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Does delay in surgical debridement increase the risk of infection in open tibia fractures in Saudi patients? A retrospective cohort study

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ABSTRACT

Background: Infection is the most common and devastating complication of open fractures, with a reported incidence of 3–40%. Tibia bone along its anteromedial surface has relatively thin soft tissue coverage; hence the open tibia fracture incidence rate ranges from 49.4% to 63.2%. Open fractures are usually classified based on the Gustilo & Anderson classification system, which is used by surgeons as an index for the severity of an injury and as a prognostic tool. Our current practice follows the 6-h rule of irrigation and debridement (I&D). Nevertheless, there is little support for this opinion in the literature. Our study concentrates on identifying the risk factors of infection in open tibia fractures and comparing the rate of infection if surgical irrigation and debridement was delayed.

Methods: The medical records of 389 patients with open fractures were reviewed. Of these cases, 113 patients with open tibia fracture who presented to our Hospital from the period 1997 to 2008 fit the inclusion criteria and were included in a retrospective cohort study.

Results: A total of 113 tibia fractures were reviewed, with an average patient age of 31.70 years; 87.1% of the fractures were high-energy fractures, and the most common mechanism of injury was a motor vehicle accident (62.4%). The data analysis revealed no difference in overall infectious outcome when comparing initial I&D performed within 6 h to when I&D was performed after 6 h ($P = 0.201$). The data analysis showed a significant relationship between infection and wound closure in first surgery in both univariate and multivariate analysis ($P = 0.0003$ and $P = 0.014$), respectively.

Conclusion: This study showed no significant evidence to support the 6-h rule, but it did demonstrate a significant relationship between the Gustilo stage and infection, as well as an increased infection rate if external fixation was used or if the wound was left open during the initial irrigation and debridement. We believe that more studies are required to identify the relationship between infection and the delay in irrigation and debridement; a meta-analysis of the currently available data may provide an answer to this question.

1. Introduction

An open fracture is one in which a break in the skin allows for direct communication of the fracture site or fracture hematoma with the external environment. Open fractures are usually classified based on the Gustilo & Anderson classification system,[1] which is used by surgeons as an index for the severity of an injury and as a prognostic tool. Infection is the most common and devastating complication of open fractures, with a reported incidence of 3%–40%.[2]

Many factors contribute to the occurrence of infection following an open fracture, including the severity of the injury, medical comorbidities, a history of smoking, proper early surgical irrigation & debridement (I&D), the timing of soft tissue coverage, the administration of antibiotics and the method of fracture stabilisation. Furthermore, infection can vary from early to late presentation. Early presentation appears as wound infection, cellulitis, pus collection and acute osteomyelitis. On the other hand, late presentation appears as chronic osteomyelitis, sinus discharge, non-union and failure of fixation.

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The current treatment protocol for open fractures begins in the emergency department, addressing life-threatening injuries first, followed by management of the open fracture. The fracture is splinted and the wound covered with sterile dressing in the emergency room. Then appropriate antibiotics and tetanus toxoid are administrated. After that, the patient is taken to the operating room for I&D; the most widely used cutoff time for I&D is 6 h from the time of injury.[3] Finally, skeletal stabilisation is performed and I&D can be repeated every 36–48 h. Our current practice follows the 6-h rule of I&D. Nevertheless, there is little support for this opinion in the literature. A Previous study Kindsfater et al.[1] showed a significant increase in infection rates if the debridement was delayed more than 5 h. On the contrary, prospective and retrospective studies showed respectively, no clinical significance if I&D was delayed more than 6 h, compared to those treated after the 6-h period.[4–6]

Templeman et al.[7] retrospective study showed that the incidence of infection was 0% in Gustilo type I, 3% in Gustilo type II and 21% in Gustilo type III open tibia fractures. Currently there are few data supporting the 6-h rule. The aim of the study is to identifying the risk factors of infection in open tibia fractures in relation to time of I&D, type of fixation in the first surgery, wound closure and Gustilo & Anderson Classification. Approval from the ethics committee was obtained before conducting this study.

2. Material and methods

The patient inclusion criteria were as follows: an open tibia fracture, initial presentation to our Hospital between 1997 and 2008; patients were aged 18 years and above and presented acutely; and at least 1 year of follow-up or follow-up until the fracture healed or an infection developed. We excluded patients younger than 18 years old, those with very severe open fractures that required an immediate amputation, patients with less than 1 year of follow-up following the trauma and patients with involvement of sites other than the tibia. All patients were under the care of an orthopaedics board-certified surgeon. There was no formal treatment protocol for the cases. The general management guidelines were as follows: There was immediate management of the life-threatening injuries by a trauma team and/or an emergency physician. The standard practice is to give all patients a dose of first generation cephalosporin antibiotics and tetanus toxoid once they are diagnosed to have an open fracture. This was established based on Advanced Trauma Life Support (ATLS) recommendation. Furthermore, adding other antibiotics for Gram-negative and anaerobic coverage is based on the surgeon's evaluation and decision. The antibiotics were continued for at least 24 h, and the duration was extended based on the clinical situation of the patient. After stabilising the patient's condition in the emergency room, I&D was performed in the operating room as soon as possible. Fracture stabilisation was left to the discretion of the treating orthopaedic surgeon. If the fracture was of type I primary fixation with plate or nail was performed depending on the location of the fracture. Other open fractures were either stabilised with an external fixation or put in a back slab.

The wound was either closed primarily or left for a delayed primary closure. No formal protocol was used. It was based on the orthopaedic surgeon decision, if the open fracture required soft tissue coverage plastic surgery was contacted. All open fractures that were not fixed definitively were taken for a second look wound inspection. Subsequent debridement was decided based on the wound condition and the presence of signs of infection.

The Gustilo classification was taken from the chart documentation of the treating physician. The development of infection was identified based on the surgeon's or infectious disease physician's documentation in the chart. Statistical analysis was performed using chi-square test and multiple logistic regression model. The primary outcome was development of infection. Secondary outcomes included the possible relationship between infection and other risk factors, including Gustilo classification, sex, ICU admission, multiple injuries, the mechanism of injury, wound closure in the first operation and the method of fracture stabilisation in the first operation.

3. Results

The medical records of 389 patients with open fractures were reviewed. These patients presented to the emergency department between the years 1997 and 2008. Of these cases, 113 fit the inclusion criteria and were included in a retrospective cohort study. The reasons for exclusion of 276 fractures were as follows: 43 patients were younger than 18 years old, one patient was transferred to another hospital, 48 cases were late presentation (they received initial treatment in another hospital and were then transferred to our hospital for further management), 4 patients had a severe open fracture requiring an immediate amputation, 13 patients died within the first year after the trauma, and 65 patients were lost to follow-up. One hundred and two cases were excluded

Table 1
Demographics of the participants and mechanism of injury with energy impact.

		Overall (N = 113)	Infection (N = 18)	No Infection (N = 95)	P-Value
Age (Years)		31.70 ± 1.12	33.06 ± 3.26	31.44 ± 1.19	0.765
Total Number Of Debridement		2.31 ± 0.18	4.50 ± 0.82	1.89 ± 0.11	0.0001[a]
Sex	Female	(4) 3.5%	(0) 0%	(4) 4.2%	1
	Male	(109) 96.5%	(18) 100%	(91) 95.8%	
Mechanism of Injury	Blast Injury	(3) 3%	(0) 0%	(3) 3.6%	0.649
	Crush Injury	(1) 1%	(0) 0%	(1) 1.2%	
	Electrical Saw Injure	(2) 2%	(1) 5.9%	(1) 1.2%	
	Fall From Height	(5) 5%	(1) 5.9%	(4) 4.8%	
	Fall From Hoarse	(1) 1%	(0) 0%	(1) 1.2%	
	Fall Of Heavy Object	(2) 2%	(0) 0%	(2) 2.4%	
	Gun Shot	(5) 5%	(1) 5.9%	(4) 4.8%	
	Hit By Camel	(1) 1%	(0) 0%	(1) 1.2%	
	Motor Bike Accident	(1) 1%	(0) 0%	(1) 1.2%	
	Motor Vehicle Accident	(63) 62.4%	(10) 58.8%	(53) 63.1%	
	Pedestrian	(16) 15.8%	(3) 17.6%	(13) 15.5%	
	Twisting Injury	(1) 1%	(1) 5.9%	(0) 0%	
Energy	High	(88) 87.1%	(14) 82.4%	(74) 88.1%	0.455
	Low Or Medium	(13) 12.9%	(3) 17.6%	(10) 11.9%	

N: Number.
[a] P-values are generated using Wilcoxon rank test for continuous data & Fishers exact test for categorical variables.

because of the involvement of other fracture sites (Humerus, elbow, radius and ulna, isolated radius, isolated ulna, femur, isolated fibula, ankle, patella, hand, or foot).

A total of 113 tibia fractures were retrospectively reviewed, with an average patient age of 31.70 years (range: 18–70 years). There were 109 male patients and 4 female patients. The Gustilo type included type I 13 cases (11.5%), type II 45 cases (39.8%), type IIIA 20 cases (17.7%), type IIIB 28 cases (24.8%), and type IIIC 7 cases (6.2%). Additionally, 87.1% of the fractures were high-energy fractures, and the most common mechanism of injury was a motor vehicle accident (62.4%); the other mechanisms of injury are shown in (Table 1). Sub classification of the energy level into either low/medium-energy or high-energy had no statistically significant relationship with infection in our data analysis ($P = 0.455$). Due to retrospective nature of the study, 12 patients had incomplete data However, it did not affect the results.

The overall incidence of infection in these cases was 18 cases; 14 cases were Gustilo type III, 3 cases were Gustilo type II, and 1 case was Gustilo type I. (Fig. 1) The presentation of infection varied in these cases, including the development of wound infection, osteomyelitis, infection non-union and implant failure; some of the patients developed more than one presentation of infection during the course of treatment. Among our patients, we observed 9 cases of osteomyelitis, 5 cases of infection non-union, 12 cases of wound infection and 1 case of implant failure. The mean time from the injury to initial debridement for all cases and infected cases were 9.1 ± 10.4 and 11.38 ± 17.02 h, respectively. The data analysis revealed no difference in overall infectious outcome when comparing initial I&D performed within 6 h to when it was performed after 6 h ($P = 0.201$) (Table 2). When comparing the risk of infection between the Gustilo type I and Gustilo type II cases to the cases with Gustilo type III injuries, our analysis revealed a statistically significant difference between the two groups ($P < 0.0001$). In total, 27% of the patients required ICU admission during their hospital stay; the data analysis showed no significant relationship between ICU admission and the development of infection. Bone stabilisation during the first operation was achieved by multiple methods.

In this series, 33 patients were stabilised initially by a cast application, 24 patients were stabilised by external fixation and 56 patients were stabilised by immediate internal fixation (either an IM nail or a plate and screws). The data analysis showed a significant relationship between infection and stabilising the fracture with an external fixator ($P = 0.001$). Wound closure during the initial operative procedure was assessed in this series; 52 patients had a primary wound closure during the first operation, and only 2 of them developed infection. The P-value was statistically significant for this relationship ($P = 0.0003$) in comparison to 15 patients out of 48 who had delayed closure. (Table 3). Using a multivariate analysis, we combine the Gustilo "I and II" in one category and Gustilo "III" in another category the data analysis showed a significant relationship between infection and wound closure in first surgery ($P = 0.014$) (Table 4).

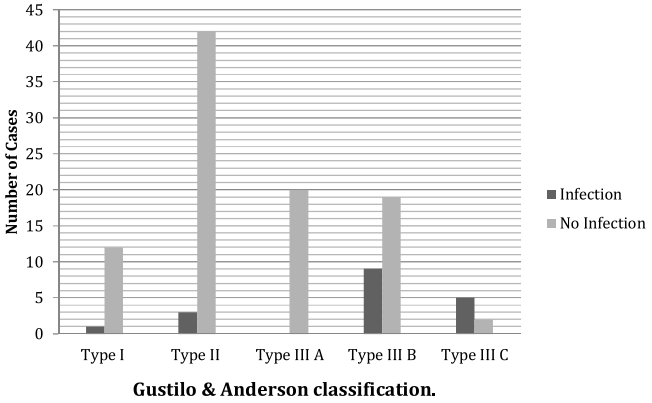

Fig. 1. Total number of infected vs. non-infected cases according to Gustilo & Anderson classification.

Table 2
Timing of initial Irrigation and debridement (I&D).

Timing of initial I&D	Overall	Infection	No Infection	P-Value
Less than 6 hours	65	13	52	0201
More than 6 hours	48	5	43	
Total	113	18	95	

P-values are generated using Fishers exact test for categorical variables.

4. Discussion

In this study, we analysed 113 cases of open tibia fracture and evaluated the risk of infection in relation to the timing of the initial I&D and other cofactors. Our institution follows the general rule of performing urgent I&D within 6 h. Unfortunately, this is not always possible due to factors including patient status and administrative policies. However, our analysis showed no relation between the 6-h rule and developing infection in open tibia fractures ($P = 0.201$). The only clinical study that supports the 6-h rule was published by Kindsfater et al.,[1] who reviewed 47 patients with Gustilo type II & III open fractures. The infection rate in their study was significantly higher if the debridement was delayed more than 5 h.

Eight human studies have failed to establish a link between delayed surgery and infection rates over the last 30 years.[2,3] Patzakis et al. reviewed 1104 open fracture cases[8] and evaluated multiple variables, including the infection rate when the debridement was performed before or after 12 h. The rates of infection were 6.8% and 7.1%, respectively, and the difference was not statistically significant. Bednar & Parikh reviewed 82 open fractures and found no difference in the infection rates for those treated within 6 h compared to those treated within 24 h.[6]

Harley et al.[9] Published a retrospective study of 215 open fractures; their primary aim was to determine if debridement delay for more than 8 h affected the infection or union rate. No evidence was found for this relationship in their review. Khatod et al. reviewed 106 open tibia fractures; no significant increase in infection was discovered with respect to patients treated after 6 h compared with those treated within 6 h. They noted that no infection occurred in the cases that underwent surgery within 2 h.[10] Spencer et al. published a 5-year prospective audit directly evaluating the time delay in open fractures. They included 142 open fractures and reported a 10% incidence of infection; they found no statistically significant results supporting the 6-h theory.[4]

Our study results are similar to most of the results reported in the literature in regards to the 6-h theory. All of the studies performed were retrospective in nature, which is expected because a randomised clinical trial would be unethical. One could argue that debridement should be performed as soon as possible, keeping in mind that the delay of debridement might be of benefit to the patient in certain conditions, such as if there is no available expert surgeon or if the patient's general condition warrants some delay until it stabilises. In our study, no relationship was identified between the infection rate and patient ICU admission. Moreover, of 28 patients who were admitted to ICU, 3 developed infection. Out of 73 patients who were not admitted to ICU, only 14 developed infection. This could be related to the fact that being in an ICU indicates the severity of the injury.

In our study, the Gustilo classification was used to assess the severity of the open tibia fractures; having a grade III fracture was a

Table 3
Details of 113 patients with open fracture of the tibia.

Variable	Category	Overall (N = 113)	Infection (N = 18)	No Infection (N = 95)	P-Value
External Fixation 1st surgery	No	(77) 76.2%	(7) 41.2%	(70) 83.3%	0.001[a]
	Yes	(24) 23.8%	(10) 58.8%	(14) 16.7%	
Internal Fixation 1st surgery	No	(45) 44.6%	(14) 82.4%	(31) 36.9%	0.001[a]
	Yes	(56) 55.4%	(3) 17.6%	(53) 63.1%	
Wound Closed In 1st surgery	No	(48) 48%	(15) 88.2%	(33) 39.8%	0.0003[a]
	Yes	(52) 52%	(2) 11.8%	(50) 60.2%	
Antibiotics given in initial presentation	No	(24) 23.8%	(4) 23.5%	(20) 23.8%	1
	Yes	(77) 76.2%	(13) 76.5%	(64) 76.2%	
Gustilo & Anderson Classification	I	(13) 11.5%	(1) 5.6%	(12) 12.6%	<0.0001[a]
	II	(45) 39.8%	(3) 16.7%	(42) 44.2%	
	III A	(20) 17.7%	(0) 0%	(20) 21.1%	
	III B	(28) 24.8%	(9) 50%	(19) 20%	
	III C	(7) 6.2%	(5) 27.8%	(2) 2.1%	
Other Systems Injures[b]	No	(77) 76.2%	(15) 88.2%	(62) 73.8%	0.348
	Yes	(24) 23.8%	(2) 11.8%	(22) 26.2%	

N: Number.
[a] P-values are generated using Wilcoxon rank test for continuous data & Fishers exact test for categorical variables.
[b] Other systems injuries: Neurological, respiratory, intra-abdominal, ophthalmology, and vascular injuries.

Table 4
Multivariate analysis of risk of infection.

Covariates	Level	OR (95% CI)	P-value
Age	One year increase	1.01(0.95–1.06)	0.958
External Fixation 1st surgery	Yes	3.04(0.66–13.97)	0.152
Internal Fixation 1st surgery	Yes	0.507(0.08–3.03)	0.456
Wound Closed In 1st surgery	No	8.92(1.53–52.63)	0.014[a]
Gustilo & Anderson Classification	I and II	2.08(0.46–9.09)	0.315
Time to debridement[b]	One unit increase	1.04(0.98–1.09)	0.153

We combined the Gustilo "I and II" in one category and "III" in another category due to small numbers.
[a] P-values are generated using multiple logistic regression model.
[b] Time unit in hours.

significant risk factor for the development of infection compared to grades I and II. Similar results were reported in the literature, with reports indicating that the rate of infection increases with the increase of the Gustilo grade.[4,11–13] The disadvantage of the Gustilo classification is poor interobserver agreement.[14] The wound should be classified after the initial debridement, because what may initially appear to be a grade I injury may be a grade IIIB injury following debridement.[15]

Our results showed that 2 cases of open tibia fracture with immediate wound closure during the initial I&D developed infection; most of the patients who developed infection had their wound closed during a different operative procedure, and this difference was statistically significant in both univariate and multivariate analysis ($P = 0.0003$ and $P = 0.014$), respectively. Therefore, keeping the wound open after the initial I&D appears to be associated with higher infection rates. This result should be handled with caution because leaving the wound open during the initial surgery is an indirect reflection of the severity of the patient injury; injury severity is associated with higher infection rates, as shown by the Gustilo classification.

Previous studies evaluating the association between early and late wound closure and infection rates have reported different results. Some papers advocated early wound closure,[16–19] while other papers were delayed-closure advocates.[8,20,21] Gustilo type IIIB requires a team approach with the involvement of both plastic and orthopaedic surgeons. Gopal et al. reported the results of a 'fix & flap' approach for such injuries to obtain flap coverage within 72 h. The infection rates were 6% in the early group and 30% in the late group, and the author recommended this approach as the 'gold standard' for Gustilo IIIB injuries.[22]

In our study, fracture stabilisation after the initial I&D procedure was achieved by external fixation, internal fixation with IM nail or plates and screws, or with a cast. We did not include the type of definitive final fixation in our data. Five of 33 patients treated initially with cast immobilisation developed infection, 10 of 24 patients treated initially with external fixation developed infection and 3 of 56 patients treated by internal fixation during the first procedure developed infection. The relationship between infection and applying external fixation was statistically significant in univariate analysis ($P < 0.001$). (Fig. 2)

This result might be influenced by the stage of the open fracture and severity of the injury, higher stages were more likely to be treated using external fixation, affecting the rate of infection rather than being a true effect of the external fixation. This was proven by a multivariate analysis as shown in (Table 4). Regardless of the infection rate, external fixation has some great advantages; it is easy and fast to apply, making it a good option in damage control orthopaedics; it does not require hardware implantation at the site of the open injury, limiting further soft-tissue damage[23]; and it provides a good area for evaluating an open fracture wound.

The main limitations of our study include its retrospective nature, which subjects it to missing data from the old charts. The Gustilo & Anderson classification system can hold a great amount of interobserver variation in the classification of open fracture. However, one must consider that a clinical trial for open fractures would have many obstacles, and most of the currently available

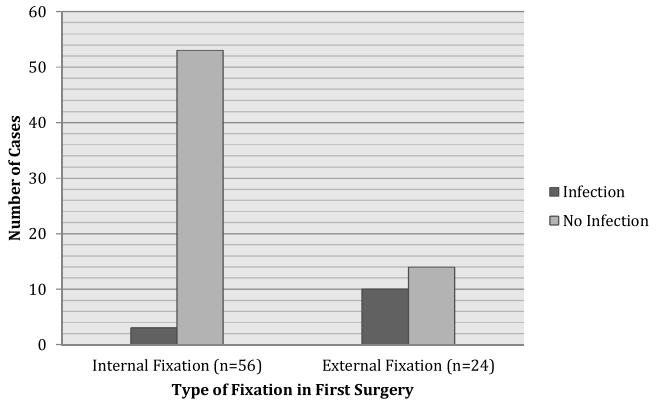

Fig. 2. Fixation type in first surgery and infected cases.

literature is of a similar level of evidence. Additionally, the study lacks details about factors that might affect the infection rate, such as history of smoking, medical conditions of the patient, the time of antibiotic administration and the type and duration of the antibiotics used. Although this study cannot provide a solid recommendation for the treatment of open fractures, we hope that, when combined with other papers in the literature, it will provide a general guideline for the management of open tibia fractures.

5. Conclusions

This study showed no significant evidence to support the 6-h rule, but it did demonstrate a significant relationship between the Gustilo stage and infection, as well as an increased infection rate if external fixation was used or if the wound was left open during the initial I&D. We believe that more studies are required to identify the relationship between infection and the delay in I&D; a meta-analysis of the currently available data may provide an answer to this question.

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Conflict of interest

The author and co-authors do not have any conflicts of interest to disclose.

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