CT evaluation of torsional malalignment after intertrochanteric fracture fixation

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Summary
Introduction: Trochanteric fractures are commonly stabilized either by intramedullary nailing or plate and screw fixation after reduction on the orthopaedic surgical table under radiological guidance.
Hypothesis: Closed trochanteric fracture anatomic reduction is difficult in the transversal plane.
Objectives: The objective of this prospective study was to assess the rotational malalignment induced after reduction and osteosynthesis of trochanteric fractures.
Patients and methods: Prospective study including 40 patients (mean age, 78 years; range, 51–90 years) operated for a trochanteric fracture between January 2007 and September 2008. Fourteen fractures were treated using DHSTM (SynthesTM) plate and screw fixation and 26 with intramedullary nailing (trochanteric nailTM, StrykerTM). All these patients underwent postoperative CT of the pelvis during their hospitalization with measurement of anteversion of the operated and healthy femoral necks at the posterior condyles. The evaluation criterion was whether or not there was malalignment greater than 15° on the operated side compared to the healthy side.
Results: The mean anteversion was 14.2° for the healthy side and 23° for the operated side. The mean rotational malalignment was 15.3°. Forty percent of the rotational malalignments were greater than 15°, with a majority of cases showing excess internal rotation (35%) of the distal fragment.
Conclusion and discussion: The rate of internal rotational malalignment of the distal fragment greater than 15° was high (40% of this series). This should encourage surgeons to reduce the excess internal rotation that tends to be attributed to the distal fragment during preoperative reduction of these fractures.
Level of evidence: Level III. Prospective diagnostic study with no control group.

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**Introduction**

Trochanteric fractures are very frequent in France, with an incidence of 100 for 100,000 inhabitants [1]. The most commonly used surgical treatment is reduction on an orthopaedic surgical table followed by osteosynthesis with plate and screw fixation or locked nailing [2]. The quality of the postoperative reduction of these fractures is determined for the most part at the time of the pre- and intraoperative reduction maneuvers. Although the quality of the reduction in the frontal plane is easy to measure and has already been reported in the literature [3–5], the same does not hold true for rotational malalignment. These fractures have been studied mainly within femoral diaphyseal fractures [6–10], and the incidence of trochanteric fractures today remains incompletely known. The objective of this prospective study was the CT evaluation of the quality of reduction in the horizontal plane.

**Patients and methods**

**Patients**

We conducted a single-center prospective study from January 2007 to September 2008. All the patients operated on for a trochanteric fracture were included except those who had had surgery on the contralateral femur and those who could not undergo computed tomography (CT) examination to measure anteversion of the femoral necks. Forty patients, nine males and 31 females (mean age, 78 years; range, 51–90 years) were operated on for a trochanteric fracture and underwent postoperative CT (Table 1). The Ender classification was used to classify these fractures [11] (Table 1).

**Surgical technique**

All the patients were operated under general anesthesia in supine position on an orthopaedic surgical table with image intensifier after reduction. Intraoperatively, the implants placed guided by the image intensifier were either DHS™ plate and screw fixation (Synthes™, Étupes, France) or a trochanteric nail™ (Stryker™, Meyzieu, France). The surgeon’s preference and experience determined the choice of osteosynthesis material with the two types of implant.

**Evaluation of results**

Postoperatively, a CT with measurement of anteversion in both femoral necks was prescribed. Anteversion of the femoral neck was measured (Fig. 1) using the method described by Jeanmart et al. [13], determining for each femur the angle between the tangent passing through the line of the posterior condyles and the neck axis. This measurement was taken digitally by a senior radiologist. A second measurement was taken by a senior surgeon using a goniometer on the printed images. Interoperator reliability was studied by calculating the kappa correlation coefficient between the two measurements. For each patient, the value of D was calculated, which corresponded to the difference between anteversion of the operated side and anteversion of the healthy side. When D was positive, there was excess internal rotation of the distal fragment during reduction. On the other hand, if D was positive, there was excess external rotation during surgical reduction. Rotational malalignment corresponded to the absolute value of D. Based on this value, we defined three groups of patients: group A, with reduction considered satisfactory (0 < D ≤ 5); group B included the patients whose reduction was unsatisfactory (5 < D ≤ 15); in group C, the patients presented clear malunion (D > 15). The mean anteversion for the healthy sides and the operated sides was also calculated.

**Results**

The mean anteversion value of the healthy sides was $14.2 ^\circ \pm SD 5.6$ (range, $5^\circ$–$25.1^\circ$) and the operated sides $23.2 ^\circ \pm SD 16.8$ (range, $-33^\circ$–$47^\circ$) (Table 2). The mean rotational malalignment for each patient was $15.3 ^\circ \pm SD 11.7$ (range, $1.4^\circ$–$45^\circ$). The interoperator reliability study found a 0.99 kappa concordance coefficient. The patient distribution showed that nine of them (22.5%) belonged to group A and had satisfactory reduction. Group B included 15 cases (37.5%) with a mean rotational malalignment of $10.4 ^\circ \pm 2.6^\circ$ (range, $5.1^\circ$–$13.7^\circ$). Sixteen patients (40%) belonged to group C, with a mean rotational malalignment measuring $26.6 ^\circ \pm 10.3^\circ$ (range, $15.5^\circ$–$45^\circ$) (Table 3).

These 40% were distributed into 35% (14 cases) internal overrotation of the distal fragment (Fig. 2) and only 5% (two cases) external overrotation (Fig. 3) of the distal fragment.

**Table 1** Distribution of patients depending on fracture type (Ender classification) and internal fixation device used.

<table>
<thead>
<tr>
<th>Osteosynthesis</th>
<th>DHS™ plate and screw fixation</th>
<th>Trochanteric nail™</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Fracture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 1</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Type 2</td>
<td>2</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Type 3</td>
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<td>6</td>
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</tr>
<tr>
<td>Type 4</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Type 5</td>
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<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Type 7</td>
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<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Type 8</td>
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<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>26</td>
<td>40</td>
</tr>
</tbody>
</table>

**Table 2** Mean anteversion.

| Mean anteversion, healthy side | $14.2 ^\circ \pm SD 5.6$ (range, $5^\circ$–$25.1^\circ$) |
| Mean anteversion, operated side| $23.2 ^\circ \pm SD 16.8$ (range, $-33^\circ$–$47^\circ$) |
Figure 1  Anteversion of the femoral neck is measured in relation to the plane of the posterior condyles. Here the differential D (anteversion of the operated side [left] – anteversion of the healthy side [right]) was 39.8° – 16.2° (23.6°). This positive value shows that there was internal overrotation during reduction maneuvers.

Table 3  Distribution of differentials D.

<table>
<thead>
<tr>
<th>Differential D</th>
<th>Number of cases</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A (0° &lt; D ≤ 5°)</td>
<td>9</td>
<td>22.50</td>
</tr>
<tr>
<td>Group B (5° &lt; D ≤ 15°)</td>
<td>15</td>
<td>37.50</td>
</tr>
<tr>
<td>Group C (D &gt; 15°)</td>
<td>16</td>
<td>40.00</td>
</tr>
</tbody>
</table>

D: anteversion of operated side — anteversion of healthy side.

The type of osteosynthesis did not seem to influence the rotational malalignment measured since it was 14.9° SD 14.2° (range, 1.4°–45°) in the group of patients with DHSTM screw plate fixation versus 15.5° SD 10.6° (range, 2°–32.7°) in the group of patients with trochanteric nailingTM (Table 4). There was no early disassembly requiring surgical revision. The patients whose reduction showed internal

Figure 2  Example of an intratrochanteric fracture reduced and fixated with a gamma nailTM (StrykerTM) with a good postoperative result. CT showed 13.1° anteversion on the healthy side and 33.9° on the operated side. The differential D is therefore 20.8°, which corresponds to excessive internal rotation.

Figure 3  A case of intratrochanteric fracture reduced and fixated using DHSTM screw plate fixation (SynthesTM) with a good postoperative radioscopic result. CT actually showed 12° anteversion on the healthy side and −33° anteversion of the operated neck, indicating retroversion. The differential D was −45°, corresponding to excessive external rotation during reduction maneuvers.

overrotation did not require surgical revision. Despite their gait with internal rotation, these patients had no particular request for correcting this malalignment. A single patient presented 45° external overrotation (Fig. 3), requiring femoral derotational osteotomy 1 year after the initial management of the fracture.

Discussion

To our knowledge, this is the first study measuring rotational malalignment after osteosynthesis of trochanteric fractures. Radiographic analysis of the quality of the reduction of this type of lesion is not systematic in all the series reported.

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When it is done, it is most often limited to deformities in the frontal plane. These are most often varus malunions, whose incidence is around 5% \cite{3–5}.

Analysis of rotational malalignment of the femur is frequently reported, however, after nailing of diaphyseal fractures. Several measurement techniques have been described. The clinical method, the simplest, compares external and internal rotations between the two hips (operated and healthy). We did not report data on these measurements and are aware that this is a shortcoming of the study. However, for several authors \cite{9,14}, this exam has a very low sensitivity and specificity. Alone it cannot quantify rotational malalignment. Radiographic and ultrasound measurement techniques have also been described in the literature. However, they are no longer used given their complexity \cite{14,15}. Currently, the reference method used to measure rotational malalignment is CT. It was described by Jeanmart et al. \cite{13} determining the angle between the tangent passing through the line of the posterior condyles and the axis of the neck on each femur. The difference between the two measurements determines the rotational malalignment. For Jaarsma and Pavkis \cite{9}, this value is deemed pathological if it is greater than 15°. In the present study, we used the measurement criteria described by Jeanmart et al. \cite{13} and also retained the threshold value of 15°.

In our series, we observed 40% rotational malalignment greater than 15°. This percentage varies in the literature between 20 and 30% after nailing of the femoral diaphysis \cite{8,9}. Comparing our results with those reported in the literature shows rates that are comparable with or even higher than our series. In addition, this is more a question of excessive internal overrotation of the distal femur (excessive anteversion of the neck) for trochanteric fractures (90% of the cases of malunion in our series), whereas excessive external rotation (reduction of neck or even retroversion) largely predominates after nailing diaphyseal fractures. For Jaarsma and Pavkis \cite{9}, these differences can be explained by the fracture location. When they are centered in the trochanter, two explanations can be given as for the internal rotation malunions. Jaarsma and Pavkis \cite{9} consider that the proximal fragment is subjected to external rotation from the gluteus medius, the pelvichroanterior muscles, and the iliohipsoas. This is true displacement in extradigital fractures, but these fractures are not the most frequent. Poor reduction leads to unsatisfactory osteosynthesis because it allows external overrotation of the proximal fragment to remain. For extradigital fractures, the distal fragment is displaced in external rotation through the action of the three gluteus muscles. Malunion is therefore caused by femoral overcorrection at reduction. This displacement, related to the action of the hip muscles, is substantially less when the fracture is in the diaphyseal zone. What are the consequences of these rotational malalignments after osteosynthesis of trochanteric fractures? Few data are available in the literature. Using digital models, Gugenheim et al. \cite{16} studied the consequences of rotational femoral osteotomy on the frontal or sagittal axis of the lower limb as well as on the orientation of the knee joint space. Three levels of osteotomy were tested: subtrochanteric, mid-diaphyseal, and supracondylar. In the subtrochanteric zone, beyond 30° of internal rotation, the axis of the lower limb showed significant valgus deviation. External rotation caused very little modification of this axis. In addition, the orientation of the joint space remained constant for either type of rotation.

The functional repercussions of rotational nonunions is poorly known. Only a few studies were found after nailing of diaphyseal fractures. However, these results should be interpreted with caution. The mean age of the present series is much higher for a population of trochanteric fractures than diaphyseal fractures. The functional expectation is therefore totally different for each lesion group. According to Jaarsma and Pavkis \cite{9}, it is difficult to evaluate the functional consequences of rotational malunion of the femur because no currently validated score has been published on this type of fracture. In addition, it has been observed that absence of rotational malalignment could lead to a variety of problems when performing certain activities \cite{9,14,15}. For Johnson and Greenberg \cite{15}, malunions external rotation are poorly tolerated. According to these authors, compensating for these malunions during walking requires retroverting the femoral neck. Different studies have shown that this position could be a source of pain and was much less well tolerated \cite{17,18}. In the present series, the functional consequences of rotational malalignment were not evaluated. However, one patient underwent revision for pain and discomfort while walking. This was a case of malunion in external rotation. Corrective osteotomy improved the patient’s symptoms.

Given the severity of these rotational malalignments induced after trochanteric fracture fixation, improving the quality of the reduction seems necessary. After installing the patient on the orthopaedic surgical table, placing the foot in internal rotation sufficiently to center the patella is recommended \cite{12}. We used this method in the present study, and it seems we induced internal overrotation of the distal fragment greater than 15° in 40% of the cases. Also in a context of femur fractures, Tornetta and Ritz \cite{8} proposed what they called the ”c-arm” protocol, which consists of radioscopic measurement of femoral anteversion of the healthy side. The angle measured guides the operator in reducing the fracture on the operated side. Rotation of the distal fragment should make it possible to obtain the same anteversion as on the healthy side. In their study, Tornetta and Ritz \cite{8} showed that there was less rotational malalignment in

<table>
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</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>14</td>
<td>26</td>
<td>40</td>
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<tr>
<td>Mean rotational malalignment</td>
<td>14.9° SD 14.2 (range, 1.4°–45°)</td>
<td>15.5° SD 10.6 (range, 2°–32.7°)</td>
<td>15.3° SD 11.5 (range, 1.4°–45°)</td>
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</table>
patients operated on using this method. With femoral fractures, this procedure adds a minimum of 15 min of surgical time. This method’s feasibility and the lengthening of the surgical time for trochanteric fractures, for which surgical treatment must be rapid in elderly subjects, has not been evaluated.

We are fully aware of the biases of this study. It can be criticized for its lack of homogeneity in that several surgeons participated and different implants were used. In addition, after reduction of the fracture on the orthopaedic surgical table, no radioscopic criterion was defined to account for its quality. This was left to the discretion of the operator. However, we believe that this series is a good reflection of current management of trochanteric fractures.

Conclusion

The rate of rotational malunions of operated trochanteric fractures is very high: around 40%, with a majority of internal overrotation occurring during reduction maneuvers (35%). The mean rotational malalignment per patient was 15.3°. There was no early disassembly of the osteosynthesis material. These reduction defects had minimal functional consequences. However, this deformity would not necessarily have been tolerable for a younger population. The criteria normally used for reduction of intratrochanteric fractures are insufficient to prevent rotational malalignment. The increase in the number of radioscopic images (notably with measurement of anteversion of the healthy side) seems to be an advantageous solution to avoid these reduction errors during pre- and intraoperative maneuvers.

Conflict of interest statement

None.

References