What Are the Risk Factors and Complications Associated With Intraoperative and Postoperative Fractures in Total Wrist Arthroplasty?

Eric R. Wagner MD, MS, Jason J. Srncic MD, Kapil Mehrotra MD,
Marco Rizzo MD

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Abstract

Background Total wrist arthroplasty (TWA) can relieve pain and preserve some wrist motion in patients with advanced wrist arthritis. However, few studies have evaluated the risks and outcomes associated with periprosthetic fractures around TWAs.

Questions/purposes (1) What is the risk of intraoperative and postoperative fractures after TWAs? (2) What factors are associated with increased risk of intraoperative and postoperative fracture after TWAs? (3) What is the fracture-free and revision-free survivorship of TWAs among patients who sustained an intraoperative fracture during the index TWA?

Methods At one institution during a 40-year period, 445 patients underwent primary TWAs. Of those, 15 patients died before 2 years and 5 were lost to followup, leaving 425 patients who underwent primary TWAs with a

minimum of 2-year followup. The primary diagnosis for the TWA included osteoarthritis (IOA] 5%), inflammatory arthritis (90%), and posttraumatic arthritis (5%). Indications for TWA included pancarpal arthritis combined with marked pain and loss of wrist function. The mean age of the patients was 57 years, BMI was 26 kg/m², and 73% were females. Six different implants were used during the 40-year period. Mean followup was 10 years (range, 2–18 years).

Results Intraoperative fractures occurred in nine (2%) primary TWAs, while postoperative fractures occurred after eight (2%) TWAs. After analyzing demographics, comorbidities, and surgical factors, intraoperative fractures were found to be associated with only age at surgery (hazard ratio [HR], 1.10; 95% CI, 1.03–1.20; $p = 0.006$) and use of a bone graft (HR, 5.80; 95% CI, 1.18–23.08; $p = 0.03$). No factors were found to be associated with increased risk of postoperative fractures; specifically, intraoperative fracture was not associated with subsequent fracture development. The 5-, 10-, and 15-year Kaplan–Meier survival rates free of postoperative fracture were 99%, 98%, and 95%, respectively. The 5- and 10-year revision-free survival rates after intraoperative fracture were 88% and 88%, respectively, compared with 84% and 74% without an intraoperative fracture ($p = 0.36$). Furthermore, the survival-free of revision surgery rates for aseptic distal loosening at 5 and 10 years were 88% and 88%, respectively, compared with 93% and 87% without a fracture ($p = 0.85$).

Conclusions Intraoperative fractures occur in approximately 2% of TWAs. These fractures do not appear to affect long-term implant survival or risk of fracture. Patient age and the need for bone graft were the only factors in the risk of intraoperative fractures. Postoperative fractures also occur in 2% of TWAs, but often result in revision surgery.

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E. R. Wagner, J. J. Srncic, K. Mehrotra, M. Rizzo (✉)
Department of Orthopedic Surgery, Division of Hand Surgery,
Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA
e-mail: rizzo.marco@mayo.edu

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Introduction

In cases of advanced wrist degeneration, a patient might choose between total wrist arthroplasty (TWA) and total wrist arthrodesis. Wrist arthrodesis is able to provide a stable, pain-free solution, but at the cost of motion and in some patients, decreased function [4]. TWA is an established alternative that preserves some motion and improves patient satisfaction. Particularly in patients with bilateral disease, patients with a TWA on one side and arthrodesis on the other preferred the side with the arthroplasty [13]. However, historically TWA has been associated with a high number of complications and concerns regarding survivorship [1, 4, 6, 7, 9–11, 14–16].

Complications associated with TWA include carpal component loosening and joint instability [1, 4, 6, 7, 9–11, 14–16]. However, there have been few reports regarding intraoperative or postoperative periprosthetic fractures [1, 2, 5, 6, 11], with no reports, to our knowledge, examining the risk of these occurring, the risk factors associated with them, the outcomes of different treatments, or their effect on postoperative outcomes after TWA. These fractures have the potential to compromise implant fixation, joint stability, wrist motion, and implant survivorship. The incidence of this intraoperative and postoperative complication and its effect on risk of revision surgery, postoperative fracture, or other complications has not been well established.

Therefore, we asked: (1) What is the risk of intraoperative and postoperative fractures after TWAs? (2) What factors are associated with increased risk of intraoperative and postoperative fractures after TWAs? (3) What is the fracture-free and revision-free survivorship of TWAs among patients who sustained an intraoperative fracture during the index TWA?

Patients and Methods

Total Joint Registry and Electronic Medical Record

After approval of our institutional review board, our institution's longitudinally maintained total joint registry database [3] was used to analyze all patients who underwent primary TWA from January 1, 1974, to December 31, 2013. This registry collects information pertaining to patients, surgeries, and surgical outcomes after total joint arthroplasty at routine followup intervals during the first year and then again at postoperative years 2 and 5, and subsequently at 5-year intervals [8]. This registry seeks to

capture all subsequent procedures done at our institution or elsewhere. Additional patient information was collected using validated automated digital algorithms to identify Charlson comorbidities and perioperative factors from the patient's electronic medical records [12]. The outcome measures included postoperative fractures, revision surgical procedures, revision for aseptic distal loosening, reoperations, dislocations, and other complications captured through the registry and confirmed by medical record review. Removal or replacement of any implant at reoperation was defined as revision surgery. Wrist instability is defined as any clinical or radiographic evidence of joint dislocation requiring evaluation by an orthopaedic surgeon.

Demographics

At one institution during a 40-year period, 445 patients underwent primary TWAs. Of those, 15 patients died before 2 years and five were lost to followup, leaving 425 patients with primary TWAs performed by 12 different surgeons, with a minimum 2-year followup. The mean followup was 10 years (range, 2–18 years). The mean age of the patients at surgery was 57 years, BMI was 26 kg/m², and 73% were females. The mean operating room time was 185 minutes, whereas the mean tourniquet time was 135 minutes. The primary diagnosis for the TWA included osteoarthritis [OA] (5%), inflammatory arthritis (90%), and posttraumatic arthritis (5%). The indications for TWA included pancarpal arthritis with pain and loss of wrist function in a patient who desired preservation of wrist motion compared with a total wrist fusion. The implants used were: RE-MOTIONTM (Small Bone Innovations Inc, Morrisville, PA, USA) (n = 33), BIAxTM (DePuy Orthopaedics Inc, Warsaw, IN, USA) (n = 157), Volz (Howmedica Osteonics Corp, Mahwah, NJ, USA) (n = 33), Meuli (Sulzer Orthopaedics Ltd, Winterthur, Switzerland) (n = 138), Universal (Integra LifeSciences Corporation, Austin, TX, USA) (n = 7), and Swanson (Wright Medical Group, Memphis, TN, USA) (n = 57). Cemented components were used in 356 (84%), whereas 36 (8%) required bone graft for insufficient bone stock. Cement was used in rare cases when the patient's wrist was between sizes and the surgeon felt the need to fill the canal with cement rather than impaction graft.

Statistical Analysis

To answer our first question, we assessed the risk of factors for our entire study cohort. To assess the second question, we used Kaplan Meier analysis and the log rank test to assess the risk factors associated with fractures (Table 1). Each variable was analyzed in a univariate fashion owing

to the limited number of fractures and postoperative complications, limiting our ability to perform multivariable analyses. Using the Kaplan–Meier model to answer our third question, survival curves were constructed to assess fracture-free survival, revision-free survival, and revision-free of aseptic distal loosening. We set statistical significance at a probability less than 0.05.

Results

Risk of Intraoperative Fractures and Associated Factors

Intraoperative fractures occurred in nine of 425 (2%) primary TWAs (Table 2). Briefly, the locations of the fractures were the radius ($n = 2$), capitate ($n = 2$), and metacarpals ($n = 5$). The fractures occurred either during bone preparation (broaching, reaming) in three or implant insertion in six, involving the BIAx ($n = 6$), RE-MOTION ($n = 2$), and Swanson ($n = 1$) implants. Bone graft augmentation was performed to supplement two fractures of the metacarpals, whereas suture stabilization was performed in two metacarpal fractures and one capitate fracture. Four of the metacarpal fractures and one of the capitate fractures occurred before cementation of the distal components.

Intraoperative fractures were associated with age at surgery (hazard ratio [HR], 1.10; 95% CI, 1.03–1.20; $p < 0.01$) and use of bone graft (HR, 5.80; 95% CI, 1.18–23.08; $p = 0.03$) (Table 1).

Table 1. Risk factors for intraoperative fractures in primary TWA

Risk factor	Hazard ratio	Confidence interval	p Value
Age at surgery	1.10	1.03–1.20	0.006*
BMI	1.14	0.99–1.30	0.06
Female	1.32	0.32–8.95	0.72
Osteoarthritis	6.32	0.90–28.46	0.06
Inflammatory arthritis	0.38	0.09–2.62	0.28
Posttraumatic arthritis	< 0.01	None	0.31
Tourniquet time	1.00	0.98–1.02	0.90
Operative time	0.99	0.97–1.01	0.12
Implant			
RE-MOTION™	3.55	0.51–15.44	0.17
BIAx™	3.51	0.91–16.82	0.07
Volz	< 0.01	None	0.23
Meuli	< 0.01	None	0.008*
Universal	< 0.01	None	0.58
Swanson	0.80	0.04–4.50	0.83
Bone graft	5.80	1.18–23.08	0.03*
Cemented implant	0.38	0.10–1.82	0.20

TWA = total wrist arthroplasty; * $p < 0.05$.

Risk of Postoperative Fractures and Associated Factors

Eight of 425 (2%) patients sustained postoperative fractures at an average 7.9 years postoperatively after the primary TWA (Table 3). Only two (one radius and one metacarpal fracture) of the eight fractures healed via immobilization only without eventual revision surgery to either treat the fracture or owing to distal component loosening. Three fractures (one metacarpal, two radius fractures) were treated with immediate revision surgery, whereas three other fractures (all metacarpal fractures) had distal component loosening develop, resulting in revision surgery. The implants for these fractures were Swanson ($n = 1$), Volz ($n = 0$), Meuli ($n = 3$), BIAx ($n = 3$), RE-MOTION ($n = 1$), and Universal ($n = 0$). No patient who experienced a postoperative fracture later sustained a postoperative dislocation.

There were no factors that were associated with postoperative fracture risk (Table 4). Furthermore, having an intraoperative fracture was not an associated factor for having a postoperative fracture develop; one (of nine; 11%) patient who had an intraoperative metacarpal fracture sustained a postoperative metacarpal fracture (Table 2). There were seven (of 416; 2%) postoperative fractures in patients without intraoperative fractures ($p = 0.13$; relative risk [RR], 1.11; 95% CI, 0.88–1.39). Another patient who had an intraoperative metacarpal fracture underwent revision surgery for aseptic distal loosening 4.8 years after the initial operation. One additional patient had a carpal tunnel release at 3 months postoperatively for persistent paresthesias. No other patients experienced any complications and all intraoperative fractures were radiographically healed by latest followup.

Survivorship

The 5-, 10-, and 15-year survivals free of postoperative fracture were 99% (± 1), 98% (± 1), and 95% (± 2), respectively (Fig. 1). The survivorship free of postoperative fracture was not different with the numbers available between those who did and did not have an intraoperative fracture ($p = 0.16$) (Table 5); however we were quite underpowered on this endpoint, and it is possible that a modest size difference could have been missed.

In addition to the one patient with an intraoperative and a postoperative fracture, another patient who had an intraoperative metacarpal fracture underwent revision surgery for aseptic distal loosening 4.8 years after the initial operation. No other patients with an intraoperative fracture had any signs of component loosening. One additional patient had a carpal tunnel release at 3 months postoperatively for persistent paresthesias. No other patients required

Table 2. Intraoperative fractures

Patient number	Fracture location	Fracture type	Implant type	Timing of fracture	Fracture treatment	Bone graft	Postoperative complications
1	Metacarpal, ulnar cortex	Nondisplaced	BIAX™	Preparation	None	None	Nondisplaced metacarpal metaphyseal fracture treated nonoperatively
2	Capitate, dorsal cortex	Minimally displaced	Swanson	Preparation	Suture	None	None
3	Metacarpal shaft	Displaced, spiral	BIAX	Insertion	Suture, long stem bypassing fracture	None	None
4	Capitate, dorsum, and base	Minimally displaced	BIAX	Insertion	Immobilization (6weeks)	None	None
5	Metacarpal shaft, tip of prosthesis	Nondisplaced	BIAX	Insertion	Long stem bypassing fracture	None	Revision TWA for distal component loosening.
6	Radius, dorsal cortex	Nondisplaced	BIAX	Preparation	Immobilization (6 weeks)	None	Carpal tunnel release 3 months postoperatively
7	Metacarpal, dorsal cortex at base	Displaced	RE-MOTION™	Insertion	Graft, suture, immobilization (8 weeks)	Autologous (ulna)	None
8	Metacarpal shaft, ulnar	Nondisplaced	BIAX	Insertion	Long stem bypassing fracture, graft	Autologous (ulna)	None
9	Radius, dorsal	Nondisplaced	RE-MOTION	Insertion	None	Autologous (ulna) used for carpal implant	None

Table 3. Postoperative fractures

Patient number	Fracture location	Fracture type	Implant type	Time to fracture (years)	Fracture treatment	Future fracture treatment?
1	Metacarpal shaft	Nondisplaced	BIAX™	9	Immobilization	None, healed
10	Metacarpal shaft	Displaced, spiral	Swanson	18	Revision TWA	N/A
11	Metacarpal, dorsal cortex	Minimally displaced	RE-MOTION™	5	Immobilization	Distal loosening requiring revision TWA
12	Radius, involving distal tip of stem	Minimally displaced	Meuli	1	Immobilization	None, healed
13	Radius involving stem	Displaced	Meuli	3	Revision TWA	N/A
14	Radius, involving stem	Displaced	Meuli	20	Resection arthroplasty	N/A
15	Metacarpal, metaphysis	Minimally displaced	BIAX	7	None	Distal loosening requiring revision TWA
16	Metacarpal	Minimally displaced	BIAX	1	Immobilization	Nonunion and distal loosening requiring revision TWA

TWA = total wrist arthroplasty; N/A = not applicable.

Table 4. Postoperative fracture-free survivorship

Endpoint	5-year		10-year	
	Survivorship (%) [*]	Number at risk	Survivorship (%) [*]	Number at risk
Overall percent free of fracture	99 (±1)	300	98 (±1)	160
Intraoperative fracture	100	8	80	5
No intraoperative fracture	99	292	98	155

^{*}Values are given as the Kaplan–Meier survival estimate (± standard error).

any reoperations or had any complications, and all intraoperative fractures were radiographically healed by final followup. The -5 and 10-year revision-free survival rates after intraoperative fracture were 88% (± 11) and 88% (± 11), respectively, compared with 84% (± 2) and 74% (± 3) without an intraoperative fracture ($p = 0.36$) (Fig. 2). Furthermore, the survival-free of revision surgery rates for aseptic distal loosening at 5 and 10 years were 88% (± 11) and 88% (± 11), respectively, compared with 93% (± 1) and 87% (± 2) without a fracture ($p = 0.85$). No patients who had an intraoperative fracture experienced a postoperative dislocation.

Discussion

TWA has been associated with a relatively high rate of complications, with high rates of distal component

loosening and joint instability with various types of implants [1, 4, 6, 7, 9–11, 14–16]. Although some studies mention the possibility of fracture associated with TWA [1, 2, 5, 6, 11], to our knowledge, nothing has been reported specifically regarding fractures related to this procedure. We aimed to study the prevalence, risk factors, revision rates, and outcomes associated with periprosthetic fractures during and after primary TWA.

The findings of this study should be considered in light of its limitations. Our study is retrospective and thus has inherent limitations. However, prospective data collection through the total joint registry improves on this limitation regarding patient followup, analysis, and comprehensive postoperative outcome collection. This study was subject to transfer bias, as 15 patients died before 2 years and 5 were lost to followup before 2 years. There was also selection bias, as six types of implants were used, the indications for surgeries and implants were not standardized among the 40 years of the study, and the study did not specifically look at the indications for TWA compared with fusion. Additionally, through our joint registry we do not routinely collect validated wrist outcome measures such as the Patient Rated Wrist Evaluation, Mayo Wrist Scores, or the Michigan Hand Questionnaire. Further limitation arises from a single institution's referral bias while avoiding confounding variables associated with multicenter trials. The numbers of intraoperative and postoperative fractures are small, therefore, this limits our ability to perform a comprehensive or multivariate analysis. Furthermore, surgeries occurring during many years limited the conclusions we were able to draw. Finally, not all fractures may have been recognized by the treating surgeon intraoperatively and,

Fig. 1A–B (A) The 5- and 10-year revision-free survival rates after intraoperative fracture (blue line) were 88% and 88%, respectively, compared with 84% and 74% without an intraoperative fracture (red line) ($p = 0.36$). (B) The rates for survival free of revision surgery for

aseptic distal loosening at 5 and 10 years were 88% and 88%, respectively, for patients with an intraoperative fracture (blue line) compared with 93% and 87% for patients without a fracture (red line) ($p = 0.85$).

Table 5. Hazards ratios for postoperative fractures in primary TWA

Risk factor	Hazard ratio	Confidence interval	p Value
Age at surgery	1.00	0.94–1.06	0.931
BMI	1.11	0.91–1.33	0.283
Female	1.01	0.23–6.92	0.990
Osteoarthritis	<0.01	None	0.502
Inflammatory arthritis	0.60	0.10–11.23	0.654
Posttraumatic arthritis	2.69	0.14–15.20	0.409
Tourniquet time	1.00	0.98–1.02	0.738
Operative time	1.00	0.98–1.01	0.601
Implant			
RE-MOTION TM	8.96	0.42–71.22	0.133
BIAX TM	0.87	0.18–3.56	0.850
Volz	< 0.01	None	0.341
Meuli	1.28	0.26–5.23	0.738
Universal	< 0.01	None	0.759
Swanson	0.59	0.03–3.39	0.610
Intraoperative fracture	6.66	0.35–39.05	0.160
Bone graft	2.12	0.11–12.02	0.521
Cemented implant	0.39	0.09–2.71	0.302

TWA = total wrist arthroplasty.

therefore, would not have been documented in the operative reports or in the joint registry database.

Rizzo and Beckenbaugh [11] examined 17 TWAs that used the BIAX implants with long-stem metacarpal components. Two patients (12%) had an intraoperative transverse metacarpal base fracture treated with casting, but this did not affect outcomes. In the series of 10 revision TWAs using the BIAX component, four had intraoperative fractures of the cortex of the third metacarpal [5]. One patient experienced a postoperative fracture requiring revision arthroplasty. Barrera-Ochoa et al. [2] reported on a

Fig. 2 The rates for 5-, 10-, and 15-year survival free of a postoperative fracture for patients with an intraoperative fracture were 100%, 80%, and 80% (blue line) compared with 99%, 98%, and 97%, respectively, for those without a fracture (red line) ($p = 0.16$).

periprosthetic fracture 9 years after a TWA using the Universal implant in a patient with rheumatoid arthritis [2]. The patient was treated with a locking compression plate and achieved healing by the 12-month followup. That case report is the only dedicated series examining either intraoperative or postoperative fractures [2].

In the current series, we noted a 2% incidence of fracture associated with TWA. This rate compares favorably with the above-mentioned rates of 12% and 40% from the studies by Rizzo and Beckenbaugh [11] and Cobb and Beckenbaugh [5]. However, Rizzo and Beckenbaugh [11] examined outcomes using a long stem BIAX implant, which intuitively would invite higher risk of fracture. Cobb and Beckenbaugh [5] looked at revision surgeries and, given the complexity of revision TWA, it would be unfair to compare fracture rates between these two cohorts. Given the absence of a similar published analysis, our review sets

the incidence of fracture at 2% and establishes a foundation for future comparisons.

In patients who experienced an intraoperative fracture, the 5- and 10-year implant survival rates were both 88%. The rates of postoperative fracture and revision surgery were not different in the patients with or without intraoperative fractures. Two percent of patients with TWAs experienced postoperative periprosthetic fractures. The rates for 5-, 10-, and 20-year survival free of postoperative fracture were 99%, 98%, and 95%, respectively.

The Meuli implant had lower fracture risks postoperatively. The reasons for this are somewhat unclear. The implant has a spherical articulation and it may be that this minimized torque across the radius and carpus with motion. However, this is speculation.

Among the nine fractures, six occurred with the BIAx implant. Again, we can only speculate, but the BIAx implant has a long single stem that requires precise insertion and broaching through the carpometacarpal joint, which invites the possibility of fracture. Interestingly, despite the potentially compromised bone quality in patients with rheumatoid arthritis, it was actually patients with OA who had a higher incidence of intraoperative fractures.

Although patient factors also may play a role, meticulous surgical technique can help to prevent this complication. It is critical when inserting the implants to identify the central canal and fully prepare the radius and metacarpals. Fluoroscopy can aid in bone preparation and prosthetic implantation [1]. When these fractures occur, it is critical to determine if they compromise the stability of the implant. In the case of radius fractures, cerclage wiring with or without bone graft and cement fixation can help to stabilize the fracture. The carpal fractures can be stabilized by longer screws or stems with bone graft or cement in cases of inadequate fixation or poor bone quality. As seen in this study, if implant and fracture stability can be obtained in the setting of these fractures, the occurrence of an intraoperative fracture does not have an effect on implant survivorship or complications after TWA.

With the numbers available, when properly stabilized, intraoperative fractures do not affect long-term outcomes. Nonoperative management appears to be effective with nondisplaced periprosthetic fractures of the metacarpals or radius, but the patients and surgeons should understand the risk and potential need for revision surgery in the future. By having established the incidence and identifying factors

associated with fracture risks, this information can serve as a foundation for future direction and will help mitigate future risk of this complication.

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