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A Retrospective Review on Atypical Femoral Fracture: Operative Outcomes and the Risk Factors for Failure

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Abstract

Background: Atypical femoral fractures have been demonstrated to have high risks of reoperation and nonunion. The aim of this study is to evaluate whether the quality of reduction following operative fixation of atypical femoral fracture predicts failure. **Methods:** This is a 6.5-year retrospective review of atypical femoral fractures from 2 centers in a high-income region. A total of 56 patients with 66 fractures met our inclusion criteria. The quality of reduction was evaluated from postoperative films according to Hoskins' modification of Baumgartner criteria for subtrochanteric fractures. Our primary outcome measure was failure of treatment, defined as either reoperation or nonunion at 12 months. **Results:** There were a total of 8 reoperations (12% of all fractures) and 8 nonunion (12% of all fractures), affecting a total of 12 fractures (18%) in 12 patients (21%). Closed reduction ($P = .04$) and poor quality of reduction ($P = .0227$ Fisher exact test) are statistically significant risk factors for failure. **Conclusions:** An aim for anatomical reduction with both <4 mm maximal cortical displacement and <10° angulation can improve the operative outcome of atypical femoral fractures. The addition of open reduction may be beneficial.

Keywords

atypical femoral fracture, bisphosphonate, fracture healing, subtrochanteric fracture, osteoporosis

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Introduction

Since the first case reports of atypical femoral fractures (AFFs) were published by Odvina et al,[1] there had been a continued debate on the epidemiology, associations, and pathogenesis of AFF.[2,3] Asians are thought to be at risk of developing AFF, with reports in the United States by both Lo and Dell showing overrepresentation of Asian patients.[3-5] As it is a relatively rare condition and with a lack of randomized controlled trials, there is no strong evidence to guide the management of AFF.[6] Expert opinions suggest a multidisciplinary approach, including discontinuation of bisphosphonates (BPs), adequate calcium and vitamin D, and consideration of teriparatide, a recombinant form of parathyroid hormone, as adjuvant.[3,7] Surgical intervention has been emphasized in treating AFFs, and techniques that allow for endochondral ossification, such as intramedullary nailing and bridging plate, are recommended.[6]

Atypical femoral fractures have also been demonstrated to have a high risk of complications. Reports have indicated that these fractures are more difficult to treat surgically, more prone to delayed healing or nonunion, and have a higher incidence of implant failure and reoperations when compared to the usual femoral fractures.[8-11] In Weil et al's series, there was an alarming surgical revision rates of 46%[11] and in Teo et al's retrospective review 33%.[8] However, the risk factors for developing these complications are not well known.

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Table 1. ASBMR 2014 Criteria.[2]

Fracture located along the femoral diaphysis from just distal to the lesser trochanter to just proximal to the supracondylar flare, in the presence of at least 4 of 5 major features
• The fracture is associated with minimal or no trauma, as in a fall from a standing height of less
• The fracture line originates at the lateral cortex and is substantially transverse in its orientation, although it may become oblique as it progresses medially across the femur
• Complete fractures extend through both cortices and may be associated with a medial spike; incomplete fractures involve only the lateral cortex
• The fracture is noncomminuted or minimally comminuted
• Localised periosteal or endosteal thickening of the lateral cortex is present at the fracture sites ("beaking" or "flaring")

Abbreviation: ASBRM, American Society for Bone and Mineral Research.

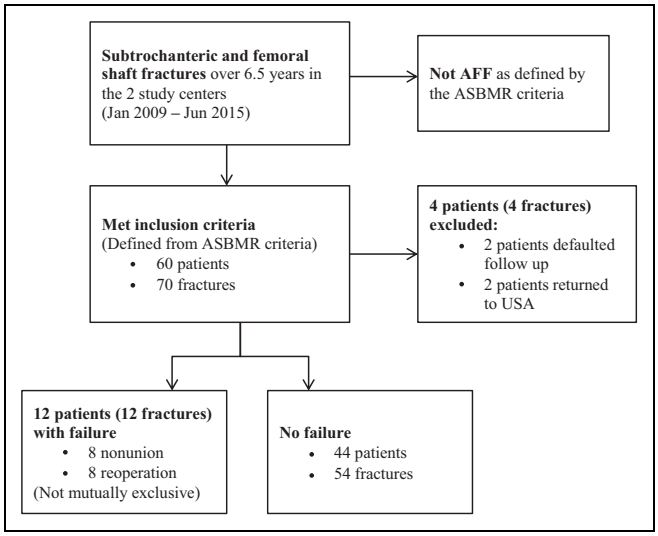

Figure 1. Study flow diagram.

Experience from subtrochanteric fracture without atypical features suggest malreduction will result in increased delayed union or nonunion.[12] The aim of our study is to look at if the quality of reduction following operative fixation of AFF predicts failure. The primary outcome measure is a composite measure of major complications, defined as reoperation for fixation failure at any time point, or nonunion at 1 year postoperatively. Local ethical committee approved the study with consent exemption due to retrospective observational nature of data collection.

Methods

Study Design

This is a retrospective observational cohort study in 2 centers in a high-income region. During the period January 1, 2009, to June 30, 2015, all consecutive adult patients admitted with the *International Classification of Disease, Ninth Revision* coding 821.01 or 821.11/820.22 or 820.32 for subtrochanteric or shaft fractures were evaluated with respect to the following inclusion and exclusion criteria. Inclusion criteria are based on the clinical and radiological features of AFF as defined by the American Society for Bone and Mineral Research major criteria (Table 1).

Patients were excluded if they did not have a minimum follow up of 1 year or if they had pathological features not related to atypical fracture or osteoporosis.

Outcome Measures

Surgeries were performed by trauma surgeons, and patients underwent standard rehabilitation following the procedure. Demographic information and surgical details were recorded from the hospital electronic records. The quality of reduction was evaluated by the postoperative standard X-rays in the anteroposterior (AP) and lateral views using digital picture archiving and communication system and based on Hoskins' modification of Baumgartner criteria for subtrochanteric fractures.[13,14] This method is based on both residual displacement and angulation at the fracture site after fixation; reduction is classified as good (both maximal cortical displacement <4 mm and angulation <10°), acceptable (either maximal cortical displacement <4 mm or angulation <10°), or poor (maximal cortical displacement >4 mm and angulation >10°).[13]

All patients had follow-up duration of at least 12 months. The primary outcome measure is the failure of treatment, defined as either reoperation or nonunion at 12 months. Reoperation is defined as any unplanned operation of the same limb following the index operation, excluding planned staged approach for initial fracture management. Nonunion is defined as the absence of bridging callus on 3 of 4 cortices on AP and lateral X-ray views. Procedure-related complications and mortality within 1 year were also recorded.

Study Patients

During the study period of 6.5 years (between January 1, 2009, and June 30, 2015), there were 60 patients with 70 subtrochanteric or femoral shaft fractures treated in the 2 hospitals that met the inclusion criteria. Of these, 7 patients had bilateral fractures on presentation, while 3 patients had subsequent fracture of the contralateral femur within the study period. Four patients defaulted follow-up after 1 month, and they were excluded from the analysis (Figure 1). The overall inclusion rate was 56 (93%) of 60 patients or 66 (94%) of 70 fractures.

Statistical Analysis

Data were captured using REDCap,[15] and statistical analyses were performed using Stata13.[16] Descriptive statistics were used for demographics and fracture characteristics, with mean $\pm$ standard deviation (SD) presented for continuous variables and frequency (percentage) presented for categorical variables. Hypothesis testing for the binary outcomes were performed using Fisher exact tests with Freeman-Halton extension at a

Table 2. Demographics and Fracture Characteristics.

Age	75 years ± 9.5		
Gender: female/male	52 (93%)	4 (7%)	
Baseline mobility: independent/assisted	54 (96%)	2 (4%)	
Bisphosphonate: alendronate/others/unknown	35 (63%)	14 (25%)	7 (12%)
Fracture site: right/left	31 (47%)	35 (53%)	
Displaced fractures/undisplaced incomplete fractures	53 (80%)	13 (20%)	
Subtrochanteric/femoral shaft	30 (45%)	36 (55%)	

significance level of $P < .05$ due to the relative infrequence occurrence of nonunion or reoperation.

Results

The baseline demographics are presented in Table 2. The average age is 75 years, with the majority being female (93%). In all, 96% of them walked independently prior to the fracture. The most common BP used was alendronate (63% of patients). There were 30 (45%) subtrochanteric fractures and 36 (55%) femoral shaft fractures.

The mean operative time was 100 minutes (range: 39-199 minutes; SD = 40 minutes). Closed reduction was performed in 62% of fractures, whereas 36% required some form of open reduction using minor incisions and fracture manipulation with instruments. One patient had periprosthetic AFF and required a formal open reduction (details below). In all, 95% of implants were from Synthes (Solothurn, Switzerland) and the rest from Stryker (Kalamazoo, MI, USA). The majority underwent intramedullary nailing (93%) with the remaining with plate fixation. The most common intramedullary devices used were A2FN and PFNA (47% and 40%, respectively). Locking compression plates were used in 3 incomplete femur shaft fractures, spanning the whole femur with minimal invasive plate osteosynthesis technique. The patient who had periprosthetic AFF had a history of Austin Moore hemiarthroplasty many years ago for fragility hip fracture and a history of ipsilateral total knee replacement for degenerative joint disease. A formal open reduction with locking cable plate spanning the whole femur shaft was used, proximally with 3 screws and 2 Dall-Miles cables and distally 6 locking screws. There were 4 other fractures with supplementary fixation with cerclage and 2 with bone graft/substitute as augmentation.

In terms of complications, there were 2 intraoperative fractures or perforation of femoral cortex. Otherwise 4 patients had procedure-related complications including broken screw in 1 patient, superficial wound infection in 2 patients, and postoperative foot drop in 1 patient. In our series, there was 1 mortality unrelated to the index operation and was due to incarcerated incisional hernia that occurred 5 months after the index operation.

Regarding our primary outcome measures (Figure 2), there were a total of 8 reoperations (12% of all fractures) and

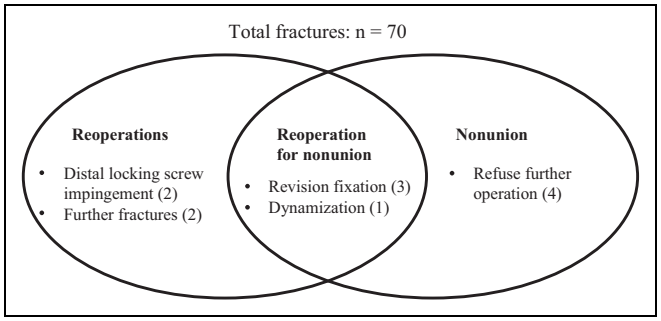

Figure 2. Primary outcome measures.

Table 3. Logistic Regression Analysis of Failure.

Variables	Coefficient	Standard Error	Z	P > |z|	95% Confidence Interval
Age	0.13	0.066	2.02	.043	0.0043 to 0.263
Complete fracture	0.34	1.25	0.27	.78	−2.11 to 2.79
Shaft fracture	−1.79	1.00	−1.78	.075	−3.76 to 0.18
Closed reduction	2.31	1.12	2.05	.040	0.106 to 4.50

Table 4. Quality of Reduction and Failure Rate.[a]

	Poor	Acceptable	Good	Total
Failure	3 (50%)	4 (31%)	5 (11%)	12 (18%)
No Failure	3 (50%)	9 (69%)	42 (89%)	54 (82%)
Total	6	13	47	66

[a]Fisher exact (with Freeman-Halton extension) = 0.0227

8 nonunion (12% of all fractures), affecting a total of 12 (18%) fractures in 12 (21%) patients. Among the 8 reoperations, 4 were due to nonunion: 3 of these patients underwent revision fixation and 1 underwent dynamization. Other reoperations include 2 patients with removal of distal locking screws due to impingement and 2 patients due to further fractures requiring further operative fixation. The other 4 nonunion patients refuse further operation.

Baseline variables, fracture characteristics, and surgery characteristics were analyzed and summarized in Tables 3 and 4. Age seemed to be a potential risk factor for failure ($P = .043$), whereas gender, ethnicity, and baseline mobility were not analyzed due to the small number of patients. In our series, there is no significant association between the fracture pattern (completeness and location) and failure. With regard to the potential modifiable factors, closed reduction ($P = .04$) and poor quality of reduction ($P = .0227$ Fisher exact test) were statistically significant risk factors for failure. The implant choice, supplementary cerclage, and augmentation could not be analyzed due to the small number of patients, but the 4 fractures with cerclage and the 2 with augmentation did not result in failure.

The quality of reduction is based on Hoskins' modification of Baumgartner criteria for subtrochanteric fractures[13,14] and

classified as good (both maximal cortical displacement <4 mm and angulation <10°), acceptable (either maximal cortical displacement <4 mm or angulation <10°), or poor (maximal cortical displacement >4 mm and angulation >10°).

Discussion

Our study reported a similar failure rate as that of a systematic review by Koh et al, where the revision surgery due to delayed union, nonunion, or implant failure was 12.6%.[17] In contrast to the series reported by Teo et al's with a surgical revision rate of 33%,[8] our series demonstrated better surgical outcomes. One contributing factors of their high reoperation rate could be due to the use of plates instead of intramedullary fixation devices, where in our series, 93% of fractures underwent intramedullary fixation. The implant choice could not be analyzed in our study due to the small number of patients, but a study by Prasarn et al demonstrated an alarming 44% major complication rates in his series of atypical fractures, but 40% of those fractures were treated with plate fixation.[10] His group observed that there were higher rates of implant failure when plates were chosen as the fixation device. Indeed Koh et al have demonstrated that there was a significantly greater percentage of revision surgery in those treated with plate fixation (31.3%) compared to intramedullary nailing (12.9%, $P < .01$) in his systematic review.[17] In more recent retrospective studies on the surgical outcomes of atypical fractures treated with only intramedullary nailing, the rate of union even reaches 95.7% to 98%.[18,19] Thus, many studies now advocate intramedullary fixation as the main surgical device in the management of AFF.

Another possible modifiable variable that predicts the failure of AFF fixation is the quality of operative reduction. Egol et al noted that a varus malreduction at the fracture site had negative impact on healing; specifically those fixed in varus required an average of 3.7 months more to heal compared to anatomically reduced fractures.[18] Another extensive study by Lim et al also demonstrated the importance of anatomical reduction in healing of AFF.[20] The reduction in coronal plane as well as the remaining gap at the fracture site were significant factors associated with delayed union or union. Most importantly, they concluded that the ratio of remaining gap to cortical thickness of ≥ 0.2 on the anterior and lateral sides of fracture sites was associated with problematic healing. Similarly, Cho et al's group showed that the quality of reduction is an important factor for healing and time to union.[21] They recommended cutoff values for measuring reduction for successful healing: neck-shaft angle greater than 125.6°, difference in neck-shaft angle with the normal side of less than 4.4°, and sagittal angulation less than 5.5°.

In our study, we looked at the quality of operative reduction under strict criteria by the Hoskins' modification of Baumgartner criteria for subtrochanteric fractures[13,14] and found that good reduction with both <4 mm maximal cortical displacement and angulation <10° is associated with lower failure rates ($P = .0227$ Fisher exact test). The benefit of using these criteria compared to the cutoff values quoted in previous studies is the ease of implementation intraoperatively using image intensifier. The addition of open reduction also appears to be beneficial ($P = .04$), likely through facilitating a more anatomical reduction. Hoskins et al suggested that the supplementation with cerclage wire statistically improves the fracture displacement, angulation, and quality of reduction in common subtrochanteric fractures.[13] Unfortunately, in our series, the numbers with cerclage were too small for statistical testing, but all 4 patients with cerclage were not shown to be harmful.

We recognize some limitations in our study. Since AFF is a rare condition, it is difficult to recruit a large sample for analysis. The current study is based on date from 2 centers in a high-income region and is one of the largest series available to date. Local registry is currently planned for systematic collection of data for further evaluation. Also, as a retrospective study, there would be observer bias, including no standardized quality and duration of follow-up, missing data and inability to control confounding variables. The failure rate may be overreported due to our definition of failure; in some patients, reoperation was not due to poor healing after the index operation. Functional outcomes were not included, as functional limitation is another measure of failure of treatment.

Conclusion

This study suggests that there is an 18% failure rate after surgical fixation of AFF, defined as either reoperation or nonunion at 12 months. The key to success in managing these fractures is good reduction with intramedullary fixation device under the strict criteria from Hoskins' modification of Baumgartner's criteria. Those who had a good reduction with both <4 mm maximal cortical displacement and <10° angulation had significantly less reoperation or nonunion. In certain cases, the addition of open reduction with or without cerclage may be beneficial.

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Declaration of Conflicting Interests

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