR	5 Yrs	6 Yrs	7 Yrs	8 Yrs	9 Yrs	10 Yrs
Humeral Hemiarthroplasty	6.6 (4.0, 10.7)	7.5 (4.6, 12.1)	9.7 (6.0, 15.7)	9.7 (6.0, 15.7)	9.7 (6.0, 15.7)	
Total Elbow	8.5 (6.2, 11.6)	9.5 (6.9, 12.9)	10.0 (7.3, 13.7)	10.9 (7.8, 15.1)	11.9 (8.5, 16.6)	13.2 (9.2, 18.8)

CI, confidence interval

Table 3: Revision of Primary Elbow Replacement by Type of Primary and Age, Primary Diagnosis Fracture/Dislocation (95% CI)

Type of Primary	Age	N Revised	N Total	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs
Humeral Hemiarthroplasty	<55	7	32	9.4 (3.1, 26.3)	16.3 (7.1, 35.0)	24.0 (12.1, 44.0)	24.0 (12.1, 44.0)	24.0 (12.1, 44.0)
	55-64	4	75	2.8 (0.7, 10.7)	2.8 (0.7, 10.7)	2.8 (0.7, 10.7)	6.5 (1.9, 21.5)	12.8 (4.1, 35.7)
	65-74	3	91	2.2 (0.6, 8.5)	2.2 (0.6, 8.5)	2.2 (0.6, 8.5)	5.7 (1.6, 19.8)	
	≥75	6	95	4.5 (1.7, 11.7)	6.0 (2.5, 14.1)	6.0 (2.5, 14.1)	11.3 (4.1, 28.8)	
Total Elbow	<55	4	15	20.0 (6.9, 50.0)	28.0 (11.4, 58.9)	28.0 (11.4, 58.9)		
	55-64	5	34	3.3 (0.5, 21.4)	7.2 (1.8, 26.0)	7.2 (1.8, 26.0)	21.5 (8.1, 49.9)	32.7 (13.6, 65.8)
	65-74	14	156	2.7 (1.0, 7.1)	7.2 (3.8, 13.4)	13.3 (8.0, 21.9)		
	≥75	22	408	1.9 (0.9, 3.9)	4.8 (2.9, 7.7)	5.8 (3.6, 9.2)	6.6 (4.1, 10.4)	
TOTAL		**65**	**906**					

CI, confidence interval

Table 4: Revision of Primary Elbow Replacement by Type and Gender, Primary Diagnosis Fracture/Dislocation (95% CI)

Type of Primary	Gender	N Revised	N Total	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs
Humeral Hemiarthroplasty	Male	1	40	0.0 (0.0, 0.0)	3.1 (0.4, 20.2)	3.1 (0.4, 20.2)	3.1 (0.4, 20.2)	3.1 (0.4, 20.2)
	Female	19	253	4.5 (2.5, 8.0)	5.5 (3.2, 9.4)	7.1 (4.2, 11.7)	10.7 (6.5, 17.5)	
Total Elbow	Male	11	104	5.2 (2.2, 12.0)	11.3 (5.9, 20.9)			
	Female	34	509	2.1 (1.1, 3.9)	5.2 (3.4, 7.8)	7.6 (5.2, 11.0)	8.8 (6.1, 12.7)	12.4 (8.2, 18.7)
TOTAL		**65**	**906**					

CI, confidence interval

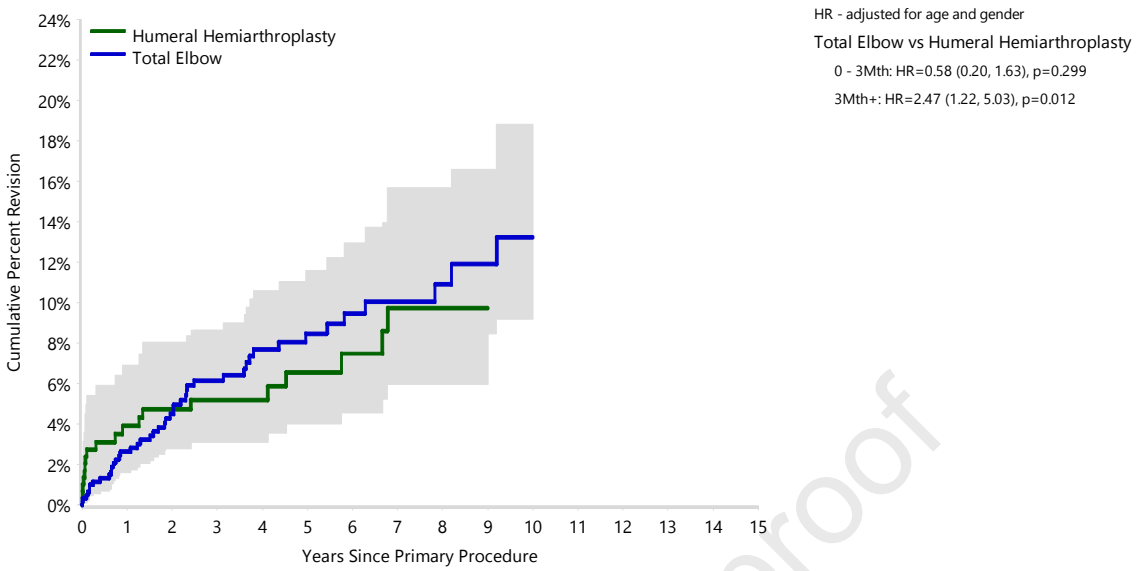
Table 5: Revision Diagnosis of Primary Elbow Replacement by Type, Primary Diagnosis Fracture/Dislocation.

	Humeral Hemiarthroplasty			Total Elbow		
Revision Diagnosis	Number	% Primaries Revised	% Revisions	Number	% Primaries Revised	% Revisions
Loosening	4	1.4	20.0	22	3.6	48.9
Infection	4	1.4	20.0	9	1.5	20.0
Fracture	1	0.3	5.0	8	1.3	17.8
Instability	5	1.7	25.0	1	0.2	2.2
Prosthesis Dislocation	2	0.7	10.0			
Heterotopic Bone	1	0.3	5.0			
Incorrect Sizing				1	0.2	2.2
Malposition				1	0.2	2.2
Pain	1	0.3	5.0			
Progression Of Disease	1	0.3	5.0			
Other	1	0.3	5.0	3	0.5	6.7
N Revision	**20**	**6.8**	**100.0**	**45**	**7.3**	**100.0**
N Primary	**293**			**613**		

Table 6: Type of Revision of Primary Elbow Replacement by Type, Primary Diagnosis Fracture/Dislocation.

	Humeral Hemiarthroplasty			Total Elbow		
Type of Revision	Number	% Primaries Revised	% Revisions	Number	% Primaries Revised	% Revisions
Humeral Component				16	2.6	35.6
Ulna Component	7	2.4	35.0	8	1.3	17.8
Elbow Pin Only				7	1.1	15.6
Humeral/Ulnar	6	2.0	30.0	3	0.5	6.7
Removal of Prostheses	2	0.7	10.0	4	0.7	8.9
Minor Components				3	0.5	6.7
Cement Spacer	1	0.3	5.0	2	0.3	4.4
Reoperation	2	0.7	10.0			
Radial Head Only				1	0.2	2.2
Radial/Ulnar	1	0.3	5.0			
Reinsertion of Components	1	0.3	5.0			
Ulna Cap Only				1	0.2	2.2
N Revision	**20**	**6.8**	**100.0**	**45**	**7.3**	**100.0**
N Primary	**293**			**613**		

Figure 1: Cumulative Percent Revision of Primary Elbow Replacement by Type of Primary (Primary Diagnosis Fracture/Dislocation). *HR*, hazard ratio.

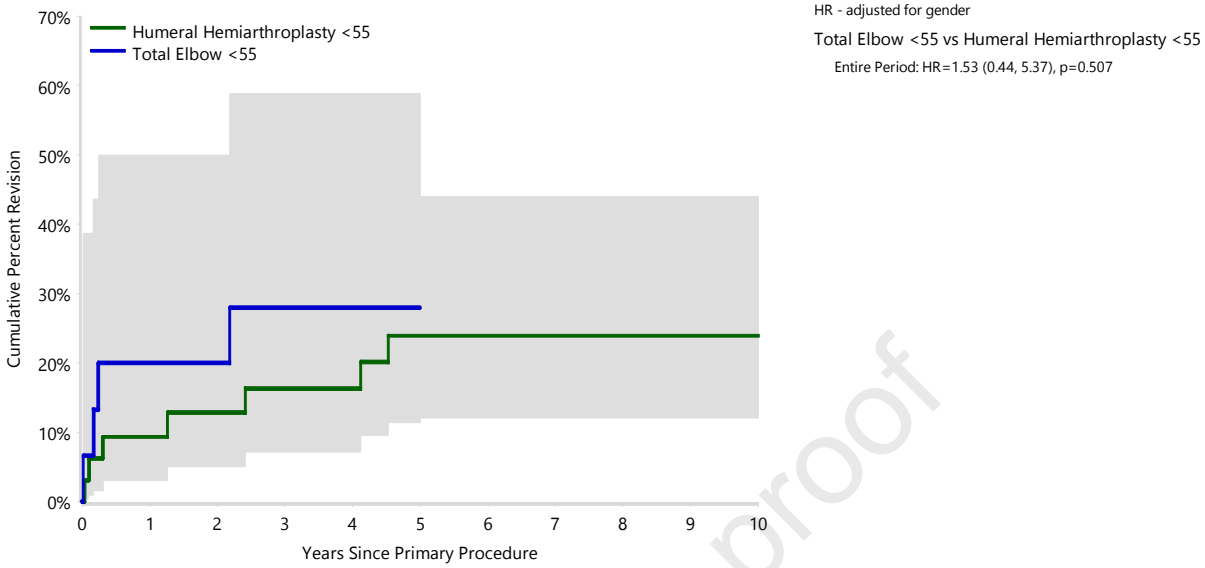


Number at Risk	0 Yr	1 Yr	2 Yrs	3 Yrs	4 Yrs	5 Yrs	6 Yrs	7 Yrs
Humeral Hemiarthroplasty	293	238	209	182	145	126	96	76
Total Elbow	613	511	428	345	272	216	167	134

Number at Risk	8 Yrs	9 Yrs	10 Yrs	11 Yrs	12 Yrs	13 Yrs	14 Yrs	15 Yrs
Humeral Hemiarthroplasty	60	47	32	20	15	8	1	1
Total Elbow	100	69	47	31	22	11	4	0

Cox regression adjusted age and gender

Figure 2: Cumulative Percent Revision of Primary Elbow Replacement by Type of Primary and Patient Age <55 years (Primary Diagnosis Fracture/Dislocation) *HR*, hazard ratio.

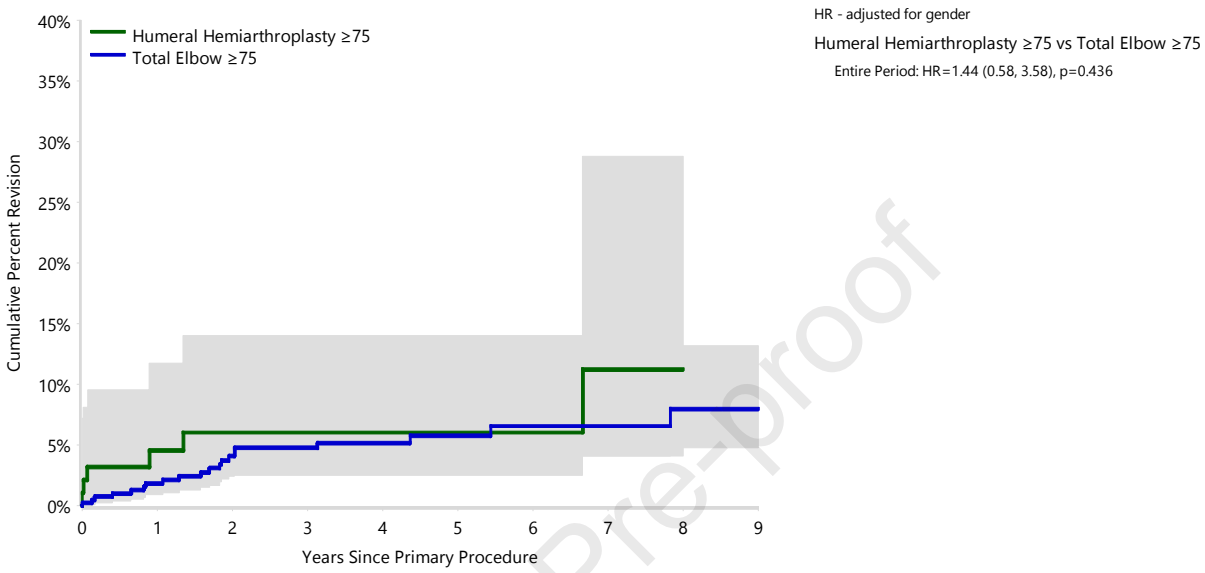


Number at Risk		0 Yr	1 Yr	2 Yrs	3 Yrs	4 Yrs	5 Yrs
Humeral Hemiarthroplasty	<55	32	26	25	24	22	20
Total Elbow	<55	15	12	10	7	5	4

Number at Risk		6 Yrs	7 Yrs	8 Yrs	9 Yrs	10 Yrs	11 Yrs	12 Yrs
Humeral Hemiarthroplasty	<55	18	16	15	13	7	4	3
Total Elbow	<55	2	2	1	0	0	0	0

Cox regression adjusted gender

Figure 3: Cumulative Percent Revision of Primary Elbow Replacement by Type of Primary and Patient Age ≥75 years (Primary Diagnosis Fracture/Dislocation) *HR*, hazard ratio.



Number at Risk	0 Yr	1 Yr	2 Yrs	3 Yrs	4 Yrs	5 Yrs	6 Yrs
Humeral Hemiarthroplasty ≥75	95	68	57	51	37	31	21
Total Elbow ≥75	408	339	285	231	178	137	106

Number at Risk	7 Yrs	8 Yrs	9 Yrs	10 Yrs	11 Yrs	12 Yrs	13 Yrs	14 Yrs
Humeral Hemiarthroplasty ≥75	15	11	5	2	0	0	0	0
Total Elbow ≥75	85	62	43	30	19	11	5	2

Cox regression adjusted gender

Figure 4: Cumulative Incidence Revision Diagnosis of Primary Elbow Replacement by Type of Primary (Primary Diagnosis Fracture/Dislocation) *HR*, hazard ratio.