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Original Article

Evaluation of femoral malrotation after intramedullary nailing

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Abstract: Background: Intramedullary nailing and closed reduction are one of the most important treatment strategies for femoral shaft fractures. Malrotation in the femoral shaft is a complication that requires exact investigations. Here we aimed to evaluate and report the outcomes of malrotation of femur in patients with femoral shaft fractures following antegrade intramedullary nailing. Methods: In this cross-sectional study, 140 patients who had referred to Shahid-Beheshti Hospital in Abadan, Iran and had undergone antegrade intramedullary fixation for isolated femoral shaft fracture during a 6-year period from 2015 to 2021 were enrolled. Demographic information and disease-related information were collected. During operation, the patients were assessed clinically for malrotation of femur with 90° of the knee flection and with the hip in 0° flexion and then in the postoperative follow-up period, the patient was examined again and a computed tomography scan requested to identify the degree of malrotation of femur and the observers were unaware of the CT scan result at the time of the clinical examination. We also measured the amount of internal and external rotation while the patient in the lying supine position with 90° flexion in the knee and hip joint and lying prone position with hip extension. In CT imaging to determine the amount of malrotation of femur, the angle between a line drawn across the two femoral condyles in the posterior aspect and the femoral neck shows the amount of rotation. Results: Degree of rotational deformity, less than 5°, 5 to 10° and 10 to 15° was less than 8.6%, 75.7% and 15.7% respectively and did not relate to age, sex, fracture location and activity of the patients ($P>0.05$). There was a strong linear correlation with the average predictive power between clinically detected torsional deformity in comparison with the CT detected torsional deformity ($r=0.333$ and $P=0.005$), which was stronger in women than men ($r=0.336$ in men and $r=0.659$ in women) ($P<0.05$). There was a strong linear correlation with the average predictive power between clinically detected torsional deformity in comparison with the CT detected torsional deformity was observed only in external malrotation of femur ($r=0.541$ and $P=0.001$). A poor inverse linear relationship was observed between clinically detected and CT detected torsional deformity with the age of the patients which the correlation of clinically detected was more than the CT detected (r in clinical examination =-0.285 and r in CT measurement =-0.246) ($P<0.05$). Conclusion: In this study, there was no femoral malrotation over 15° that was associated with clinical symptoms. However, a CT scan should be performed for accurate diagnosis and necessary measures but it does not seem necessary to perform in all patients.

Keywords: Intramedullary nailing, femoral fracture, malrotation

Introduction

The femoral bone is the strongest bone among the long bones in the human body. Among the long bone fractures, the most common type of fracture is a femoral shaft fracture [1]. The average annual incidence of femoral shaft fractures is more than 37 per 100,000 patients, with the highest incidence in young males with a mean age of 38 years (62%) [2, 3]. The most common mechanisms that caused femoral shaft fractures are high-energy trauma and direct impact trauma mechanism which mostly correlated with multiple systemic injuries [4].

There are various methods of fixation of the femur including plates and screws, intramedullary nailing (IMN), traction and bracing. Over

time, the management of the femoral fractures has significantly progressed [5]. External fixation is commonly used for the treatment of open femoral shaft fractures, comminuted shaft fractures, and also unstable operative candidates. The most common postoperative complication of external fixation of femoral fractures is the stiffness in knee joint [6].

Gerhard Küntscher started intramedullary nailing for the femoral shaft fractures during the Second World War [5]. Today, the gold standard for the treatment of fractures of the shaft of the femur in adults is intramedullary nailing (IMN). Intramedullary nailing commonly performed with antegrade or retrograde entry points and both of these are safe and suitable [7].

Intramedullary nailing and closed reduction has many advantages that make it superior to open reduction and internal fixation with plates and screws [8, 9]. This technique caused a significant reduction in soft tissue damage, early limb mobilization, increased union rates, preserved the periosteum and hematoma of the fracture [10].

Despite the high union rate, the most complication in the treatment of femoral shaft fractures managed with closed intramedullary nailing is malrotation [11]. The incidence of postoperative rotational malalignment in fractures of the femoral shaft following closed intramedullary nailing varies from 17 to 35% [12]. Torsional deformity or rotational malalignment is expressed as a difference in femoral anteversion between the affected and unaffected sides [13]. Femoral malrotation can be evaluated clinically and by ultrasound, radiography, and computed tomography. The method of choice currently used to evaluate the rotational malalignment is CT [14].

So far, various studies have evaluated the results of rotational malalignment of the femur following antegrade intramedullary nailing in different populations but to the best of our knowledge, very few studies have investigated these results in our country. The current study aims to evaluate and report the outcomes of femoral malrotation in patients with femoral shaft fractures following antegrade intramedullary nailing.

Methods and material

Study design

In this cross-sectional study, 140 patients who had been referred to Shahid-Beheshti Hospital in Abadan, Iran and had undergone antegrade intramedullary fixation for isolated femoral shaft fracture during a 6-year period from 2015 to 2021 were enrolled. The study protocol was approved by the Research Committee of Abadan University of Medical Sciences and the Ethics committee has confirmed it (Ethics code: IR.ABADANUMS.REC.1392.13).

Study population

Demographic information and disease-related information were collected from all patients by a checklist. The total number of patients referred to the hospital who underwent femoral intramedullary nailing was 220 (174 men and 46 women). Seventeen of the above patients had pathological femoral fractures. Thirteen patients with the delayed union which undergone bone-grafting and removal of the proximal femoral screw and eventually led to the union. There were four cases of infected non-union that turned into infected union and eventually the femoral nail was removed. Sixteen of the above patients underwent retrograde nailing. There were 8 bilateral femoral shaft fractures and 22 fractures were open. One-hundred and forty of the above patients who underwent antegrade femoral nailing were enrolled in the study.

Inclusion and exclusion criteria

Inclusion criteria included isolated femoral shaft fracture, undergoing antegrade intramedullary nailing and signing the written informed consent to participate in this study. Exclusion criteria were spontaneous ipsilateral tibial fracture or pelvic fracture, contralateral femoral fracture, the femoral fracture that had fixed using plate or external fixator, or retrograde intramedullary nailing and patient's will to exit the study.

Procedures

During operation, the patients were assessed clinically for malrotation of femur with 90° of the knee flection and with the hip in 0° flexion

Table 1. Demographic data and rotation degree of patients

Variable		Amount
Age (years) (mean ± SD)		28.21±14.0
Gender (N (%))	Male	112 (80%)
	Female	28 (20%)
Malrotation (degree) (mean ± SD)	Based on clinical exam	4.67±0.23
	Based on CT scan	7.02±0.62

Table 2. Regression analysis and risk managements for different variables and malrotation

Variable	Crude model	
	OR (95% CI)	P
Clinically detected torsional deformity	0.333 (1.45-1.97)	0.005
Clinically detected torsional deformity in men	0.336 (1.44-1.91)	0.003
Clinically detected torsional deformity in women	0.659 (0.86-0.99)	0.002
Age (in reference to clinical examination)	-0.285 (1.27-2.10)	0.001
Age (in reference to CT measurement)	-0.246 (1.12-2.03)	<0.001

and then in the postoperative follow-up period, the patient was examined again and a computed tomography [12] scan requested to identify the degree of malrotation of femur and the observers were unaware of the CT scan result at the time of the clinical examination. Clinical examination measured the amount of internal and external rotation while the patient in the lying supine position with 90° flexion in the knee and hip joint and lying prone position with hip extension. In CT imaging to determine the amount of malrotation of femur, the angle between a line drawn across the two femoral condyles in the posterior aspect and the femoral neck shows the amount of rotation. A torsional difference of this angle between the uninjured and injured sides determines the amount of rotation. Decreasing in this angle indicated an increase in external rotation and increasing in this angle indicated internal rotation of the distal fragment of the femoral shaft fracture.

Data analysis

Statistical analysis was performed using SPSS software version 24 and we used independent t-test and chi-squared to analyze the data. P<0.05 was considered significant.

Result

Study population

The mean age of the patients was 28.21 years with a standard deviation of 14 years. The mean of malrotation of femur degree in the clinical examination was 4.67 and the mean of malrotation of femur degree in CT scan was 7 degrees (**Table 1**).

Rotation analysis

Degree of rotational deformity, less than 5°, 5 to 10° and 10 to 15° was less than 8.6%, 75.7% and 15.7% respectively and did not relate to age, sex, fracture location and activity of the patients (P>0.05). 112 cases (80%) were male and 28 cases (20%) were female. 78 patients (55.7%) had external malrotation of femur and 62 patients (44.3%) had internal malrotation of femur.

Correlation assessments

There was a strong linear correlation with the average predictive power between clinically detected torsional deformity in comparison with the CT detected torsional deformity (r= 0.333 and P=0.005), which was stronger in women than men. (r=0.336 in men and r= 0.659 in women) (P<0.05). There was a strong linear correlation with the average predictive power between clinically detected torsional deformity in comparison with the CT detected torsional deformity was observed only in external malrotations (r=0.541 and P=0.001) and patients with CT detected internal malrotation of femur did not coincide with those who had clinically detected rotational deformity. A poor inverse linear relationship was observed between clinically detected and CT detected torsional deformity with the age of the patients which the correlation of clinically detected was more than the CT detected (r in clinical examination =-0.285 and r in CT measurement =-0.246) (P<0.05) (**Table 2**; **Figure 1**).

Discussion

The rotational deformity is a common complication after intramedullary nailing of femoral shaft fracture. Femoral malrotation is expressed as a difference in femoral anteversion

Figure 1. CT scan reveling the femoral malrotation and its assessments.

between the affected and unaffected sides. Femoral malrotation can be evaluated clinically and by ultrasound, radiography, and computed tomography [12]. The method of choice currently used to evaluate the rotational malalignment is CT. The amount of the deformity is not clear, but the rotational difference in torsion angle rose to above 15° appeared to cause symptoms [15-17].

Our study was performed on 140 cases who undergone antegrade intramedullary fixation for isolated femoral shaft fracture during 6 years. The average age of the patients was 28.21 years with a standard deviation of 14 years. The mean of malrotation of femur degree in the clinical examination was 4.67 and the mean of malrotation of femur degree in CT scan was 7. Degree of rotational deformity, less than 5°, 5 to 10° and 10 to 15° was less than 8.6%, 75.7% and 15.7% respectively and didn't relate to age, sex, fracture location and activity of the patients (P>0.05). The significant point of our study was the absence of rotational deformity over 15° which may be due to the surgical procedure and the high experience of our trauma center surgeons. Also unlike other studies, we investigated the high number of cases.

In 2016, Vetter and colleagues [12] reported a retrospective review of 107 cases who underwent closed intramedullary nailing with a 5-year analysis. In this study, a postoperative CT scan determined that the average degree of femoral malrotation after intramedullary nailing was 11°±9.16°. The data analysis showed that 16 patients (14.9%) had femoral malrotation greater than 15° following closed reduction and intramedullary nailing. Overall, this study concluded that the treatment of femoral fractures with closed reduction and intramedullary nailing may cause postoperative rotational malalignment despite accurate monitoring during the operation. Also, this study recommended that the femur alignment be evaluated postoperatively by CT scan and corrected the malalignment in revision surgery to prevent the range of motion limitation.

In a study of 21 patients with femoral malrotation over 15°, it was found that these patients had functional problems, especially during sports activities, climbing stairs, and running. In this study, patients with external rotation deformity were more symptomatic than patients with internal rotational deformity. A rotational difference between the uninjured and injured side can be determined clinically or by radiography. Although clinical measurement of rotational deformity is the method that is often used, its accuracy has been questionable. Radiographic measurement methods are difficult to use because of patient positioning conditions [16, 17]. Studies showed that ultrasound and CT scans are reliable methods for

measuring malrotation of femur [18, 19]. Because ultrasound relies significantly on the experience of the observer, in this study, a CT scan was used to determine the degree of malrotation of femur deformity and compare it with clinical examination.

In 1993, Braten and others evaluated 110 patients with femoral shaft fractures after intramedullary nailing, 19% of patients had rotational deformity over 15°, and among these patients 38% were symptomatic [20]. In patients with a rotational malalignment of 10° to 15°, clinical symptoms were present in only 12% of cases. There was no clinical manifestation in patients with malrotation of femur of less than 10°, and also in our study, no relationship was found between malrotation and clinical complications. In Jaarsma and colleague's study, 112 patients with isolated femoral fractures were undergone antegrade femoral nailing [16]. The study was prospective and 31 cases did not refer for postoperative follow-up. Four patients died of causes not related to femoral fractures, and finally, 76 patients were studied consisted of 59 men and 17 women. The mean age of patients was 28 years. During operation, malrotation of femur was monitored by C-arm imaging and clinical examination (place the lower limb in 0° flexion).

Many studies have been done on the extent of the rotational deformity of the femur following antegrade intramedullary nailing but in our study, we investigated the high number of cases and to the best of our knowledge, very few studies have investigated these results in our country.

In the postoperative follow-up, the rotational deformity was measured and evaluated by clinical examination and CT scan. Clinical examination measured the amount of internal and external rotation while the patient in the lying supine position with 90° flexion in the knee and hip joint and lying prone position with hip extension. In computed tomography [12] imaging to determine the amount of malrotation of femur, the angle between a line drawn across the two femoral condyles in the posterior aspect and the femoral neck shows the amount of rotation. A torsional difference of this angle between the uninjured and injured sides determines the amount of rotation. Decreasing in this angle indicated an increase in external rotation and increasing in this angle indicated internal rotation of the distal fragment of the femoral shaft fracture. Twenty-eight percent of patients had a rotational deformity of 15° or more and this complication did not relate to fracture location. These patients had difficulties with activities like sports, running, and climbing stairs.

Patients with external malrotation of femur were more symptomatic than patients with internal rotation deformity, although in our study there was no statistically significant relationship in this regard. In Jiang and colleague's study, 36 patients with femoral shaft fractures who underwent femoral intramedullary nailing were studied. In the postoperative phase, based on the CT measurement a rotational deformity of 15° or more and 10 to 15° were detected in 19.4% and 47% of patients respectively. There were no correlations between age, gender and clinical complications of the surgery, which in this respect is similar to the findings of our study [21]. In Arpacioglu and other's study, 46 patients with femoral shaft fractures who underwent femoral intramedullary nailing were examined and found that only one patient had a rotational deformity of 15° or more and also only one patient had a complication in form of osteomyelitis. However, in our study, a case of osteomyelitis was observed, but the frequency of rotational deformity over 15° was not observed [17]. Kent and others reported that patients with femoral shaft fractures undergone femoral intramedullary nailing should be evaluated for rotational deformity. For this purpose, the CT scan is a useful and accurate method that confirms the findings of our study [15]. Overall, based on all aspects, it is inferred that the use of CT scan is an accurate tool to measure the amount of rotational deformity after intramedullary nailing in patients with femoral shaft fracture and its findings are not affected by age, sex, functional limitations, and patient type.

Conclusion

In this study, due to the absence of rotational deformity over 15° that was associated with clinical symptoms, it does not seem necessary to perform a CT scan in all patients and it is recommended to examine the patient in the operating room after the femoral intramedul-

lary nailing and in patients with rotational deformity after surgery in terms of clinical examination, CT scan should be performed for accurate diagnosis and necessary measures. We also recommend that further studies should be conducted in this regard.

Disclosure of conflict of interest

None.

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