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Dr. Mrudev V Gandhi
Senior Resident, GMERS Medical College and Hospital, Dharpur, Patan, Gujarat, India

Dr. Vimal P Gandhi
Associate Professor, GMERS Medical College and Hospital, Dharpur, Patan, Gujarat, India

Dr. Yash P Oza
Resident, Dr. D. Y. Patil Medical College, Pune, Maharashtra, India

Corresponding Author:
Dr. Mrudev V Gandhi
Senior Resident, GMERS Medical College and Hospital, Dharpur, Patan, Gujarat, India

Utility of the 30° oblique tangential view for evaluation of anteromedial cortical reduction in reconstruction of intertrochanteric fractures

Dr. Mrudev V Gandhi, Dr. Vimal P Gandhi and Dr. Yash P Oza

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Abstract
Background: Intertrochanteric fractures are one of the most commonly presented cases at a tertiary care center. While operating them reduction of the fracture is a prime factor deciding the prognosis. Anatomical reduction of anteromedial cortex per se is the key parameter for stable reconstruction of the fracture. To evaluate this reduction conventional AP and Lateral projections are in wide use. A study was done to check the utility a novel 30 degree oblique tangential fluoroscopic projection to evaluate the quality of anteromedial cortical reduction.
Methods: To conduct this study normal side calibration confirmation was used in initial cases. Using steel wires along five anatomic landmarks: Greater trochanter, Lesser trochanter, Intertrochanteric line, Anterolateral tubercle and the Anteromedial cortical line were identified, after which conventional AP and lateral fluoroscopic views were taken. The C-arm of the machine was then rotated by every 10°increments until a clear tangential view of the anteromedial-inferior corner cortex was observed. 100 operative cases of intertrochanteric hip fractures were studied from September 2021 to May 2022. In all of those intra-operative AP, Lateral and 30degree oblique tangential views were used after reduction as well as after final fixation to assess the quality of anteromedial cortical reduction. For 28 cases fluoroscopic results were compared with the post-operative 3D-CT reconstruction images.
Results: The study on normal specimens showed that internal rotation of the C-arm to approximately 30° can remove all the obscure shadows and clearly display the anteromedial cortical tangent line. Intra-operative positive, neutral and negative apposition of anterior and medial cortices showed 78, 22 and 0 cases of medial cortical apposition in AP views; 17, 75 and 8 cases of anterior cortices in lateral views; and 70, 28 and 2 cases of anteromedial cortical apposition in oblique views respectively. The post-operative 3D-CT reconstruction images revealed that the final anteromedial cortical contact was noted in 72 cases (72.0%), and lost in 28 cases (28%). The coincidence rate between intra-operative fluoroscopy and post-operative 3D-CT was 89.0% (89/100) in AP view, 78.0% (78/ 100) in lateral view, and 82.0% (82/100) in oblique view (p<0.001).
Conclusions: Along with conventional AP and lateral projections, an additional oblique view of 30° becomes a very useful means for evaluation of the intra-operative anteromedial cortical reduction of fracture.

Keywords: Inter-trochanteric fracture, anteromedial cortical reduction, C-Arm fluoroscopy, oblique 30 degree tangential view, 3D-CT

Introduction
Hip fracture cases in geriatric population are presumed to reach around 4.5 million worldwide by the year 2050. The inter-trochanteric femur fracture is the most life- threatening fracture in the elderly which is also called the last fracture of the life, with mortality rate of about 30%in one year [1]. Operative management with intramedullary nail is recommended, especially in the unstable fracture patterns [2]; A wide variety of intramedullary nails off different patterns are available in market [3], but the postoperative complications are still high [4].
In operative management quality of fracture reduction is the prime pre- requisite for better prognosis. Chang *et al.* [5] was the first who introduced the concept of anteromedial cortical support reduction in 2015, which allowed the head-neck fragment contact with the anteromedial cortex of the femoral shaft via limited and controlled sliding. As the reduction of the displaced lesser trochanter is difficult in the unstable 31A2 pertrochanteric fracture type,

the cortex-to-cortex apposition which stands as a non-anatomic functional buttress reduction is an important element to effectively support the head-neck fragment, i.e. the anteromedial cortices of the inferior corner become the key position for the cortex-to-cortex support and fracture reduction.

In current clinical practice standard anteroposterior (AP) and lateral views are used during intraoperative fluoroscopic evaluation means to evaluate the quality of fracture reduction with clear knowledge on the view of the tangent position and adequate reduction of the anteromedial cortices of the inferior corner still lacking. The aim of this study was to evaluate the usefulness of 30 degree oblique tangential view in judging the quality of anteromedial cortical reduction in intertrochanteric fractures.

Methods

Fluoroscopic study using three proximal femur specimens; with steel wires over the five anatomic landmarks: the Greater trochanter, the Lesser trochanter, the Intertrochanteric line, the Anterolateral tubercle, and the Anteromedial cortical tangent line were marked. After obtaining the standard AP and lateral views under the C-arm fluoroscopy, the machine was adjusted at every 5° increment until the complete elimination of the overlapping shadow to finally obtain a clear tangential view of the anteromedial cortex.

According to the criteria proposed by Chang *et al*., there are three reduction types of the anteromedial cortex:

(1) Positive apposition: the anteromedial cortex of the head-neck fragment located slightly superomedial to the anteromedial cortex of the femoral shaft (less than one cortical thickness) which is also called as an extra-medullary cortex position, (2) Neutral apposition: a smooth cortical apposition of the anteromedial aspect of the two cortices, also can be called as fluoroscopic anatomic position and (3) Negative apposition: the anteromedial cortex of the head-neck fragment located superolateral to the anteromedial cortex of the shaft, which is also called as an intra- medullary cortex position.

Clinical patients

After getting approval from the IEC ethics committee, 100 patients who sustained intertrochanteric hip fractures from September 2020 to May 2021 were included in the study. There were 48 males and 52 females, with an average age of 78.2 years (range 61–97 years). For all the patients selected, standard Pelvis with both hips AP view and Hip lateral views were taken and all the fractures were classified using AO Foundation and Orthopaedic Trauma Association (AO/OTA) classification. Amongst them 12, 74 and 14 cases were of type A1, type A2 and type A3 respectively. Inclusion criteria were as follows: (1) Fresh Intertrochanteric femur fractures, (2) Managed with closed reduction and intramedullary nail fixation and (3) Complete intraoperative fluoroscopy images and postoperative 3D-CT scanning. Exclusion criteria were: (1) age younger than 60 years, (2) pathological fractures and (3) pure subtrochanteric fractures.

After complete physical fitness and eliminating the surgical contraindication with proper consents patients were taken on traction table under appropriate anesthesia. Closed reduction was attempted on traction table. If the fracture reduction quality by closed maneuver was not of satisfactory value, then the minimal open reduction with instruments such as bone hook was performed. All fractures were fixed with proximal femoral nails.

After fixation, first we got the standard lateral view (true sagittal) of the femoral neck i.e. neck screws in the femoral head was aligned in a straight line with the nail in the femur medullary canal (set as 0°). Then the C-arm was rotated to get the new anteromedial oblique tangential view, usually at 30 °C-arm rotations (Fig. 1).

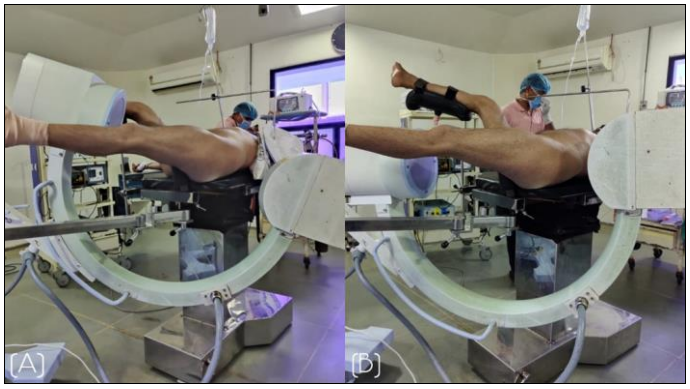

Fig 1: (A) Standard lateral view (true sagittal) of femoral neck and (B) By rotating the C-arm 30 degrees down, the anteromedial oblique tangential view

Post-operative CT-scanning was performed for all the patients after one week and 3D images were reformed. The 3D-CT reconstruction images were considered the gold standard as they can be rotated 360° to observe the complete view of the cortex apposition between the head-neck and shaft fragments. The fracture reduction quality of the anteromedial cortex in 3D-CT was categorized into two types: true anteromedial cortical support (positive and anatomic) or loss of anteromedial cortical support (negative).

The results of intra-operative fluoroscopic and post- operative 3D-CT reconstruction images were compared and statistically analyzed. Chi-square test was done to determine the difference. Statistical significance was defined as $p<0.05$.

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Results

Experimental study

Anteromedial cortex could not be clearly displayed due to the overlapping of the greater trochanter, the intertrochanteric line and the anterolateral tubercle on the standard femoral neck lateral view. After internally rotating the C-arm to 30°, the overlapping shadows (mostly by the anterior part of the greater trochanter and the anterolateral tubercle of the intertrochanteric line) were completely eliminated, and the tangential projection of the anteromedial cortex was clearly displayed.

Clinical study

Intra-operative positive, neutral and negative apposition of anterior and medial cortices showed 78, 22 and 0 cases of medial cortical apposition in AP views; 17, 75 and 8 cases of anterior cortices in lateral views; and 70, 28 and 2 cases of anteromedial cortical apposition in oblique views respectively.

The post-operative 3D-CT reconstruction images revealed that the final anteromedial cortical contact was noted in 72 cases (72.0%), and lost in 28 cases (28%). The coincidence rate between intra-operative fluoroscopy and post-operative 3D-CT was 89.0% (89/100) in AP view, 78.0% (78/ 100) in lateral view, and 82.0% (82/100) in oblique view. For the true anteromedial cortical support group, 46cases (46/62, 74.2%) showed a little bit of anterior shift of the inferior cortical spike by flexion rotation of the head-neck fragment (less than 15 degrees), which was an important mechanism of anteromedial cortex-to-cortex buttress. The overall coincidence rate in different fluoroscopic views showed the significant difference (p<0.001). For coincidence between the intra-operative oblique fluoroscopic and post-operative 3D-CT images, 21 cases (21/22, 95.5%) were consistent in the positive group, 40 cases (40/51, 78.4%) in neutral group and 24 cases (24/25, 96%) in negative group. The results demonstrated that a neutral oblique cortex apposition in fluoroscopy would have a post-operative change rate (20%) to negative category.

Table 1: Difference in anteromedial cortical contact between intra-op fluoroscopy and post-op 3D CT. (a) Intra-op fluoroscopy

AP view	Lateral view	Oblique view	No. of cases
positive	positive	positive	4
positive	neutral	positive	16
positive	neutral	neutral	35
positive	neutral	negative	5
positive	negative	positive	4
positive	negative	neutral	8
positive	negative	negative	9
neutral	neutral	neutral	8
neutral	neutral	negative	4
neutral	negative	negative	7
			Total:100

(b) Post op 3D CT

True cortical contact no. (%)	Loss of cortical contact no. (%)
3 (100%)	0 (0%)
15 (100%)	0 (0%)
31 (88.6%)	4 (11.4%)
1 (20%)	4 (80%)
3 (75%)	1 (25%)
3 (37.5%)	5 (62.5%)
0 (0%)	9 (100%)
6 (75%)	2 (25%)
0 (0%)	4 (100%)
0 (0%)	7 (100%)

As both positive and smooth neutral cortical appositions in fluoroscopy are accepted in the operation, we also made a comparison between negative group and non-negative group (Table 2). It is demonstrated that the oblique cortical position determined whether the final anteromedial cortical contact is present or not. If a negative oblique position was seen on intra-operative fluoroscopy, regardless of the AP and lateral views, it was highly predictive of a final loss of cortical support as demonstrated by 3D CT (24/25 cases, 96%). In contrast, non-negative oblique cortical position was highly associated with a true cortical contact, as demonstrated by 3D CT (61/73 cases, 83.6%). This was an independent predictive factor as significant difference was showed in oblique view (p<0.001).

Table 2: Four combinations patterns of anteromedial cortical contact between intra-op fluoroscopy and post-op 3D CT.

Intra-op fluoroscopy		Oblique view	No. of cases	Post-op 3D CT	Loss of cortical contact no. (%)
AP view	Lateral view			True cortical contact no. (%)	
Non-negative	Non-negative	Non-negative	62	53 (90.2%)	4 (9.8%)
Non-negative	Non-negative	negative	9	1 (11.1%)	8 (88.9%)
Non-negative	negative	Non-negative	14	8 (50%)	6 (50%)
Non-negative	negative	negative	15	0 (0%)	18 (100%)
			Total:100		

Illustration of anteromedial oblique tangential view in a case is demonstrated in fig. 2.

Fig 2: A 67 year old male with inter-trochanteric fracture (AO/OTA-A2.3) managed with closed reduction and fixation with proximal femoral nail. Along with conventional AP and Lateral intra-operative radiographs, a 30 degree oblique tangential view showing anteromedial cortical alignment providing a stable construct, also verified on post operative 3D CT images.

Discussion

For the stable reconstructions after fracture reduction and fixation, 5 influencing factors have been summarized, i.e. bone quality (osteoporosis), fragment geometry (comminution), fracture reduction quality, implant selection, and implant placement (TAD/Cal-TAD) [6]. Fracture reduction quality is the first pre-requisite for the treatment of the pertrochanteric fracture [7]. Insufficient fracture reduction can result into the incorrect position of the lag screw/helical blade and even the failure of the mechanical stability of the internal fixation system which may impair the patients' functional out- comes [8].

Previously, a lot of fracture reduction quality criteria have been described in the literature. These criteria include two aspects which are Garden alignment and fragment displacement. The alignment is similar, and the Garden index is used. However, the displacement criteria are different among different authors. For example, greater than 5 mm by Sernbo (1988) [9], 4 mm by Baumgaetner (1995) [10], and 20% by Fogagnolo (2004) [11]. Fracture reduction quality is categorized as good (presence of both alignment and displacement criteria), acceptable (either one criterion) or poor (absence of both criteria). In practice, as the detached lesser trochanteric fragment in unstable fracture patterns is usually not reduced and secured clinically by most implants [12], it is hard to achieve "good" reduction quality. Most patients can only meet an "acceptable" quality according to Baumgaertner's criteria.

In 2015, Chang *et al*. [5] put forward the new reduction quality criteria: (1) alignment (Garden index): nor- mal or slight abduction of the neck-shaft angle in the AP view, and less than 20° in the lateral view; (2) apposition: the medial cortices positive or neutral to each other in the AP view; and the anterior cortices smooth or neutral in contact to each other in the lateral view. The reduction quality could also be divided into three grades: good, acceptable and poor. In 2019, Mao *et al.* [13] explored the reliability of predicting mechanical complications by using Baumgaertner's criteria and Chang's criteria. The authors believed that the Chang's criteria which emphasized anteromedial cortical contact was more reliable and effective than the Baumgaertner's criteria in predicting postoperative mechanical complications and worthy of clinical applications.

Biomechanical [14] and clinical [15] researches have confirmed that the anteromedial cortical contact can not only share stress load from the internal fixation device (mechanical role), but also can promote close contact and fracture healing at the fracture sites (biological role), both of which are benefit for maintaining the normal femoral neck length and the neck-shaft angle.

The anteromedial cortical contact is the key element in evaluation of fracture reduction quality. In 2018, Chang *et al*. [16] conducted a study on the medial and anterior cortical reduction quality by intraoperative AP and lateral fluoroscopic images and compared it with the post-operative 3D-CT reconstruction images to judge the accuracy of intraoperative fluoroscopic alignment of anteromedial cortex indirectly. The results showed that a positive AP position combined with a positive/neutral lateral position had a high predictive value of the cortical support as confirmed by 3D CT re- construction images (15/17, 88.2%). While the negative lateral position observed on intra-operative fluoroscopy, regardless of the AP position, was predictive of the final loss of cortical support as demonstrated by 3D-CT re- construction images (6/7, 85.7%).

Intraoperative flouroscopy allows the surgeon to do a live rotation arc across the fracture to verify reduction. It is ideal to see the AP, lateral and all the obliques to verify fracture reduction is maintained. However, full range view of 360 degrees is impossible in daily practice, and has a greater amount of radiation exposure.

It is apparent that the detection of an anteromedial tangential view without obstruction of other structures may probably enhance the accuracy in interpretation of the relationship between cortices of the head-neck and the shaft fragments. In this study, five anatomical land- marks on the proximal femur were marked with steel wires: the Greater trochanter, the Lesser trochanter, the Intertrochanteric line, the Anterolateral tubercle and the

Anteromedial cortical tangent line. After obtaining the standard lateral view of the femoral neck by intra- operative fluoroscopy, we gradually rotated the machine internally to eliminate the overlapping structures on the anterior aspect. We found out that with 30° of rotation, a clear tangential projection of the anteromedial cortex can be obtained.

Clinically, the anteromedial oblique fluoroscopic view of 30° was used to evaluate the alignment of the anteromedial-inferior corner cortex. Compared with AP and lateral views, the oblique fluoroscopic view had a higher accuracy in evaluation of

anteromedial apposition. The final loss of cortical contact in 3D-CT was seen in al- most all in the negative groups (24/25, 96%). This suggested that the negative reduction of the anteromedial cortices needs further re-correction during the operation. Postoperative 3D-CT images revealed that approximately 20% (10/51) of cases in neutral group (observed via oblique fluoroscopic view) did not attain the anteromedial cortical support in the final. In reality, the neutral group shown on intra-operative fluoroscopy may actually have three sub-patterns: 1) an exact anatomic position, 2) a slightly positive position and 3) a slightly negative position. However, as the intra- operative fluoroscopic image resolution is limited, 2-mm cortical steps may not be able to be distinguished clearly. Thus, it becomes unfavorable for a slightly negatively positioned pattern. As the head-neck fragment gets influenced by postoperative muscle contraction and weight-bearing, a slight negative position might become a true negative in postoperative period and finally leading to the loss of the cortical contact.

Several factors may affect the rotation of the head- neck fragment: (1) it is difficult to accurately reduce the anterior and medial cortices in closed reduction, which means exact anatomic reduction of the anteromedial cortices is rare. (2) The intra-operative fluoroscopic image resolution is limited with two dimensional image, which is difficult to observe the rotation of the head- neck fragment. (3) High speed driving of guide pin or reamer, wrenching in the lag screw, or hammering in the helical blade may cause rotation of the head-neck fragment. (4) Post-operative axial telescoping may be interfered by head-neck rotation and tilting [17]. Our experience showed that a slightly flexed rotation of the head-neck fragment (less than 15 degrees) is preferable for anterolateral cortical support (46/62, 74.2%).

Conclusions

Intra-operative 30° oblique tangential view in addition to standard AP and Lateral views, can eliminate the occlusive overlapping shadows and is a very useful technique in the evaluation of the anteromedial cortical reduction quality, and has a high prognostic value with the final postoperative 3D-CT.

Abbreviations

AP: Antero-posterior; AO/OTA: AO Foundation and Orthopaedic Trauma Association; 3D-CT: Three dimension computed tomography; TAD/cal- TAD: Tip apex distance/calcar referenced tip-apex distance

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Conflicts of interests

The authors have no conflicts of interest to declare.

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