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Outcomes of Ankle Fractures in Patients with Uncomplicated Versus Complicated Diabetes

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ABSTRACT

Background: **Patients with diabetes who sustain an ankle fracture are at increased risk for complications including higher rates of in hospital mortality, in-hospital postoperative complications, length of stay and non-routine discharges. The purpose of this study was to retrospectively compare the complications associated with operatively treated ankle fractures in a group of patients with uncomplicated diabetes versus a group of patients with complicated diabetes. Complicated diabetes was defined as diabetes associated with end organ damage such as peripheral neuropathy, nephropathy and/or PAD. Uncomplicated diabetes was defined as diabetes without any of these associated conditions. Our hypothesis was that patients with uncomplicated diabetes would experience fewer complications than those patients with complicated diabetes.** ***Materials and Methods:*** **We compared the complication rates of ankle fracture repair in 46 patients with complicated diabetes and 59 patients with uncomplicated diabetes and calculated odds ratios (OR) for significant findings.** ***Results:*** **At a mean followup of 21.4 months we found that patients with complicated diabetes had 3.8 times increased risk of overall complications 3.4 times increased risk of a non-infectious complication (malunion, nonunion or Charcot arthropathy) and 5 times higher likelihood of needing revision surgery/arthrodesis when compared to patients with uncomplicated diabetes. Open ankle fractures in this diabetic population were associated with a three times higher rate of complications and 3.7 times higher rate of infection.** ***Conclusion:*** **Patients with complicated diabetes have an increased risk of complications after ankle fracture surgery compared to patients with uncomplicated diabetes. Careful preoperative evaluation of the neurovascular status is mandatory, since many patients with diabetes do not recognize that they have neuropathy and/or peripheral artery disease.**

Level of Evidence: III, Retrospective, Case Control Study

Key Words: Diabetes; Ankle; Fractrures; Complications; Neuropathy

INTRODUCTION

Approximately 260,000 ankle fractures occur annually in the United States, and patients with diabetes are at increased risk for complications.[9,16,28,31,45,49,36,49] In 2007, it was estimated that 23.6 million people in the United States had diabetes mellitus representing 7.8% of the population.[1,2] A recent report projected that between 2009 and 2034, the number of people with diagnosed and undiagnosed diabetes will increase from 23.7 million to 44.1 million.[18] The rise in the prevalence of diabetes has been characterized as a worldwide epidemic, particularly in developing nations.[7] A recent study of 57,000 surgically treated ankle fractures reported that diabetes was a strong predictor of short term complications.[45] Ankle fracture patients with diabetes have significantly higher rates of in hospital mortality , in-hospital postoperative complications, length of stay and non-routine discharges.[17] Additional retrospective case series have demonstrated that patients with diabetes sustaining ankle fractures have infection rates ranging from 17% to 50% and amputation rates from 4% to 17%.[4,16,47]

Patients with additional comorbidities including peripheral neuropathy and peripheral artery disease (PAD), have the highest rates of complications in the operative setting.[12] In the United States, 10% of diabetic patients have some degree of neuropathy at the time of the initial diagnosis, and up to 40% will be diagnosed with peripheral neuropathy within the first decade following diagnosis. Recently, higher rates of postoperative infection, malunion, nonunion, and acute Charcot arthropathy have been found in this population following surgical intervention.[49] Over the past decade some

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authors have recommended additional fixation and prolonged nonweightbearing in an attempt to decrease postoperative complications.[19,20,32]

The purpose of this study was to retrospectively compare early outcomes associated with operatively treated ankle fractures in a group of patients with uncomplicated diabetes versus a group of patients with complicated diabetes. Our hypothesis was that patients with uncomplicated diabetes would experience fewer complications than those patients with complicated diabetes.

MATERIALS AND METHODS

Prior to beginning the study, the investigational review board at our medical center designated this as an exempt study. Using a searchable computerized hospital database, all patients with diabetes mellitus who underwent operative management of an ankle fracture between December 2003 and July 2008 were identified. Ankle fractures were identified with the International Classification of Diseases-9th edition (ICD-9) codes 824 (medial malleolus fracture), 824.2 (lateral malleolus fracture), 824.4 (bimalleolar fracture) and 824.6 (trimalleolar fracture). Patients with diabetes were identified with ICD-9 codes 250.0 to 250.9. Patients who are coded 250.0 have no reported complications of diabetes, while codes 250.1–250.9 are utilized to designate various complications of diabetes. For example, code 250.4 represents diabetes associated with renal manifestations, code 250.6 represents diabetes associated with neurological manifestations and code 250.7 represents diabetes associated with peripheral circulatory disorders. Additionally, we also searched for ICD-9 code 357.2 which codes for polyneuropathy in diabetes and ICD-9 code 440.2 which codes for atherosclerosis of a native extremity. This was done in conjunction with a search for Current Procedural Terminology (CPT) codes 27766 (ORIF of the medial malleolus), 27792 (ORIF of the lateral malleolus), 27814 (ORIF of a bimalleolar fracture), 27822 (ORIF of a trimalleolar fracture without fixation of the posterior malleolus), and 27823 (ORIF of a trimalleolar fracture with posterior fracture fixation). Ankle fractures which were identified by the database were further confirmed by a chart review and radiographic analysis. Any patient with an improperly coded tibial pilon or talus fracture was excluded by review of the radiographs. Seven surgeons who regularly treated foot and ankle trauma performed the procedures at two university teaching hospitals. Patients under the age of 18 years, patients with incomplete medical records, and patients with less than 6 months followup were excluded from the study.

Electronic inpatient medical records, typewritten outpatient office notes and electronic digital radiographs were available for all patients. Demographic data including age, gender, body mass index (BMI), date of surgery and the type of fracture were recorded. Laboratory values such as fasting glucose of the day of surgery, serum creatinine and hemoglobin A1-C levels were extracted from the medical records. Complicated diabetes was defined as diabetes associated with end organ damage such as peripheral neuropathy, nephropathy and/or PAD. Uncomplicated diabetes was defined as diabetes without any of these associated conditions.[13,37,45] Patients were diagnosed to have peripheral sensory neuropathy if they were insensate to the 5.07 Semmes Weinstein monofilament. The peripheral vascular examination included palpation of the dorsalis pedis and posterior tibial pulses, and each pulse was defined as present or absent. Patients with an abnormal vascular examination or who previously had undergone lower extremity revascularization, either open or endovascular, were also considered to have PAD. Nephropathy was defined as a serum creatinine of greater than or equal to 1.5.[39] All followup clinical notes and radiographs were subsequently reviewed, specifically looking for the presence or absence of complications. The primary outcomes that we analyzed included superficial infections, deep infections, nonunion and malunion. We also examined the development of Charcot arthropathy, the requirement of amputation, and the need for revision of the fixation or ankle fusion. Additionally, the length of time from the initial injury to the latest followup was calculated to ensure all patients had at least a 6-month postoperative followup. Superficial infections were defined as those treated with local wound care and oral antibiotics, without the need for surgical debridement. These included both pin tract infections in the external fixation group and superficial surgical wound infections. Deep infections were counted as those which required deep surgical debridement and intravenous antibiotics. Malunion and nonunion were determined from both the clinical notes and a review of the radiographs, and were defined as failure of healing at a minimum of 6-month followup or radiographic malalignment of the ankle. Charcot arthropathy was diagnosed if characteristic bone destruction and joint subluxation were present.[51]

The specific type of treatment was at the discretion of the operating surgeon; however certain basic principles were followed uniformly. Closed fractures were treated with initial reduction and splint immobilization in the emergency department. Definitive stabilization of closed fractures was generally performed on a semi-elective basis during normal working hours. Preoperative antibiotics were given immediately prior to the surgical incision and continued for 24 hours. Open fractures were treated with immediate antibiotic therapy in the emergency department, followed by operative debridement of devitalized tissue. Antibiotics were continued for 72 hours postoperatively in open fractures. In general, Grade I open fractures were treated with definitive open reduction internal fixation at the time of surgical debridement. Grade II and III open fractures were treated with external fixation after debridement and staged open reduction internal fixation (ORIF) once the soft tissues were acceptable. Select fractures with severe soft tissue injury were treated with external fixation methods solely. Wounds that could be closed the day of injury with minimal tension were closed, while the remaining wounds were treated with initial negative pressure wound therapy placement followed by plastic surgery consultation for definitive coverage if necessary. Open reduction internal fixation (ORIF) was performed using standard techniques, although the decision to use supplemental internal or external fixation was left to the discretion of the treating surgeon.[46] For the purposes of this study we categorized our fixation into several different groups based on the use of standard techniques, supplemental internal fixation and/or external fixation. Those patients who underwent fixation of the distal fibula with a plate and lag screw were categorized as standard ORIF.[46] Patients who had similar fixation of the distal fibula and the use of two or more tetracortical tibiofibular screws and/or transarticular pin fixation were categorized as ORIF Plus (Figure 1).[19,41] Those patients who had both internal and external fixation were categorized as combined fixation while those who only had the utilization of external fixation for definitive treatment were categorized as external fixation alone. Fractures of the medial or posterior malleoli were stabilized with standard techniques using screws, tension band wiring or bridge plates when indicated.[46] Postoperatively, our treatment included nonweightbearing for a minimum of 8 weeks in patients who did not have neuropathy and 12 weeks if neuropathy was present. Transarticular pins and external fixation were generally removed between 8 and 12 weeks after the injury.

Patients were generally seen at 2, 4, and 8 weeks, and subsequently at 1 month intervals until fracture healing was complete. At each visit, AP, lateral, and oblique radiographs were obtained to evaluate fracture healing. Additionally, any evidence of pin site infection or surgical wound infection was noted. All of the patients in this study had been diagnosed with diabetes prior to sustaining the ankle fracture and were receiving oral agents, insulin or combination therapy.

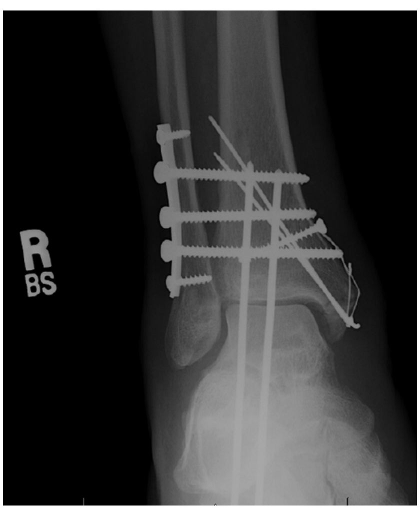

Fig. 1: Radiograph illustrating ORIF Plus with tetracortical tibiofibular screws and Steinman pins.

For data analysis patients were separated into two groups: complicated and uncomplicated diabetes. Analysis was started by calculating descriptive statistics. The rate of overall complications was determined including both infectious and non-infectious complications. Infections were then analyzed as an overall infection rate, and individually as superficial or deep infections. Because of our small numbers and overlap between variables, nonunion, malunion and Charcot arthropathy were aggregated and analyzed as non-infectious complications. Combining individual variables such as this has been used in previous studies of ankle fractures in patients with diabetes.[21,45] The rate of amputation and need for revision surgery were analyzed separately. Since the vast majority of papers dealing with ankle fractures in patients with diabetes report on the impact of peripheral neuropathy, we also analyzed this as a separate variable. T-test analysis, with a p value less than 0.05 was used for continuous variables and univariate logistic regression analysis (SPSS) was used to calculate odds ratios (OR), p values and 95% confidence intervals (95% CI) for categorical values.

During the study period, 163 patients with diabetes and ankle fractures were treated at our two trauma centers. Fifty-eight of the 163 patients (36%) did not have a minimum followup of 6 months and were not included in the data analysis. The remaining 105 patients with diabetes (46 complicated and 59 uncomplicated) had a mean followup of 21.4 (range, 6 to 62) months. The preoperative demographics of our complicated and uncomplicated diabetic patients were similar with regard to age, BMI level, serum fasting glucose on the morning of surgery, hemoglobin A1-c levels (Hgb A1-C), and the type of fracture (open versus closed, unimalleolar, bimalleolar or trimalleolar). More complicated diabetic patients were female, and patients with complicated diabetes had higher preoperative serum creatinine levels than patients with uncomplicated diabetes (Table I). The majority of patients with complicated diabetes in this study had peripheral neuropathy (33 of 46) (71.6%), while PAD (10 of 46) (21.7%) and nephropathy (12 of 46) (26.1%) were less common. Multiple comorbidities were present in some patients due to the common etiology of microvascular disease and impaired glucose metabolism. By definition, none of the patients with uncomplicated diabetes had neuropathy, PAD or impaired renal function. Eight fractures (7.6%) were treated nonoperatively, 35 fractures (33.3%) were treated with standard ORIF, 24 fractures (22.8%) were treated with ORIF plus, 32 fractures (30.4%) were treated with combined ORIF and external fixation and six fractures (5.7%) were treated with external fixation solely. Table 1 illustrates the type of fixation and the number of patients treated by each method in complicated and uncomplicated diabetes.

RESULTS

Thirty-six of the 105 patients experienced a complication (34.2%). Complicated diabetes mellitus was associated with

Table 1: Demographic Data and Fracture Characteristics

Patient Characteristics	**Diabetes Status**	
	Complicated	**Uncomplicated**
Number of Patients (%)	46 (43.8%)	59 (56.2%)
Age (mean years, SD)	63.7 (12.6)	60.8 (15.0)
Male (%)	32.6*	52.5
Female (%)	67.4*	47.5
BMI level (mean kg/m^2, SD)	32.0 (8.2)	31.1 (7.6)
Peripheral Neuropathy (%)	76.1‡	0
Peripheral Artery Disease (%)	21.7‡	0
Nephropathy (%)	26.1‡	0
Laboratory Studies		
HgA1C level (mean%, SD)	7.0 (0.61)	7.0 (0.87)
Glucose level (mean mg/dl, SD)	160.8 (71.5)	170.3 (62.2)
Creatinine level (mean mg/dL, SD)	1.5 (1.1)‡	0.97 (0.3)
Fracture Characteristics		
Open	6 (13%)	14 (23.7%)
Closed	40 (87%)	45 (76.3%)
	100%	*100%*
Unimalleolar	8 (17.4%)	12 (20.3%)
Bimalleolar	23 (50%)	29 (49.2%)
Trimalleolar	15 (32.6%)	18 (30.5%)
	100%	*100%*
Method of Treatment		
Nonoperative	4 (8.7%)	4 (6.8%)
ORIF	15 (32.6%)	20 (33.9%)
ORIF Plus	5 (10.9%)‡	19 (32.2%)
ORIF External Fixation	17 (36.9%)	15 (25.4%)
Plain External Fixation	5 (10.9%)*	1 (1.7%)
	100%	*100%*

*, $p < 0.05$; ‡, $p < 0.01$.

more overall complications, more aggregate non-infectious complications, and increased rate of revision surgery when compared to uncomplicated diabetes. Twenty-three of the 46 patients with complicated diabetes (50%) experienced a complication postoperatively which was more than double the percentage of complications experienced by patients with uncomplicated diabetes. Although patients with complicated diabetes had substantially higher rates of postoperative infections than patients with complicated diabetes, this difference did not reach statistical significance (Table 2). The presence of peripheral neuropathy in diabetic patients was associated with more overall complications, a higher rate of deep infection, more aggregate non-infectious complications and an increased rate of revision surgery when compared to those patients without peripheral neuropathy (Table 3). Open fractures were associated with higher rates of overall complications, total infections and superficial infections. Patients with open fractures had a higher rate of amputation than patients with closed fractures, however this difference did not reach statistical significance ($p = 0.06$) (Table 4). We did not find that gender had a statistically significant impact on complications. Patients who had the utilization of supplemental fixation (ORIF plus) had significantly fewer overall complications than patients who were treated with other techniques. Patients who were treated with combined internal fixation and external fixation and external fixation alone had higher rates of complications than those patients treated with standard ORIF and ORIF plus (Table 5). When comparing those diabetic patients who experienced a postoperative complication to those who did not experience a complication, we found that age, sex, BMI, fasting serum glucose, Hgb A1-c levels, serum creatinine and the

Table 2: Comparison of Patients with Complicated and Complicated Diabetes Mellitus

	Diabetes Status			
	Complicated $n = 46$	**Uncomplicated $n = 59$**	**Odds Ratio (95% CI)**	***p* value**
Overall Complications (%)	50.0	22.8	3.8 (1.6–8.9)	0.003
Total Infections (%)	30.4	17.5		0.13
Superficial Infections (%)	28.3	17.5		0.20
Deep Infections (%)	17.4	5.3		0.06
Total Non Infectious (%) (Nonunion, Malunion and/or Charcot Arthropathy)	28.9	11.9	3.4 (1.2–9.2)	0.02
Amputation (%)	8.7	3.4		0.26
Revision Surgery (%)	26.7	6.8	5.0 (1.4–16.8)	0.009

Table 3: Impact of Diabetic Neuropathy on Complication Rate

	With Neuropathy ($n = 35$) v. Without Neuropathy ($n = 70$)
Any Complication	**[OR = 4.7, 95% CI (1.2–9.2), $p = 0.001$]**
Overall Infection	[$p = 0.06$]
Superficial Infection	[$p = 0.12$]
Deep Infection	**[OR = 6.4, 95% CI (1.6–26.1), $p = 0.009$]**
Aggregate Noninfectious Complication (Nonunion, Malunion and/or Charcot Arthropathy)	**[OR = 3.5, 95% CI (1.3–9.4), $p = 0.01$]**
Amputation	[$p = 0.10$]
Revision Surgery	**[OR = 4.4, 95% CI (1.5–13.6), $p = 0.009$]**

OR, Odds Ratio; CI, Confidence Interval. Significant findings in **bold**.

type of fracture (i.e., unimalleolar, bimalleolar or trimalleolar) were not significantly different ($p > 0.05$). Two of the eight patients (25%) who were treated nonoperatively developed asymptomatic nonunions which did not require any additional treatment.

DISCUSSION

Our hypothesis that ankle fracture patients with uncomplicated diabetes would experience fewer complications than patients with complicated diabetes was confirmed in this study. In the early 1980's, Kristiansen[24,25] reported that patients with diabetes and ankle fractures had an increased rate of infection and longer hospital stays than a control group of non-diabetic patients. Since then, several retrospective case series as well as retrospective controlled studies have confirmed this observation.[3,4,10,12,17,19,21,31,45] Nonoperative treatment of unstable ankle fractures in patients with diabetes has been associated with poor results, and most authors currently recommend open reduction and stable fixation in this difficult group of fractures.[9–12,21,49] Connelly and Csenczitz[10] reported a very high complication rate in diabetic ankle fractures which were treated nonoperatively. Their case series of six ankle fractures in five diabetic patients noted that nonoperative treatment of these injuries resulted in poor outcomes in five of the six fractures (83%). One of the five patients required a below knee amputation due to sepsis, and three other patients developed Charcot arthropathy. Due to their poor results, the authors recommended operative stabilization of ankle fractures in diabetic patients with careful postoperative nonweightbearing immobilization.[10] Over the past 15 years some authors have advocated supplemental fixation in addition to standard ORIF technique in an effort to reduce complications.[9,19,20,41,49] Over the past two decades, several authors have also described a prodromal stage of Charcot arthropathy in patients with neuropathic

Table 4: Comparison of Open Versus Closed Ankle Fractures in Patients with Diabetes Mellitus

	Open (n = 20) v. Closed Fractures (n = 85)
Any Complication	**[OR = 3.0, 95% CI (1.1–2.2), p = 0.03]**
Overall Infection	**[OR = 3.7, 95% CI (1.3–10.5), p = 0.01]**
Superficial Infection	**[OR = 3.0, 95% CI (1.1–8.7), p = 0.04]**
Deep Infection	[$p = 0.49$]
Aggregate Noninfectious Complication (Nonunion, Malunion and/or Charcot Arthropathy)	[$p = 0.52$]
Amputation	[$p = 0.06$]
Revision Surgery	[$p = 0.50$]

OR, Odds Ratio; CI, Confidence Interval. Significant findings in **bold**.

Table 5: Methods of Fixation and Complication Rates

	Patients n = 105	**Complications n = 36**	**[OR, CI, p value]**
Nonoperative Treatment	8 (7.6%)	2 (5.7%)	[OR = 3.63, 95% CI (0.12-3.3), p = 0.58]
Open Reduction Internal fixation	35 (33.3%)	7 (20%)	[OR = 4.95% CI (0.15-1.1), p = 0.07]
ORIF Plus	**24 (22.8%)**	**2 (5.7%)**	**[OR = 13,95% CI (0.03-0.58), p = 0.008]**
ORIF and External Fixation	**32 (30.5%)**	**19 (54.3%)**	**[OR = 4.6, 95% CI (1.9-11.1), p = 0.001]**
Plain External Fixation	**6 (5.8%)**	**6 (17.1%)**	**[OR = 13.9, 95% CI (1.6-120.4), p = 0.02]**

OP, Odds Ratio; CI, Confidence Interval. Significant findings in **bold**.

fractures prior to the development of frank radiographic changes.[8,20,41–43] Various names have been utilized to depict this stage such as Charcot *in situ*, Stage 0 Charcot, incipient Charcot or pre Eichenholtz Stage 1. Schon et al.[40,41] recommended that all diabetic patients with peripheral neuropathy and ankle fractures be treated as Stage 0 Charcot patients with prolonged nonweightbearing, increased fixation and immobilization until the signs of inflammation had resolved.

The mechanism by which diabetes mellitus negatively impacts the outcome of ankle fractures is complex. Hyperglycemia leads to impaired soft tissue and osseous healing.[9] Diabetic neuropathy predisposes patients to hardware failure and postoperative infections due to premature weightbearing and inability to detect infection.[19,40,50] Diabetic nephropathy can lead to renal osteodystrophy and decreased quality of bone, thus predisposing to hardware failure.[21] Impaired immune function in diabetic patients predisposes to these patients to postoperative infection.[6] Diabetic angiopathy affects both the macrovascular and microvascular circulation which further impedes normal healing.[14] Recently, the expression of vascular endothelial growth factor (VEGF), which promotes angiogenesis, has been shown to be reduced in diabetic animals and humans with diabetic neuropathy.[23,38] It is likely that infections, delayed wound healing and osseous healing are impacted by alterations at the molecular level in patients with diabetes.

Lillmars and Meister[26] performed a systematic review of five series of ankle fractures in diabetic patients.[4,11,16,28,31] They were able to identify 127 patients who underwent ORIF and reported a combined complication rate of 30%. Thirty-two of the 37 reported complications involved infection, affecting 25% of all surgically treated patients. Nineteen of the 32 infections were characterized as deep, and the authors found that diabetic patients as a group experienced more severe infections than a control group of non-diabetic patients. Three of the five studies documented the presence of peripheral arterial disease (PAD) and 66% of the patients with PAD and diabetes mellitus who were treated surgically developed an infection. The presence of peripheral neuropathy was documented in four of the five studies, and 72% of patients with neuropathy and diabetes who were treated surgically developed postoperative complications. Five percent of the patients with diabetes underwent below knee amputation versus none of the patients without diabetes. Seven percent of the diabetic patients developed Charcot arthropathy.

In addition to those studies cited in the systematic review by Lillmars and Meister[26], several additional case series have been reported. Bibbo et al.[3] reported on 13 diabetic patients who underwent ORIF of ankle fractures and found that six of these patients (46%) experienced a postoperative complication. More than one complication occurred in some of these patients which included six superficial infections, one delayed union, one deep infection and three cases of Charcot arthropathy. None of the 13 patients required an ankle arthrodesis or amputation at a mean follow up of nearly 4 years.

Jani et al.[19] utilized a transarticular pin in addition to standard ORIF for the management of unstable ankle fractures in a series of 16 fractures in 15 patients with diabetes. All of the patients in this series had loss of protective sensation and the major complication rate was 25%. Despite a vigilant and experienced surgical team, two of the fractures (12.5%) required below knee amputation to manage their deep infection. One of these occurred in an open fracture and one in a closed fracture.

Schon et al.[40] reported their series on the surgical management of ankle fractures as a part of a more comprehensive article regarding the treatment of neuropathic fractures. Nine displaced ankle fractures in patients with diabetes were managed with ORIF. Four of these nine patients (44%) experienced surgical complications including one infected nonunion, one wound complication requiring a free flap, one Charcot arthropathy requiring arthrodesis and one failure of fixation. None of the nine patients required an amputation.

Jones et al.[21] compared a cohort of 42 ankle fractures in patients with diabetes to a control group of 42 ankle fractures patients without diabetes. Nineteen control patients and 19 diabetic patients underwent surgical management, representing 45% of all patients with ankle fractures. Although 31% of diabetic patients developed a complication versus 17% in non diabetic patients, this difference was not found to be statistically significant. The authors did note that patients with diabetes were more likely to require continued bracing at 6 months. They further stratified their study group into uncomplicated (21 patients) and complicated (21 patients) diabetic patients. Those patients with uncomplicated diabetes did not have a higher complication rate than non-diabetic control group. Patients with complicated diabetes, however, experienced a significantly higher rate of complications than the control group of patients without diabetes (47% versus 14%). In arriving at their conclusions the authors did not separate out those patients who were treated surgically from those who were managed nonoperatively.[21]

The largest series of ankle fractures in patients with diabetes that we are aware of was reported by Costigan et al.[12] This study was a continuation of a previous study that was presented in 1997 and a part of the systematic review which was discussed previously.[10,11] They noted a modest overall complication rate of 14% (12 of 84 patients) compared to other studies. This may be explained in part by the fact that only 12 of 84 patients (14%) had peripheral neuropathy. It is noteworthy that 11 of these 12 neuropathic patients (91%) developed a complication and 10 of 12 patients (83%) with absent pedal pulses developed a complication. Two patients in this series ultimately required below knee amputation to control infection.

Ganesh et al.[17] analyzed data from the Nationwide Inpatient Sample regarding the hospitalizations of over 160,000 adult patients with ankle fractures. They noted that patients with diabetes mellitus experienced increased hospital mortality, rate of postoperative complications and length of stay compared to non-diabetic patients. Egol et al.[15] reported on the short term functional outcome of nearly 200 patients who underwent ankle fracture surgery. The authors found that 92% of non-diabetic patients recovered more than 90% of their preoperative function whereas only 71% of patients with diabetes recovered more than 90% of preoperative function.[15]

SooHoo et al.[45] reviewed the California discharge database and identified over 57,000 patients who had undergone ORIF of an ankle fracture. They defined short term complications as pulmonary embolism, below knee amputation, readmission for an infection or wound complication, or reoperation for hardware problems in the first 90 days after surgery. They noted that patients with uncomplicated diabetes (Odds Ratio 1.32) and complicated diabetes (Odds Ratio 2.30) had significantly higher short term complication rates compared to a control group of non-diabetic patients. They defined intermediate term complications as a reoperation for an ankle fusion or ankle replacement which occurred at least 6 months postoperatively. Complicated diabetes was also a significant predictor of reoperation for end stage arthritis (Hazard Ratio 3.36) while uncomplicated diabetes was not. The authors did not compare patients with uncomplicated diabetes to those patients with complicated diabetes.[45]

Our results are consistent with recent reports that patients with diabetes and ankle fractures have high complication rates after surgery, and these complications can result in loss of limb and reduced quality of life. A recent presentation at the Musculoskeletal Infection Society described infection after operative treatment of ankle fractures as a limb threatening complication, especially in patients with comorbidities such as diabetes mellitus.[53] In this series of 26 patients who developed postoperative infection, the authors reported that two of five patients (40%) with diabetes and a postoperative infection underwent below knee amputation.[53]

A review of previous case controlled studies from 1995 to 2009 has demonstrated two important findings pertinent to our results.[4,16,21,28,31,45] The first observation that we noted is that the initial controlled studies from 1995–2000 compared diabetic patients as one group (i.e., without discriminating between those with and without comorbidities) to patients without diabetes.[4,16,28,31] Secondly, while the more recent studies analyzed both complicated and uncomplicated diabetes independently, the control for both groups was patients without diabetes.[21,45] To the best of our knowledge, no study thus far has compared the complication rates of ankle fractures between uncomplicated and complicated diabetic patients. Our results demonstrate that patients with complicated diabetes have significantly higher complication rates when compared to patients with uncomplicated diabetes. We did not find any significant differences with regard to age, fasting serum glucose, BMI, Hgb A1C or fracture characteristics in those patients with complicated versus uncomplicated diabetes. As a result it appears that we have a reasonably matched group of patients in this study, with the major difference being the presence or absence of complicated diabetes. Initially, we were surprised that the use of external fixation was associated with a higher complication rate since we thought it would be somewhat protective in nature. Upon further review we recognized that external fixation tended to be used in those patients with open fractures and a less optimal soft tissue envelope. These patients are known to be at high risk for postoperative complications.[47] Additionally, external fixation is associated with an increased rate of pin tract infections in diabetic patients.[48] We recorded pin tract infections as a superficial infection in this study despite the fact that the infection was typically remote from the surgical site. The combination of ORIF and supplemental external fixation resulted in increased risk for both superficial and deep infections, while external fixation as definitive treatment alone resulted in increased superficial infections but not deep infections. Perhaps a prudent reappraisal of our use of internal fixation in the subgroup of patients with impaired soft tissues is indicated. It is not surprising that these patients had significantly higher rates of infection and need for revision surgery given their impaired soft tissues. The results of this study should not condemn the use of external fixation in diabetic patients with ankle fractures. A certain subset of these patients will have impaired soft tissues, and clearly external fixation plays a role in the management of this particular subgroup of ankle fractures. A protocol similar to the current methods of staged treatment for pilon fractures may be particularly applicable in diabetic patients with ankle fractures and a compromised soft tissue envelope.[22,34,44] In addition, some diabetic patients with ankle fractures may be unable to comply with prolonged nonweightbearing status due to poor cardiovascular reserve, neuropathy and balance issues, obesity or upper extremity weakness. Perhaps these particular patients may benefit from placement of a neutral circular ring fixator in addition to ORIF, in an effort to minimize potential problems from premature weightbearing. This strategy has been implemented with success in Charcot reconstruction.[35] We recognize that evaluation of the various methods of fixation used in this study involved relatively small groups of patients, and that meaningful conclusions regarding the ideal fixation method cannot be determined from this study.

Complicated diabetes was associated with a 3.8 times higher rate of overall complications, 3.4 times higher rate of aggregate non-infectious complications and five times higher rate for revision surgery which is consistent with other studies.[3,21] With the numbers available we were unable to establish significant differences between patients with complicated and uncomplicated diabetes with regard to the rate of amputations or infections. Given the observed rates of all infections and deep infections for those with uncomplicated and complicated diabetes we performed a post-hoc power analysis to determine the number of patients needed to achieve 80% to detect significant changes at the alpha $= 0.05$ level. This power analysis indicated that we would need approximately 170 patients per group (340 total) to detect a significant difference in the total infection rate (superficial and deep) between those with uncomplicated and complicated diabetes. For deep infections we would need 105 patients per group (210 total) to detect a significant difference. It is important to note that the presence of peripheral neuropathy was found to be associated with higher rates of deep infection.

Our amputation rate of 6% is consistent with other studies especially in view of the fact that 44% of our patients had complicated diabetes and 19% of the treated fractures were open injuries.[4,19,28,31] Open fractures of the ankle in diabetic patients are associated with a dismal prognosis as five of 13 patients (38%) in one study ultimately required a below knee amputation.[47] In this series of 14 open fractures in 13 patients, nine extremities had wound complications (64%). Only three of 14 open fractures healed without complications. The type of fracture (i.e., open or closed, unimalleolar, bimalleolar or trimalleolar) was not associated with an increased rate of non-union, malunion or the development of Charcot arthropathy.[47] Our diabetic patients with open ankle fractures had a threefold increased risk of overall postoperative complications and trended toward an increased risk for below knee amputation compared to those patients with closed fractures.

A valid criticism of this study is that the role of perioperative glucose control was not addressed. Our retrospective review of the medical records did not find a consistent pattern of management, and we could not determine if glucose levels were fasting or random. Consequently, we did not include the postoperative glucose levels in our analysis and that is a weakness of this study. It is clear from other studies that optimal glucose management is associated with better outcomes. Surgical site infections after spinal surgery have been associated with elevated glucose levels on the day of surgery and on the fifth postoperative day.[33] Preoperative levels greater than 125 mg/ml (random or fasting) and any postoperative glucose level (within 5 days of surgery) greater than 200 mg/ml increased the risk of a surgical site infection by nearly a factor of five.[33] Another recent study has demonstrated that patients with uncontrolled diabetes mellitus exhibited significantly increased odds of surgical and systemic complications, higher mortality, and increased length of stay during the index hospitalization following lower extremity total joint arthroplasty.[29] The importance of optimizing perioperative glucose management cannot be overemphasized since hyperglycemia is an independent predictor of morbidity and mortality in patients who are admitted for the treatment of acute medical and surgical emergencies.[27,30,52]

This study is limited by the relatively small number of patients, and in particular, the fact that only 35 patients experienced at least one complication of surgery. The wide range in our confidence intervals is indicative of these small numbers, and this study is underpowered when evaluating certain variables such as the relationship of postoperative infections, open fractures and below knee amputations. Approximately one-third of the patients who were treated at our institutions during the study period did not have the requisite minimum followup of 6 months, and thus were not included in this analysis. The most common reason for this was due to travel distance. Our institutions serve as tertiary referral and trauma centers, and many patients chose to have local followup after the initial postoperative period. Interpretation of our results must be viewed with the understanding that this study represented two-thirds of the patients treated during this time period, and no conclusions can be drawn on the remaining patients.

The most obvious weakness of our study is its retrospective design. Even well conducted retrospective studies are subject to large number of biases. The selection of a control group itself can introduce bias, and we attempted to minimize such bias by using all patients with uncomplicated diabetes as a control group rather than attempting to match them to our study group of complicated diabetic patients. Retrospective studies rely on the accuracy of the medical records, and the data obtained for analysis is only as good as the documentation in the medical record. For instance, we were unable to record the time of injury until the time of surgery for most patients. This study also did not address other medical complications such as thromboembolism or myocardial infarction.

Measurement bias may be present in this study since a standard protocol was not followed by the treating surgeons. The surgeons followed standard technique; however, the decision to use supplemental fixation (ORIF plus) and/or external fixation was at the discretion of the operating surgeon. Nonetheless, all of the surgeons felt that unstable ankle fractures in patients with diabetes required definitive surgical treatment based on standard principles. This study is subject to non-responder bias due to the fact that some patients were followed longer than others, and additional complications may have been detected with longer followup. Our minimum followup of 6 months may be considered less than ideal, however the vast majority of complications after ankle fracture surgery manifest during the first 6 months. Our primary outcome measure, the presence or absence of a postoperative complication, was assessed and treated by the operating surgeon. Therefore, interviewer bias is potentially present since the primary surgeon determined the primary outcome and recorded this in the medical record.

Many different risk factors potentially play a role in postoperative complications (i.e., age, gender, neuropathy and vascular disease) and we have attempted to address this through the proper statistical methods. Other limitations of this study are that we have not evaluated the effects of type I or II diabetes, duration of diabetes, insulin dependence, nutritional status or tobacco use as contributing factors for complications. It is well known that poorly controlled diabetic patients of longer duration are more likely to experience complications of diabetes (neuropathy, nephropathy and PAD).[5] However, it should be recognized that some patients with type II diabetes who are not “insulin” dependent are not well controlled. The lack of a non-diabetic control group is also a potential weakness of this study, although the retrospective controlled ankle fracture literature of the past 15 years clearly demonstrates that patients with diabetes mellitus are at higher risk for postoperative complications than patients without diabetes.[4,16,21,28,31]

At the present time there is conflicting evidence whether uncomplicated diabetes increases the complication rate compared to a group of patients without diabetes. Jones et al.[20] found that uncomplicated diabetic patients did not experience increased complication rates compared to non-diabetic patients while SooHoo et al.[45] reported that uncomplicated diabetic patients had a 1.3 fold increased risk of short-term complications compared to a non-diabetic control group. Finally, we have attempted to analyze many variables that are important in evaluating the outcomes of ankle fractures. Given the sample size, we recognize that further research is needed to confirm our findings.

CONCLUSION

Complicated diabetes is associated with an increased risk of complications after ankle fracture surgery compared to patients with uncomplicated diabetes. Careful preoperative evaluation of the neurovascular status is mandatory, since many patients with diabetes do not recognize that they have neuropathy and/or PAD. Our current practice is to treat patients with diabetic neuropathy and unstable ankle fractures as Stage 0 Charcot arthropathy, utilizing additional fixation and prolonged nonweightbearing of at least 3 months. Ideally, a prospective, randomized multicenter study comparing standard techniques of internal fixation with supplemental fixation should be done in patients without diabetes, uncomplicated diabetes and complicated diabetes to determine the optimal method of fixation in this challenging group of fractures.

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