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Implant survival of total elbow arthroplasty: analysis of 514 cases from the Dutch Arthroplasty Registry

A. A. Macken,
A. Prkić,
I. van Oost,
A. Spekenbrink-Spooren,
B. The,
D. Eygendaal

From Erasmus Medical Centre, Rotterdam, the Netherlands

Aims

The aim of this study is to report the implant survival and factors associated with revision of total elbow arthroplasty (TEA) using data from the Dutch national registry.

Methods

All TEAs recorded in the Dutch national registry between 2014 and 2020 were included. The Kaplan-Meier method was used for survival analysis, and a logistic regression model was used to assess the factors associated with revision.

Results

A total of 514 TEAs were included, of which 35 were revised. The five-year implant survival was 91%. Male sex, a higher BMI, and previous surgery to the same elbow showed a statistically significant association with revision ($p < 0.036$). Of the 35 revised implants, ten (29%) underwent a second revision.

Conclusion

This study reports a five-year implant survival of TEA of 91%. Patient factors associated with revision are defined and can be used to optimize informed consent and shared decision-making. There was a high rate of secondary revisions.

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Keywords: Total elbow arthroplasty, Implant survival, Revision, National registry, Infection, Loosening, Re-revision

Introduction

Total elbow arthroplasty (TEA) is indicated for severe symptomatic cases of rheumatoid arthritis, primary osteoarthritis, post-traumatic sequelae, and in selective trauma cases.[1-4] The revision rate of TEA is relatively high compared to arthroplasties of other joints; a systematic review of 9,308 cases found a revision rate of 14% with a mean follow-up of 82 months.[2] Common reasons for revision are polyethylene or bushing wear, aseptic and septic loosening ultimately leading to instability, or dislocation in some cases. Previous studies examining the factors influencing the risk of revision or a complication highlighted age, sex, socioeconomic status, smoking, indication for surgery, comorbidity, implant designs, and hospital or surgeon volume as potential factors of influence.[4-13]

A revision comprises a significant burden on the patient and healthcare system. Consequently, expected implant survival plays an important role in the shared decision-making process when considering TEA. The currently available follow-up data for total elbow implants are limited to relatively small cohort studies, except for one study including 461 elbows published by the designer of the implant.[3,14-21] Cohort studies are potentially prone to bias and conflicts of interest. To circumvent these issues, data from a national registry can be used. Furthermore, analysis of a large cohort may aid in identifying trends and factors associated with revision, which may prove helpful in reducing the revision rate in the future. This is specifically relevant for prostheses that are placed in limited numbers such as TEA.

Correspondence should be sent to Arno A Macken; email: arnomacken@gmail.com

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Table I Characteristics of patients undergoing a primary total elbow arthroplasty in the Netherlands between 2014 to 2020 (n = 514).

Variable	Data
Mean age, yrs (SD)	66 (12)
Female, n (%)	386 (75)
Smoking, n (%)	63 (12)
Mean BMI, kg/m² (SD)	27 (5)
ASA classification, n (%)	
I	45 (9)
II	294 (57)
III to IV	174 (34)
Unspecified	1 (0)
Previous surgery, n (%)	**215 (42)**
Arthroscopy	17 (3)
Lateral arthrotomy	101 (20)
Medial arthrotomy	27 (5)
Posterior arthrotomy	69 (13)
Ulnar nerve decompression	11 (2)
Osteosynthesis	105 (20)
Arthrodesis	3 (1)
Hardware removal	64 (12)
Other	56 (11)
Indication for TEA, n (%)	
Rheumatoid arthritis	170 (33)
Post-traumatic sequelae	145 (28)
Osteoarthritis	106 (21)
Acute fracture	52 (10)
Inflammatory arthritis	4 (1)
Haemophilic arthropathy	4 (1)
Osteonecrosis	4 (1)
Primary tumour	3 (1)
Metastasis of a tumour	3 (1)
Other	23 (4)

ASA, American Society of Anesthesiology; SD, standard deviation; TEA, total elbow arthroplasty.

Table II. Treatment characteristics of primary total elbow arthroplasty performed in the Netherlands between 2014 to 2020 (n = 514).

Variable	Data
Surgery on dominant limb, n (%)	215 (42)
High-volume centre, n (%)	142 (28)
Surgical approach, n (%)	
Posterior	487 (95)
Triceps on	218 (42)
Triceps off	179 (35)
Triceps split	38 (7)
Olecranon osteotomy	2 (0)
Unspecified	50 (10)
Lateral	8 (2)
LCL intact	1 (0)
LCL off	7 (1)
Other	19 (4)
Implant design, n (%)	
Linked	392 (76)
Unlinked	53 (10)
Unspecified	69 (13)
Fixation, n (%)	
All components cemented	480 (94)
Ulnar component cemented	16 (3)
Humeral component cemented	1 (0)
Uncemented	7 (1)
Unspecified	10 (2)
Autograft bone used, n (%)	298 (58)
Ulnar nerve transposition, n (%)	123 (24)

LCL, lateral colateral ligament.

Although some national registries include TEA (Australia, New Zealand, Norway, Sweden, and the UK) and publish annual reports, they generally do not include comparative analyses of the outcomes.[22,23] To our knowledge, only five studies have been published using registry data to analyze and compare the outcomes of TEA.[7,12,13,24,25] Therefore, the primary aim of this study is to report the implant survival of TEA, using data from the Dutch arthroplasty registry (Landelijke Registratie Orthopedische Implantaten (LROI)). The secondary aim is to identify factors associated with revision.

Methods

Data acquisition. Data on elbow arthroplasties are recorded in the registry since January 2014. Data were extracted from the LROI for all primary TEA procedures between January 2014 and December 2020. Data are reported to the registry using a standardized form for all primary or revision elbow arthroplasties, which is completed after surgery (see Supplementary material). Demographic and surgical data are collected (implant characteristics and surgical techniques). Although registration is not strictly obligatory for TEA, it is required by the Netherlands Orthopaedic Association (NOV) and routinely monitored. The registration of TEAs is considered an important quality metric during hospital audits. The completeness is checked annually with hospital records. The overall completeness was 86% for primary TEA from 2014 to 2020, and 83% for revision arthroplasties from 2014 to 2020.[26] Patient's death is obtained by actively cross-checking with Vektis, the national healthcare insurance database, which records deaths of Dutch citizens. After approval of the study protocol by the LROI, anonymous data were made available for analysis by the research team. These data cannot be traced back to individual patients, surgeons, or institutions. Implant model and manufacturers were blinded, but the implant design (linked or unlinked) was made available.

Data classification. Based on previous literature, centres that performed an average of 18 procedures or more annually were considered high-volume centres.[10] For the implant survival analysis, a revision was set as the end point and defined as an operation to the same elbow with removal or exchange of at least one of the components of the implant. Survival time was defined as time from the primary TEA to a revision or the end of the study

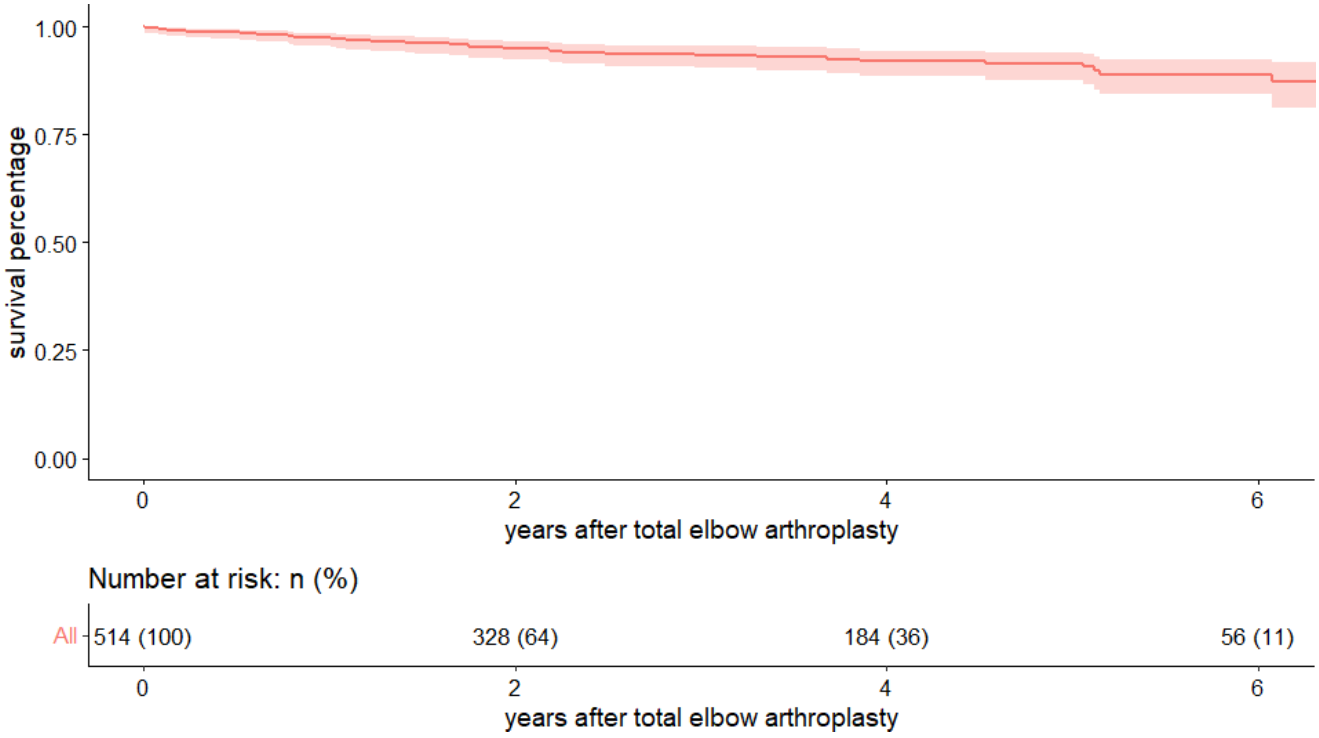

Fig. 1

Kaplan-Meier plot for revision-free survival of total elbow arthroplasties performed in the Netherlands between 2014 to 2020.

Table III. Patient characteristics associated with revision of primary total elbow arthroplasty.

Variable	No revision (n = 402)	Revision (n = 34)	p-value	Corrected p-value*
Mean age, yrs (SD)	66 (12)	62 (10)	0.059†	0.221
Female, n (%)	302 (75)	21 (62)	0.088‡	0.264
Smoking, n (%)	52 (13)	8 (24)	0.114§	0.285
Mean BMI, kg/m² (SD)	27 (5)	30 (7)	0.00361¶†	0.054
ASA classification, n (%)			0.510§	0.588
I	35 (9)	4 (12)		
II	235 (58)	21 (64)		
III to IV	132 (33)	8 (24)		
Previous surgery, n (%)	158 (39)	21 (62)	0.01057¶	0.080
Indication, n (%)			0.240§	0.393
Rheumatoid arthritis	145 (36)	8 (25)		
Post-traumatic sequelae	107 (27)	13 (41)		
Osteoarthritis	76 (19)	7 (22)		
Acute fracture	45 (11)	1 (3)		
Other	28 (7)	3 (9)		

*Corrected using Benjamini-Hochberg procedure.
†Student's *t*-test.
‡Chi-squared test.
§Fisher's exact test.
¶Added to the initial regression model.
ASA, American Society of Anesthesiology; SD, standard deviation.

period. Deceased patients were censored at the time of death. To differentiate between a re-revision and a two-stage revision, the characteristics for both procedures were compared; if the first procedure is logically followed by the second procedure (i.e. removal and placement of a spacer followed by placement of a new implant in a second procedure), it is considered a two-stage revision. If the two procedures are unrelated, they are considered separate revisions.

Table IV. Treatment characteristics associated with revision of total elbow arthroplasty.

Variable	No revision (n = 402)	Revision (n = 34)	p-value	Corrected p-value*
Surgery on dominant limb, n (%)	169 (42)	10 (29)	0.151†	0.345
High-volume centre, n (%)	110 (27)	7 (21)	0.392†	0.570
Implant model (anonymized)			0.262‡	0.420
Implant design, n (%)			0.784‡	0.896
Linked	308 (87)	29 (91)		
Unlinked	48 (13)	3 (10)		
All components cemented, n (%)	374 (93)	32 (94)	1.000‡	1.000
Bonegraft used, n (%)	71 (18)	3 (9)	0.187†	0.374
Ulnar nerve decompression, n (%)	217 (54)	12 (35)	0.03616	0.193
Ulnar nerve transposition, n (%)	85 (21)	9 (26)	0.468‡	0.624
Surgical approach, n (%)			0.850‡	0.907
Posterior, triceps on	151 (42)	12 (43)		
Posterior, triceps off	157 (44)	11 (39)		
Posterior, triceps split	31 (9)	3 (11)		
Other	19 (5)	2 (7)		

*Corrected using Benjamini-Hochberg procedure.
†Chi-squared test
‡Fisher's exact test.
§Added to initial regression model.

Table V. Logistic regression analysis of factors associated with revision of primary total elbow arthroplasty – final model.

Variable	Coefficient	Standard error	z-value	p-value
Female sex	-0.814	0.388	-2.100	0.03577
BMI	0.089	0.032	2.810	0.00495
Previous surgery	1.000	0.383	2.582	0.00981
AIC 222.21; McFadden's pseudo R^2 0.0781 (p-value < 0.0005)				

AIC, Akaike information criterion.

Statistical analysis. Demographic, surgical, and outcome data are reported using descriptive statistics. Kaplan-Meier survival analysis was performed and a survival plot including a 95% confidence interval (CI) was generated.

Statistical analysis was performed comparing the patient and treatment characteristics of patients that underwent a revision with patients that did not undergo revision surgery. For this analysis, the minimum follow-up was set at one year by excluding the primary surgeries performed in 2020. For categorical data, chi-squared tests were used. If the expected value for a cell was less than five, a Fisher's exact test was used. For continuous data with a normal distribution, student's *t*-tests were used, and in case of skewed data, Mann-Whitney U tests were used. To avoid excluding patients due to missing data and thereby introducing a potential source of bias, each analysis was performed with all the available data and data completeness was reported. A Benjamini-Hochberg procedure was performed to correct for multiple testing. A p-value of 0.05 (after correction) was considered statistically significant.

Additionally, a multiple logistic regression model was fitted by including all variables with a p-value below 0.1 on the initial bivariable analysis. Backwards elimination was used to arrive at a model containing a maximum of one independent variable per ten revisions. Due to the limited capacity of the regression analysis, not all confounding factors could be included. Therefore, other potential confounding factors outside the final regression model were identified by analyzing associations between the variables in the final regression model and the remaining patient and treatment characteristics not included in the model. Furthermore, the frequency of specific reasons for revision was assessed separately for each of the variables in the final model.

Statistical analysis was performed using R version 4.0.5 (R Foundation for Statistical Computing, Austria).

Results

A total of 514 patients that underwent a TEA between 2014 and 2020 were included with a median follow-up of four years (interquartile range (IQR) 2 to 6). The mean age at the time of surgery was 66 years (standard deviation (SD) 12), and most patients were female (75%; 386/514). The most common indication for a TEA was rheumatoid arthritis (33%; 170/514), followed by posttraumatic sequelae (28%; 145/514), osteoarthritis (21%; 106/514), and an acute fracture (10%; 52/514). Overall, 42% of patients (215/514) had undergone previous surgery of the same elbow (Table I). The most common previous

Table VI. Characteristics of primary revision cases of total elbow arthroplasty (n = 35).

Variable	Data
Median age, yrs (IQR)	66 (58 to 73)
Median BMI, kg/m² (IQR)	28 (25 to 33)
ASA classification, n (%)	
I	3 (9)
II	18 (51)
III to IV	13 (37)
Unspecified	1 (3)
Smoking, n (%)	7 (20)
Revision type, n (%)	
Total arthroplasty	8 (23)
Partial arthroplasty	16 (46)
Humeral component	2 (6)
Ulnar component	12 (34)
Radial component	1 (3)
Unspecified	1 (3)
Removal and spacer placement	1 (3)
Allograft bone used, n (%)	2 (6)

ASA, American Society of Anesthesiology; IQR, interquartile range.

(95% CI 90% to 95%), and 91% after five years (95% CI 88% to 94%; Figure 1).

The exclusion of surgeries performed in 2020 resulted in 436 patients with a minimum follow-up of one year, of which 34 underwent a revision; one patient that received TEA in 2020 underwent a revision within the same year. After correction of the p-values, none of the characteristics was associated with revision surgery (Table III and Table IV). After backwards elimination of the least influential variables, the multiple logistic regression analysis found a higher BMI, previous surgery of the same elbow, and male sex to be independently associated with revision surgery (Table V). Potential confounding factors outside the regression model were identified; patients with obesity (BMI > 30 kg/m²) receiving a TEA were younger compared to non-obese patients (mean age 62.8 years vs 66.9 years; p = 0.013). Patients that had undergone previous surgery were older, underwent TEA more often due to post-traumatic sequelae, were more often treated in the high-volume centre, more often received

Table VII. Indications in primary revision cases of total elbow arthroplasty (n = 35).

Previous surgeries before TEA	n (%)	Indications for primary TEA	n (%)	Reasons for revision	n (%)
Total	**22 (63)**				
Arthroscopy	3 (9)	Rheumatoid arthritis	8 (23)	Aseptic loosening	12 (34)
Lateral arthrotomy	9 (26)	Posttraumatic sequelae	14 (40)	Humeral component	5 (14)
Medial arthrotomy	3 (9)	Osteoarthritis	7 (20)	Ulnar component	7 (20)
Posterior arthrotomy	9 (26)	Acute fracture	1 (3)	Radial component	3 (9)
Ulnar nerve decompression	2 (6)	Inflammatory arthritis	0 (0)	Infection	8 (23)
Ulnar nerve transposition	0 (0)	Haemophilic arthropathy	0 (0)	Instability	8 (23)
Osteosynthesis	9 (26)	Osteonecrosis	1 (3)	Polyethylene wear	5 (14)
Arthrodesis	0 (0)	Primary tumour	0 (0)	Periprosthetic fracture	5 (14)
Hardware removal	9 (26)	Metastasis of a tumour	0 (0)	Metallosis	4 (11)
Other	2 (6)	Other	2 (6)	Other	6 (17)

TEA, total elbow arthroplasty.

surgeries were osteosynthesis (20%; 105/514), (subsequent) hardware removal (12%; 64/514) and decompression or transposition of the ulnar nerve (8%; 40/514). Surgeries were performed at 24 different centres. Of the 24 included centres, only one was considered high-volume, performing 20 procedures a year on average. A total of 28% surgeries (142/514) were performed in this centre. The most common surgical approach was a posterior approach leaving the triceps intact (42%; 218/514). In total, seven different implant models were used; 76% of the implants were a linked design (392/514) and 10% unlinked (53/514) (Table I). Overall data completeness for the variables, stated in Table II, was 98.4%.

Of the 514 included patients, 35 underwent a subsequent revision within five years, which was performed at 14 different centres. The median time to revision was 1.5 years (IQR 0.7 to 2.7). The implant survival was 98% after one year (95% CI 96% to 99%), 93% after three years

ulnar nerve decompression, and more often had a linked design compared to patients without previous surgery (p < 0.045). Male patients were also younger, underwent TEA more often due to osteoarthritis, were less likely to smoke, had a lower American Society of Anesthesiology (ASA) classification, and were more often treated in the high-volume centre compared to female patients (p < 0.033). Other potential confounding factors were not significantly associated with BMI, previous surgery, or sex.

The 35 patients who underwent a revision had a median age of 66 years (IQR 58 to 73), and a median BMI of 29 kg/m² (IQR 25 to 36) at the time of revision surgery (Table VI). The most common reason for revision was aseptic loosening (34%; 12/35), followed by an infection (23%; 8/35), elbow instability (23%; 8/35), polyethylene wear (14%; 5/35), and a periprosthetic fracture (14%;

Table VIII. Characteristics of secondary revision cases of total elbow arthroplasty (n = 10).

Case	Sex	Age in yrs, range	BMI in kg/m², range	ASA grade	Components replaced	Cemented
1	Female	55 to 60	35 to 40	II	Ulnar	Yes
2	Female	55 to 60	35 to 40	II	Ulnar	Yes
3	Female	75 to 80	20 to 25	II	Removed and spacer placed	No
4	Female	55 to 60	25 to 30	II	Ulnar	Yes
5	Male	45 to 50	20 to 25	II	Removed and spacer placed	No
6	Male	70 to 75	20 to 25	III to IV	Removed and spacer placed	No
7	Female	50 to 55	Missing	Missing	Ulnar	Yes
8	Male	55 to 60	≥ 40	II	Humeral and radial	Yes
9	Male	65 to 70	35 to 40	III to IV	Ulnar	Yes
10	Female	65 to 70	20 to 25	II	Ulnar	No

Age is the patient's age category at primary arthroplasty.
ASA, American Society of Anesthesiology.

Table IX. Indications in secondary revision cases of total elbow arthroplasty (n = 10).

Case	Initial diagnosis	Reason for primary revision	Reason for secondary revision
1	Osteoarthritis	Aseptic loosening	Periprosthetic fracture
2	Osteoarthritis	Aseptic loosening	Periprosthetic fracture
3	Rheumatoid arthritis	Infection	Infection
4	Other	Other	Periprosthetic fracture
5	Post-traumatic sequelae	Infection	Infection
6	Rheumatoid arthritis	Infection	Infection and loosening
7	Other	Aseptic loosening	Instability and aseptic loosening
8	Osteonecrosis	Polyethylene wear	Polyethylene wear, metallosis, and loosening
9	Rheumatoid arthritis	Polyethylene wear and instability	Aseptic loosening
10	Post-traumatic sequelae	Infection	Infection

5/35). Polyethylene wear was more common in male patients (3% vs 0.3%; p = 0.0173), and instability was more common in obese patients (4% vs 1%; p = 0.0386) (Table VII). In some cases, there were several reasons for a revision or loosening of several components. There were no cases of two-stage revisions.

After the first revision, the median follow-up was 2.8 years (IQR 1.5 to 4.5). Overall, 10/35 patients (29%) underwent a secondary revision within the inclusion period, with a median time between the primary and secondary revision of 1.4 years (IQR 0.3 to 2.6). In seven cases, one or more components were replaced. In the remaining three cases, the implant was removed and replaced with a spacer. The characteristics of the patients that underwent a secondary revision are described in Table VIII and Table IX.

Discussion

This study includes 514 TEAs from the LROI, with a median follow-up of four years. Overall, 35 TEAs were revised, resulting in a five-year implant survival of 91%. A higher BMI, previous surgery of the ipsilateral elbow, and male sex showed a statistically significant association with revision. Notably, of the 35 patients who underwent a revision, ten of which required a second revision.

The most common indication for a TEA was rheumatoid arthritis (33%), followed by post-traumatic sequelae (28%). This is congruent with other registry studies, reporting rheumatoid arthritis as the most common indication.[1,24,25] Globally, the indications for TEA are shifting from rheumatoid arthritis and primary arthritis to trauma-related indications.[1] The trend toward traumatic indications for TEA is supported by a study by McKee et al,[27] which, to date, has been cited 439 times. In this study, patients aged over 65 years with a complex distal humerus fracture who were randomized to TEA had favourable PROM scores compared to patients who underwent open reduction and internal fixation.[27] Long-term results of this study revealed no difference in complications between the groups after a mean follow-up of 7.7 years.[28] Instead of using a national implant registry, other options exist to assess data on a national level. Two studies from the USA using data from the Integrated Health Care System and the National Surgical Quality Improvement Programme revealed that the most common indication for TEA was a fracture (40.6% in both studies).[29,30] This is in contrast with data from the European, Australian, and New Zealand registries.[1] It must be noted that these studies do not mention the completeness of the data, and are therefore more at risk of selection bias and missing data

compared to the national registries, which are actively monitored.

The implant survival after five years was 91% in the Netherlands. These results are in line with the three previously published studies of national registries reporting five-year survival rates between 90% and 95%.[13,24,25] Considering the amount of low-volume centres in the current study, these results may reflect a lack of experience; it may be beneficial to concentrate TEA in fewer centres.

The most common reason for revision of TEA in the Netherlands was aseptic loosening, followed by a periprosthetic joint infection and instability. This is in line with results from the Norwegian and Danish arthroplasty registry, as well as other previous studies.[13,15,25] In contrast, in a study from the Australian registry, an infection was a more common reason for revision than aseptic loosening (35% vs 34%, respectively).[7] A low-grade infection may be misdiagnosed as aseptic loosening, especially in infections with microorganisms that are low-virulent. Previous studies have shown the relevance of occult or chronic infections with low-virulent organisms, such as *Cutibacterium acnes* to the outcomes of upper limb arthroplasty.[31,32] Low-grade, occult infections can lead to loosening and pain and are difficult to detect.[33,34] Furthermore, instability may also be caused by polyethylene wear, but not reported as such, leading to an underrepresentation of cases with polyethylene wear.

This study revealed BMI to be associated with a higher risk of revision. Although significant ($p = 0.00495$), the coefficient (0.089) demonstrates only a weak correlation. The correlation between BMI and risk of revision has been reported in previous literature; a meta-analysis of 12 studies showed that obesity increases the chance of an infection and venous thromboembolism after upper limb arthroplasty. The odds of infection were five times greater in morbidly obese patients (BMI 40 kg/m^2 or higher) compared to non-obese patients (BMI 30 kg/m^2 or lower).[35] Increased risk of infection due to a thicker layer of poorly vascularized adipose tissue, attenuated immune systems, and a proinflammatory state has been suggested as a possible explanation for this association.[36] In the current study, infections were not significantly more common in obese patients. Another factor that may contribute to higher revision rates in obese patients is accelerated implant wear or loosening due to increased and altered mechanical forces on the elbow.[36] Our results indicate that obese patients are more likely to undergo a revision due to instability (4% vs 1%), which may occur secondary to polyethylene wear. As a result of the larger circumference of the chest and upper arm in obese patients, the shoulder is naturally held more in abduction.[37,38] In contrast to non-obese patients, this altered position leads to increased torsional and varus forces on the elbow joint. Previous studies have suggested torsional, asymmetrical, and gravitational forces to be the major drivers in implant wear and loosening.[39,40] Although the forearm mass as a percentage of the total body mass is lower in obese patients (1.39% vs 1.56%),[41] the increased total mass still leads to a significant increase in forces on the elbow. The combination of these factors in obese patients may put a greater strain on the implant leading to increased polyethylene wear, resulting in instability and ultimately early loosening.[36]

This study also found previous surgery of the same elbow before TEA to be associated with a higher risk of revision. To our knowledge, previous studies have not found this association. One previous study identified previous surgery as a risk factor for infection specifically.[42] In the current study, six of the eight infections that led to a revision occurred in patients that underwent previous surgery before TEA, resulting in an infection rate of 2.8% vs 0.7% in patients who did not undergo previous surgery, which was not statistically significant. Furthermore, pseudoarthrosis or nonunion after open reduction and internal fixation of a distal humerus fracture may occur due to an undiagnosed low-grade infection; a TEA placed in such conditions would consequentially have a higher chance of loosening, without being recognized as septic. A study of 17 patients undergoing total shoulder arthroplasty due to failed open reduction and internal fixation found positive preoperative bacterial aspirations in four patients (24%); six revisions (35%) were performed after a 4.6-year follow-up, of which two were due to aseptic loosening.[43] Age, comorbidity, and compromised bone and soft-tissue conditions may also influence the change of a revision.[44] In our study, previous surgery was significantly associated with posttraumatic sequelae as an indication for TEA, older age, treatment in the high-volume centre, and ulnar nerve decompression.

In the current study, male sex was associated with a higher risk of revision. A possible explanation for this could be a lower proportion of traumatic indications in males, which has been linked with revision rates in previous studies. However, the correlation is still unclear; some studies have associated trauma-related TEA with lower revision rates compared to other indications,[15] while other studies have identified traumatic indications as a risk factor for revision.[5,25,45,46] Trauma-related TEA was significantly less common in males (30% vs 41% in females). Male sex was also associated with lower age, a lower percentage of smokers, lower ASA classification, and treatment in the high-volume centre. Logically, these factors would decrease rather than increase the chance of complications. However, they may also influence decision-making favouring revision surgery. Other factors may also play a role, such as level of activity, strength, and weight, leading to accelerated implant wear or loosening. As a percentage of total body mass, the male forearm weighs more (1.58% compared to 1.37% in

females).[41] One previous study found a higher incidence of radiological signs of loosening or bushing wear in males (71% vs 25%).[47] In the current cohort, polyethylene wear was more common in males compared to females (3% vs 0.3%).

Interestingly, the number of patients who had to undergo a second revision in this study is high; ten patients (29%) had to undergo another operation after their first revision of a TEA. This is in line with previous literature. A systematic review of 532 patients who underwent a revision after TEA reported a secondary revision in 21.8% of cases.[48] In the current study, two out of three cases where a periprosthetic fracture was the reason for the secondary revision, aseptic loosening was the indication for the first revision, which is suggestive of poor bone conditions. Four out of eight patients (50%) with a revision for an infection underwent a second revision. In all four cases, the indication for the second revision was the same as the first, highlighting the difficulty in treating (chronic) infections. Surprisingly, there were no cases of a two-stage revision for an infected implant. Previous studies report recurrence rates between zero and 20% after two-stage revisions, which is considerably lower than the current study (50%).[49–52] However, these studies include few patients and in a about a quarter of cases the second stage is never completed.[53] Furthermore, a systematic review comparing infection recurrence rate between one- and two-stage revisions did not find a significant difference.[52] The 35 revisions in the current cohort were performed at 14 different centres. This is an underestimation of the centre volume since revisions of primary TEAs performed before 2014 are not taken into account. However, the high re-revision rate may reflect a low level of experience and it may be beneficial to the re-revision rate to concentrate the revisions in fewer, high-volume centres.

The results of this study must be interpreted considering its limitations. First, in collecting data from a registry, the study relies on the completeness and accuracy of reporting by third parties. The overall completeness was 86% in the study period. Second, data from the registry is less detailed in comparison to hospital records. For example, volume can be calculated per centre, but not per individual surgeon. Furthermore, only revision surgeries including replacement or removal of one or more components of the implant are included in the registry. Complications that do not lead to a revision of the implant are not included. The registry also does not record clinical outcomes, such as range of motion or patient-reported outcomes. However, using data from a registry also provides several advantages; it allows for the identification of trends and associations in a larger cohort, which is specifically relevant for rare procedures, and it increases the generalizability of the results. Third, despite using a large database, the regression analysis was limited to three variables. As a result, not all confounding factors could be taken into account. However, potential confounding factors are reported separately and should be considered when interpreting the results. Finally, only one centre was classified as high-volume, introducing a chance of bias.

In conclusion, this study reports the implant survival of TEA, factors associated with revision and a high rate of re-revisions. The survival estimate from a large national database will aid orthopaedic care providers to optimize shared decision making. The risk factors for revision and the high risk of a second revision should be taken into account when considering TEA in suboptimal conditions and attention should be paid to conditions influencing polyethylene wear such as altered angles of force transmission over the elbow or increased load bearing in obese or male patients. Concentrating revision TEA in high-volume centres may proof beneficial to the outcomes. Future research could focus on early identification and treatment of complications after TEA in order to curb the downward spiral of complications and revisions in complex cases.

Take home message

- The five-year implant survival of total elbow arthroplasty (TEA) is 91%.
- Male sex, a higher BMI, and previous surgery of the same elbow may be associated with revision and can be considered in the decision-making for TEA.
- The short-term re-revision rate is high; ten out of 35 patients (29%) underwent a second revision.

Supplementary material

Standardized form for all primary or revision total elbow arthroplasties for reporting data to the Dutch Arthroplasty Registry (Landelijke Registratie Orthopedische Implantaten (LROI)).

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Author information:
- A. A. Macken, MD, Research Fellow, PhD Candidate
- A. Prkić, MD, PhD, Orthopaedic Resident
  Department of Orthopaedics and Sports Medicine, Erasmus Medical Centre, Rotterdam, the Netherlands; Department of Orthopaedic Surgery, Amphia Hospital, Breda, the Netherlands.
- I. van Oost, MSc, Research Coordinator, Foundation for Orthopaedic Research Care & Education (FORCE), Amphia Hospital, Breda, the Netherlands.
- A. Spekenbrink-Spooren, MSc, Epidemiologist, Registry Coordinator, Dutch National Arthroplasty Registry (LROI), 's-Hertogenbosch, the Netherlands.

- B. The, MD, MSc, PhD, Orthopaedic Surgeon, Epidemiologist, Department of Orthopaedic Surgery, Amphia Hospital, Breda, the Netherlands.
- D. Eygendaal, MD, PhD, Head of Department, Professor of Orthopaedics, Orthopaedic Surgeon, Department of Orthopaedics and Sports Medicine, Erasmus Medical Centre, Rotterdam, the Netherlands.

Author contributions:
- A. A. Macken: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Visualization, Writing – original draft.
- A. Prkić: Methodology, Supervision, Writing – review & editing.
- I. van Oost: Project administration, Methodology, Writing – review & editing.
- A. Spekenbrink-Spooren: Validation, Resources, Methodology, Project administration, Data curation, Writing – review & editing.
- B. The: Methodology, Supervision, Writing – review & editing.
- D. Eygendaal: Methodology, Supervision, Writing – review & editing.

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