Precision of Using Contralateral Lesser Trochanter as a Landmark to Prevent Rotational Malalignment in Fracture Shaft of Femur: A Human Cadaveric Study

Arun Sawasdipong MD, FRCOST*,
Rattasat Sudnongbua MD*

** Department of Orthopaedic, Phramongkutklao Hospital, Bangkok, Thailand*

Background: *Rotational Malalignment is abnormal rotational alignment between proximal and distal parts of femoral bone. If there is more than 15 degrees of rotational malalignment in femoral bone, the patient will have abnormality of gait and they will have difficulties to perform their daily life activities. The chances to have rotational malalignment in femoral fracture are increased after intramedullary nailing which is more than plate and screws fixation. In this study, we used contralateral Lesser Trochanter to be the reference for rotational determiner.*

Material and Method: *17 pairs of never-broken cadeveric femur in the same person were randomly sampling and then measured the anteversion of both cadeveric femurs. Lessor trochanter of normal leg was measured to be as the landmark. The rotational malalignment was determined based on the differences between the starting angle and measured angle. Repeated measurements were done by the same investigators, other staffs, residents, and medical students to examine the precision.*

Results: *There was no statistically significance of both bone sides reported by intra-inter examiners (p-value = 0.904). However, we found high correlation for rotational malalignment in all 3 intra-examiners (p-value < 0.0001), and the intraclass-correlation coefficient was 0.919(0.819-0.968). Moreover, there was also a good correlation in all 3 Inter-examiners; statistically significant (p-value = 0.009), and ICC was 0.726 (0.198-0.926).*

Conclusion: *Our finding confirmed that the accuracy of contralateral lessor trochanter which was used to be a landmark for prevention of rotational malalignment in fracture of femoral shaft was highly reliable.*

Keywords: *Rotational Malalignment, Intramedullary Nail, Femoral shaft fracture, Lesser trochanter, Fluoroscopic control*

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Nowadays, intramedullary nailing fixation has been a gold standard treatment for femoral shaft fracture in adult as it requires a small incision, and minimum dissection of soft tissue. It also provides an excellent healing of the fracture and rapid recovery. Since the closed insertion technique of intramedullary nail requires technically demanding procedure, it is not feasible to secure an anatomical reduction under indirect reduction. This results in less rotational control in comparison to the opened reduction and internal fixation by plate and screws[1-5].

Correspondence to: Sawasdipong A, Department of Orthopeadic, Phramongkutklao Hospital, Bangkok 10400, Thailand.

Rotational malalignment is commonly established during the operation. This is due to the inadequate reduction of the fracture. In proximal fracture, the initial rotation of the proximal fragment is drawn towards external rotation due to action of glutei and iliopsoas muscles including external rotators of the hip. In a distal fracture, the distal fragment rotates outward because of the action of the plantaris and lateral gastrocnemius muscles. Rotational deformities may cause many clinical problems related to clinical significance if they are more than 15 degree[6-7]. This could cause a functional impairment, particularly in demanding daily life activities, such as climbing stairs, running, and playing sports. Degenerative arthritis of hips and knees are well recognized for long-term complications. Surgical correction is immediately required in some severe rotational malalignment. Patients with external malrotation score were significantly worse on functional scores based on the Knee Society scores than those with internal malrotation[7].

Previous studies reported that there were several methods to prevent rotational malalignment during intramedullary insertion, such as observing skin line, checking cortical thickness at fracture site from fluoroscope in AP and lateral view, comparing anteversion in normal side from lateral view through fluoroscope. Tornetta, Ritz and Kantorused two C-arm images to check-one with a true lateral image of the femoral neck and the other with the posterior condyles aligned[8]. The difference of inclination of the position of the C-arm reflects the angle of anteversion of the femoral neck. CT examination at follow-up revealed that only 5° of rotation was inaccurate. Braten et al described an alternative fluoroscopic technique to control femoral rotation[9]. The proximal femur was imaged with a horizontal beam at the angle of 30°, 45° or 60° to the long axis of the shaft. The angle between the horizontal plane and the central head-neck axis showed a good correlation with the real angle of anteversion. Ultrasound examination at follow-up revealed an average inaccuracy of 4.8°; however, they still have the same disadvantages. Both Tornetta et al and Braten et al did not considered the angle of anteversion of the unaffected side. The angle of femoral anteversion varies between 0° and 30°, with an average of 10° to 15° which is used as the standard for comparison. When assessing the degree of rotational malalignment following a fracture, it is essential to determine the degree of anteversion in the opposite side and then a proper calculation can be made. Hofstetter et al described the reduction of femoral fractures and correction of antetorsion by using computer-assisted fluoroscopy. This method allowed three-dimensional measurement of anatomical landmarks; and thus, the calculation of anteversion has a good degree of precision[10]. If femoral anteversion is not related to the standard 10° to 15° range, but is still associated with that of the uninjured side, the computer-assisted surgery may eliminate rotational malalignment.

Another method used as anatomical landmark is shape and appearance of contralateral lessor trochanter[11-13]. Deshmukh et al divided patients into two groups. In group A, the rotational alignment was simply determined by rotating the distal fragment in order to obtain uniform soft tissue tension around the fracture and a skin fold geometry resembling the normal limb[12]. In group B, the investigators used the shape and appearance of contralateral lessor trochanter intra-operatively to obtain rotational alignment, subsequently, they found rotational malalignment were 12.49° (6.4°-17.7°) and 4.1° (0°-9.9°) respectively. There was significant reduction of the malalignment by using the lessor trochanter technique.

In conclusion, using the contralateral lesser trochanter as a reference is an accurate method to minimize malrotation of a femur. Quantifying the profile of the lesser trochanter with computer assistance did not much improve the accuracy comparing to non-computerize technique, as rotational malalignments from these two techniques were found to be 2.2° (± 1.5°) and 2.3° (± 1.7°) respectively. From curve shape of lessor trochanter geometry, the graph showed that they can be used as a reliable reference, including lacking of inter and intra observers difference[14].

In this study, we used shape and appearance of contralateral lesser trochanter from fluoroscope to be the landmark and rotational malalignment control. We also did inter- and intra-observations.

Material and Method

We collected data from 17 pairs of cadeveric femur of the same person which were never-broken and in perfect condition, at Phramongkutklao hospital. We obtained the approval from ethic committee. There were no lesser trochanteric fractures, congenital abnormality, differences in length, and previous surgery. We prepared cadeveric femur of same person by adhering the number each pairs of cadeveric femur. We consequently randomly chose cadeveric femur male and female, measured anteversion of both cadeveric femur comparing to the other pairs, and then wrapped it with sponge to ensure the invisible inner broken bone. We measured lessor trochanter of the normal leg and used it as the landmark. We then placed cadeveric femur in neutral position by using inclinometer. Fluoroscopy was done to clearer see the shape and position of lesser trochanter of the normal leg, and we finally took the photos. We carried out trial the leg by stretching the cadeveric femur by the holder in the neutral posture and used K-wire around intercondylar area to measure the starting angle by using inclinometer. Consequently, we took the cadeveric femur out of the holder and used fluoroscope to re-size lessor trochanter and to have the closest size of lessor trochanter that recorded the normal leg as the landmark in which the space of fluoroscope is equal.

To determine the rotational malalignment, we measured the tested angle using inclinometer and calculate the difference between the starting angle and the measured angle. We performed the same process by the same investigator for cadeveric femur of all 17 pairs and another 3 times for each by another staff, a resident, and a medical student. Reliability of contralateral lesser trochanter was also calculated by (1) intra-observer and (2) inter-observer reliabilities.

Results

Demographic data

The average age of cadaveric bone was 59.71 $\pm$ 4.37 years, obtained from 7 males and 10 females (Table 1).

Reliability of contralateral lesser trochanter

We found that (1) intra-observer of each examiner had excellent correlation which is statistically significant (p-value < 0.001, ICC = 0.919 (95% CI: 0.819-0.968) and (2) inter-observer of all examiners also had good correlation which was considered statistically significant (p-value = 0.009, ICC = 0.726 (95% CI: 0.198-0.926) (Table 2).

Femoral anteversion

The average mean of femoral anteversion between right and left side was found no statistical significant in all cadeveric samples (p-value = 0.904) (Table 3).

Discussion

Rotational malalignment of femur can occur after intrameduallry nail fixation. If malrotation was much more than 15 degrees, it will result in clinical problems for patients. Moreover, we found that more malrotation usually happens after using a closed intramedullary nailing technique than opened reduction and internal fixation with plate and screws. This was because the plate and screws fixation can be performed direct vision of fracture site. We did not study malrotation after plate and screws fixation under minimally invasive technique.

Rotational malalignment can be reduced by several simple techniques such as obtaining uniform soft tissue tension around the fracture and a skin fold geometry resembling the normal limb and using contralateral lessor trochanter to be a reference. Deshmukh et al found significant reduction of the malalignment using the lessor trochanter technique. Jaarsma et al reported the profile quantification of the lesser trochanter with computer-assisting did not

Table 1. Demographic data (n = 17)

Variable	Number	Percent
Age (mean $\pm$ SD)	59.71 $\pm$ 4.37	
Sex		
Male	7	41.18
Female	10	58.82

Table 2. Reliabilities of contralateral lesser trochanter

Reliability	Intra-examiner	Inter-examiner
	Examiner 1 (1st , 2nd, and 3rd time)	Examiner 1 (1st time), Examiner 2, and Examiner 3
ICC (95% CI of ICC)	0.919 (0.819-0.968)	0.726 (0.198-0.926)

CI = confidence interval, ICC = intra-class correlation co-efficient

Table 3. The average mean of femoral anteversion

Side	Mean $\pm$ SD	Mean difference $\pm$ SD	p-value
Right	16.18 $\pm$ 10.17	-0.24 $\pm$ 7.96	0.904
Left	16.41 $\pm$ 9.08		

Table 4. Results

	Age	Anteversion		Difference	Malrotation			Mean of malrotation
		Right	Left		1st	2nd	3rd	
Mean	59.71	16.18	16.14	6.12	5.29	5.76	5.12	5.39
SD	4.37	10.17	9.08	4.86	4.24	3.55	4.58	3.84

much improve this clinical benefit comparing to non-computerize technique.

In the present study, we found that there was no statistically significant difference between intra-examiners and inter-examiners regardless of the unequal femoral anteversion between both sides. We also found the excellent correlation of intra-examiners which was statistically significant (p-value < 0.001), ICC = 0.919 (95% CI: 0.819-0.968). Inter-examiners also were significantly correlated, (p-value = 0.009), ICC = 0.726 (95% CI: 0.198-0.926). As a result of the unequal anteversion, there were 3 different observations found in anteversion of the cadeveric bone. Firstly, there were 9 pairs (53%) that produced less than 5 degrees differences. Secondly, there were 5 pairs (29%) with a 5-10° differences, and thirdly, 3 pairs (18%) with a 10-15° differences. We also found 6 pairs (35%) of cadeveric femur that had the same anteversion. Possible sources of measurement error related to rotational malalignment included measurement method, examiner, inclinometer which we found technical error about 1 degree in our pilot study, and error that might cause from magnification of fluoroscope which is a distance between bone and fluoroscope.

Other causes of rotational malalignment could occur as a result of the torsion of the nail and the distal fragment during insertion. This can be accentuated by a combination of the natural ante-rolateral bow of the femur and a rigid nail. In addition, the over-reaming of the femur can minimize the likelihood of torsion by easing insertion of the nail.

Conclusion

The shape and position of contralateral lesser trochanter can help prevent the rotational malalignment, especially in a closed technique from both intra-examiners and inter-examiners. In femoral shaft fracture that was treated with either closed intra-medullary nailing technique or minimal invasive plate osteosynthesis, the shape and position of contralateral lesser trochanter can be used with an aim to reduce the incidence of rotational malalignment, particularly in case of the comminuted fracture configuration.

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ความถูกต้องของการใช้ปุ่มกระดูก lesser trochanter ข้างตรงข้ามอ้างอิงตำแหน่งเพื่อป้องกันการบิดหมุนในกระดูกต้นขาหัก

อารัญ สวัสดิพงษ์, รัฐศาสตร์ สุดหนองบัว

ภูมิหลัง: *ภาวะ rotational malalignment คือมีการบิดหมุนของกระดูกในส่วน proximal และ distal ใน fracture shaft of femur ซึ่งถ้าการบิดหมุนเกิดขึ้นมากกว่า 15 องศา จะทำให้เกิดปัญหาทางคลินิก มักพบ rotational malalignment เกิดขึ้นภายหลังการใส่ Intramedullary nailling มากกว่าการใส่ plate and screws ซึ่งสามารถพบได้ประมาณ 20-30%*

วัสดุและวิธีการ: *การใช้ปุ่มกระดูก lesser trochanter ข้างตรงข้ามที่ปกติ อ้างอิงตำแหน่ง เพื่อป้องกันการบิดหมุนในกระดูกต้นขาหักโดยศึกษาความแตกต่างใน intra-examiner และ inter-examiner พบว่าจากกระดูกต้นขา (femoral bone)ที่นำมาทดลองจำนวน 17 คู่*

ผลการศึกษา: *อายุผู้ป่วยเฉลี่ย 59.71ปี (SD = 4.37) กระดูกต้นขาเป็นเพศชาย 7 คู่ (41.18%) เพศหญิง 10 คู่ (58.82%) มีค่าเฉลี่ยของ femoral anteversion ระหว่างขาขวา 16.18 องศา (SD = 10.17) และขาซ้าย 16.41 องศา (SD = 9.08) พบว่ามีความแตกต่างกันอย่างไม่มีนัยสำคัญทางสถิติ (p-value = 0.904) และพบว่า การเกิด rotational malalignment ใน Intra-examiner ทั้ง 3 ครั้ง มีความสอดคล้องกันในระดับดีมากอย่างมีนัยสำคัญทางสถิติ (p-value < 0.001) โดยมีค่า ICC = 0.919 (0.819-0.968) ส่วนการเกิด rotational malalignment ใน inter-examiner ทั้ง 3 ท่าน มีความสอดคล้องกันในระดับดีและมีนัยสำคัญทางสถิติ (p-value = 0.009) โดยมีค่า ICC = 0.726 (0.198-0.926)*

สรุป: *การใช้ปุ่มกระดูก lesser trochanter ของขาข้างตรงข้ามที่ปกติ เพื่ออ้างอิงตำแหน่งการบิดหมุนของกระดูกต้นขาที่ต้องการวัด มีความแม่นยำเพียงพอ ในการนำไปใช้ในการป้องกันการบิดหมุนผิดรูป (rotational malaligment) ของ femoral shaft fracture ด้วยวิธีการใส่ intramedullary nail*