Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jor

Original Article

Risk factors of deep infection in operatively treated pilon fractures (AO/OTA: 43)

Cesar S. Molina*, Daniel J. Stinner, Andrew R. Fras, Jason M. Evans

Vanderbilt Department of Orthopaedic Surgery and Rehabilitation, Orthopaedic Trauma Institute, Nashville, TN 37232, United States

ARTICLE INFO

Article history:

Received 6 December 2014

Accepted 27 January 2015

Available online 21 February 2015

Keywords:

Pilon fracture

Deep infection

Orthopedic trauma

ABSTRACT

Background/Aims: The purpose of this study is to evaluate risk factors of deep infection following pilon fractures.

Methods: This investigation was performed after gathering a six-year retrospective database from a single academic trauma center.

Results: These include an overall incidence of deep infection of 16.1% (57/355). Deep infection was diagnosed at an average of 88 days (± 64 days) from initial injury with a range of 10–281 days. Development of deep infection occurred in 23.2% (33/142) of open fractures, vs 11.3% (24/213) of closed fractures.

Conclusion: Open fractures, hypertension and male gender were associated with an increased risk of developing deep infection. In addition, even optimal surgical management may not significantly modify rates of deep surgical site infection.

Copyright © 2015, Professor P K Surendran Memorial Education Foundation. Publishing Services by Reed Elsevier India Pvt. Ltd. All rights reserved.

1. Introduction

Pilon fractures encompass a spectrum of combined osseous and soft tissue injuries that present unique challenges to orthopaedic trauma surgeons. The result of an axial load to the foot, these articular fractures of the distal tibia occur following high energy mechanisms, such as motor vehicle collisions and falls from height.^{1–3} The thin soft tissue envelope surrounding the ankle is susceptible to disruption with violent injury, and resultant open fracture wounds commonly require secondary coverage procedures.^{4,5} Even when not associated with open wounds, the closed soft tissue injury is often severe enough to

alter surgical treatment in a variety of ways.⁶ The combination of these soft tissue injuries, and the frequently seen osteo-articular comminution make surgical treatment complex, with long term morbidity remaining high.

Early reports of high complication rates associated with immediate open reduction and internal fixation^{7,8} have led to modern management utilizing a staged approach allowing surgical timing to be dictated by the associated soft tissue injury.^{7–10} Even when treated according to modern standard of care, complications of infection and wound dehiscence occur and can result in considerable morbidity for patients.^{11,12} Although several studies have reported deep

* Corresponding author. 1215 21st Avenue South, Medical Center East, South Tower, Suite 4200, Nashville, TN 37232, United States. Tel.: +1 615 875 5591.

E-mail address: cesar.molina@vanderbilt.edu (C.S. Molina).

<http://dx.doi.org/10.1016/j.jor.2015.01.026>

0972-978X/ Copyright © 2015, Professor P K Surendran Memorial Education Foundation. Publishing Services by Reed Elsevier India Pvt. Ltd. All rights reserved.

infection rates, the general applicability is limited due to small sample size, and, no single study has evaluated for potential identifiable risk factors specific to the development of deep infection.

Several literature reports have identified smoking, diabetes, duration of surgery, and/or open injuries to be risk factors for infection in operatively treated rotational ankle fractures.^{13–16} The purpose of this study is to determine which patient-specific or injury-specific characteristics are predictive of development of deep infection in the setting of pilon fractures. We hypothesize that AO/OTA 43C3, open injuries, presence of diabetes and an active smoking status are all risk factors of deep infection following open reduction and internal fixation of pilon fractures.

2. Materials and methods

Institutional review board approval was obtained for this study. All patients fifteen years or older treated definitively with ORIF of pilon fractures at our institution between January 1, 2006 and December 31, 2011 were identified from an institutional billing database. A search of Current Procedural Terminology (CPT) codes for pilon fractures (27827, 27826 and 27828) using the above criteria. Radiographic confirmation of all injuries was performed by the study team using the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification of tibial pilon fractures (43A, 43B, 43C).

Patient variables, including Age, sex, race, body mass index (BMI), past medical history (hypertension, diabetes mellitus, substance abuse, psychiatric disorder), smoking status, and injury variables, including AO/OTA classification, open vs. closed, Gustilo and Anderson classification. Additionally the use of staged treatment and days from injury to definitive fixation were recorded for each injury.

The primary outcome measure was the diagnosis of deep surgical site infection. Classification of deep surgical site infection was performed utilizing the criteria defined by the Center for Disease and Control National Healthcare Surveillance Network.¹⁷ Effectively, all deep infections underwent surgical debridement. For this subset days from injury to diagnosis of infection and culture results were recorded. Additionally, open and closed injuries were separately analyzed with regard to each variable.

Statistical analysis was performed using deep infection as the dependent variable. Pearson chi-square analysis and Fisher exact test were used for dichotomous variables to identify association of deep infection with potential risk factors. Wilcoxon Rank–Sum test was used for continuous variables with abnormal distribution. Two variables, BMI and days to definitive fixation in patients treated with external fixation, were analyzed as continuous and dichotomous variables (BMI ≤ 30 vs. >30 ; Days to definitive fixation ≤ 14 days vs. >14 days). Bivariate logistic regression analysis was performed on all statistically significant associations identified ($p < 0.05$). Furthermore, bivariate analysis and a multivariate regression model were performed. Spearman correlation was used to identify

association between time to definitive fixation and time to diagnosis of deep infection.

3. Results

A total of 408 pilon fractures were identified in 400 patients. Of those, 355 had more than 6 months follow-up, or had healed at last follow-up, and were included in the final analysis of this study. Thirty-six fractures were excluded after being identified as either tibia shaft fracture or rotational ankle fracture pattern. The average follow up time was 12.8 months. Other patient and injury characteristics of this study population are seen in Table 1.

The overall incidence of deep infection in the study population was 16.1% (57/355). Deep infection was diagnosed at an average of 88 days (± 64 days) from initial injury with a range of 10–281 days. Table 2 shows overall deep infection rates per patient history and injury characteristics. There were no cases of bilaterally infected pilons. Cultures and antibiotic sensitivities were obtained for all fifty-seven patients. The most common pathogens identified were Methicillin-Sensitive *Staphylococcus Aureus* (33% (19/57)), *Enterobacter* spp. (24.5% (14/57)) and Methicillin-Resistant *S. Aureus* (14.0% (8/57)). Polymicrobial infections were seen in 26.3% (15/57) of patients. No identifiable pathogen was isolated in 3.5% (2/57) of patients. Table 3 shows the results of the bivariate analysis for deep infection vs. patient demographics and injury characteristics. Patient and injury characteristics were then entered into a multivariate analysis model seen in Table 4.

Additional results show a statistically significant concomitant comminution in open fractures. The majority of open fractures, 91.6% (130/142), demonstrated some degree of comminution (AO/OTA: 43A3, 43B3, 43C2 and 43C3) compared to closed fractures, 78.9% (168/213), $p = 0.001$. A deep infection rate of 17.8% (53/298) was seen in comminuted fractures compared to 7.0% of non-comminuted fractures, $p = .067$.

The majority of fractures in the study group, 73.5% (261/355), were AO/OTA: 43C. Thirty nine fractures were classified as 43A and the remaining injuries were classified as 43B ($n = 55$). There was no statistically significant difference in deep infection rates between non-comminuted fractures vs. comminuted fractures (43A3, 43B3, 43C2 and 43C3, $p = 0.067$) regardless of skin status. Deep infection rates in closed comminuted vs. open comminuted fractures were compared and showed a deep infection rate of 14.3% (24/144) and 22.3% (101/130) respectively, $p = .073$.

External fixation was performed in 64.2% (228/355) of fractures. The average time to definitive fixation for this study subgroup ($n = 228$) was 20.7 days (± 12 days). The deep infection rate was 24.7% in those receiving definitive fixation within the first 14 days vs. 13.4% (11/82) in those definitively fixed after 14 days. This difference is statistically significant, ($p = .04$). This difference was not seen when calculating deep infection at different time points (<4 days vs. >4 days, <7 days vs. >7 days, <10 days vs. >10 days).

Development of deep infection occurred in 23.2% (33/142) of open fractures, vs 11.3% of closed fractures, $p = .01$. Open fractures were classified according to the Gustilo-Anderson classification.¹⁸ Deep infection was diagnosed in 8% (2/25) of

Table 1 – Differences in patient demographic and clinical characteristics by deep infection.

Characteristics	Total (N = 355)	No infection (N = 298)	Deep infection (N = 57)	P value
Age	42.3 ± 14.2	42.0 ± 14.2	44.4 ± 14.2	.27
Race				.28
Non-white	36 (10.1)	33 (11.1)	3 (5.3)	
White	319 (89.9)	265 (88.9)	54 (94.7)	
Sex				.01*
Female	162 (45.6)	145 (48.6)	17 (29.8)	
Male	193 (54.4)	153 (51.4)	40 (71.2)	
Hypertension				.01*
No	279 (78.6)	242 (81.2)	37 (64.9)	
Yes	76 (21.4)	56 (18.8)	20 (35.1)	
Diabetes mellitus				.07
No	317 (89.3)	270 (90.6)	47 (82.5)	
Yes	38 (10.7)	28 (9.4)	10 (17.5)	
Active smoker				.08
No	206 (58.0)	179 (60.1)	27 (47.4)	
Yes	149 (42.0)	119 (39.9)	30 (52.6)	
Open				.01*
No	213 (60.0)	189 (63.4)	24 (42.1)	
Yes	142 (40.0)	109 (36.6)	33 (57.9)	
AO/OTA classification				.13
Non-43C3	177 (49.9)	154 (51.7)	23 (40.4)	
43C3	178 (50.1)	144 (48.3)	34 (59.6)	

Age is presented as Mean (SD). All other variables are presented as N(%). * $p < .05$.

type 1 fractures, 21.9% (14/64) of type 2 and 32% (17/53) of type 3 fractures. This difference was not statistically significant ($p = .06$). Other characteristics of this study population are seen in Table 5. Eighteen of sixty-six (27%) smokers with open

fractures developed and infection. Fourteen of thirty-seven (37.8%) hypertensive patients with open fractures developed infection.

Hypertension remained a risk factor for deep infection (OR: 2.76; 95% CI = 1.20–6.32) among patients with open pilon fractures. No other variables were found to be significantly associated with deep infection in this group. Higher infection rates were seen in active smokers (20.1% vs. 13.1%, $p = .08$) as well as diabetics (26.3% vs. 14.8%, $p = .07$), but did not reach statistical significance.

A 30.5% (21/69) infection rate was found among patients with open fractures who underwent definitive fixation after 14 days from initial injury. The infection rate for open fractures definitively fixed before this time frame was 16.4% (12/73), $p = .048$. Bivariate logistic regression analysis shows that patients with open fractures are 2.3 times more likely to develop deep infection if treated after 14 days, this result trended towards significance (95%CI: 0.99, 4.97. $p = .051$).

Table 2 – Overall deep infection rates per patient demographic and clinical characteristics.

Characteristics	Deep infection rate
Sex	
Female	17/355 (4.8)
Male	40/355 (11.3)
Hypertension	20/355 (5.6)
Diabetes mellitus	10/355 (2.8)
Active smoker	30/355 (8.5)
Open fractures	33/355 (9.3)
AO/OTA: 43C3	34/355 (9.5)

Table 3 – Results of bivariate regression analyses for deep infection vs. patient demographics and clinical characteristics.

Characteristics	OR	95% CI	p
Age	.97	(0.92, 1.02)	.24
Race	2.24	(0.66, 7.57)	.19
Sex	2.23	(1.21, 4.11)	.01*
Hypertension	2.34	(1.26, 4.33)	.01*
Diabetes	2.05	(0.93, 4.50)	.07
Active smoker	1.67	(0.95, 2.95)	.08
Open	2.38	(1.34, 4.24)	.01*
AO/OTA 43C3	1.58	(0.89, 2.81)	.12

Note. CI = Confidence interval for odds ratio (OR); * $p < .05$.

Table 4 – Results of multivariate regression analyses for deep infection vs. patient demographics and clinical characteristics.

Characteristics	OR	95% CI	p
Age	1.00	(0.98, 1.03)	.74
Race	1.09	(0.45, 2.63)	.19
Sex	2.19	(1.16, 4.15)	.02*
Hypertension	2.29	(1.09, 4.82)	.03*
Diabetes	1.36	(0.55, 3.30)	.67
Active smoker	1.75	(0.94, 3.26)	.08
Open	1.92	(1.05, 3.51)	.04*
AO/OTA 43C3	2.50	(0.83, 7.50)	.10

Note. CI = Confidence interval for odds ratio (OR); * $p < .05$. Model explained variance (R^2) was 9.1%.

Table 5 – Differences in patient demographic and clinical characteristics by deep infection in open injuries.

Characteristics	Total (N = 142)	No infection (N = 109)	Deep infection (N = 33)	P value
Age	42.8 ± 14.2	41.7 ± 14.0	46.5 ± 13.2	.09
Race				.16
Non-white	19 (13.4)	17 (15.6)	2 (6.1)	
White	123 (89.9)	92 (84.4)	31 (93.9)	
Sex				.06
Female	59 (41.5)	50 (84.7)	9 (27.2)	
Male	83 (58.5)	59 (15.3)	24 (72.8)	
Hypertension				.01*
No	105 (73.9)	86 (78.9)	19 (57.6)	
Yes	37 (26.1)	23 (21.1)	14 (42.4)	
Diabetes mellitus				.24
No	121 (85.2)	95 (87.1)	26 (78.8)	
Yes	21 (14.8)	14 (12.9)	7 (21.2)	
Active smoker				.29
No	76 (53.5)	61 (56.0)	15 (45.5)	
Yes	66 (46.5)	48 (44.0)	18 (54.5)	
AO/OTA classification				.80
Non-43C3	63 (44.4)	49 (45.0)	14 (42.4)	
43C3	79 (55.6)	60 (55.0)	19 (57.6)	
Days to definitive fixation	16.3 ± 14.6	14.9 ± 13.7	20.8 ± 16.6	.07

Age is presented as Mean (SD). All other variables are presented as N(%). *p < .05.

The incidence of deep infection in a closed pilon fracture was 11.2% (24/213). Comminuted fractures (AO/OTA: 43A3, 43B3, 43C2 and 43C3) compose 78.9% (168/213) of this subset. The rate of deep infection in closed comminuted fractures was 14.3% (24/168) versus a 0% (0/45) rate of deep infection in non-comminuted closed injuries ($p = .007$). Other characteristics of this study population are seen in [Table 6](#).

BMI was calculated for 316 patients with a mean value of 28.0 ± 6.4 kg/m², ranging from 15.4 to 51.6 kg/m² (39 non-infected pilon patients did not have a recorded height and/or weight in their chart for BMI calculation). Deep infection was diagnosed in 10.9% (11/102) of obese patients (BMI > 30 kg/m²) vs. 21.5% (46/214) of non-obese patients ($p = .02$). Logistic

regression analysis showed that obese patients were less likely to develop deep infection when compared to the non-obese after controlling for all other variables, OR = 0.35, 95% CI 0.17–0.77.

The rate of deep infection in patients undergoing staging with the use of external fixation was 20.6% (47/228). Patients undergoing primary ORIF or staged treatment with a splint, 7.9% (10/127) $p = .002$. The average number of days to definitive fixation in the former group was 20.7 days versus 4.1 days in the latter.

The average number of days to diagnosis of deep infection in the 57 patients was 88.0 ± 64.5 . The majority of patients, 89.5% (51/57), were diagnosed with deep infection after

Table 6 – Differences in patient demographic and clinical characteristics by deep infection in closed injuries.

Characteristics	Total (N = 213)	No infection (N = 189)	Deep infection (N = 24)	P value
Age	42.0 ± 15.2	42 ± 14.4	41.3 ± 15.2	.78
Race				.74
Non-white	17 (7.9)	16 (8.5)	1 (4.2)	
White	196 (92.1)	173 (91.5)	23 (95.8)	
Sex				.12
Female	103 (48.4)	95 (50.2)	8 (33.3)	
Male	110 (51.6)	94 (48.8)	16 (66.7)	
Hypertension				.34
No	174 (81.7)	156 (82.5)	18 (75.0)	
Yes	39 (18.3)	33 (17.5)	6 (25.0)	
Diabetes mellitus				.64
No	196 (92.0)	175 (92.6)	21 (87.5)	
Yes	17 (8.0)	14 (7.4)	3 (12.5)	
Active smoker				.24
No	130 (61.0)	118 (62.4)	12 (50.0)	
Yes	83 (39.0)	71 (37.6)	12 (50.0)	
AO/OTA classification				.10
Non-43C3	114 (53.5)	105 (55.6)	9 (37.5)	
43C3	99 (46.5)	84 (44.4)	15 (62.5)	
Days to definitive fixation	13.7 ± 12.5	12.9 ± 12.0	20.1 ± 15.6	.02*

Age is presented as Mean (SD). All other variables are presented as N(%). *p < .05.

definitive fixation with average days to infection of 95.7 ± 63.6 post injury.

In addition to these factors, the average number of days from injury to open reduction and internal fixation (ORIF) was shown to be significantly different between the groups. Patients diagnosed with deep infection had an average number of 20.9 ± 15.5 days to ORIF versus an average of 13.6 ± 12.7 days in the non-infected group ($p = .01$).

A sub-analysis was performed to determine if a higher period of time in external fixation was associated with an increased risk of developing deep infection in patients diagnosed with deep infection after definitive treatment. The results were indifferent with an OR of 1.009 (95% CI = .98, 1.04), ($p = .51$). The number of days to ORIF in the external fixation group diagnosed with deep infection after ORIF is not a risk factor for the diagnosis of deep infection.

4. Discussion

The purpose of this study was to determine which commonly encountered patient and injury characteristics could be identified as independent risk factors for development of deep infection. Multivariate logistic regression analysis of our retrospective series identifies male gender, hypertension, and open fractures are independent risk factors for deep infection in operatively treated pilon fractures.

Our series overall incidence of deep infection is 16.1%, which is higher than most previous reports utilizing modern treatment protocols including the use of staging and respect for the soft tissue injury. Recent literature reports show deep infection rates ranging from 2 to 4.5%.^{5,19–21} Helfet et al demonstrated a 5.9% deep infection rate in 34 patients undergoing primary ORIF.²² More recently, White et al reported a 6% infection rate in primary ORIF of 99 pilons, but this included nearly 20% infection in those open fractures treated primarily. Our subset of patients who were treated with primary ORIF based on surgeon discretion with respect to the soft tissue readiness, had a deep infection rate of 7.8%, and included 127 fractures treated within 4 days of injury. Bacon et al evaluated complication rates in 42 pilon fractures treated with ORIF or external Ilizarov fixation and found an osteomyelitis rate of 20.0% and 23.1% respectively.²³ This data is similar in number to the results from this study. We believe that our results are generally applicable, as most academic trauma centers have faculty with varying experience managing pilon fractures. Also, like most previously published reports on pilon fractures, relatively small numbers studied perhaps have underrepresented the true incidence.

Several studies have identified obesity as a contributor to development of wound complications in the orthopaedic population.^{24–27} Graves et al evaluated the soft tissue envelope of 114 pilon fractures. They identified a major wound complication rate of 12.9% (4/31) in the obese group vs. 4.8% (4/83) in non-obese. This was statistically significant after controlling for smoking status, AO/OTA fracture classification, surgical approach and time from injury to definitive fixation.²⁸ Although ankle dimensions were not considered for our study, we believe ankle dimension patterns remain true. With deep infection occurring in 10.9% (11/102) of obese patients

compared to 21.5% (46/214) in non-obese, our study showed that a BMI of $>30 \text{ kg/m}^2$ was protective of deep infection, which remained significant after controlling for other variables. We suspect this highlights the importance of the soft tissue injury in the development of complications. Increased soft tissue redundancy around the ankle may minimize the cutaneous manifestations of edema, such as fracture blisters, and tenuous wound closure that is not uncommonly encountered in lean patients following placement of relatively bulky implants.

Open fractures were identified as a risk factor for deep infection, with a deep infection rate of 23.2%, compared to 11.3% in closed injuries. Infection rates by Gustilo-Anderson classification were 8% in Type 1, 21.9% in Type 2 and 32% in Type 3. This suggests that any soft tissue disruption, independent of severity, increases the risk of deep infection in operatively treated pilon fractures. Additionally, this trend is consistent with the concept that increasing severity of soft tissue injury impacts complication rates.

Although we did not account for specific mechanism of injury, the fact that 73.5% (261/355) of all fractures in this study were classified as being AO/OTA 43C may indicate they were the result of a high-energy axial mechanism. Presence of comminution was found to be a risk factor for deep infection in closed fractures with comminuted fractures showing a 14.3% infection rate vs. 0% in non-comminuted fractures. This may be partially explained by the high-energy nature required to produce a comminuted injury.²⁹ Other surgical factors, such as possible increased time for surgical reconstruction of increasingly complex osseous and soft tissue injury may contribute. The statistically significant difference in the average number of days from injury to ORIF, 20.9 ± 15.5 days in the infected versus 13.6 ± 12.7 days in the non-infected ($p = .01$), represents the proper treatment allocation and adequate decision making process of orthopaedic surgeons with the more severe injuries requiring a higher time interval for surrounding soft tissue optimization.

Known diagnosis of hypertension was identified as a risk factor for infection. It has been identified that the relationship between blood pressure and cardiovascular risk is not only strong but continuous, independent, and highly predictive of risk for adults of all ages up to 89 years.³⁰ An article published in 2004 by Cohn et al discusses surrogate functional markers in cardiovascular disease. Although hypertension is not an optimal individual cardiovascular surrogate, it is still a well-established risk marker and it is something that can be identified in the patients electronic medical record as having a preexisting diagnosis of hypertension.³¹ Although there are no previous reports identifying hypertension as a risk factor for deep infection in operatively treated pilon fractures, a recent literature report identified an association between peripheral vascular disease and surgical site infection in operatively treated ankle fractures.³² Possible confounders such as variable antihypertensive therapeutic regimens, antiplatelet therapy and varying degrees of severity of disease may be possible confounders.

While hypertension remained an independent risk factor on multivariate analysis, presence of diabetes did not. While several studies have identified an association between diabetes and deep infection in operatively treated ankle

fractures,^{33,34} we identified only a non-significant trend with over a quarter of diabetic patients developing infection vs. 14.8% of non-diabetic patients. We did not have information regarding duration of the diabetes, or its status of control.

Previous reports have identified an association between smoking and surgical site infection after operative treatment of ankle fractures.^{16,33,35} Ovaska and Nasell identified that patients identified as tobacco users were 3.5–5 times more likely to develop surgical site infection after ankle fracture surgery.^{33,35} Tobacco use in our series was similar between infected and non-infected groups, and we showed no statistical correlation with development of infection.

The limitations of this study are the same as for any other retrospective study design. Another limitation was that we did not account for the number of surgeons performing the procedures. Surgical years of experience ranged from 1 year to 25 years among the treating surgeons in this study. This could have allowed controlling for surgical experience among participating surgeons. On the contrary, generalizability of these results may be facilitated as most academic trauma centers have a similar surgical years of experience distribution among their faculty. The main strengths of this study are the large number of operatively treated pilon fractures at a single institution and the quality of charting in the electronic medical record, which allowed for identification of a large number of variables to be used for our analysis.

5. Conclusion

This study represents the single largest series of operatively treated pilon fractures in the current literature as well as the first to identify risk factors of deep infection. The results of this study reiterate the morbidity represented by pilon fractures and how even optimal surgical management may not significantly modify rates of deep surgical site infection. The future focus of our group is to further analyze the subset patients diagnosed with deep infection and evaluate the rate of successful salvage as well as quantify the morbidity for these patients in the form of additional debridements or reconstructive procedures. We strongly believe this information will improve patient-physician communication and expectations.

Conflicts of interest

All authors have none to declare.

REFERENCES

- Wilson Jr LS, Mizel MS, Michelson JD. Foot and ankle injuries in motor vehicle accidents. *Foot Ankle Int.* 2001;22:649–652.
- Funk JR, Crandall JR, Tourret LJ, et al. The axial injury tolerance of the human foot/ankle complex and the effect of Achilles tension. *J Biomech Eng.* 2002;124:750–757.
- Michelson J, Moskovitz P, Labropoulos P. The nomenclature for intra-articular vertical impact fractures of the tibial plafond: pilon versus pylon. *Foot Ankle Int.* 2004;25:149–150.
- Sirkin M, Sanders R, DiPasquale T, Herscovici Jr D. A staged protocol for soft tissue management in the treatment of complex pilon fractures. *J Orthop Trauma.* 1999;13:78–84.
- Boraiah S, Kemp TJ, Erwtaman A, Lucas PA, Asprinio DE. Outcome following open reduction and internal fixation of open pilon fractures. *J Bone Joint Surg Am.* 2010;92:346–352.
- Liporace FA, Mehta S, Rhorer AS, Yoon RS, Reilly MC. Staged treatment and associated complications of pilon fractures. *Instr Course Lect.* 2012;61:53–70.
- Teeny SM, Wiss DA. Open reduction and internal fixation of tibial plafond fractures. Variables contributing to poor results and complications. *Clin Orthop Relat Res.* 1993;108–117.
- Bourne RB, Rorabeck CH, Macnab J. Intra-articular fractures of the distal tibia: the pilon fracture. *J Trauma.* 1983;23:591–596.
- Tornetta 3rd P, Weiner L, Bergman M, et al. Pilon fractures: treatment with combined internal and external fixation. *J Orthop Trauma.* 1993;7:489–496.
- Sirkin M, Sanders R. The treatment of pilon fractures. *Orthop Clin North Am.* 2001;32:91–102.
- Wyrsh B, McFerran MA, McAndrew M, et al. Operative treatment of fractures of the tibial plafond. A randomized, prospective study. *J Bone Joint Surg Am.* 1996;78:1646–1657.
- Anglen JO. Early outcome of hybrid external fixation for fracture of the distal tibia. *J Orthop Trauma.* 1999;13:92–97.
- Flynn JM, Rodriguez-del Rio F, Piza PA. Closed ankle fractures in the diabetic patient. *Foot Ankle Int.* 2000;21:311–319.
- Blotter RH, Connolly E, Wasan A, Chapman MW. Acute complications in the operative treatment of isolated ankle fractures in patients with diabetes mellitus. *Foot Ankle Int.* 1999;20:687–694.
- Miller AG, Margules A, Raikin SM. Risk factors for wound complications after ankle fracture surgery. *J Bone Joint Surg Am.* 2012;94:2047–2052.
- Thangarajah T, Prasad PS, Narayan B. Surgical site infections following open reduction and internal fixation of ankle fractures. *Open Orthop J.* 2009;3:56–60.
- Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol.* 1992;13:606–608.
- Gustilo RB, Anderson JT. JSBS classics. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones. Retrospective and prospective analyses. *J Bone Joint Surg Am.* 2002;84-A:682.
- Grose A, Gardner MJ, Hettrich C, et al. Open reduction and internal fixation of tibial pilon fractures using a lateral approach. *J Orthop Trauma.* 2007;21:530–537.
- Howard JL, Agel J, Barei DP, Benirschke SK, Nork SE. A prospective study evaluating incision placement and wound healing for tibial plafond fractures. *J Orthop Trauma.* 2008;22:299–305. discussion -6.
- Wang C, Li Y, Huang L, Wang M. Comparison of two-staged ORIF and limited internal fixation with external fixator for closed tibial plafond fractures. *Arch Orthop Trauma Surg.* 2010;130:1289–1297.
- Helfet DL, Koval K, Pappas J, Sanders RW, DiPasquale T. Intraarticular “pilon” fracture of the tibia. *Clin Orthop Relat Res.* 1994;221–228.
- Bacon S, Smith WR, Morgan SJ, et al. A retrospective analysis of comminuted intra-articular fractures of the tibial plafond: open reduction and internal fixation versus external Ilizarov fixation. *Injury.* 2008;39:196–202.
- Karunakar MA, Shah SN, Jerabek S. Body mass index as a predictor of complications after operative treatment of acetabular fractures. *J Bone Joint Surg Am.* 2005;87:1498–1502.

25. Porter SE, Graves ML, Qin Z, Russell GV. Operative experience of pelvic fractures in the obese. *Obes Surg*. 2008;18:702–708.
26. Tucker MC, Schwappach JR, Leighton RK, Coupe K, Ricci WM. Results of femoral intramedullary nailing in patients who are obese versus those who are not obese: a prospective multicenter comparison study. *J Orthop Trauma*. 2007;21:523–529.
27. Porter SE, Graves ML, Maples RA, Woodall Jr J, Wallace JG, Russell GV. Acetabular fracture reductions in the obese patient. *J Orthop Trauma*. 2011;25:371–377.
28. Graves ML, Porter SE, Fagan BC, et al. Is obesity protective against wound healing complications in pilon surgery? Soft tissue envelope and pilon fractures in the obese. *Orthopedics*. 2010;33.
29. Pollak AN, McCarthy ML, Bess RS, Agel J, Swiontkowski MF. Outcomes after treatment of high-energy tibial plafond fractures. *J Bone Joint Surg Am*. 2003;85-A:1893–1900.
30. Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for 1 million adults in 61 prospective studies. *Lancet*. 2003;360:1903–1913.
31. Cohn JN, Quyyumi AA, Hollenberg NK, Jamerson KA. Surrogate markers for cardiovascular disease: functional markers. *Circulation*. 2004;109:IV31–46.
32. SooHoo NF, Krenke L, Eagan MJ, Gurbani B, Ko CY, Zingmond DS. Complication rates following open reduction and internal fixation of ankle fractures. *J Bone Joint Surg Am*. 2009;91:1042–1049.
33. Ovaska MT, Makinen TJ, Madanat R, et al. Risk factors for deep surgical site infection following operative treatment of ankle fractures. *J Bone Joint Surg Am*. 2013;95:348–353.
34. Wukich DK, Joseph A, Ryan M, Ramirez C, Irrgang JJ. Outcomes of ankle fractures in patients with uncomplicated versus complicated diabetes. *Foot Ankle Int*. 2011;32:120–130.
35. Nasell H, Ottosson C, Tornqvist H, Linde J, Ponzer S. The impact of smoking on complications after operatively treated ankle fractures – a follow-up study of 906 patients. *J Orthop Trauma*. 2011;25:748–755.