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Does timing of total elbow arthroplasty after distal humerus fracture affect 2-year complication rates?

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Background: Open reduction and internal fixation (ORIF) remains the gold standard for adult distal humerus fractures (DHF). However, indications for total elbow arthroplasty (TEA) continue to expand and the incidence of primary and salvage TEA for DHF has increased. The objective of this study was to compare complication and reoperation rate for acute vs. delayed primary and salvage TEA performed for DHF.

Methods: Patients who underwent TEA for DHF were identified in the PearlDiver database. Patients were sorted into 3 cohorts: (1) acute TEA (within 2 weeks of diagnosis), (2) delayed TEA (between 2 weeks and 6 months after diagnosis), and (3) salvage TEA (after failed ORIF, malunion, nonunion, delayed treatment between 6 months and 1 year or post-traumatic arthritis). Multivariate analysis was used to assess for confounding variables and covariates when identifying differences in complications between cohorts.

Results: A total of 788 patients underwent acute TEA, 213 patients underwent delayed TEA, and 422 patients underwent salvage TEA after DHF. The incidence of periprosthetic joint infection (PJI) (8.5% vs. 3.4%, odds ratio [OR] 2.60, $P = .002$) and triceps injury (2.4% vs. 0.4%, OR 6.29, $P = .012$) were higher in the delayed compared to acute cohort. The incidence of revision (8.5% vs. 2.1%, OR 3.76, $P < 0.001$), periprosthetic fracture (4.3% vs. 1.1%, OR 3.64, $P = .002$), PJI (14.7% vs 3.4%, OR 4.36, $P < .001$), triceps injury (2.6% vs. 0.4%, OR 5.70, $P = .008$), and wound complications (6.9% vs 2.9%, OR 2.33, $P = .002$) were higher in the salvage compared to acute cohort. There was an increased rate of revision (8.5% vs. 1.9%, OR 6.08, $P = .002$) in the salvage compared to delayed cohort.

Conclusion: Patients undergoing salvage TEA after DHF have increased rates of revision, periprosthetic fracture, PJI, triceps injury, and wound complications at 2 years post-operatively. The salvage cohort also had an increased risk of revision when compared to the delayed cohort. However, other than revision rates, patients in the salvage and delayed cohorts have similar postoperative complication rates.

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

Keywords: Total elbow arthroplasty; distal humerus fracture; surgical timing; surgical complications; medical complications; arthroplasty

Institutional review board approval was not required as this work is derived from anonymized data from the PearlDiver database.

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The incidence of primary total elbow arthroplasty (TEA) for elderly distal humerus fracture (DHF) has increased substantially over the last decade,[20] specifically in the low-demand patient for whom open reduction and internal fixation (ORIF) is not attainable.[28] These fractures were

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historically treated nonoperatively with the "bag-of-bones" technique which still provides good functional outcomes for patients who may not be able to tolerate surgery.[1,2] However, surgical intervention is associated with better functional outcomes.[25] Although ORIF remains the gold standard treatment for these DHFs, long-term outcomes after TEA have been shown to be comparable.[6,13,23]

Union rates for nonoperative management of DHF in the elderly population have been shown to be as low as 53%.[1] Fractures with significant comminution and poor bone stock that were once indicated for nonoperative management or ORIF may now be better indicated for primary TEA.[16] Prior studies have demonstrated increased range of motion and decreased elbow stiffness for patients undergoing TEA when compared to ORIF.[21,23] Additionally, reoperation rates have been found to be lower for TEA performed for fracture vs. ORIF.[8,23,29]

TEA for DHF may be performed in acute, delayed, or salvage fashion either after trial of nonoperative management or previous ORIF.[14,15] Reasons for delayed surgical intervention include inadequate pain relief, stiffness, and poor function.[25] Previous studies have found that although TEA performed for salvage after previous ORIF have similar clinical outcomes and reoperation rates,[15] complication rates may be higher for those who underwent delayed vs. acute TEA.[14] To date, no study has been able to assess the effect of timing of acute vs. delayed vs. salvage TEA after ORIF, nonunion, malunion, or post-traumatic arthritis on complication rates in a large population.

The purpose of the present study was to use a national database to compare surgical and medical complication rates for acute vs. delayed primary and salvage TEA performed for DHF. We hypothesized that there would be no difference for delayed primary and salvage TEA when compared to TEA acutely performed for DHF.

Materials and methods

This is a retrospective case-control study assessing medical complications and reoperation in patients who underwent primary TEA for fracture based on operative timing. Patients who underwent primary TEA from 2015 to 2022 were identified in the Mariner subset of the PearlDiver database (PearlDiver Technologies, Colorado Springs, CO, USA). The PearlDiver database is a national for-fee insurance claim database of patient records, with patients from both private insurers and the Medicare patient population. The data are organized in a trackable but anonymous fashion, and this study was therefore exempt from the authors' institutional review board.

Study cohort

Patients were identified using both *International Classification of Diseases, Tenth Revision* (*ICD-10*), and *Current Procedural Terminology* (*CPT*) codes, provided in Appendix 1. Patients were specifically included for a primary TEA with the *CPT* code 24363 (total elbow arthroplasty) and *ICD-10* procedure codes including laterality of the procedure (0RRL0JZ for right, and 0RRM0JZ for left.) Laterality for the *CPT* code was identified through the PearlDiver database through their laterality filter and by excluding any patients who underwent bilateral TEAs. Patients were also excluded if they underwent any other arthroplasty procedure before the TEA to ensure that prosthetic complications were due to the TEA, rather than a different arthroplasty procedure. All TEAs were specifically performed for DHFs, using *ICD-10* diagnosis codes listed in Appendix 1. Additional inclusion criteria included a minimum 2-year database follow-up after the index TEA procedure. Patients were excluded if they underwent TEA for pathologic fracture because of malignancy.

Three overall cohorts were created for this study as depicted in Figure 1. Patients undergoing acute TEA for DHF within 2 weeks of diagnosis were included in the acute TEA cohort. The cut-off of 2 weeks, or 14 days, has been previously described in the literature to define delayed fixation of upper extremity fractures.[9,22] Patients undergoing delayed treatment for DHF were defined as patients undergoing TEA for DHF after the 2-week mark. This included patients between 2 weeks after diagnosis until 6 months. Six months was determined to be a cutoff for delayed treatment, as prior literature has defined 6 months as the time frame until nonunion is diagnosed.[11,25] These patients specifically had *ICD-10* codes for initial visit and routine healing of the fracture (Appendix 1). Patients undergoing acute or delayed treatment were only included if they had no record of a distal humerus nonunion or malunion in their record. Another cohort of patients, salvage TEA, was identified and comprised patients who underwent TEA after prior ORIF for DHF or had a diagnosis of malunion or nonunion or post-traumatic arthritis. This cohort also included anyone who underwent TEA after fracture greater than 6 months from initial diagnosis. Similarly, any diagnosis code of a routine healing fracture or initial encounter within 6 months of the index TEA excluded patients from the salvage cohort.

Patients were also identified who underwent TEA after DHF in a subacute fashion. Subacute timing was defined as TEA after DHF between 2 weeks and 12 weeks (3 months) after initial DHF diagnosis. The patients in the subacute time frame were incorporated in the delayed cohort for statistical analysis.

Demographics and comorbidities

The following demographics and comorbidities of each cohort were identified: age, gender, and the presence of obesity, tobacco use, diabetes mellitus, hypertension, chronic kidney disease, coronary artery disease, chronic liver disease, rheumatoid arthritis, and depression.

Study outcomes

The primary outcomes of interest were 90-day medical and 2-year postoperative surgical complications, and to compare the rates between the 3 cohorts defined above. Surgical complications assessed were revision TEA, periprosthetic fracture, prosthetic joint infection, stiffness, instability, nerve injury, mechanical loosening, wound complications, and triceps injury. Nerve injury included any damage to the ulnar nerve ipsilateral to the TEA. Wound complications were defined as disruption of surgical wounds or surgical site infections. Major medical complications assessed were

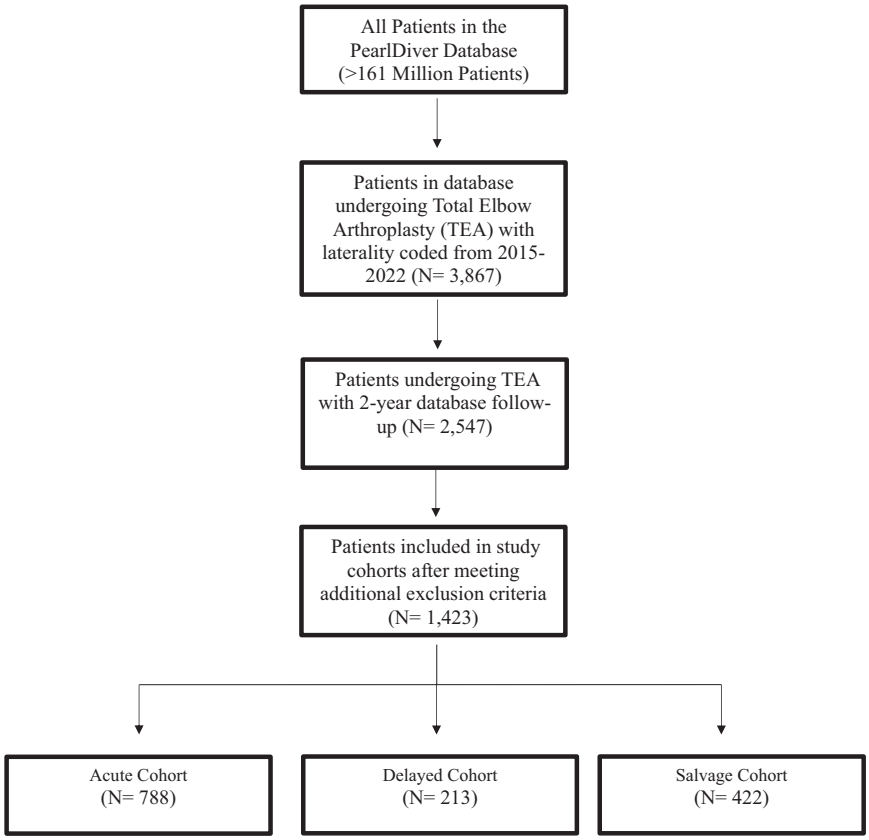

Figure 1 Flowchart depicting the inclusion and exclusion criteria for the respective cohorts identified.

myocardial infarction, pulmonary embolism, pneumonia, and sepsis. Minor complications assessed were acute kidney injury, blood transfusions, urinary tract infection, and venous thromboembolisms. Additionally, emergency department visits and readmission within 90 days postoperatively were queried.

Statistical analysis

Pairwise testing was performed between each cohort and included comparisons of acute vs. delayed, acute vs. salvage, and delay vs. salvage. The subacute cohorts of 2-12 weeks were incorporated into the delayed cohort for statistical comparisons. Univariate analysis using χ^2 tests and Student t tests were performed to analyze any differences in patient demographics and comorbidities. Multivariate analysis using logistic regression was subsequently performed to control for differences in complication rates to account for any confounding variables and covariates. Demographics and comorbidities that were statistically significant ($P < .05$) on univariate analysis were included in the multivariate logistic regression model. Odds ratios (ORs) were calculated with associated 95% confidence intervals (CIs). The open-source R software embedded within the PearlDiver database (R Foundation for Statistical Computing, Vienna, Austria) was used for all statistical analysis. Bonferroni-adjusted P values were used to report differences in complications after multivariate logistic regression because of multiple pairwise comparisons, and thus statistical significance was set at $P < .017$.

Results

A total of 1423 TEA patients were included in the study. Overall, 788 patients (55.4%) underwent acute TEA for DHF, 213 patients (15.0%) underwent delayed TEA for DHF, and 422 patients (29.6%) underwent salvage TEA for DHF. Of the delayed treatment, 125 were delayed between 2 and 6 weeks, 39 were delayed between 6 and 12 weeks, and 49 were delayed between 12 weeks and 6 months. Of the salvage patients, 35 underwent ORIF before TEA, 203 underwent TEA for a diagnosis of distal humerus malunion or nonunion, 218 underwent TEA for a diagnosis of posttraumatic elbow arthritis, and 64 underwent TEA for a DHF 6 months after initial diagnosis. The average ages were 72.1 $\pm$ 10.9 years in the acute cohort, 71.3 $\pm$ 10.4 years in the delayed cohort, and 67.5 $\pm$ 10.8 years in the salvage cohort. The acute cohort was significantly older than the salvage cohorts ($P < .001$) and there were more females in the acute cohort compared with the salvage cohort (83.8% vs. 77.3%, $P = .007$). The incidence of diabetes (29.9% vs. 19.8, $P = .036$), hypertension (61.5% vs. 53.0%, $P = .034$), and depression (19.7% vs. 13.1%, $P = .020$) were higher in the delayed cohort when compared to the acute cohort. Additionally, the incidence of tobacco use (30.2% vs. 15.0%, $P < .001$) and depression (22.0% vs. 13.1%, $P = .026$) were higher in the salvage cohort when compared to the acute

Table I Comorbidities and demographics

	Acute (n = 788)		Delay (n = 213)		Salvage (n = 422)		Acute vs. delay	Acute vs. salvage	Delay vs. salvage
	n	%	n	%	n	%	*P* value		
Age, yr, mean	72.1	—	71.3	—	67.5	—	.373	**<.001**	**<.001**
Sex							.651	**.007**	.184
Male	128	16.24	38	17.84	96	22.75			
Female	660	83.76	175	82.16	326	77.25			
Comorbidities									
Obesity (BMI ≥ 30)	72	9.14	22	10.33	53	12.56	.692	.078	.489
Tobacco use	118	14.97	37	17.37	98	23.22	.453	**<.001**	.110
Diabetes mellitus	130	16.50	49	23.00	85	20.14	**.036**	.133	.464
Hypertension	418	53.05	131	61.50	223	52.84	**.034**	.995	**.047**
Chronic kidney disease	75	9.52	20	9.39	38	9.00	.999	.850	.990
Coronary artery disease	103	13.07	24	11.27	47	11.14	.558	.378	.999
Liver disease	16	2.03	6	2.82	9	2.13	.666	.999	.795
Rheumatoid arthritis	12	1.52	5	2.35	8	1.90	.598	.804	.934
Depression	103	13.07	42	19.72	76	18.01	**.020**	**.026**	.678

BMI, body mass index.
Bold indicates statistical significance set at $P < .05$.

cohort. The incidence of hypertension was higher in the delayed cohort when compared to the salvage cohort (61.5% vs. 52.8%, $P = .047$). The remaining demographics and comparisons of comorbidities are listed in Table I.

Acute vs delayed TEA

Univariate analysis demonstrated that patients in the delayed cohort experienced an increased incidence of periprosthetic joint infection (PJI) (8.5% vs. 3.4%, $P = .003$) and triceps injury (2.3% vs. 0.4%, $P = .015$) when compared to the acute cohort. After multivariate analysis, the differences in incidence of PJI (OR 2.60, 95% CI 1.40-4.82, $P = .002$) and triceps injury (OR 6.29, 95% CI 1.49-26.53, $P = .002$) remained significant when compared to the acute cohort. Remaining comparisons are provided in Tables II and III.

Acute vs. salvage TEA

Univariate analysis demonstrated the patients in the salvage cohort experienced an increased incidence of revision (8.5% vs. 2.2%, $P < .001$), periprosthetic fracture (4.3% vs. 1.1%, $P < .001$), PJI (14.7% vs. 3.4%, $P < .001$), instability (4.7% vs. 1.8%, $P = .005$), triceps injury (2.6% vs. 0.4%, $P = .002$), wound complications (6.9% vs. 2.9%, $P = .002$), mechanical loosening (6.4% vs. 2.8%, $P = .004$), and readmission (11.1% vs. 7.2%, $P = .028$) compared to the acute cohort.

In the regression analysis, patients in the salvage cohort had an increased incidence of revision (OR 3.76, 95% CI 2.06-6.83, $P < .001$), periprosthetic fracture (OR 3.64, 95% CI 1.60-8.30, $P = .002$), PJI (OR 4.36, 95% CI 2.70-7.02, $P < .001$), triceps injury (OR 5.70, 95% CI 1.57-20.7, $P = .008$), and wound complications (OR 2.33, 95% CI 1.32-4.11, $P = .003$) compared to the acute cohort. The difference in mechanical loosening was no longer statistically significant after multivariate logistic regression using Bonferroni correction ($P = .031$). Similarly, the difference in readmission ($P = .028$) and instability ($P = .027$) was no longer significant after Bonferroni correction. Remaining comparisons between acute and salvage TEA are provided in Tables II and III.

Delayed vs. salvage TEA

Univariate analysis demonstrated that the patients in the salvage cohort experienced an increased incidence of revision (8.5% vs. 1.9%, $P = 0.002$) and PJI (14.7% vs. 8.5%, $P = .035$) when compared to the delayed cohort. After multivariate regression analysis patients in the salvage cohort had an increased incidence of revision (OR 6.08, 95% CI 1.43-25.70, $P = .014$) only when compared to the delayed cohort.

The were no differences in the remaining surgical and medical complications on univariate analysis or multivariate analysis between delayed and salvage TEA (Tables II and III).

Discussion

The present study demonstrates an increased incidence of surgical complications including periprosthetic fracture, PJI, triceps injury, and wound complications in patients undergoing salvage TEA compared with acute TEA . The rate of PJI and triceps injury are also increased for patients undergoing delayed TEA as opposed to acute TEA. Additionally, the overall risk of early revision is higher when TEA is performed for salvage. There were no remaining differences in complications between the delayed and salvage cohorts.

Table II Comparisons of complications after univariate analysis

	Acute (n = 788)		Delay (n = 213)		Salvage (n = 422)		Acute vs. delay	Acute vs. salvage	Delay vs. salvage
	n	%	n	%	n	%	*P* value		
Revision	17	2.16	4	1.88	36	8.53	.999	**<.001**	**.002**
Periprosthetic fracture	9	1.14	4	1.88	18	4.27	.617	**<.001**	.186
PJI	27	3.43	18	8.45	62	14.69	**.003**	**<.001**	**.035**
Stiffness	123	15.61	39	18.31	61	14.45	.398	.654	.253
Instability	14	1.78	3	1.41	20	4.74	.944	**.005**	.058
Ulnar nerve injury	9	1.14	3	1.41	2	0.47	.999	.396	.434
Triceps injury	3	0.38	5	2.35	11	2.61	**.015**	**.002**	.999
Wound complications	23	2.92	11	5.16	29	6.87	.164	**.002**	.507
Loosening	22	2.79	8	3.76	27	6.40	.613	**.004**	.233
Major medical	35	4.44	6	2.82	18	4.27	.386	.999	.494
Minor medical	70	8.88	19	8.92	37	8.77	.999	.999	.999
Readmission	57	7.23	22	10.33	47	11.14	.179	**.028**	.862
ED visit	99	12.56	27	12.68	69	16.35	.999	.084	.270
Hematoma	2	0.25	0	0.00	4	0.95	.999	.227	.371

PJI, periprosthetic joint infection; *ED*, emergency department.
Bold indicates statistical significance set at $P < .017$ with Bonferroni correction.

Table III Comparisons of complications after multivariate analysis

	Delay vs. acute (control)			Salvage vs. acute (control)			Delay vs. salvage (control)		
	OR	95% CI	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Revision	0.87	0.29-2.61	.801	3.76	2.06-6.83	**<.001**	6.08	1.43-25.80	**.014**
Periprosthetic fracture	1.66	0.51-5.43	.405	3.64	1.60-8.30	**.002**	1.59	0.53-4.87	.408
PJI	2.6	1.40-4.82	**.002**	4.36	2.70-7.02	**<.001**	1.42	0.70-2.48	.396
Stiffness	1.21	0.81-1.80	.343	0.79	0.56-1.11	.175	0.58	0.35-0.96	.030
Instability	0.79	0.22-2.77	.713	2.23	1.09-4.53	.027	3.06	0.70-13.40	.137
Ulnar nerve injury	1.24	0.33-4.61	.752	0.39	0.08-1.86	.238	0.23	0.04-1.41	.111
Triceps injury	6.29	1.49-26.53	**.012**	5.70	1.57-20.70	**.008**	1.19	0.32-4.41	.796
Wound complications	1.81	0.87-3.78	.113	2.33	1.32-4.11	**.003**	1.06	0.46-2.44	.884
Mechanical loosening	1.36	0.60-3.10	.466	1.92	1.06-3.47	.031	1.87	0.63-5.57	.261
Hematoma	—	—	.975	3.04	0.53-17.37	.211	—	—	.984
Major medical	0.63	0.26-1.50	.293	1.06	0.58-1.91	.858	1.41	0.50-3.95	.519
Minor medical	1.00	0.59-1.71	.987	1.06	0.69-1.63	.800	1.26	0.63-2.54	.509
Readmission	1.49	0.88-2.48	.139	1.60	1.05-2.43	.028	0.98	0.53-1.83	.959
ED visit	1.01	0.64-1.59	.965	1.26	0.89-1.78	.189	1.36	0.77-2.41	.291

PJI, periprosthetic joint infection; *ED*, emergency department; *OR*, odds ratio; *CI*, confidence interval.
Bold indicates statistical significance set at $P < .017$ with Bonferroni correction.

Complications after TEA for DHF are broad including hardware irritation, wound dehiscence, PJI, aseptic loosening, and periprosthetic fracture.[10,14,21] In a retrospective study comparing primary TEA for distal humerus fracture vs. TEA after failure of internal fixation or conservative treatment (delayed), Prasad and Dent[18] reported an overall complication rate of 21.9%. Liu et al[14] recently performed a retrospective cohort comparing patients with primary TEA for DHF vs. TEA after failed ORIF. In their study, there was a significantly increased complication rate for patients undergoing acute (22%) vs. delayed TEA (58%). However, to observe a significant difference, the ORIF and salvage groups were combined into the delayed cohort group. Prasad and Dent[18] similarly reported no significant difference in complication rates for acute vs. delayed TEA. However, of the 21.9% of complications reported, 13.3% occurred in the early cohort, whereas 29.4% occurred in the delayed cohort.[18] The findings in the current study demonstrated that performing a TEA acutely for DHF within 2 weeks of injury may be associated with decreased overall complications compared to those fixed for salvage, with the incidence of PJI being less when compared to both delayed and salvage cohorts.

The current study reports an overall PJI rate of 7.5% across the 1423 patients included. Specifically, there was increased incidence in the delayed treatment, and salvage cohorts displayed elevated rates at 8.5% (OR 2.6, $P = .002$) and 14.7% (OR 4.4, $P < .001$) respectively when compared

to a rate of 3.4% in acute cohort. Although not statistically significant when compared to their acute cohort, Liu et al reported a rate of 10% in the delayed cohort.[14] Prasad and Dent[18] reported 5 complications in their delayed cohort at a rate of 29.4% with one PJI (20% rate) requiring removal of implant. The findings in the current study echo previous knee arthroplasty literature that has shown significantly increased rates of PJI when comparing conversion after prior ORIF to primary arthroplasty.[24] Additionally, recent arthroplasty literature has focused on characterizing the microbiome of non-arthritic and arthritic knees suggesting that some biomes may be more permissive to infection.[7,27] It is possible that that delayed or salvage treatment after fracture and/or prior ORIF may portend a microbiome that leads to increased susceptibility to infection, but future studies are needed to assess this risk.

Salvage TEA was associated with a trend towards increased mechanical, or aseptic loosening when compared to acute TEA (6.4% vs. 2.8%, OR 1.92, $P = .031$). Mechanical, or aseptic, loosening has previously been associated with increased age, obesity, male sex, and concomitant opioid use disorder.[19] Loosening has been shown to be common after TEA performed for rheumatoid at long-term follow-up but few studies have assessed the risk of aseptic loosening in TEA performed for fracture.[17] Logli et al reported an aseptic loosening rate of 9% and 11% in patients undergoing acute and salvage TEA for fracture, respectively, without significant difference in risk between the two groups.[15] Liu et al reported a 4.5%, 28.5%, and 40% incidence of aseptic loosening for acute TEA, TEA after failed nonoperative management, and TEA after ORIF, respectively.[14] The results of the current study demonstrate that while the overall rate of aseptic loosening after TEA performed for fracture may be lower than previously reported, there may be a trend towards increased incidence if TEA is performed for salvage. While not conclusive, patients should be counseled on this risk when discussing treatment options after malunion, nonunion, or failed ORIF as this is a common reason for a painful, failed TEA.[4,5]

Salvage TEA was also associated with an overall increased incidence of all-cause revision when compared to TEA performed acutely (8.5 vs. 2.2%, OR 3.76, $P < .001$) at 2 years postoperatively. Although previous studies have reported a relatively high rate of revision TEA for DHF at 11.9% at 9 years,[26] none have reported an increased rate of revision when comparing acute vs. salvage TEA.[15,18] Additionally, the current study reports an increased incidence of revision for TEA performed for salvage when compared to those performed in delayed fashion (8.5% vs. 1.8%, OR 6.08, $P = .014$). It is important to note that rates of all other surgical or medical complications did not differ between the delayed and salvage cohorts. Although ORIF remains the gold standard and nonoperative management may be indicated in patients who may not tolerate ORIF, patients should be educated that conversion to TEA after prior ORIF or development of nonunion, malunion, and post-traumatic arthritis may lead to increased revision rates when compared to TEA performed acutely or delayed. Additionally, although the revision rate was increased in the salvage cohort when compared to the delayed cohort, the rates of remaining complications may be comparable in the salvage and delayed cohorts.

The current study is a retrospective, database study and has limitations that should be considered when interpreting the results. The results are dependent on accurate documentation and coding. The results are also unable to account for heterogeneity in surgeon experience and skill level and cannot differentiate or assess surgical factors including fracture severity, surgical approach, implant type, etc. Implant type may be important to consider as unlinked implants have been associated with instability,[12] whereas semiconstrained or linked implants have been associated with bushing wear and aseptic loosening.[3,12] Additionally, although the current study was able to determine complication and overall revision rates, it was unable to differentiate the etiology of revision. Lastly, the current study selected based on the minimum follow-up of 2 years, whereas previous retrospective studies that have been able to assess complication and revision rates for acute and salvage TEA used longer follow-up lengths. [15,18]

Conclusion

Patients undergoing salvage TEA for DHF have increased rates of major complications including periprosthetic fracture, PJI, triceps injury, and wound complications when compared to patients undergoing acute TEA performed within 14 days of injury. There are increased rates of revision when TEA is performed in delayed fashion or for salvage. Salvage TEA is associated with 6 times higher odds whereas delayed TEA is associated with 3 times higher odds of early revision within 2 years. However, patients in the salvage and delayed cohorts may have similar postoperative complication rates other than revision. Although the indication for TEA has expanded to include DHF, patients should be counseled about the increased risk of early major complications and revision when TEA is delayed or used in a salvage manner.

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Supplementary data

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