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Original Article

A retrospective study of open reduction and traction bed-assisted closed reduction intramedullary nailing for femoral shaft fracture

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Abstract: Objective: To compare treatment of femoral shaft fractures using traction bed assisted closed reduction (CR) or conventional open reduction (OR) for intramedullary nail fixation. Methods: The study group consisted of 126 patients with femoral shaft fractures who were treated via intramedullary nail fixation from July 2009 to May 2013. Traction bed assisted CR was adopted in 71 patients, while OR was performed in 55 cases. Data regarding surgery duration, intraoperative blood loss, complications and recovery of postoperative hip and knee function were abstracted and analyzed. Results: In patients with non-comminuted fractures, no significant differences were observed between the CR and OR groups in operation time (P = 0.560) or blood loss (P = 0.739). However, in patients with comminuted fractures, operation time (P = 0.024) and blood loss (P = 0.008) were significantly reduced in the table traction group when compared with the OR group. All patients in the CR group had prolonged positioning time (P = 0.000), but no statistically significant differences were found between the open and CR groups in the function of the hip (P = 0.058) or knee (P = 0.625) of the injured limb. Conclusions: Treatment of comminuted femoral shaft fractures using traction bed assisted CR during intramedullary nail fixation had the advantages of reduced surgical time and less intraoperative blood loss when compared with conventional OR.

Keywords: Femoral shaft fracture, closed reduction, open reduction, traction bed, intramedullary nailing

Introduction

Fracture of the femoral shaft is a common clinical injury, and comprises 6% of all fractures. Management strategies include conventional traction, external fixation, open reduction (OR) and plate fixation, and open or closed intramedullary nailing [1].

Closed intramedullary nailing is the gold standard for adult femoral shaft fracture management [1]. However, closed intramedullary nailing is technically demanding and not appropriate for inexperienced practitioners. Complications that can further increase the challenge of the procedure include difficult reduction secondary to soft tissue interposition, an abducted proximal fragment with a strong muscular pull and unstable reduction in comminuted fractures. To circumvent these problems, Kuntscher *et al.* [2] developed the traction bed. The traction bed can generate longitudinal traction, aid fractured fragment alignment and help restore length and normal anatomy during fracture management procedures.

Comparisons of the different management techniques for femoral fractures have been reported [3-5]. However, few comparisons of traction bed assisted closed reduction (CR) and OR during intramedullary nailing of femoral fractures have been reported. This retrospective study compared specific operation processes and patient outcomes associated with these techniques.

Materials and methods

Patients

This study was reviewed and approved by the Ethical Commission of The Second Affiliated Hospital of Soochow University. The clinical data of 126 consecutive patients treat-

Table 1. Demographics and clinical data

	Open reduction (n = 55)	Closed reduction (n = 71)	*P*-value
Age (yr)	42.4 ± 17.8	42.8 ± 18.0	0.896
Gender (male)	44 (80%)	48 (68%)	0.120
Glasgow coma score (points)	14.8 ± 0.9	14.9 ± 0.4	0.283
Cause of injury			0.686
Recreation/Sports	14 (25%)	20 (28%)	
Motor vehicle	32 (58%)	35 (49%)	
Fall injury	5 (9%)	11 (15%)	
Crush injury	4 (7%)	5 (7%)	
AO fracture type			0.410
A	22 (40%)	37 (52%)	
B	25 (45%)	25 (35%)	
C	8 (15%)	9 (13%)	
Gustilo fracture type			0.784
O	46 (84%)	59 (83%)	
I	5 (9%)	6 (8%)	
II	4 (7%)	4 (6%)	
III	0 (0%)	2 (3%)	

ed between July 2009 and May 2013 at The Second Affiliated Hospital of Soochow University were retrospectively reviewed. Femoral shaft fractures were diagnosed clinically and radiologically. Intramedullary nailing was used in all cases. Exclusion criteria included severe infection, immune-compromised status and pregnancy. Traction bed-assisted CR was performed in 71 cases, and OR with interlocking procedures in 55 cases.

OR

The patient was put into the lateral position. A 5-cm curved incision was made superior to the greater trochanter of the injured limb. A guide pin was inserted to localize the fracture site. After confirming the fracture position, a 10-cm incision centered over the fracture was made on the lateral aspect of the femur. The fracture ends were cleaned and the distal end of the bone was delivered through the incision. A guide wire was passed through the distal fragment after which reaming was performed. The nails (TRIGEN, Smith & Nephew) were inserted and locked under the image intensifier and C-arm fluoroscopy.

Traction bed-assisted CR

The patient was placed in a supine position on a traction bed with the normal limb in the lithotomy position with the hip and knee in flexion. The injured extremity was placed in an extended position, and the ankle fixed on the traction bed with a traction bow. To induce pelvic protrusion and position the patient for more convenient greater trochanter opening and nailing, the patient's torso was laterally bent towards the uninjured side and a *barrier apparatus* was set to maintain the position. The traction bed was initially set up with the exterior and interior limb rotation control handle in the loose position. After the initial reduction, the injured limb was given traction in a position with 20° flexion and adduction until mild over traction was achieved (the broken ends of fractured bone were slightly distracted). The traction induced muscle tension reduced the rotational deformity of the injured limb. Once correctly positioned, all traction posts and fixtures were tightened and the entire operating bed was inclined to raise the injured side approximately 20 degrees for more convenient greater trochanter opening and nailing.

Initial reduction was performed using C-arm fluoroscopy before sterilization and draping. C-arm fluoroscopy was performed in both the anteroposterior and lateral planes with traction bed assistance. The process of creating the incision and entry point through the trochanteric fossa was similar to that used in the OR technique. Adequate reduction was achieved after guide pin insertion, then reamed intramedullary nailing was performed and two distal interlocking nails and one proximal screw were carefully placed. Intra and postoperative C-arm fluoroscopy showed a reduced and aligned fracture.

Postoperative evaluation

Data regarding surgery duration, intraoperative blood loss, complications and the progress of the postoperative recovery of hip and knee function were abstracted and analyzed. Hip function was assessed using the Harris Hip

Table 2. Comparison of surgical outcomes between patients treated with open or closed reduction

	Open reduction (n = 55)	Closed reduction (n = 71)	*P*-value
Operative time (min)			
Positioning	20.6 ± 6.1	31.0 ± 7.7	< 0.001
Operation	190.9 ± 62.9	170.7 ± 48.9	0.052
Fluoroscopy time (time)	24.8 ± 5.4	26.0 ± 4.5	0.148
Hemoglobin (g/L)			
Preoperative	121.0 ± 17.9	115.9 ± 16.8	0.102
Postoperative	89.5 ± 16.0	87.3 ± 15.3	0.433
Hematocrit (%)			
Preoperative	36.1 ± 4.9	34.6 ± 5.4	0.120
Postoperative	26.8 ± 4.3	25.8 ± 4.5	0.242
Range of motion			
Hip flexion (°)	117.1 ± 9.6	117.8 ± 18.5	0.783
Knee flexion (°)	116.3 ± 9.0	114.7 ± 8.4	0.292
Limb-length discrepancy	4	7	0.848
Malrotation	7	6	1
Lower-extremity function			
Knee hss (score)	89.4 ± 7.4	90.0 ± 7.1	0.625
Hip harris (score)	92.6 ± 5.7	90.4 ± 6.7	0.058

Table 3. Comparison of surgical outcomes between AO type A fractures treated with open or closed reduction

	Open reduction (n = 22)	Closed reduction (n = 37)	*P*-value
Operative time (min)			
Positioning	19.3 ± 5.4	29.6 ± 8.4	< 0.001
Operation	157.7 ± 43.1	163.9 ± 36.8	0.560
Fluoroscopy time (time)	26.1 ± 6.1	26.1 ± 4.4	0.994
Hemoglobin (g/L)			
Preoperative	122.2 ± 20.0	115.6 ± 17.9	0.196
Postoperative	93.2 ± 14.7	85.2 ± 15.5	0.055
Hematocrit (%)			
Preoperative	36.7 ± 5.3	35.0 ± 5.5	0.258
Postoperative	27.7 ± 4.1	25.6 ± 4.8	0.095
Range of motion			
Hip flexion (°)	119.8 ± 7.9	120.1 ± 21.8	0.941
Knee flexion (°)	116.4 ± 9.8	114.2 ± 8.3	0.366
Limb-length discrepancy	2	3	1
Malrotation	3	4	1
Lower-extremity function			
Knee hss (score)	89.5 ± 6.9	89.9 ± 7.40	0.834
Hip harris (score)	92.6 ± 5.3	90.3 ± 7.5	0.177

Score, and knee function was assessed using the Hospital for Special Surgery Knee Scoring System.

Statistical analysis

Data were expressed as means ± standard deviation. Normally distributed data were compared using the Student's *t*-test; otherwise, rank-sum tests were conducted. All statistical analyses were performed using SPSS 17.0 (SPSS, Chicago, IL). A $P < 0.05$ was considered statistically significant.

Results

There was no significant difference in age, sex, cause of trauma or fracture type between the CR and OR groups (**Table 1**). All patients were followed for at least one year after the procedure. CR and OR group comparisons are shown in **Table 2**. The CR group required a longer positioning time than the OR group ($P < 0.001$). There were no other statistically significant differences in treatment parameters between the groups. However, some differences were observed when patents were classified with non-comminuted AO type A fractures and comminuted AO types B and C fractures.

In patients with non-comminuted AO type A fractures, no significant differences were seen in operative time ($P = 0.560$) or intraoperative blood loss ($P = 0.739$) between the OR and CR techniques (**Table 3**). However, in patients with comminuted AO type B and C fractures, the CR technique achieved significantly better outcomes than OR (**Table 4**). Operation time and intraoperative blood loss were significantly reduced for the type B and C fractures in the CR group ($P = 0.024$ and $P = 0.008$, respectively). One drawback observed in the CR group

Table 4. Comparison of surgical outcomes between AO types B and C fractures treated with open reduction or closed reduction

	Open reduction (n = 33)	Closed reduction (n = 34)	*P*-value
Operative time (min)			
Positioning	21.4 ± 6.4	32.5 ± 6.7	< 0.001
Operation	213.1 ± 64.7	178.1 ± 59.1	0.024
Fluoroscopy time (time)	23.9 ± 4.8	26.0 ± 4.7	0.072
Hemoglobin (g/L)			
Preoperative	120.2 ± 16.7	116.1 ± 15.9	0.311
Postoperative	87.0 ± 16.5	89.5 ± 14.9	0.508
Hematocrit (%)			
Preoperative	35.7 ± 4.6	34.2 ± 5.3	0.233
Postoperative	26.1 ± 4.4	26.1 ± 4.2	0.948
Range of motion			
Hip flexion (°)	115.3 ± 10.2	115.3 ± 13.9	0.986
Knee flexion (°)	116.3 ± 8.5	115.2 ± 8.5	0.609
Limb-length discrepancy	2	4	0.697
Malrotation	3	2	0.641
Lower-extremity function			
Knee hss (score)	89.3 ± 7.8	90.2 ± 6.8	0.639
Hip harris (score)	92.6 ± 6.0	90.6 ± 5.8	0.169

was a prolonged positioning time (P < 0.001). There was no significant difference in fluoroscopy time or hip and knee function between the CR and OR groups.

Discussion

Intramedullary nailing using OR and CR are the two common methods of femoral shaft fracture management. In this study, we described traction bed assisted CR and compared the two reduction techniques in terms of their immediate performance, complication rates and long-term outcomes.

Interlocking intramedullary nails have been the most widely used type of intramedullary nails since their first use in femoral shaft fracture repair by Kuntscher in the 1960s [2]. This method is widely accepted among orthopedic trauma surgeons, and has the reported advantages of central fixation, anti-rotation and early recovery of weight bearing capacity [6]. Additionally, interlocking intramedullary nailing assisted CR avoids damaging the circulation of the periosteum and promotes osteogenic callus formation [7, 8]. It has been suggested that the success of interlocking intramedullary nailing depends on the design of an appropriate treatment strategy. Surgical skill level, the quality of surgical materials and the choice of the proper rehabilitation exercises were all shown to be crucial to successful operation performance and optimal outcomes [9]. This study emphasized a specific process of traction bed assisted closed reduction with the intent of sharing clinical experience and providing optimal suggestions for the performance of intramedullary nailing operations.

Optimal traction along the desired trajectory plays an important role in reduction. With the assistance of the traction bed, it was relatively easy to distract and align the broken ends of fractured bone longitudinally. Once the patient was placed in the ideal traction position, all the attachments of the table were secured in their respective positions and the entire operating bed was inclined to raise the injured side approximately 20 degrees for more convenient greater trochanter opening and nailing. Traction is released immediately once the intramedullary nail crosses the fracture site. This prevents over distraction at the fracture site, as well as any complications due to prolonged traction. When preoperative preparation was assisted by the traction bed, the displacement trend of the femoral shaft fracture could be accurately diagnosed with a pre-reduction procedure. This technique simplifies the intraoperative reduction and the insertion of the guide pin. However, according to previous studies comparing traction bed assisted treatment of femoral shaft fractures to manual reduction, the traction bed did not effectively decrease surgery time or improve the quality of the operation. Preoperative preparation also increased the risks associated with X-ray exposure [3, 5, 10]. Nevertheless, our experience with manual closed reduction has shown that this technique requires significant radiographic exposure. Additionally the technique requires additional personnel, is often hard to accomplish and frequently requires subsequent open reduction, especially in muscular or obese patients.

A comminuted fracture represents a bone that has been splintered, crushed, pulverized or broken into several pieces, giving rise to many small fragments [11]. In this study, we found that the operative time and intraoperative blood loss could be reduced in comminuted B and C type fractures of the femoral shaft by employing CR with traction bed assistance. Similarly, Wu, Y. Y. *et al.* examined the treatment of proximal tibial multi-segment comminuted fractures using either CR or the less invasive stabilization system (LISS). They concluded that CR was the superior option due to its ability to provide rigid internal fixation, with a high rate of union and a low rate of infection [12]. However, Chrcanovic, B. R. suggested that if the surgical team is not well versed in the nuances of rigid internal fixation, or if the necessary equipment is not available, it may be better to perform an OR and internal fixation or a simple CR and immobilization [11]. Though OR is presented with certain advantages in simple fractures, its operation in comminuted fractures may cause difficulties for load-sharing osteosynthesis. This is because small fragments cannot be compressed and are not capable of sharing loads. For patients with comminuted fractures, we recommended CR as an optimal and superior management technique, whereas, in these patients, OR would lengthen operative time and cause a significant increase in blood loss. As for simple fractures of the femoral shaft, no differences were found between CR and OR management. Here, we demonstrated that, despite prolonged preoperative positioning time, traction bed assisted CR is a feasible comminuted fracture management technique that significantly decreases operative time and blood loss.

Previous research demonstrated that one of the advantages of CR was that the technique did not destroy the circulation of the periosteum, and could reverse hematoma during fracture restitution. Fractures treated by CR had a higher proportion of restitution and a lower rate of infection [7]. Nevertheless, since femoral shaft fractures are associated with complications, such as avascular necrosis (AVN), some considered CR treatment inferior to other available techniques. A recent meta-analysis conducted by Wang, W. *et al.* showed that femoral head AVN risk was significantly higher after CR when compared with OR, but drew no association between the healing rate in the two reduction techniques [13]. Other studies demonstrated similar results, determining that OR resulted in fewer complications [14-16]. The CR results in our study were satisfactory with regard to both intraoperative and postoperative complications. Additionally, there were no significant differences between the postoperative knee and hip function of the CR and OR groups. Based on the favorable clinical outcome observed in our study, we suggest that CR is an optimal treatment for femoral shaft fracture, particularly with comminuted fracture.

However, there are still inevitable limitations in this study. During follow-up, the hip and knee function of patients was assessed instead of performing specific analysis to detect probable complications (such as AVN and its relevant risk factors). Considering prior research, the apparently higher risk of complications with CR needs to be assessed more comprehensively.

Conclusions

Though requiring longer positioning time, treatment of comminuted femoral shaft fractures using traction bed assisted CR during intramedullary nail fixation had the advantages of reduced surgical time and less intraoperative blood loss when compared with conventional OR.

Disclosure of conflict of interest

None.

Authors' contribution

ZFL and YF, carried out the studies, performed data analyses and drafted the manuscript. MHC and YTM performed analyses of samples. JL and XFL participated in study design and performed the statistical analysis. YL and Xiao-Xiang Xu conceived of the study, and participated in study design, coordination and drafting of the manuscript. All authors read and approved the final manuscript.

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