AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY.

Foot & Ankle International
34(9) 1238–1244

DOI: 10.1177/1071100713484718
fai.sagepub.com

Risk Factors for Postoperative Wound Complications of Calcaneal Fractures Following Plate Fixation

Liang Ding, MD[1*], Zhimin He, MD[1*], Haijun Xiao, MD[1], Leizi Chai, MD[1], and Feng Xue, MD[1]

Abstract

Background: A fairly high prevalence of wound complications after open reduction and internal plate fixation (ORIF) of closed calcaneal fractures via the extensile lateral approach has been reported. The goal of this study was to analyze and identify independent risk factors for wound complications among closed calcaneal fractures undergoing ORIF.

Methods: The medical records of all closed calcaneal fracture patients who underwent ORIF from July 2005 to July 2012 were reviewed to identify those who developed a wound complication. Then we constructed a univariate and multivariate logistic regression to evaluate the independent associations of potential risk factors for surgical wound complication. Records showed 479 patients who underwent ORIF of a closed calcaneal fracture from July 2005 to July 2012. The patients were followed for 3 to 28 months, with an average follow-up period of 14.2 months. Eleven patients had bilateral fractures, for a total of 490 fractured calcanei.

Results: The overall rate of postoperative wound complications following ORIF of closed calcaneus fractures was 17.8% (87 wound complications in 490 operations). With the regression model, smoking history (odds ratio, 5.79; 95% CI: 1.55 to 21.70; $P = .009$), diabetes mellitus (odds ratio, 6.23; 95% CI: 1.37 to 28.31; $P = .018$), Sanders type (odds ratio, 5.44; 95% CI: 2.02 to 14.64; $P = .001$), number of residents and/or fellows present during the case (odds ratio, 1.63; 95% CI: 1.06 to 2.52; $P = .028$), duration of surgery (odds ratio, 4.54; 95% CI: 1.46 to 14.12; $P < .001$), estimated blood loss (odds ratio, 1.02; 95% CI: 1.01 to 1.04%; $P < .001$), and 10 or more people present in the operating room during the entire case (odds ratio, 2.30; 95% CI: 1.79 to 2.94; $P < .001$) were risk factors for wound complication. Tourniquet use (odds ratio, 0.02; 95% CI: 0.00 to 0.08; $P < .001$), which was associated with a decreased risk for the development of a wound complication, was observed as a protective factor. Diabetes mellitus, Sanders type, and smoking were the strongest risk factors for postoperative wound complication after adjusting for all other variables.

Conclusions: Smoking, diabetes mellitus, Sanders type, number of residents and/or fellows present during the case, duration of surgery, estimated blood loss, and high number of persons present in the operating room during the entire case were related to an increased risk for postoperative wound complication of closed calcaneal fractures following ORIF. Tourniquet use was associated with a decreased risk for the development of a wound complication.

Level of Evidence: Level III, retrospective comparative series.

Keywords: calcaneus, fracture, wound complication, ORIF, open reduction, internal fixation

Since the 1950s, the frequency of calcaneal fractures has been estimated to be around 2% of all fractures and the proportion of intra-articular calcaneal fractures with involvement of the posterior subtalar joint approximately 75%.[22,23] Intra-articular fractures carry a high morbidity; 40-85% of patients return to work within 9 months but approximately 20% are not able to return to work within a year.[6,16] Currently, open reduction and internal plate fixation (ORIF) is widely used in the surgical treatment of calcaneal fractures.[18] In general, surgical fixation has been offered to patients with displaced intra-articular fractures of the calcaneus that are at risk for posttraumatic arthritis if left untreated. ORIF has been proven to be an effective way in providing enough stability for bone union. Displaced

[1]Shanghai Fengxian Central Hospital, Shanghai, China

*These authors contributed equally to this study.

Corresponding Author:
Feng Xue, MD, Department of Orthopaedics, Shanghai Fengxian Central Hospital, Branch of the Sixth People's Hospital Affiliated to ShanghaiJiao Tong University, Shanghai 201400, China.
Email: xuefengky@yahoo.cn

calcaneus fractures treated nonoperatively often heal with malunion and a variety of associated problems.[5,6,7,10] However, short- and long-term complications and adverse outcomes are frequently documented.[10] Wound healing complication is the specific topic of this article.

The rate of wound complications after ORIF of closed calcaneal fractures via the extensile lateral approach has ranged from 0-27% in closed fractures.[5,24] Established patient-related risk factors associated with postoperative wound complications include diabetes, a higher body mass index (BMI), extended time (> 5 days) between injury and surgery, and smoking.[1,3,8] However, prior investigations were limited methodologically by small sample sizes, and lack of adjustment for confounders. Our goal was to conduct a retrospective study and multivariate analysis to assess previously identified risk factors as well as to report other risk factors for wound complications in patients with closed calcaneal fractures undergoing ORIF.

Methods

The records of all closed calcaneal fracture patients who underwent ORIF at our institution between July 2005 and July 2012 were reviewed retrospectively. Data were obtained from patients' charts and from a prospectively collected database compiled by the senior author. Records showed 479 patients who underwent ORIF of a closed calcaneal fracture. The patients were followed for 3 to 28 months, with an average follow-up period of 14.2 months. Eleven patients had bilateral fractures, for a total of 490 fractured calcanei. Patients were treated according to a standard protocol established by the senior author. All patients were admitted to the hospital for foot elevation. Once swelling had diminished so that skin wrinkles were visible, surgery was performed.

The age, sex, preexisting medical conditions, social history, mechanism of injury, and other injuries of each patient were recorded. The initial management of the calcaneus fracture was scrutinized. The time from injury to surgical stabilization was recorded, as well as the fracture type according to Sanders's classification, the type of incision used, use of bone graft, use of preoperative antibiotics, and type of wound closure. Investigators collected data also including patient demographics, operating room number, date of procedure, specific type of procedure, number of operating room personnel present, peri- and postoperative data with laboratory values, and symptoms due to surgical wound complications from the patients' medical records. Surgical treatments recorded also included surgical irrigation and debridement, hardware removal, and free myocutaneous flap wound coverage. Postoperative care was also noted, as was the time to wound healing. The patients' records were retrospectively reviewed for wound complications including surgical site infection (SSI), dehiscence or separation, hematoma, erythema, and marginal wound necrosis. According to the Centers for Disease Control and Prevention (CDC) criteria, SSIs are defined as infections occurring within 30 days after a surgical operation (or within 1 year if an implant is left in place after the procedure) and affecting either the incision or deep tissue at the operation site.[13] Any SSI category can be diagnosed on a clinical or laboratory basis (wound culture). These data underwent extensive logic checks by other coinvestigators to identify illogical or impossible data. All illogical data were repeatedly reviewed by comparing both the medical and electronic patient records.

Data Analysis

Biostatisticians at our institution completed statistical analysis of the collected data. Potential risk factors were evaluated for a univariate association with wound complications, with use of independent-samples *t* tests for continuous variables and chi-square or Fisher exact tests for categorical or discrete variables. Unadjusted odds ratios and 95% confidence intervals (CIs) were calculated and presented for discrete variables. A multivariate logistic regression was then used to evaluate the independent associations of each potential explanatory variable. All variables that had been previously identified in the literature, those with clinical and/or biologic plausibility, and those with a univariate *P* value of ≤ .10 were considered eligible for inclusion in the model. With use of a forward stepwise procedure, variables that achieved a *P* value of ≤ .10 remained in the final model, with significant variables defined as those that achieved a *P* value of ≤ .05. Adjusted odds ratios and their respective 95% CIs were reported in the final model.

Results

The overall rate of postoperative wound complications of close calcaneus fractures during the 7-year period of the study was 17.8% (87 wound complications in 490 operations). Analyzing the postoperative complications in 87 cases, we found wound edge necrosis in 13.8% (12 cases), hematoma in 10.3% (9 cases), dehiscence or separation in 12.7% (11 cases), erythema in 21.8% (19 cases), SSI in 41.4% (25 cases of soft tissue infection, and 11 cases of bone infection). Most of the complications, such as wound edge necrosis, hematoma, dehiscence or separation, erythema, and soft tissue infection, occurred within the first month after the surgery. All cases of bone infection occurred later in the postoperation course (2 to 6 months after operation). Twenty-eight cases were treated conservatively with local wound care and systemic antibiotic therapy. Fifty-nine cases developed a wound complication that required surgical treatment: 36 required a surgical wound debridement, 15 required hardware removal, and 8 eventually required free myocutaneous flap coverage of the wound. No patient went on to amputation.

Table 1. Distribution of Patient-Related Risk Factors for Patients With a Wound Complication and Controls.

	Wound Complication (N = 87)	No Wound Complication (N = 403)	Odds Ratio (95% Confidence Interval)	*P* Value
Patient characteristics[a]				
Age	48.0 ± 16.3	44.4 ± 13.8	—	.012[b]
Female[c]	30	168	0.74 (0.45–1.20)	.214
Obesity[c]	28	46	3.68 (2.14–6.35)	< .001[b]
Smoking history[c]	46	143	2.25 (1.41–3.59)	< .001[b]
Medical history[c]				
Diabetes mellitus	27	27	6.22 (3.48–11.11)	< .001[b]
Hypertension	20	87	1.08 (0.62–1.89)	.774
Hypercholesterolemia	11	49	1.05 (0.52–2.10)	.900
Osteoporosis	9	55	1.15 (0.55–2.42)	.713
Causes of injuries[c]				.657
Assault	2	13	(Reference)	
Pedestrian falls	10	45	1.44 (0.28–7.44)	
Sports accidents	11	34	2.10 (0.41–10.80)	
Motor vehicle accidents	25	104	1.56 (0.33–7.37)	
Fall from height	39	207	1.23 (0.27–5.64)	
Sanders types[c]				< .001[b]
Sanders II	21	171	(Reference)	
Sanders III	44	202	1.77 (1.02–3.10)	
Sanders IV	22	32	5.60 (2.76–11.35)	

[a]Obesity was defined as a body mass index of ≥ 30 kg/m^2. The values for age are given as the mean and the standard deviation.
[b]Significant at α = .05.
[c]The values are given as the number of patients or controls.

Overall, the average time elapsed from injury to surgery was 8 days (range, 0 to 21 days). Each surgery was performed by the senior author. Patients at our institution were treated according to published CDC/NNIS guidelines for preventing SSIs. With the dose based on the patient's weight, 1 to 2 g of cefazolin, a first-generation cephalosporin, was administered to all patients within 1 hour prior to the skin incision. During the first 24 hours following wound closure, surgical patients were treated with a prophylactic antibiotic regimen per this protocol.

A standard L-shaped lateral approach to the calcaneus was used in each case. A full-thickness soft tissue flap was created. Great care was taken in each case to protect the flap with a "no-touch" technique. The flap was retracted by means of Kirschner wires placed in the fibula, talus, and cuboid. The wounds were kept moist with regular irrigation. Subperiosteal dissection was performed to expose the lateral aspect of the calcaneus. Stabilization was achieved by using standard techniques, with low profile plates and screws, as described by Benirschke and Sangeorzan.[5] In all cases, a 2-layer wound closure was used. Bone graft was used in 133 cases: autogenous bone graft in 86 cases and hydroxyapatite bone graft substitute in 47 cases.

Foot elevation with the foot in a posterior splint was used in all patients. The splint was removed for a wound check on the second postoperative day. If the wound was dry, active range of motion was allowed at the ankle and subtalar joints. All patients had begun active range of motion by at least postoperative day 10. They were encouraged to move their ankles during the day. They were told not to bear any weight on the injured foot for 3 months.

Patient-Related Factors

The patient-related factors that were investigated are shown in Table 1. According to the univariate analysis, advanced age was associated with postoperative wound complications, and within the groups the mean age was 48.0 years for the patients with a wound complication and 44.4 years for the control group (P = .012).

According to the univariate analysis, obesity (defined as a BMI of ≥ 30kg/m2), smoking history, diabetes mellitus (either type 1 or type 2), and Sanders type were also associated with a surgical wound complication (P < .05).

Procedure-Related Factors

The result of univariate analysis of procedure-related risk factors is displayed in Table 2. Factors analyzed included the number of surgeons, number of scrub technicians, number of nurses, number of residents and/or fellows present during the case, total number of persons present in the operating room during the entire case, duration of surgery, number of drains used in the procedures, estimated blood loss,

Table 2. Distribution of Procedure-Related Risk Factors for Patients With a Wound Complication and Controls.

	Wound Complication (N = 87)	No Wound Complication (N = 403)	Odds Ratio (95% Confidence Interval)	*P* Value
Operative characteristics[a]				
Number of surgeons	1.41 ± 0.45	1.38 ± 0.53	—	.623
Number of scrub technicians	3.01 ± 1.26	2.79 ± 1.40	—	.177
Number of nurses	1.95 ± 0.57	1.92 ± 0.75	—	.250
Number of residents and/or fellows	1.49 ± 0.91	1.16 ± 0.74	—	< .001[b]
Number of drains	1.18 ± 0.39	1.23 ± 0.42	—	
Postanesthesia care unit time (hr)	1.17 ± 0.63	1.20 ± 0.57	—	.309
Duration of surgery (min)[c]	150.80 ± 25.46	132.67 ± 30.19	—	.663
≥180	33	34	6.63 (3.80–11.58)	< .001[b]
Duration of antibiotics (hr)	47.60 ± 19.83	50.35 ± 22.12	—	.285
From injury to surgery (days)	7.86 ± 3.81	8.19 ± 4.17	—	.497
Hospital stay (days)	14.34 ± 6.93	12.26 ± 4.85	—	< .001[b]
Estimated blood loss (mL)	200.40 ± 47.56	166.23 ± 33.81	—	.017[b]
Bone graft[c]	34	99	1.97 (1.21–3.20)	.006[b]
Tourniquet use[c]	30	220	0.44 (0.27–0.71)	.001[b]
Personnel in operating room				
Total persons[a]	9.56 ± 1.29	7.31 ± 1.16	—	< .001[b]
Number per procedure[c]				
1 to 5 persons	7	77	(Reference)	
6 to 9 persons	67	314	2.35 (1.04–5.32)	
≥10 persons	13	12	11.92 (4.00–35.87)	

[a]The values are given as the mean and the standard deviation.
[b]Significant at $\alpha = .05$.
[c]The values are given as the number of patients or controls.

time from injury to surgery, hospital stay, estimated blood loss, bone graft, and tourniquet use.

A greater number of persons present in the operating room during the entire case was identified as a risk factor for wound complication ($P < .001$), and specifically the number of residents and/or fellows present during the case was significantly higher in the wound complication group than the control group ($P < .001$). A longer duration of surgery was associated with wound complication ($P < .001$). Strongly associated procedure-related factors in the univariate analysis also included the hospital stay ($P < .001$), the use of bone graft ($P = .006$), and tourniquet use ($P = .001$).

Perioperative Laboratory Data

Perioperative laboratory values were collected during the study to determine association with wound complications and are presented in Table 3. Serum glucose, hemoglobin, hematocrit, and lymphocyte counts were collected both preoperatively and postoperatively. Postoperative serum glucose levels were higher in the wound complication group ($P = .004$).

Multivariate Analysis

Table 4 shows the results of a multivariate logistic regression analysis used to assess the association of risk factors when adjusting for all other potential risk factors. In the final model, smoking history ($P = .009$), diabetes mellitus ($P = .018$), Sanders type ($P = .001$), number of residents and/or fellows present during the case ($P = .028$), duration of surgery ($P < .001$), estimated blood loss ($P < .001$), tourniquet use ($P < .001$), duration of surgery ($P < .001$), and 10 or more people present in the operating room during the entire case ($P < .001$), were independent risk factors for the onset of wound complication.

A smoking history (odds ratio, 5.79; 95% CI: 1.55 to 21.70), Sanders type (odds ratio, 5.44; 95% CI: 2.02 to 14.64), and diabetes mellitus (odds ratio, 6.23; 95% CI: 1.37 to 28.31) were the strongest risk factors for postoperative wound complication after adjusting for all other variables. Likewise, duration of surgery (odds ratio, 4.54; 95% CI: 1.46 to 14.12), 10 or more people present in the operating room during the entire case (odds ratio, 2.30; 95% CI: 1.79 to 2.94), number of residents and/or fellows present during the case (odds ratio, 1.63; 95% CI: 1.06 to 2.52), and estimated blood loss (odds ratio, 1.02; 95% CI: 1.01 to 1.04) were also important risk factors for the development of a postoperative wound complication.

Tourniquet use (odds ratio, 0.02; 95% CI: 0.00 to 0.08) was an important protective factors for the development of a postoperative wound complication. Hospital stay was

Table 3. Distribution of Perioperative Laboratory Values for Patients with a Wound Complication and Controls.

Perioperative Laboratory Characteristics	Wound Complication (N = 87)	No Wound Complication (N = 403)	Odds Ratio (95% Confidence Interval)	*P* Value
Albumin (preop) (g/dL)[a]	3.75 ± 0.31	3.90 ± 0.43	—	.002[b]
Glucose level (mg/dL)[a]				
Preop	108.07 ± 13.98	98.18 ± 10.50	—	< .001[b]
Postop	121.94 ± 20.11	116.5 ± 17.55	—	.004[b]
Glucose level of > 125[c]				
Preop	17	13	7.29 (3.39–15.67)	< .001[b]
Postop	39	102	2.40 (1.49–3.87)	< .001[b]
Hemoglobin[a]				
Preop	11.40 ± 1.43	12.56 ± 1.28	—	.102
Postop	10.71 ± 4.36	11.10 ± 5.01	—	.501
Hematocrit[a]				
Preop	35.02 ± 10.39	36.35 ± 9.19	—	.233
Postop	30.38 ± 5.45	30.87 ± 5.70	—	.464
Lymphocyte[a]				
Preop	1.73 ± 1.01	1.81 ± 1.19	—	.560
Postop	1.53 ± 0.97	1.60 ± 1.09	—	.580

[a]The values are given as the mean and the standard deviation.
[b]Significant at $\alpha = .05$.
[c]The values are given as the number of patients or controls.

Table 4. Multivariate Logistic Regression Analysis of Risk Factors for a Postoperative Wound Complications.

	Adjusted Odds Ratio (95% Confidence Interval)	*P* Value
Smoking history	5.79 (1.55–21.70)	.009[a]
Diabetes mellitus	6.23 (1.37–28.31)	.018[a]
Sanders type	5.44 (2.02–14.64)	.001[a]
Total of >10 persons in the operating room	2.30 (1.79–2.94)	< .001[a]
Number of residents and/or fellows	1.63 (1.06–2.52)	.028[a]
Duration of surgery	4.54 (1.46–14.12)	< .001[a]
Hospital stay	1.06 (0.99–1.13)	.084
Estimated blood loss	1.02 (1.01–1.04)	< .001[a]
Tourniquet use	0.02 (0.00–0.08)	< .001[a]

[a]Significant at $\alpha = .05$.

significant in the univariate analysis, but did not meet significance in the final logistic regression model.

Discussion

ORIF has been proven to be an effective treatment method to improve outcomes and lower morbidity. But the reported rate of wound complications can be quite high.[1,4,5,12,24] Wound complications that require surgical debridement, hardware removal, or myocutaneous flap coverage to eradicate infection can have a profound negative impact on the patient's outcome. Many articles have examined wound complications that can occur after ORIF of calcaneus fractures. Reports show a superficial skin infection or wound dehiscence rate of about 10-20%.[1,4,12] Stephenson reported a 27% rate of marginal wound necrosis in an article describing a combined medial and lateral approach to the calcaneus.[24] The largest prospective, randomized multicenter study of Buckley et al in 2002 showed a superficial infection and wound complication rate of 17% and a deep infection rate of 5% for ORIF.[7] Compared to historical reports, the complication rate in our study was 17.8%.

Patient-Related Risk Factors

In previous reports, diabetes, a higher BMI, extended time between injury and surgery, and smoking all increased the risk of a significant wound complication.[3,8] The focus of our study was to further define significant patient-related and procedure-related risk factors that contributed to a higher rate of wound complication postoperatively and that may be unique to ORIF following closed calcaneal fractures.

We identified associations between risk factors, including diabetes, smoking, Sanders type, and postoperative wound complication. Diabetes was a significant independent risk factor identified by our multivariate analysis, a finding consistent with other multivariate analyses performed on calcaneus fracture surgery patients.[8] It has been demonstrated that diabetes can impede wound healing and predispose patients to infection through ischemia secondary to microvascular abnormality.

Smoking has consistently been reported as a risk factor for postoperative delayed wound healing.[8,9,14] Nicotine is a vasoconstrictor that reduces nutritional blood flow to the skin, resulting in tissue ischemia and impaired wound healing. Nicotine also increases platelet adhesiveness, raising the risk of thrombotic microvascular occlusion and tissue ischemia. In addition, carbon monoxide diminishes oxygen transport and metabolism, whereas hydrogen cyanide inhibits the enzyme systems necessary for oxidative metabolism and oxygen transport at the cellular level.[2]

The fracture type as measured by Sanders classification was identified as a risk factor for wound complication in our study. Sander's analysis of soft tissue and late complications and its relevance to type II to IV fractures found that the rate of complications and patient dissatisfaction grew with fracture severity.[19,20] Serious fractures can be inferred to contribute to increased operative time and estimated blood loss and have a greater soft tissue injury and therefore associated increased wound complication risk.

Procedure-Related Risk Factors

Intraoperative risk factors associated with postoperative wound complication through univariate and multivariate logistic regression analysis include the duration of the surgical procedure, high number of people present in the operating room during the entire case, estimated blood loss, tourniquet use, and number of residents and/or fellows present during the case. Consistent with previous studies, duration of the surgical procedure and estimated blood loss remained significantly associated with postoperative wound complication in the multivariate analysis.[11,17]

As in previous studies, a high number of people in the operating room present during the entire case was associated with an increased risk of wound infection. This may be an indirect marker for complex cases in medically fragile patients rather than a direct increased opportunity for contamination. We also identified number of residents and/or fellows as an increased risk of wound complication. In a teaching hospital environment, inexperience of residents and fellows may increase the incidence of contamination and prolonged operative time. Meticulous identification of the anatomy and preservation of the full-thickness soft tissue flap is essential in calcaneal fracture surgery, and surgical experience is critical for the surgeon to recognize and protect these structures. Technical complications, such as wound edge necrosis, hematoma, and wound infection occur as a consequence of several factors, including surgical inexperience. Less experience of residents and fellows may also increase the risk for technical complications.

Tourniquet use (odds ratio, 0.02; 95% CI: 0.00 to 0.08; $P < .001$) was an important protective factor for the development of a wound complication. Pneumatic tourniquets maintain a relatively bloodless field during extremity surgery, minimize blood loss, aid identification of vital structures, and expedite the procedure. Although using a tourniquet may decrease operating time and total blood loss, it is potentially associated with injury to underlying muscles, vessels, and nerves if excessive time or pressure occurs.[21] Bone graft and hospital stay were significant in the univariate analysis, but did not meet significance in the final logistic regression model in our study.

Our study is subject to some limitations. We made the assumption that a patient who was not diagnosed with an infection within 30 days and did not return specifically for treatment of an infection within the next 12 months did not have an infection. Therefore we may have missed a few patients who were diagnosed with infection between 1 and 12 months elsewhere. The patients were encouraged to move their ankles during the postoperative period in our study. There are many potential advantages of an early motion program, including decreasing soft tissue edema, decreasing disuse effects, and retarding capsular contractures.[15] However, we have no data to support this conclusion. In addition, the study did not include an analysis of the skill of an occasional senior operator as a risk factor for wound complication, but unsatisfactory surgical skills can be inferred to contribute to increased operative time and technical complications. We feel that the operations should be performed by specially trained surgeons with a higher volume.

In conclusion, this analysis identified smoking, diabetes mellitus, Sanders type, number of residents and/or fellows during the case, duration of surgery, estimated blood loss, and high number of persons present in the operating room during the entire case as potential independent risk factors for postoperative wound complication of ORIF following closed calcaneal fractures. Patients who have the risk factors identified in this study should be counseled as to the possible complications that may arise after ORIF. Tourniquet use, which was associated with a decreased risk for the development of a wound complication, was observed as a protective factor in this study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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