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Postsurgical complications following distal radius volar plating in a diabetic population at short-term follow-up

Daniel M. Koehler[1] · Yubo Gao[1] · Justin J. Guan[1] · Ericka A. Lawler[1] · Brian D. Adams[1] · Apurva S. Shah[1]

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Abstract
Background Diabetes mellitus increases the risk of complications following operative treatment of lower extremity fractures. There is little published data establishing the impact of diabetes following surgical treatment of upper extremity fractures. This investigation aimed to compare the incidence of short-term postsurgical complications following volar locked plating of distal radius fractures in patients with and without diabetes.
Methods A retrospective matched cohort investigation of 33 diabetics matched 1:2 to 66 non-diabetics was performed, accounting for age, gender, fracture type, and smoking status. Electronic medical records and radiographs were reviewed for all major and minor postsurgical complications. Demographic characteristics, postoperative radiographic parameters, and final range of motion were also compared. Mean follow-up was 5.3±8.2 and 5.5±7.8 months for diabetics and non-diabetics, respectively.
Results The diabetic cohort had a significantly higher overall complication rate with 24 postsurgical complications affecting 12 patients (36 %) compared to 16 complications affecting 12 patients (18 %) in the non-diabetic cohort. There was no difference in the incidence of major complications requiring operative intervention. Minor complications were significantly more common in the diabetic group and were largely accounted for by peripheral neuritis with an incidence of 30 %. Final radiographic outcomes and range of motion were similar.
Conclusions Diabetics experienced a greater incidence of minor postsurgical complications following volar locked plating of distal radius fractures when compared to a matched, control population. The difference in outcomes is largely accounted for by the increased incidence of peripheral neuritis among diabetics. Diabetic patients should be counseled preoperatively regarding their elevated risk profile.

Keywords Diabetes mellitus · Distal radius fracture · Volar locked plating

✉ Apurva S. Shah
apurva.shah@aya.yale.edu

[1] Department of Orthopaedic Surgery and Rehabilitation, University of Iowa Hospitals and Clinics, 200 Hawkins Drive, 01008 JPP, Iowa, IA 52242, USA

Introduction

Distal radius fractures are among the most common fracture patterns in the adult patient population [6, 7, 26]. Over the last 15 years, there has been an increasing trend toward fixation of distal radius fractures through open reduction and internal fixation via a volar approach utilizing a pre-contoured plate with fixed-angle locking screws [5, 19, 22, 28, 29, 35, 45]. Advantages of volar plate internal fixation include stable subchondral fixation of intra-articular fragments, early postsurgical active wrist motion, and more rapid return of function compared with external fixation or percutaneous fixation [9, 13, 30, 36, 44]. In addition, restoration of normal articular anatomy appears critical for the prevention of posttraumatic osteoarthritis, especially in comminuted, intra-articular injury patterns [17, 21, 24, 40]. On the other hand, multiple studies have documented the intrinsic risks of volar plate fixation with complication rates as high as 27 % [2, 4, 11, 14, 15, 34, 35, 43].

In the lower extremity, the incidence of postsurgical complications is impacted by the presence and severity of pre-

existing medical co-morbidities. Specifically, diabetes mellitus has been identified in multiple investigations as a significant, independent risk factor for postoperative complications following open treatment of lower extremity fractures [8, 25, 31, 33]. The presence of diabetic related co-morbidities including neuropathy, retinopathy, nephropathy, and Charcot arthropathy is further predictive of complications in ankle fracture management [16]. Despite this association, a paucity of data exists for comparative interventions for acute fractures of the upper extremity in diabetic patients.

The objective of this investigation was to compare the incidence of short-term postsurgical complications and radiographic outcomes following volar locked plate fixation of distal radius fractures in patients with and without diabetes mellitus. We hypothesized that there would be a significantly increased incidence of complications in the diabetic patient population when compared to non-diabetic patients via a matched cohort study design.

Materials and Methods

A retrospective query for open reduction and internal fixation of distal radius fractures was completed at a single level 1 trauma institution over a 6-year interval from January 2007 to December 2012 via Current Procedural Terminology (CPT) code search (25607, 25608, 25609). A matched cohort study design with a diabetic cohort and a non-diabetic cohort was planned. Approval for the investigation was obtained from the Institutional Review Board. Inclusion criteria included patients with distal radius fractures treated with a single pre-contoured anatomic volar locking plate, age ≥18 years, and minimum clinical follow-up of 3 months. Patients were excluded for open fracture pattern, coexisting ipsilateral upper extremity fracture, or prior ipsilateral distal radius fracture. Two hundred forty-four patients met the inclusion and exclusion parameters including 35 diabetic and 209 non-diabetic patients. Patients were not enrolled in the study secondary to the following inclusion/exclusion criteria: alternative internal fixation technique (n=21), age <18 years (n=32), inadequate clinical follow-up (n=98), open fracture pattern (n=35), ipsilateral acute upper extremity fracture (n=90), and prior treatment for an ipsilateral distal radius fracture (n=19).

Basic demographic data and injury characteristics were recorded including age, gender, body mass index (BMI), tobacco use, hand dominance, side of injury, mechanism of injury, and duration of follow-up. Preoperative injury radiographs (posteroanterior, lateral, and oblique) were reviewed independently by two physician investigators, and the fracture pattern was classified via the AO/OTA system [23]. If a discrepancy in the fracture classification was identified, consensus was obtained through inter-observer discussion.

Patients with diabetes mellitus were identified via detailed review of the electronic medical record as defined by current utilization of an oral anti-hyperglycemic medication or insulin. Hemoglobin A1c was recorded when available. Diabetic patients were matched 1:2 to non-diabetic patients by age, gender, smoking status (smoker vs. non-smoker), and fracture type (AO/OTA classification). A 1:2 study design was employed to maximize enrollment of the non-diabetic controls. Only exact matches for gender and smoking status were accepted as these were determined to be binary variables. The closest available match was utilized for age and fracture classification. The maximal acceptable deviation for age was 10 years and fracture classification was matched within one subdivision (i.e., 23-C1 to 23-C2). Any patient in the diabetic cohort for whom two non-diabetic matches could not be identified was excluded from the study. A power analysis was not performed; rather, all diabetic patients meeting study inclusion criteria were enrolled into the study population. Data regarding the treatment course, including subsequent procedures and complications, was collected for both patient cohorts.

All follow-up examinations of the involved upper extremity were scrutinized for development of postsurgical complications. Screening was completed to assess for bone/hardware complications including loss of reduction (defined as a change in bony alignment during the postoperative period), malunion (dorsal radial tilt >10°, volar radial tilt >20°, or radial inclination <15° without postoperative change), delayed union (no radiographic evidence of bridging trabeculae across the fracture site at 4 months), non-union (no radiographic evidence of bridging trabeculae across the fracture site at 6 months), failure of hardware, refracture, and symptomatic hardware [12, 37]. Nerve (permanent peripheral nerve injury, delayed carpal tunnel release, median neuritis, superficial radial neuritis, ulnar neuritis, complex regional pain syndrome), tendon (extensor/flexor rupture, extensor/flexor tendinitis, trigger finger), and other complications (deep/superficial infection, wound dehiscence, stiffness requiring manipulation under anesthesia, compartment syndrome, hypertrophic scar, 30-day rehospitalization) were similarly assessed. Peripheral neuritis was diagnosed by the presence of persistent symptomatic numbness, tingling, or paresthesia in a defined anatomic distribution as identified at two consecutive postoperative appointments. Major complications were defined to require a secondary surgical intervention while minor complications were successfully managed conservatively with observation, splinting, injections, or antibiotics.

Final radiographic outcomes including radial inclination, ulnar variance, and volar tilt were determined by review of posteroanterior, lateral, and oblique radiographs. Posteroanterior radiographs were obtained in neutral rotation in order to accurately evaluate ulnar

variance using the technique of perpendiculars [39]. Measurements were obtained via calibrated digital measuring tools incorporated into the X-ray software. Final range of motion outcomes were obtained from the patient's final clinical visit documentation as assessed and recorded by the treating physician.

The demographic characteristics of the two study cohorts were compared using the Student's *t* test for continuous variables and the Pearson chi-square statistic/Fisher's exact test for categorical variables. Postsurgical complications were also compared using the Pearson chi-square statistic/Fisher's exact test. All radiographic end points and range of motion measurements were reported as continuous variables and compared using the Student's *t* test. The threshold for significance was defined as $p<0.05$.

Results

The final matched cohort study population included 33 diabetic patients matched 1:2 to 66 non-diabetic patients. No significant difference was identified between the two cohorts for any of the demographic variables (Table 1). The mean population age for diabetics versus non-diabetics was 57.3±12.3 versus 55.7±11.8 years with an average follow-up of 5.3±8.2 versus 5.5±7.8 months, respectively. Complete articular AO/OTA 23-C fractures were the most common injury patterns enrolled in the study accounting for 76 % of both the diabetic and non-diabetic patient populations. There was no significant difference in the incidence of carpal tunnel release performed at the time of the index surgery between the two cohorts.

Table 1 Demographic data

	Diabetics (*n*=33)	Non-diabetics (*n*=66)	*p* value
Mean age (years)	57.3±12.3[a]	55.7±11.8[a]	0.545
Gender			1.000
Male	11 (33 %)	22 (33 %)	
Female	22 (67 %)	44 (67 %)	
Hand dominance			0.768
Right	29 (88 %)	56 (85 %)	
Left	4 (12 %)	10 (15 %)	
Side of fracture			0.375
Dominant	10 (30 %)	26 (39 %)	
Non-dominant	23 (70 %)	40 (61 %)	
Smoking status			1.000
Non-smoker	21 (64 %)	42 (64 %)	
Smoker	12 (36 %)	24 (36 %)	
Mechanism			0.856
Fall from standing	22 (67 %)	41 (62 %)	
Fall from height	5 (15 %)	12 (18 %)	
Motor vehicle collision	4 (12 %)	6 (9 %)	
Bicycle	0 (0 %)	3 (5 %)	
Other	2 (6 %)	4 (6 %)	
AO fracture classification			0.991
A1	0 (0 %)	0 (0 %)	
A2	2 (6 %)	5 (8 %)	
A3	2 (6 %)	3 (4 %)	
B1	1 (3 %)	3 (4 %)	
B2	0 (0 %)	0 (0 %)	
B3	3 (9 %)	5 (8 %)	
C1	14 (43 %)	25 (38 %)	
C2	7 (21 %)	18 (27 %)	
C3	4 (12 %)	7 (11 %)	
Mean duration of follow-up (months)	5.3±8.2[a]	5.5±7.8[a]	0.894

[a] Continuous variables reported as mean±standard deviation

The diabetic cohort had significantly more complications than the non-diabetic cohort. In total, 24 postsurgical complications were identified affecting 12 patients (36 %) in the diabetic population compared to 16 postsurgical complications affecting 12 patients (18 %) in the control population (p=0.047). No difference was identified in the incidence of major complications (p=0.683, Table 2). Collectively, there were three identified major bone/hardware complications requiring revision surgery including two among the diabetic population and one in the non-diabetic group. Complication details and management strategies are reviewed in Table 3.

The incidence of minor postsurgical complications was significantly greater in the diabetic cohort relative to the non-diabetic cohort (p<0.0001, Table 4). When comparing the two cohorts with regard to each specific complication, only ulnar neuritis was identified to independently reach statistical significance (p=0.035). Postsurgical neuritis affecting the median, superficial radial, and ulnar nerves represented the majority of minor complications (47.6 %) among the diabetic population. Collectively, the summed incidence of postoperative peripheral neuritis was significantly greater for diabetics relative to non-diabetic controls (p=0.027). A single diabetic patient required hospital readmission within the 30-day postoperative interval for management of acute pain on postoperative day #1. Conservative management was required with a combination of oral and IV analgesics with the patient subsequently discharging on hospital day #2.

A subanalysis of the diabetic cohort divided into populations with a hemoglobin A1c of <6.5 and ≥6.5 identified a significantly greater incidence of total complications (p=0.017) and minor complications (p=0.046) among the group with hemoglobin A1c levels ≥6.5. No statistical difference was identified in the incidence of major complications. Mean hemoglobin A1c levels for the two groups were 6.0±0.3 and 7.8±1.3, respectively. Twenty-four diabetic patients had hemoglobin A1c values available for review. There was no significant difference in the complication rates of insulin-dependent and non-insulin-dependent diabetics.

Final radiographic outcomes between the two cohorts were not significantly different (Table 5). Mean volar tilt, ulnar variance, and radial inclination for the diabetic versus non-diabetic populations were 6.5±5.9° versus 6.9±5.7°, +0.4±1.5 versus +0.2±2.0 mm, and 19.5±2.8° versus 18.9±3.6°, respectively. All fractures demonstrated osseous union at the time of final radiographic follow-up, including the single patient with a persistent non-union that required revision open reduction and internal fixation with allograft augmentation. Final range of motion assessments were also not significantly different between the two cohorts, including wrist extension, wrist flexion, forearm pronation, and forearm supination (Table 6).

Discussion

Although diabetes mellitus has been established as a significant, independent risk factor for postoperative complications following open treatment of lower extremity fractures, no

Table 2 Major postoperative complications following volar plating of closed distal radius fractures

Major complications	Diabetics (n=33) # (%)	Non-diabetics (n=66) # (%)	Odds ratio (95 % CI)	p value
Bone/hardware complications				
Malunion	1 (3)	0 (0)	–	0.333
Non-union	0 (0)	1 (1.5)	–	1.000
Loss of reduction	1 (3)	0 (0)	–	0.333
Failure of hardware	0 (0)	0 (0)	–	–
Refracture	0 (0)	0 (0)	–	–
Nerve complications				
Permanent peripheral nerve injury	0 (0)	0 (0)	–	–
Delayed carpal tunnel release	1 (3)	1 (1.5)	2.03 (0.12–33.54)	1.000
Tendon complications				
Extensor rupture	0 (0)	0 (0)	–	–
Flexor rupture	0 (0)	0 (0)	–	–
Other				
Deep infection	0 (0)	0 (0)	–	–
Stiffness requiring MUA	0 (0)	2 (3)	–	0.551
Compartment syndrome	0 (0)	0 (0)	–	–
Total	3 (9)	4 (6)	1.55 (0.33–7.37)	0.683

MUA manipulation under anesthesia, *CI* confidence interval

Table 3 Major bone/hardware complications

Age	Diabetes	Fracture type (AO classification)	Tobacco use	Complication	Management
46	Y	23-C2	Y	Malunion with 5 mm ulnar positive variance and ulnocarpal impaction syndrome	Removal of hardware, ulnar-shortening osteotomy
48	Y	23-B3	Y	Loss of lunate facet fixation, volar carpal subluxation, median nerve compression	Removal of hardware, carpal tunnel release, total wrist arthrodesis
52	N	23-C2	Y	Non-union, carpal tunnel syndrome	Revision distal radius open reduction and internal fixation, carpal tunnel release

Y yes, *N* no

research has been conducted to establish the risk profile of diabetics undergoing volar plate fixation for distal radius fractures [8, 25, 31, 33]. Consequently, the goal of this investigation was to evaluate the incidence of short-term postsurgical complications and radiographic outcomes in patients treated with volar locked plate fixation for distal radius fractures with and without diabetes.

This retrospective analysis of stringently matched diabetic and non-diabetic cohorts demonstrated a statistically significant difference in the overall complication rates of 36 % (12/33) and 18 % (12/66), respectively (p=0.047). The incidence of complications identified among the non-diabetic population is comparable to previously published rates. In a 2-year prospective multi-center study, Jupiter et al. identified an overall complication rate of 22 % across 125 patients undergoing volar plate fixation for distal radius fracture with a majority (20/28) classified as minor complications [18]. Other authors analyzing analogous case series have identified similar overall complication rates ranging from 8 to 27 % [2, 11, 15, 32, 34, 35, 43]. The broad range can partially be attributed to methodologic discrepancies across these studies including their prospective versus retrospective nature, inconsistencies in complication definitions, and varying accountability for minor complications. However, no previously published case series has identified a complication rate comparable to that identified in the present diabetic population.

Several prior studies have identified tendon complications including tendinitis, tenosynovitis, and tendon rupture as the most common postsurgical complication with combined incidences affecting 3–15 % of the study populations [2, 15, 18].

Table 4 Minor postoperative complications following volar plating of closed distal radius fractures

Minor complications	Diabetics (n=33) # (%)	Non-diabetics (n=66) # (%)	Odds ratio (95 % CI)	p value
Bone/hardware complications				
Symptomatic hardware	2 (6)	0 (0)	–	0.109
Delayed union	1 (3)	1 (1.5)	2.03 (0.12–33.54)	1.000
Nerve complications	11 (33)	8 (12)	3.63 (1.29–10.20)	0.016
Median neuritis	5 (15)	8 (12)	1.29 (0.39–4.32)	0.755
Superficial radial neuritis	2 (6)	0 (0)	–	0.109
Ulnar neuritis	3 (9)	0 (0)	–	0.035
CRPS	1 (3)	0 (0)	–	0.333
Tendon complications				
Extensor tendinitis	0 (0)	0 (0)	–	–
Flexor tendinitis	2 (6)	0 (0)	–	0.109
Trigger finger	1 (3)	0 (0)	–	0.333
Other				
Superficial infection	1 (3)	1 (1.5)	2.03 (0.12–33.54)	1.000
Hypertrophic scar	1 (3)	2 (3)	1.00 (0.09–11.45)	1.000
30-day rehospitalization[a]	1 (3)	0 (0)	–	0.333
Wound dehiscence	1 (3)	0 (0)	–	0.333
Total	21 (63)	12 (18)	7.88 (3.06–20.28)	<0.0001

CRPS complex regional pain syndrome, *CI* confidence interval

[a] Thirty-day rehospitalization was for management of pain on postoperative day #1

Table 5 Final radiographic outcomes

	Diabetics (n=33)	Non-diabetics (n=66)	p value
Volar tilt (degrees)	6.5±5.9	6.9±5.7	0.807
Ulnar variance (mm)	+0.4±1.5	+0.2±2.0	0.604
Radial inclination (degrees)	19.5±2.8	18.9±3.6	0.415

Positive values (+) for ulnar variance indicate ulnar positive variance. Continuous variables reported as mean± standard deviation

Extensor tendon irritation is related to hardware penetration of the dorsal radius cortex while flexor tendon injury is related to distal plate positioning adjacent to the radiocarpal articulation [1, 3, 27]. In the present investigation, no patients were identified to experience a flexor or extensor tendon rupture; however, late tendon rupture events may not have been captured in the available clinical follow-up intervals. Two of 33 (6 %) patients were clinically diagnosed with flexor carpi radialis tendinitis requiring a tendon sheath corticosteroid injection in the diabetes cohort with no identified patients in the control group. Extensor and flexor tendinitis not requiring intervention may be under-reported given the retrospective nature of this study.

Alternatively, other case series detailing outcomes following distal radius volar locked plate fixation report peripheral nerve dysfunction/compression as the predominant complication. Ward et al. identified peripheral nerve dysfunction defined as persistent numbness or subjective paresthesias accounting for 12/22 (55 %) complications among 96 fractures in 92 patients. The median nerve, including the palmar cutaneous branch, was most frequently affected [43]. Nerve compression was also documented as the most commonly experienced complication in a retrospective cohort of 665 cases published by Esenwein et al. [11]. Nerve complications were similarly the most common complication in the present study. A single patient in both the diabetic as well as the non-diabetic group required delayed carpal tunnel release for median nerve compression. Postsurgical neuritis managed non-operatively with observation, splinting, and/or injections affecting the median, superficial radial, and ulnar nerves represented the majority of minor complications among both the diabetic and non-diabetic populations. Stewart et al. documented that dorsal angulation is a risk factor for the development of median nerve compression at the carpal tunnel in distal radius fractures treated with casting [38]; however, the final volar tilt did not differ between patients with and without median nerve symptoms in the present study. Notably, the two cases of superficial radial neuritis appear secondary to placement of a temporary Kirschner wire for ancillary fixation of the radial styloid.

Collectively, the summed incidence of postsurgical peripheral neuritis affecting the median, superficial radial, and ulnar nerves was significantly greater for diabetics relative to non-diabetics (p=0.027). This increased tendency toward postoperative neuritis among the diabetic population may be rooted in disease-specific peripheral nerve susceptibility. The pathogenesis and underlying mechanisms leading to development of diabetic neuropathy are complex and continue to undergo investigation but are known to involve a combination of oxidative stress, inflammation, and altered gene expression [41]. This cascade of changes results in pathologic interactions between neurons, Schwann cells, and the microvascular endothelium [10, 42]. Electrodiagnostic testing has demonstrated that reduced nerve conduction velocity can be present early in asymptomatic individuals prior to clinical manifestations of peripheral nerve injury [20, 32]. These subclinical changes may predispose the diabetic patient to peripheral nerve injury and inflammation following a secondary surgical insult.

A subanalysis of the diabetic population demonstrated that the cohort of patients with a hemoglobin A1c of ≥6.5 had a higher incidence of total and minor postsurgical complications. Although the present study was not designed to identify independent risk factors for complication, assessment of the pre-operative hemoglobin A1c may be useful for providing prognostic information for patients during the informed consent process. It may be further beneficial to optimize glycemic control in the peri-operative interval in order to minimize complication risk.

Importantly, although there was an increased incidence of mild complications in the diabetes cohort, the final radiographic alignment as assessed by volar tilt, ulnar variance, and radial inclination as well as the final clinical range of motion were not significantly different between the two matched cohorts. Furthermore, all diabetic and non-diabetic patients demonstrated radiographic evidence of osseous union at the time of their final follow-up. Collectively, this suggests

Table 6 Final range of motion

	Diabetics (n=33)	Non-diabetics (n=66)	p value
Wrist extension	41.8±20.6	46.7±14.7	0.193
Wrist flexion	39.2±14.0	43.8±13.5	0.144
Forearm pronation	82.9±10.6	81.2±14.6	0.601
Forearm supination	70.2±19.6	73.2±14.0	0.448

All measurements are reported in degrees. Continuous variables reported as mean±standard deviation

that volar locked plate fixation reliably restores anatomy and function in both populations.

Inherently, this study has limitations secondary to its retrospective nature. Identification of complications depended on the existing records. Major complications requiring repeat surgical intervention were extensively documented in the electronic medical record, and therefore, no error is anticipated with the reported incidences. Minor complications including symptomatic hardware, peripheral neuritis, tendinitis, and stiffness may be under-reported especially if no specific treatment course was required for management. Additionally, the relatively short follow-up interval in this study is insufficient to allow for evaluation of long-term outcomes including late tendon rupture, final range of motion parameters, loss of fixation, complex regional pain syndrome, and development of posttraumatic osteoarthritis. The results of this study cannot be extrapolated to predict long-term postsurgical complications. Nearly one fifth of our patients were excluded for inadequate clinical follow-up (<3 months) which may result in selection bias. Patients who do not return for scheduled follow-up may be reasonably expected to be complication-free, which would result in a relative overestimation of complication rates among the patients enrolled in the study. Alternatively, these patients may have decided to seek care outside of our clinical practice. One notable strength of the study design is the stringently matched cohorts with no identified differences in demographic characteristics or fracture severity.

In conclusion, the total incidence of minor postsurgical complications following volar locked plate fixation of distal radius fractures is significantly greater among diabetics when compared to a matched, non-diabetic population when evaluated at short-term follow-up. The difference in outcomes is largely accounted for by the increased incidence of peripheral neurologic dysfunction in diabetics which may be reflective of disease-specific intrinsic peripheral nerve susceptibility. Importantly, however, final radiographic outcomes and range of motion are equivalent between the two populations. Diabetic patients undergoing locked volar plating for distal radius fractures should be appropriately counseled pre-operatively regarding their elevated risk profile.

Conflicts of interest Daniel M. Koehler declares that he has no conflicts of interest to disclose.

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Statement of informed consent Informed consent was obtained from all individual participants included in the study.

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