Percutaneous or Open Reduction of Closed Tibial Shaft Fractures During Intramedullary Nailing Does Not Increase Wound Complications, Infection or Nonunion Rates

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Objective: To compare the incidence of complications (wound, infection, and nonunion) among those patients treated with closed, percutaneous, and open intramedullary nailing for closed tibial shaft fractures.

Design: Retrospective review.

Setting: Multiple trauma centers.

Patients: Skeletally mature patients with closed tibia fractures amenable to treatment with an intramedullary device.

Intervention: Intramedullary fixation with closed, percutaneous, or open reduction.

Main Outcome Measurements: Superficial wound complication, deep infection, nonunion.

Results: A total of 317 tibial shaft fractures in 315 patients were included in the study. Two-hundred fractures in 198 patients were treated with closed reduction, 61 fractures in 61 patients were treated with percutaneous reduction, and 56 fractures in 56 patients were treated with formal open reduction. The superficial wound complication rate was 1% (2/200) for the closed group, 1.6% (1/61) for the percutaneous group, and 3.6% (2/56) for the open group with no statistical difference between the groups ($P = 0.179$). The deep infection rate was 2% (4/200) for the closed group, 1.6% (1/61) for the percutaneous group, and 7.1% (4/56) for the open group with no significant difference between the groups ($P = 0.133$). Nonunion rate was 5.0% (10/200) for the closed group, 4.9% (3/61) for the percutaneous group, and 7.1% (4/56) for the open group, with no statistical difference between the groups ($P = 0.492$).

Conclusions: This is the largest reported series of closed tibial shaft fractures nailed with percutaneous and open reduction. Percutaneous or open reduction did not result in increased wound complications, infection, or nonunion rates. Carefully performed percutaneous or open approaches can be safely used in obtaining reduction of difficult tibial shaft fractures treated with intramedullary devices.

Key Word: tibia, intramedullary nail, reduction techniques

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

The tibia is the most common long bone fracture.[1] Diaphyseal tibia fractures (OTA/AO type 42[2]) are commonly treated with intramedullary devices. This technique is often performed with closed reduction maneuvers. At times, closed reduction can be difficult, leading to increased surgical time, radiation exposure, or acceptance of suboptimal fracture reduction. Surgeons faced with difficult closed reductions can use percutaneous techniques to manipulate the fracture fragments, or make a formal open approach at the fracture site for direct reduction. Concerns with open technique include wound complications, increased risk of infection by exposing an otherwise closed fracture, and increased nonunion rate due to disruption of the fracture hematoma and early inflammatory response.[3]

The literature contains limited reports on closed tibial shaft fractures treated with intramedullary fixation after percutaneous or open reduction.[4–6] We have used percutaneous and open reductions of closed tibial shaft fractures at our institutions for several years, and the purpose of our study was to compare the incidence of complications (wound, infection, nonunion) among those patients treated with closed, percutaneous, and open intramedullary nailing for closed tibial shaft fractures. We hypothesized that there is no significant difference in complication rates between patients treated with the different reduction methods.

PATIENTS AND METHODS

This was a retrospective study conducted at 2 level-1 trauma centers and one level-2 trauma center. Patients with acute closed tibia fractures treated with intramedullary fixation from 2004 to 2014 were identified using our trauma databases. After Institutional Review Board exempt status was obtained, the medical records and radiographs of all patients with closed tibial shaft fractures treated during the study period were reviewed. Patients included in the study were those treated with intramedullary fixation that completed follow-up for a minimum of 12 months or until fracture union. Patients with fasciotomy incisions were excluded from the study, as those incisions were dictated by compartment syndrome, rather than a decision for open reduction.

Demographic data collected included age, sex, tobacco use, and presence of diabetes (Table 1). Injury and treatment data included nailing technique (suprapatellar or infrapatellar), reduction method as closed, percutaneous, or open. Postoperative data included length of follow-up, presence of superficial wound complications, infection requiring reoperation, and nonunion or delayed union requiring reoperation.

Patients were grouped according to reduction method. Percutaneous reduction was performed through stab incisions less than 1 cm in length; with fracture reduction and stabilization achieved using large forceps in combination with indirect reduction means such as manual traction or femoral distractor. Open reductions were performed through a sufficient exposure to perform direct reduction of the fracture, with reduction maintained by clamp or unicortical plate application, with all plates removed after placement of the intramedullary nail.

Wound complications were defined as wound dehiscence, drainage, or cellulitic changes that resolved with nonoperative treatment such as oral antibiotics or topical wound care. Deep infections were defined as infections requiring reoperation for debridement and irrigation.

There were 317 tibial shaft fractures in 315 patients included in the study. Of these, 200 fractures in 198 patients were treated with closed reduction, 61 fractures in 61 patients were treated with percutaneous reduction, and 56 fractures in 56 patients were treated with formal open reduction. A Fisher exact test using a Monte Carlo method of approximation was used to compare the groups due to small observations per cells ($n < 5$). The Fisher exact test is a nonparametric test appropriate for comparing categorical data between 2 or more groups. As an omnibus test, the results

TABLE 1. Patient Demographic and Surgical Technique Data

	Closed Reduction (n = 198)	Percutaneous Reduction (n = 61)	Open Reduction (n = 56)	Total (n = 315)
Male	122	28	34	184
Female	76	33	22	131
Average age (range), years	40.4 (16–89)	46.3 (18–82)	43 (16–77)	42 (16–89)
Mechanism of injury				
Fight (altercation)	1	0	0	1
ATV	2	2	0	4
Bicycle	9	4	2	15
Boat	2	0	0	2
Crush	5	1	2	8
Horse	3	0	0	3
Low energy fall	50	26	27	103
High energy fall	5	3	0	8
GSW	2	0	0	2
Blunt impact	4	0	3	7
MCC	35	4	8	47
MVC	34	7	4	45
Pedestrian struck	36	8	12	56
Sports	10	1	2	13
Stress fracture	0	0	1	1
	Closed Reduction (n = 198)	**Percutaneous Reduction (n = 61)**	**Open Reduction (n = 56)**	***P***
Rates of tobacco use and diabetes among patients (%)				
Tobacco	41 (20.7)	21 (37.5)	17 (27.9)	0.032
Diabetes	17 (8.6)	4 (7.1)	10 (16.4)	0.152
	Closed Reduction (n = 200)	**Percutaneous Reduction (n = 61)**	**Open Reduction (n = 56)**	***P***
Intramedullary nail insertion technique (%)				
Infrapatellar	143 (71.5)	37 (66)	41 (67)	0.658
Suprapatellar	57 (28.5)	19 (34)	20 (33)	

ORIF - open reduction internal fixation; ATV - all-terrain vehicle; GSW - gunshot wound; MCC - motorcycle collision; MVC - motor vehicle collision.

show whether there is a significant difference in proportions between at least 2 of the groups compared. If the omnibus test is significant, then a series of 2 × 2 post hoc comparisons will be conducted adjusting for multiple comparisons. The *P* value was set at 0.05 for 2-tailed test. All analyses were conducted using SPSS version 22.0 (IBM Corp, Armonk, NY).

RESULTS

Epidemiology

There were 184 men and 131 women (Table 1): 122 men and 76 women in the closed group; 28 men and 33 women in the percutaneous reduction group; and 34 men and 22 women in the open reduction group. The overall average age was 41.9 years with a range of 16–89 years. The average age in the closed group was 40.2 years, the percutaneous group was 46.3 years, and the open group was 43.0 years. The rates of tobacco use and presence of diabetes among the groups are listed on Table 1.

General Considerations

The distribution of injury mechanisms were as follows: Fighting, 1; ATV, 4; Bicycle, 15; Boat, 2; Crush injury, 8; Equestrian, 3; Low energy fall, 103; High energy fall, 8; GSW, 2; Blunt Impact, 7; MCC, 47; MVC, 45; Pedestrian Struck, 56; Sports related, 13; Stress fracture, 1 (Table 1). Average follow-up was 14.04 months (range, 3–125 months). Patients with follow-up less than 12 months were included only if they had documented clinical and radiographic union with no complications at the time of last follow-up.

Wound Complications

The overall wound complication rate was 1.6% (5/317). In the group of patients treated with closed reductions, the wound complication rate was 1% (2/200; Table 2). In the percutaneous reduction group, the wound complication rate was 1.6% (1/61). In the open reduction group, the wound complication rate was 3.6% (2/56). There was no significant difference between the groups (*P* = 0.187). All 5 patients had resolution of their superficial wound complications.

Deep Infection

The overall deep infection rate was 2.8% (9/317). In the group of patients treated with closed reductions, the deep infection rate was 2% (4/200; Table 2). In the percutaneous reduction group, the deep infection rate was 1.6% (1/61). In the open reduction group, the deep infection rate was 7.1% (4/56). There was no significant difference between the groups (*P* = 0.138). In the closed group, the average time to presentation of deep infection was 5.75 months (range, 1–12 months). Three of the 4 fractures were healed before presentation of deep infection and treated with debridement and removal of implants. One patient had an infected hematoma at 1 month and was treated with surgical debridement and went on to union. In the open group, the average time to presentation of deep infection was 6.75 months (range, 3–13 months). Two of the 4 were healed before presentation of deep infection and were treated with debridement and removal of implants. One patient was treated with multiple debridements and bone grafting, and 1 patient received an antibiotic nail exchange. Both fractures went on to union. One patient in the percutaneous group developed a deep infection at 1 month in the fibular incision after simultaneous ORIF of the lateral malleolus at the time of tibial fixation. This was treated with debridement and irrigation with removal of fibular implants upon fracture union. All 9 patients were deemed clear of infection at final follow-up.

Nonunion

The overall nonunion rate after initial surgery was 5.3% (17/317). Sixteen patients underwent revision surgery with nail dynamization or exchange nailing, and one patient was scheduled for exchange nailing at the time of data collection. At last follow-up, 15/16 operated patients had achieved union. One patient, in the closed reduction group was treated with nail dynamization, and at the 4-week postoperative visit demonstrated new callus and decreased pain, but was subsequently lost to follow-up. The distribution of nonunions within the groups was as follows: In the group of patients treated with closed reductions, the nonunion rate was 5.0% (10/200; Table 2). In the percutaneous reduction group, the nonunion rate was 4.9% (3/61). In the open reduction group, the nonunion rate was 7.1% (4/56). There was no significant difference between the groups (*P* = 0.717). Of the 16 nonunions encountered in this study, 7 were classified as hypertrophic nonunions, and 9 were classified as atrophic nonunions. The distribution of nonunion type among the groups based on reduction techniques is as follows. Of 10 nonunions in the closed reduction group, 5 were hypertrophic, and 5 were atrophic. Of the 3 nonunions in the group with percutaneous reductions, 1 was hypertrophic and 2 were atrophic. Of 3 nonunions in the group with open reductions, 1 was hypertrophic and 2 were atrophic.

DISCUSSION

Closed tibial shaft fractures treated with percutaneous or open reduction techniques for intramedullary nailing showed no difference in superficial wound complication, deep infection, or nonunion, compared with closed reduction in our series. Three previous studies have compared similar

TABLE 2. Rates of Complications Associated With Type of Reduction Performed before Intramedullary Fixation

	Closed Reduction (n = 200)	Percutaneous Reduction (n = 61)	Open Reduction (n = 56)	*P*
Wound complications (%)	2 (1)	1 (1.6)	2 (3.6)	0.179
Infection (%)	4 (2)	1 (1.6)	4 (7.1)	0.133
Nonunion (%)	10 (5)	3 (4.9)	4 (7.1)	0.492

techniques.[4–6] Tang et al showed no statistical difference between the study groups with respect to infection rates or union rates after open or closed reduction. Their study included patients treated with percutaneous techniques and reductions performed through fasciotomy incisions in the open treatment group, with only 13 patients of 40 receiving a formal open reduction. Our study differs in 2 major ways. First, we have chosen to divide the patients into 3 types of reduction techniques, rather than 2. This was done to determine whether placing formal open reductions, as its own group would yield any difference to the outcomes studied. Second, we chose to exclude patients treated for compartment syndrome. These patients would have had reductions performed through fasciotomy incisions placed for treatment of the compartment syndrome, rather than for open reduction of the fracture. Collinge et al retrospectively evaluated 28 patients treated with percutaneous reduction to 26 patients treated with closed reduction before intramedullary fixation in simple spiral or oblique tibial shaft fractures. They found that residual fracture gap was the only independent risk factor for increased time to union. In contrast, we included all tibial shaft fracture patterns in our study because percutaneous or open reduction techniques may be useful for additional injuries. Bishop et al found no difference in infection rates or union rates in 11 patients treated with formal open reduction and intramedullary fixation compared with closed reduction and intramedullary fixation. Our study reports similar findings, but with a significantly larger number of patients with open (56 fractures) or percutaneous (61 fractures) reductions.

The overall rate of wound complications was 1.6% in our study. When divided by closed, percutaneous, or open, or reduction the rates of superficial infection were 1, 1.6 and 3.6%, respectively. Interestingly, none of the superficial wound complications in the open or percutaneous group were associated with the incisions made for fracture reduction.

The deep infection rate in our study was 2.8% for 317 fractures. Published infection rates of closed tibia fractures treated with intramedullary nailing ranges between 0% and 4%.[7–11] Our overall rate of 2.8% falls within this range, as does our rate for patients treated with closed reduction (2%) and percutaneous reduction (1.6%). Our patients treated with open reduction had a 7.1% deep infection rate. Tang et al[4] reported a deep infection rate of 5% (2/40) in their open group. However, when only formal open reductions are considered in their study, the deep infection rate is 7.7% (1/13). Bishop et al[6] reported a deep infection rate of 9.1% (1/11) in their group of tibial shaft fractures treated with open reduction. Our rate or 7.1% is similar to that reported by these groups, and is not statistically significantly different than our patients treated with closed reductions. Our rate of deep infection (1.6%, 1/61) was slightly lower than that reported by Tang et al (4.5%, 1/22 patients) and Collinge et al (3.5%, 1/28).[4,5]

The overall nonunion rate for the fractures treated in our study was 5.3%. Fracture union was determined by the treating orthopaedic traumatologist, and was determined by bridging callus on 3 or more cortices on radiographs, and absence of pain with ambulation at the fracture site. The nonunion rate of fractures treated with closed reduction was 5%. This is consistent with published nonunion rates of closed tibia fractures treated with intramedullary nailing, which is reported to be between 5% and 17%.[12–16] The nonunion rates of patients treated with percutaneous or open reduction were 4.9% and 7.1%, respectively, neither of which were statistically different than the nonunion rates of fractures treated by closed means. Historical treatment of tibial shaft fractures with open reduction and plate fixation has been associated with adverse outcomes felt to be related to soft tissue stripping and devascularization of fracture fragments.[3,17] Intramedullary fixation with closed reduction preserves the soft tissue envelope of the fracture, but may come at the expense of suboptimal reduction, which has been shown to be an independent risk factor for nonunion.[5,18] With this consideration, our treatment of closed tibial shaft fractures consists of attempts at closed reduction. However, if fracture reduction is not acceptable, percutaneous or open reductions are used, with meticulous soft tissue techniques, to achieve adequate fracture alignment and decrease time to union.[5]

Limitations of this study include selection bias, as the determination of the reduction technique was at the discretion of the treating surgeon. In addition, because this was a retrospective study without standardized radiographs, we were unable to perform accurate measurements for analysis to determine if the quality of reduction was better in the percutaneous or open groups or had an influence on rates of malunion or nonunion. Additionally, we have not included functional outcome scores in the patients included in this study, as they are not available given the study design. The use of blocking screws is an additional percutaneous technique that was not analyzed. However, blocking screws are not always used in the zone of injury and therefore may not carry the additional concerns of percutaneous and open techniques at the fracture site. And finally, the findings in the study must be taken with caution given the sample size. A post hoc power analysis was conducted based on N = 322, a small effect size (w = 0.1) and an alpha = 0.05, and the results showed power (1 − b) = 0.34, which is partially due to the very low rates of complications for each comparison group. Approximately 1000 patients would be required to have a minimum power of 0.80.

In conclusion, this is the largest reported series of closed tibial shaft fractures nailed with percutaneous and open reduction. We found that percutaneous or open reduction of closed tibial shaft fractures did not result in increased wound complications, infection, or nonunion rates in comparison with closed reduction methods. As a result, we recommend that carefully performed percutaneous or open approaches can be useful in obtaining reduction of difficult tibial shaft fractures treated with intramedullary devices.

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