**Name of Journal:** *World Journal of Clinical Cases*

**Manuscript NO:** 72401

**Manuscript Type:** ORIGINAL ARTICLE

***Retrospective Cohort Study***

**Identification of risk factors for surgical site infection after type II and type III tibial pilon fracture surgery**

Hu H *et al*. Risk factors for infection after fracture

Hao Hu, Jian Zhang, Xue-Guan Xie, Yan-Kun Dai, Xu Huang

**Hao Hu, Jian Zhang, Xue-Guan Xie, Yan-Kun Dai, Xu Huang,** Department of Orthopaedics, Huai’an Second People’s Hospital, Huai’an 223300, Jiangsu Province, China

**Author contributions:** Hu H and Zhang J designed the study; Xie XG drafted the work; Dai YK and Huang X collected the data; Hu H and Zhang J analyzed and interpreted data; and Xie XG and Huang X wrote the manuscript; and all authors read and confirmed the revision of the manuscript.

**Corresponding author: Xu Huang, MD, Attending Doctor,** Department of Orthopaedics, Huai’an Second People’s Hospital, No. 62 Huaihai South Road, Huai’an 223300, Jiangsu Province, China. 2212439240@qq.com

**Received:** February 22, 2022

**Revised:** April 5, 2022

**Accepted: May 16, 2022**

**Published online:**

**Abstract**

BACKGROUND

High-energy tibial pilon fractures are complex and severe fractures that are associated with a high risk of infection following open reduction and internal fixation. Infection can negatively impact patient outcomes.

AIM

To compare risk factors for postoperative infection after open reduction and internal fixation for a pilon fracture.

METHODS

Among the 137 patients included, 67 developed a surgical site infection. Demographic, clinical, and surgical factors were compared between the two groups. A binary logistic regression analysis was used to determine the odds ratio (OR) and corresponding 95%CI for significant risk factors for postoperative infection.

RESULTS

The distribution of pathogenic bacteria among the 67 patients who developed a surgical site infection was as follows: Gram-positive, 58.2% (*n* = 39); Gram-negative, 38.8% (*n* = 26); and fungal, 2.9% (*n* = 2). The following factors were associated with postoperative infection (*P* < 0.05): a Ruedi–Allgower pilon fracture type III (OR = 2.034; 95%CI: 1.109–3.738); a type III surgical incision (OR = 1.840; 95%CI: 1.177–2.877); wound contamination (OR = 2.280; 95%CI: 1.378–3.772); and diabetes as a comorbidity (OR = 3.196; 95%CI: 1.209–8.450).

CONCLUSION

Infection prevention for patients with a Ruedi–Allgower fracture type III, surgical incision type III, wound contamination, and diabetes lowers the postoperative infection risk after surgical management of tibial pilon fractures.

**Key Words:** High-energy trauma; Pilon fracture; Surgical site infection; Ruedi–Allgower; Risk factors

Hu H, Zhang J, Xie XG, Dai YK, Huang X. Identification of risk factors for surgical site infection after type II and type III tibial pilon fracture surgery. *World J Clin Cases* 2022; In press

**Core Tip:** High-energy tibial pilon fractures are complex and severe fractures that are associated with a high risk of infection following open reduction and internal fixation. In this regard, we identified a Ruedi-Allgower pilon fracture type III, a type III surgical incision, wound contamination; and diabetes as a comorbidity as significant risk factors for postoperative infection. Our findings provide a theoretical basis for prevention strategies to lower the risk of postoperative infection for tibial pilon fractures.

**INTRODUCTION**

High-energy tibial pilon fractures are a complex and severe fracture type[1,2]. Traditionally, these fractures have been treated by early open reduction and internal fixation. However, there is a risk for delayed union or even non-healing due to incomplete cleaning of the fracture site and/or early infection of the internal fixation device[3]. To reduce the risk of delayed union, stepwise delayed surgery has been used for the treatment of tibial pilon fractures, with satisfactory results reported[4]. These fractures, however, are generally associated with severe soft tissue injury. As there is shallow coverage of tibial osteoarticular cartilage tissue and a lack of muscle tissue in this area, subcutaneous tissue, mainly composed of tendons and ligaments, is often exposed after fracture. Therefore, internal fixation, in combination with the trauma caused by surgery, increases the risk of surgical site infection, which negatively impacts patient prognosis and the recovery of tibial nerve and motor function after surgery[5,6]. There is a need in practice to identify the risk factors for non-union of these fractures to formulate and implement appropriate prevention and treatment measures during the perioperative period to reduce the likelihood of postoperative infection. Our aim in this study was to compare the risk factors associated with postoperative infection after open reduction and internal fixation for a pilon fracture to provide a theoretical basis for prevention strategies to lower the risk of postoperative infection for these fractures.

**MATERIALS AND METHODS**

***Study cohort***

This was a retrospective cohort study, with the methods approved by our institutional Medical Ethics Committee. The study cohort comprised 137 patients who underwent surgical treatment for a pilon fracture between February 2016 and May 2019. Of these, 67 patients developed a surgical site infection; the 70 patients who did not develop a surgical site infection formed the control group. The inclusion criteria were as follows: negative history of trauma resulting in a unilateral tibial pilon fracture confirmed by clinical examination, radiographs, and computed tomography (CT); a Ruedi–Allgower classification fracture type II or III; and age ≥ 19 years. Patients with a history of infectious diseases, such as lower limb skin ulcers, were excluded. Patients with missing data were also excluded.

The diagnostic criteria for surgical site infection, based on the Diagnostic Criteria for Hospital Infection Trial[7-9], were as follows: signs of infection at the surgical site, such as swelling, heat, pain; purulent discharge from the incision; and identification of pathogenic bacteria in wound tissue or secretion culture.

The infection group included 38 men and 29 women, with a mean age of 52.3 ± 8.0 (range, 21 to 76) years. These patients were treated with early open reduction and internal fixation. The control group included 45 men and 25 women, with a mean age of 51.5 ± 7.3 (range, 24 to 73) years. Patients in the control group were treated with delayed open reduction and internal fixation, after confirmation of decreased swelling of local soft tissues.

***Surgical treatment***

For both groups, open reduction and internal fixation was performed under general anesthesia. An incision of 10–12 cm was made on the lateral aspect of the tibia, and the skin, subcutaneous tissue, muscle, and deep fascia were separated, layer by layer, to expose the fracture site. The bone fragments at the fracture site were cleaned and cauterization was used to completely stop the bleeding. Subsequently, manual reduction of the fracture was performed, with internal fixation performed using steel plates. After intra-operative radiography to confirm alignment at the fracture site, the incision was closed.

For patients treated with delayed open reduction and internal fixation (the control group), calcaneal traction was applied after emergency treatment (7–8 kg fixed to the calcaneal nodule). The status of local soft tissue swelling was evaluated by CT imaging. We proceeded with open reduction and internal fixation once the local swelling had been effectively managed. The surgical procedure was the same as used for the early intervention group.

***Measured outcomes***

The following data were compared between the two groups: age, sex, delay between fracture and surgery, Ruedi–Allgower fracture classification, wound contamination, early or delayed fracture treatment, type of surgical incision, antibiotic use during the perioperative period, and comorbidities.

***Statistical analysis***

Continuous data were reported as mean ± SD, with categorical variables reported as count and percentage. Between-group differences were evaluated using *χ*2 test for categorical variables and statistical test for continuous variables. A multivariate logistic regression analysis was used to identify significant risk factors (*P* < 0.05) with postoperative infection as the independent variable. All analyses were performed using SPSS software (version 21.0).

**RESULTS**

***Between-group comparison of baseline values***

The distribution of baseline variables between the patients with and without postoperative infection is reported in Table 1. There were significant between-group differences in the Ruedi–Allgower fracture type, wound contamination, surgical incision type, and presence of diabetes mellitus as a comorbidity (*P* < 0.05). There were no between-group differences with respect to age, sex, surgical method, antibiotic use, and presence of hypertension as a comorbidity.

***Risk factors for surgical site infection***

Multivariate logistic regression found Ruedi–Allgower classification type III fracture, type III surgical incision, wound contamination, and diabetes as a comorbidity as risk factors for surgical site infection (*P* < 0.05; Table 2).

**DISCUSSION**

Tibial pilon fractures, involving the distal one-third of the tibia, are caused by high-energy external forces, such as falling from a height and motor vehicle accidents. Owing to the high energy forces causing the trauma, these fractures are accompanied by massive loss of tibial cartilage tissue, destruction of blood supply to the bone, and loss of anatomical integrity and function of the distal tibial articular surface. These fractures require reduction and internal fixation, and the trauma of surgery increases the risk for postoperative infection. In this study, we identified Ruedi–Allgower type III fracture, wound contamination, type III (compared to type I-II) surgical incision, and diabetes mellitus as significant risk factors for postoperative infection (*P* < 0.05). Therefore, although delayed treatment has been proposed to reduce the risk of postoperative infection, this clinical recommendation was not supported by our findings.

The benefits of delayed compared to those of early treatment of a tibial pilon fracture are deemed to include a clean and stable fracture environment for reduction, control of soft tissue swelling and local hematoma, and ensuring adequate microcirculation of the middle and lower segments of the tibia to support fracture healing and recovery of local soft tissues, including function of the tibial nerve[10]. Previous studies have reported a shorter time to fracture healing and full weight-bearing, as well as a reduced risk of fracture non-union, with delayed compared to early fracture reduction and internal fixation[11,12]. Our findings indicate that factors other than the time of surgery, namely the fracture type, the presence/absence of wound contamination, type of incision used, and health comorbidities influence the risk postoperative infection.

The Ruedi–Allgower classification reflects the degree of fracture comminution and the continuity of the articular surface, with type III having a higher degree of comminution and loss of articular surface[13]. Previous studies have identified this fracture type as a risk for postoperative infection[14,15], which was consistent with our findings. Previous studies have also shown that wound contamination and diabetes increase the risk of postoperative infection for tibial pilon fractures. Diabetes decreases distal limb perfusion, with the resulting decrease in blood supply to the fracture site impairing fracture healing. The incision used for open reduction and internal fixation has also been previously identified as a risk factor for postoperative infection. We identified use of type III incision as a significant risk factor for postoperative infection. This may likely be due to the larger exposed area with this incision type, which improves the visual field of fracture reduction and internal fixation but also increases exposure to bacteria[16-19].

Based on our findings, the following should be considered in the surgical treatment of tibial pilon fractures, type II and III. First, small surgical incisions, to a possible extent, should be used, to reduce the risk of contamination, particularly for patients with diabetes and possibly other health comorbidities. In this regard, monitoring of blood glucose regulation during the perioperative period is also important. Second, open reduction and internal fixation should be performed, if possible, after soft tissue swelling has subsided. For patients with a severe pilon fracture, namely a Ruedi–Allgower type III fracture, which includes large soft tissue defects, vacuum sealing drainage can be combined during primary debridement and use of an appropriate flap or autogenous venous flap for transplantation and repair in the second stage, according to the soft tissue defect, could improve outcomes, including a lower risk of infection. Again, regulation of the blood glucose level, including nutritional support, during the perioperative period could also improve outcomes.

Wu *et al*[20] evaluated the risk factors for surgical site infection, including age, sex, smoking, diabetes, and operative time, at the surgical site infection after surgical treatment of a tibial pilon fracture. However, other factors, which we included in our study, namely the type of surgical incision, fracture injury classification, antibiotic use after surgery, and wound contamination, were not considered. Therefore, further research is needed to fully confirm our findings.

**CONCLUSION**

A Ruedi–Allgower classification as type III fracture, a surgical incision type III, presence of wound contamination, and diabetes are significant risk factors for postoperative infection after open reduction and internal fixation of a tibial pilon fracture. Patients with these risk factors should be monitored closely to improve outcomes. As such, our findings provide a basis to develop prevention protocols to lower the risk of postoperative infection and improve the outcomes of patients with tibial pilon fractures.

**ARTICLE HIGHLIGHTS**

***Research background***

High-energy tibial pilon fractures are associated with a high risk of infection after open reduction and internal fixation. Infections can negatively impact patient outcomes.

***Research motivation***

In this study, the authors seek ways to prevent infection after a pilon fracture.

***Research objectives***

This study aimed to compare risk factors for infection after open reduction and internal fixation of pilon fractures.

***Research methods***

Among the 137 included patients, demographic, clinical, and surgical factors were compared between those who developed infection and those who did not.

***Research results***

The pathogen distribution in the 67 patients with surgical site infection was as follows: Gram-positive, 58.2%; Gram-negative, 38.8%; and fungal, 2.9%. The following factors were associated with postoperative infection: Ruedi-Allgower pilon type III fracture; type III surgical incision; wound contamination; diabetes as a comorbidity.

***Research conclusions***

Ruedi-Allgower type III fractures, type III surgical incisions, wound contamination, and infection prevention in diabetic patients reduce the risk of postoperative infection following surgical treatment of tibial pilon fractures.

***Research perspectives***

Ruedi-Allgower type III fractures, type III surgical incisions, wound contamination, and infection prevention in diabetic patients are feasible approaches to reduce the risk of postoperative infection after surgical treatment of tibial pilon fractures, and have broader clinical value.

**REFERENCES**

1 **Aneja A**, Luo TD, Liu B, Domingo M 4th, Danelson K, Halvorson JJ, Carroll EA. Anterolateral distal tibia locking plate osteosynthesis and their ability to capture OTAC3 pilon fragments. *Injury* 2018; **49**: 409-413 [PMID: 29305233 DOI: 10.1016/j.injury.2017.12.015]

2 **Ramlee MH**, Sulong MA, Garcia-Nieto E, Penaranda DA, Felip AR, Kadir MRA. Biomechanical features of six design of the delta external fixator for treating Pilon fracture: a finite element study. *Med Biol Eng Comput* 2018; **56**: 1925-1938 [PMID: 29679256 DOI: 10.1007/s11517-018-1830-3]

3 **Ahmed AF**, Salameh M, AlKhatib N, Elmhiregh A, Ahmed GO. Open Reduction and Internal Fixation Versus Nonsurgical Treatment in Displaced Midshaft Clavicle Fractures: A Meta-Analysis. *J Orthop Trauma* 2018; **32**: e276-e283 [PMID: 29672340 DOI: 10.1097/BOT.0000000000001174]

4 **Sun C**, Tian WJ, Liu HX, Guan PG. Outcomes of multisegmental transforaminal enlarged decompression plus posterior pedicle screw fixation for multilevel lumbar spinal canal stenosis associated with lumbar instability. *Int J Surg* 2018; **50**: 72-78 [PMID: 29329787 DOI: 10.1016/j.ijsu.2017.12.031]

5 **Zhou HQ**, Chen JY, Deng W, Nie CW, Hu GB, Ren X. [Treatment of Pilon fractures complicated with soft tissue injury by plate and lag screw fixation *via* posterolateral approach]. *Zhongguo Gu Shang* 2018; **31**: 775-778 [PMID: 30185015 DOI: 10.3969/j.issn.1003-0034.2018.08.017]

6 **Chaparro F**, Ahumada X, Urbina C, Lagos L, Vargas F, Pellegrini M, Barahona M, Bastias C. Posterior pilon fracture: Epidemiology and surgical technique. *Injury* 2019; **50**: 2312-2317 [PMID: 31630782 DOI: 10.1016/j.injury.2019.10.007]

7 **Gaulke R**, Krettek C. [Tibial pilon fractures : Advoidance and therapy of complications]. *Unfallchirurg* 2017; **120**: 658-666 [PMID: 28540568 DOI: 10.1007/s00113-017-0366-6]

8 **Lai ZB**, Zhu YZ, Zou YX, Zhang HN, Li X, Zhong DG, Yang KY, Lai JH, Shen GD. [Modified posteromedial approach *via* lateral side of flexor hallucis longus for the treatment of posterior Pilon fracture]. *Zhonghua Yi Xue Za Zhi* 2021; **101**: 1077-1082 [PMID: 33878835 DOI: 10.3760/cma.j.cn112137-20200828-02484]

9 **Chen Y**, Zhang H, Liu X, Li YX, Deng W, Ren Y, Wu SZ. [Effects of modified posteromedial approach combined raft technique for posterior Pilon fractures with collapsed articular surface]. *Zhonghua Yi Xue Za Zhi* 2019; **99**: 1631-1635 [PMID: 31189261 DOI: 10.3760/cma.j.issn.0376-2491.2019.21.008]

10 **Zeng Z**, Jin H, Sekine K, Rudolph M, Rominger F, Hashmi ASK. Gold-Catalyzed Regiospecific C-H Annulation of o-Ethynylbiaryls with Anthranils: π-Extension by Ring-Expansion En Route to N-Doped PAHs. *Angew Chem Int Ed Engl* 2018; **57**: 6935-6939 [PMID: 29633505 DOI: 10.1002/anie.201802445]

11 **Cunningham D**, LaRose M, Yoon RS, Gage MJ. Factors associated with perioperative opioid demand in lower extremity fractures: Does consumption vary by anatomic location? *Injury* 2021; **52**: 1363-1369 [PMID: 33097202 DOI: 10.1016/j.injury.2020.10.038]

12 **Rodriguez-Buitrago A**, Attum B, Enata N, Evans A, Okwumabua E, Gajari V, Obremskey WT, Jahangir A. Opiate Prescribing Practices After Common Isolated Lower Extremity Injuries. *J Orthop Trauma* 2019; **33**: e93-e99 [PMID: 30779727 DOI: 10.1097/BOT.0000000000001375]

13 **Sun Y**, Wang H, Tang Y, Zhao H, Qin S, Xu L, Xia Z, Zhang F. Incidence and risk factors for surgical site infection after open reduction and internal fixation of ankle fracture: A retrospective multicenter study. *Medicine (Baltimore)* 2018; **97**: e9901 [PMID: 29443762 DOI: 10.1097/MD.0000000000009901]

14 **Zajonz D**, Brand A, Lycke C, Özkurtul O, Theopold J, Spiegl UJA, Roth A, Josten C, Fakler JKM. Risk factors for early infection following hemiarthroplasty in elderly patients with a femoral neck fracture. *Eur J Trauma Emerg Surg* 2019; **45**: 207-212 [PMID: 29340736 DOI: 10.1007/s00068-018-0909-8]

15 **Hu ZS**, Liu XL, Zhang YZ. Comparison of Proximal Femoral Geometry and Risk Factors between Femoral Neck Fractures and Femoral Intertrochanteric Fractures in an Elderly Chinese Population. *Chin Med J (Engl)* 2018; **131**: 2524-2530 [PMID: 30381585 DOI: 10.4103/0366-6999.244118]

16 **Stewart L**, Shaikh F, Bradley W, Lu D, Blyth DM, Petfield JL, Whitman TJ, Krauss M, Greenberg L, Tribble DR. Combat-Related Extremity Wounds: Injury Factors Predicting Early Onset Infections. *Mil Med* 2019; **184**: 83-91 [PMID: 30901441 DOI: 10.1093/milmed/usy336]

17 **Johnson CT**, Wroe JA, Agarwal R, Martin KE, Guldberg RE, Donlan RM, Westblade LF, García AJ. Hydrogel delivery of lysostaphin eliminates orthopedic implant infection by *Staphylococcus aureus* and supports fracture healing. *Proc Natl Acad Sci U S A* 2018; **115**: E4960-E4969 [PMID: 29760099 DOI: 10.1073/pnas.1801013115]

18 **Quacinella M**, Bernstein E, Mazzone B, Wyatt M, Kuhn KM. Do Spatiotemporal Gait Parameters Improve After Pilon Fracture in Patients Who Use the Intrepid Dynamic Exoskeletal Orthosis? *Clin Orthop Relat Res* 2019; **477**: 838-847 [PMID: 30811361 DOI: 10.1097/CORR.0000000000000487]

19 **Mabvuure NT**, Pinto-Lopes R, Sierakowski A. Management of intraarticular proximal interphalangeal joint fracture-dislocations and pilon fractures with the Ligamentotaxor® device. *Arch Orthop Trauma Surg* 2020; **140**: 1133-1141 [PMID: 32448930 DOI: 10.1007/s00402-020-03482-8]

20 **Wu D**, Peng C, Ren G, Yuan B, Liu H. Novel anterior curved incision combined with MIPO for Pilon fracture treatment. *BMC Musculoskelet Disord* 2020; **21**: 176 [PMID: 32188447 DOI: 10.1186/s12891-020-03207-3]

**Footnotes**

**Institutional review board statement:** This study wasapproved by Huai’an Second People’s Hospital ethics committee.

**Informed consent statement:** Patients were not required to give informed consent to the study because the analysis used anonymous clinical data that were obtained after each patient agreed to treatment by written consent.

**Conflict-of-interest statement:** The authors have no conflicts of interest to declare.

**Data sharing statement:** No additional data are available.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: https://creativecommons.org/Licenses/by-nc/4.0/

**Provenance and peer review:** Unsolicited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review started:** February 22, 2022

**First decision:** March 23, 2022

**Article in press:**

**Specialty type:** Orthopedics

**Country/Territory of origin:** China

**Peer-review report’s scientific quality classification**

Grade A (Excellent): 0

Grade B (Very good): B, B

Grade C (Good): C

Grade D (Fair): 0

Grade E (Poor): 0

**P-Reviewer:** Kang KY, South Korea; Kroenke G, Germany; Nakamura Y, Japan **A-Editor:** Yao QG **S-Editor:** Wang JL **L-Editor:** A **P-Editor:** Wang JL

**Table 1 Comparison of baseline information between infected and controlled groups, *n* (%)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Factor** | **Infected group (*n* = 67)** | **Control group (*n* = 70)** | ***t*/χ2 value** | ***P* value** |
| Age (yr) | 52.3 ± 8.0 | 51.5 ± 7.3 | 0.612  | 0.542  |
| Fracture to surgery interval (d) | 13.2 ± 4.1 | 12.0 ± 4.8 | 1.570  | 0.119  |
| Gender |  |  | 0.821  | 0.365  |
| Man | 38 (56.72) | 45 (64.29) |  |  |
| Woman | 29 (43.28) | 25 (35.71) |  |  |
| Ruedi-Allgower typing |  |  | 6.295  | 0.012  |
| Type II | 36 (53.73) | 52 (74.29) |  |  |
| Type III | 31 (46.27) | 18 (25.71) |  |  |
| Wound contamination |  |  | 9.260  | 0.002  |
| Yes | 26 (38.81) | 11 (15.71) |  |  |
| No | 41 (61.19) | 59 (84.29) |  |  |
| Surgical approach |  |  | 2.603  | 0.107  |
| Early open reduction | 54 (80.6) | 48 (68.57) |  |  |
| Step delay surgery | 13 (19.4) | 22 (31.43) |  |  |
| Surgical incision type |  |  | 5.952  | 0.015  |
| I-II | 51 (76.12) | 64 (91.43) |  |  |
| III | 16 (23.88) | 6 (8.57) |  |  |
| Antibiotics administered postoperatively |  |  | 3.088  | 0.079  |
| Yes | 47 (70.15) | 58 (82.86) |  |  |
| No | 20 (29.85) | 12 (17.14) |  |  |
| Diabetes |  |  | 6.518  | 0.011  |
| Yes | 12 (17.91) | 3 (4.29) |  |  |
| No | 55 (82.09) | 67 (95.71) |  |  |
| Hypertension |  |  | 1.476  | 0.224  |
| Yes | 9 (13.43) | 5 (7.14) |  |  |
| No | 58 (86.57) | 65 (92.86) | 　 | 　 |

**Table 2 Multivariate analysis**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** |  | **SE** | **Walds** | ***P* value** | **OR** | **95%CI** |
| Ruedi-Allgower fracture type | 0.711  | 0.310  | 5.260  | 0.038 | 2.036  | 1.109-3.738 |
| Wound contamination | 0.824  | 0.257  | 10.280  | 0 | 2.280  | 1.378-3.772  |
| Surgical incision type | 0.610  | 0.228  | 7.158  | 0.006 | 1.840  | 1.177-2.877  |
| Diabetes | 1.162  | 0.496  | 5.488  | 0.034 | 3.196  | 1.209-8.450  |
| Constant term | 0.944  | 0.628  | 2.260  | 0.219 | 2.570  | 0.751-8.801 |