



# Preoperative radiographic features of trochanteric fractures irreducible by closed reduction



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## ABSTRACT

**Introduction:** The aim of this study was to clarify the relationship between the preoperative radiographic classification of trochanteric fractures and the success/failure of closed reduction. Identification of irreducible fractures would be important to proceed promptly to direct reduction.

**Patients and methods:** Our retrospective analysis included 141 trochanteric fractures, in 122 women and 17 men, with a mean age of 85.7 years (range, 45–101 years). Evans' classification of trochanteric fractures, as modified by Jensen, and the lateral view classification were used, based on preoperative plain radiographs and computed tomography images. Features predictive of irreducible fractures were identified.

**Results:** Among the 141 fractures, 16 (11.3%) were irreducible by closed reduction. The position of the proximal fragment, relative to the shaft on lateral view, and the fracture pattern of the lesser and greater trochanters were predictive of the feasibility of obtaining a successful closed reduction. These criteria identified success/failure of closed reduction in 99.3% of cases.

**Conclusion:** Our findings should be useful for identifying patients in whom closed reduction would be suitable and for avoiding ineffectual manipulation in unsuitable patients.

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## Introduction

Over the past decade, the incidence rate of femoral trochanteric and femoral neck fractures has increased to approximately 150,000 cases per year in Japan. Moreover, as the general population of Japan continues to age, the incidence of these fractures and, thus, the opportunity for surgical treatment of these fractures are projected to continue to increase. The goal of the surgical treatment of intertrochanteric fractures is to obtain a stable reduction of the major component of each fracture and to achieve internal fixation [1,2]. Bone quality, fracture pattern, success of the reduction, implant design, and implant placement are all important factors to achieve successful surgical outcomes [3]. However, fracture reduction is the first of these factors that is directly under a surgeon's control. Correct fracture reduction is a prerequisite to achieving appropriate implant placement [4], whereas malreduction causes varus collapse and screw cutout [5]. For intertrochanteric fractures, adequate reduction of the medial and anterior cortex of the femur determines the stability of the fracture site

[2,6]. Therefore, obtaining proper fracture reduction and bone contact is a necessary first step for successful treatment of trochanteric fractures [7].

Normally, intertrochanteric fractures are managed by closed reduction, applying traction to the lower limb with the patient lying on a fracture table, followed by fixation [6]. In some cases, however, the fracture cannot be reduced by traction and requires closed reduction for the reduction to be continued in the operating theatre. Ultimately, some fractures are irreducible and require percutaneous reduction under fluoroscopy or mini-open procedure [7,8]. As such, identification of irreducible cases before surgery would avoid continuing an ineffectual closed reduction in the operating room and speed up the surgical process. We hypothesized that trochanteric fractures that are irreducible by traction on a fracture table could be identified by the pattern of fracture on preoperative radiographic images.

## Patients and methods

Our study was approved by the ethics committee of our hospital, and informed consent was obtained from all patients.

Our retrospective study group included 168 patients who underwent surgical treatment for a femoral trochanteric fracture, between May 2009 and May 2013, in our hospital. Twenty-nine

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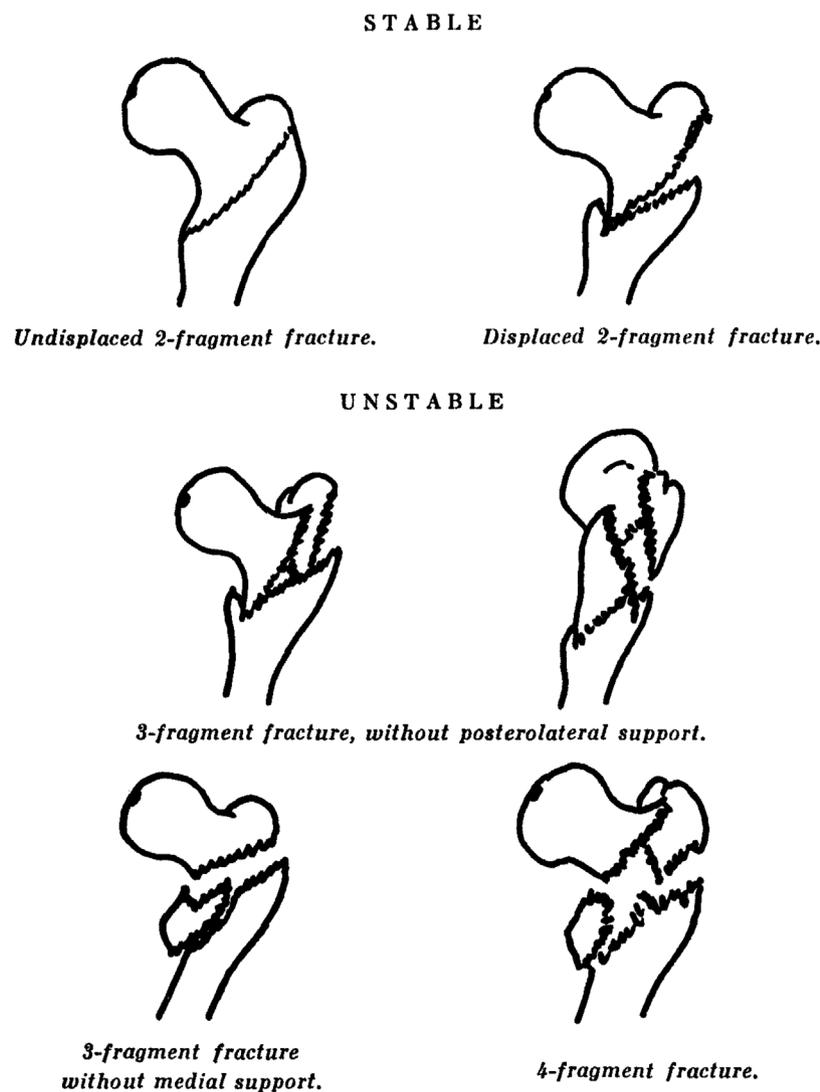
patients were excluded from the analysis as preoperative computed tomography (CT) images were not available. Ultimately, our analysis was based on 141 fractures, contributed by 122 women and 17 men, with a mean age at the time of surgery of 85.7 years (range, 45–101 years). Among these, two women underwent treatment for bilateral trochanteric fractures, sustained at different times. The mean delay from the time of fracture to surgery was 7.7 days (range, 2–33 days). None of the patients were treated with lower limb traction during the preoperative delay period, consistent with current evidence that neither skin nor skeletal traction before surgery provides a benefit [9].

#### Closed reduction technique

After administration of spinal or general anaesthesia, patients were placed in a supine position on a fracture table. The foot of the affected limb was fastened onto a traction boot. For interlocking fracture segments, traction was first applied in a direction of slight

abduction and external rotation, followed by application in neutral rotation and slight adduction for intramedullary nailing. As per a previous report [10], elevation or depression of the affected thigh, assessed on lateral radiographic view, was used to confirm reduction [10], with subsequent adjustments in varus or valgus, assessed on anteroposterior (A–P) view, and rotation, assessed on lateral view, performed, as needed, under fluoroscopy [11].

Anatomical reduction was defined as a diastasis of the fracture line of  $\leq 4$  mm [12], with the quality of the reduction classified according to the criteria of Baumgaertner et al. [3] A *good* reduction was defined by a neutral or slight valgus alignment on A–P view,  $< 20^\circ$  of angulation on lateral view and  $< 4$  mm of displacement for any of the fragments [3]. Focus was placed on the relationship between the head-neck fragment and the shaft [2,13,14], and on achieving continuity and contact on the medial cortical bone, assessed on A–P view, and the anterior cortical bone, assessed on lateral view. Based on current evidence, a displacement of the lesser trochanter was not considered [15]. Successful closed



**Fig. 1.** Jensen's classification [16] (Jensen, 1975). A fracture with 3 fragments but without posterolateral and medial support was defined as a type 3 + 4 fracture in the present study.

Type 1: 2 undisplaced fragments.

Type 2: 2 displaced fragments.

Type 3: 3 fragments without posterolateral support.

Type 3 + 4: 3 fragments without posterolateral and medial support.

Type 4: 3 fragments without medial support.

Type 5: 4 fragments.

reduction, under fluoroscopy, was defined as follows: restoration of the neutral position, with the head-neck fragment placed medially and/or anteriorly to the shaft, within the thickness of cortical bone.

#### Image-based assessment

Plain radiographs and three-dimensional computed tomography (3D-CT) images were classified into Type 1 through 5, according to Evans's classification, as modified by Jensen, [16] as follows: type 1, 2 undisplaced fragments; type 2, 2 displaced fragments; type 3, 3 fragments without posterolateral support; type 4, 3 fragments without medial support; and type 5, 4 fragments. In our study, a fracture with 3 fragments but without posterolateral and medial support was defined as a type 3 + 4 fracture (Fig. 1). Additionally, all fractures were divided into the following three subtypes<sup>17</sup> for analysis (Fig. 2): subtype-A, the head-neck fragment is located anterior to the shaft fragment; subtype-N, absence of a displacement of the head-neck fragment in both the anterior and posterior direction; and subtype-P, the head-neck fragment is located posterior to the shaft fragment. The relationship between each preoperative classification and the success/failure of closed reduction was evaluated.

#### Statistical analysis

The association between reducibility/irreducibility of the fracture and the preoperative classification was evaluated using descriptive statistics. The mean delay from the time-of-injury to surgery was compared between the reducible and irreducible groups using an independent t-test. Analyses were performed using GraphPad Prism (version 5.02 for Windows; GraphPad Software, La Jolla, CA, USA), with a p-value <0.05 considered significant.

## Results

Direct reduction under fluoroscopy, after failed closed reduction, was required in 16 patients (11.3%). The mean delay between the time-of-injury and surgery was 7.5 days (range, 133 days) in the reducible group and 8.9 days (range, 423) in the irreducible group ( $p = 0.81$ ). The distribution of Jensen's classification was as follows: type 1, 4 cases; type 2, 45 cases; type 3, 49 cases; type 4, 7 cases; and type 5, 36 cases. Using the lateral view classification, all subtype N fractures were reducible, while 9 of the 24 subtype-A and 7 of the 39 subtype-P fractures were irreducible by closed reduction. Based on 3D-CT views, the distribution of irreducible cases was as follows: 2 of the 28 type 2 fracture cases; 3 of the 51 type 3 fracture cases; 2 of the 18 type 3 + 4 fracture cases; and 9 of the 36 type 5 cases. Combining the Jensen's 3D-CT and lateral view classification, the following fracture types were irreducible (Table 1): fractures with 2 and 4 fragments in the subtype-A and -P groups; fractures with 3 fragments, without posterolateral support, in the subtype-P group; and fractures with 3 fragments, without medial and posterolateral support, in the subtype-A group. Representative images of irreducible fracture are shown (Figs. 3 and 4).

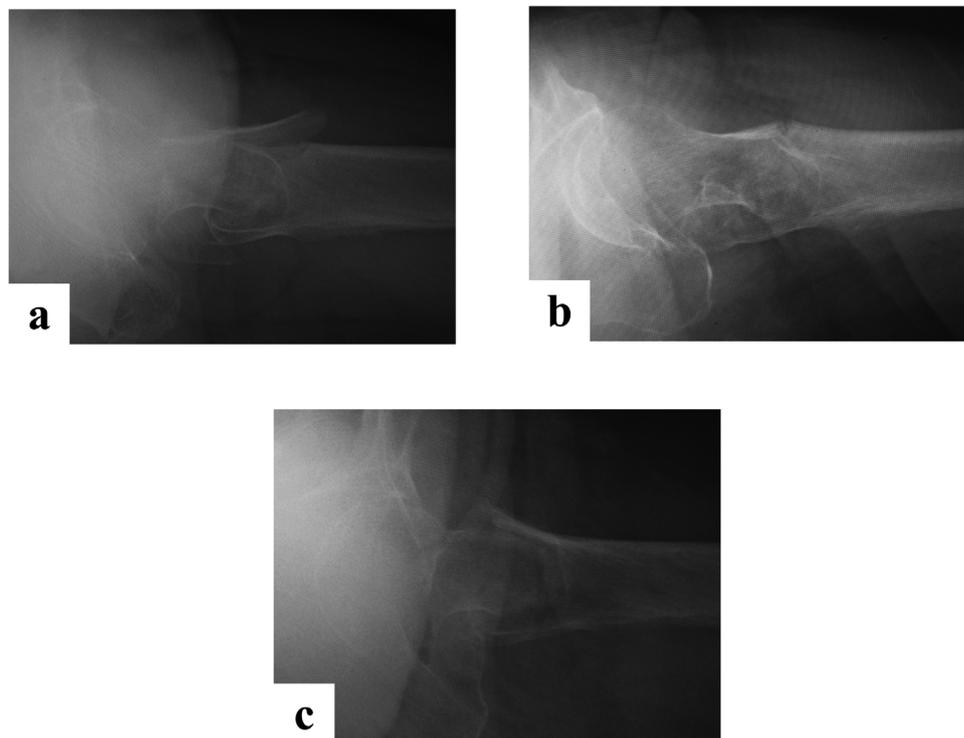
**Table 1**

Details of the fracture type and the patient distribution.

	Type 2 (n = 28)	Type 3 (n = 51)	Type 3 + 4 (n = 18)	Type 4 (n = 4)	Type 5 (n = 36)
<b>Subtype-A</b> (n = 24)	1/3	0/9	2/4	N/A	6/8
<b>Subtype-N</b> (n = 74)	0/23	0/31	0/4	0/4	0/12
<b>Subtype-P</b> (n = 39)	1/2	3/11	0/10	N/A	3/16

The 4 patients with Type 1 fractures (undisplaced 2 fragments) were excluded from the data presented.

Number of irreducible cases by closed reduction / Total number of each subgroup.

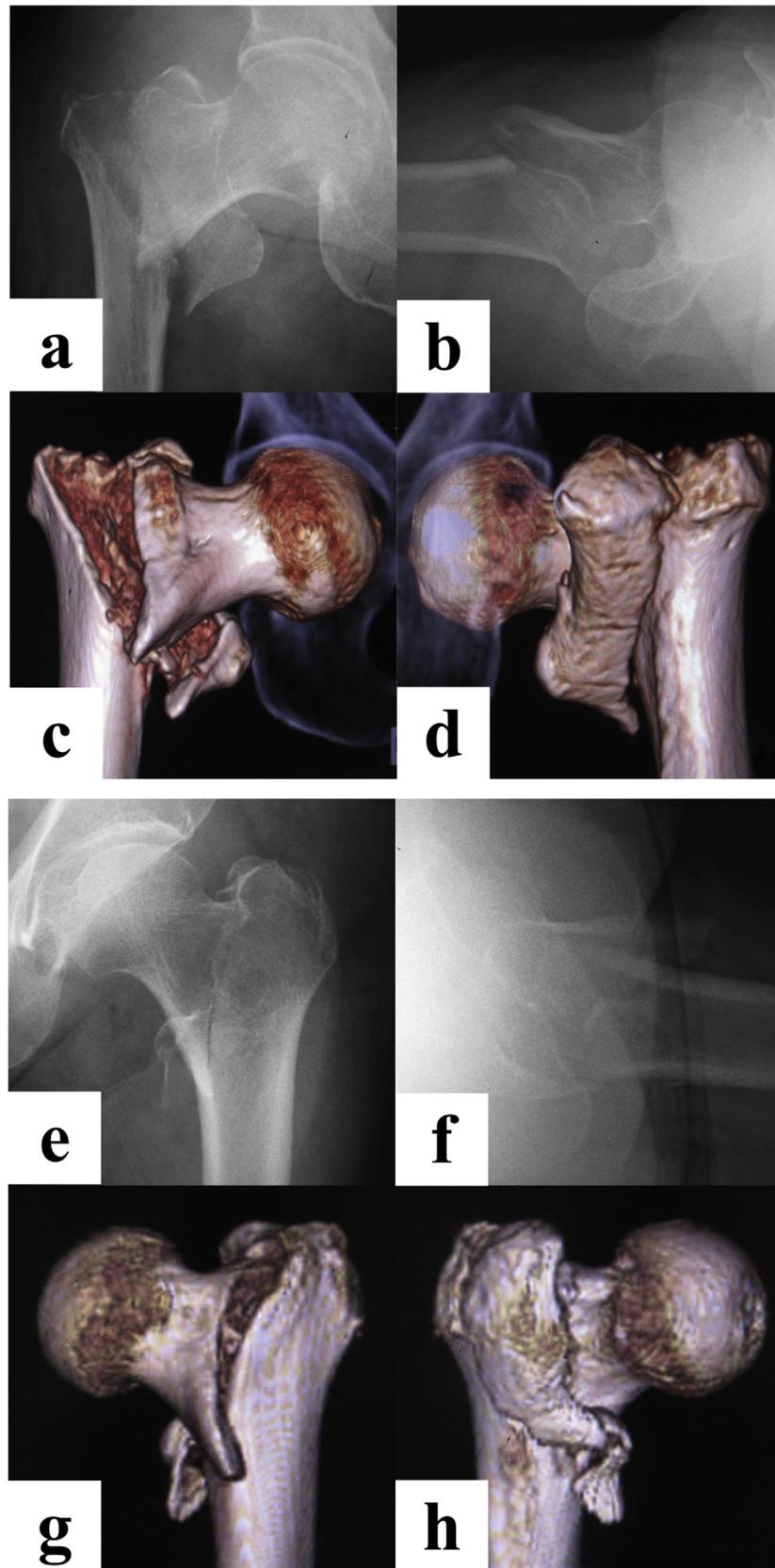


**Fig. 2.** Fracture classification on lateral view radiographs [17].

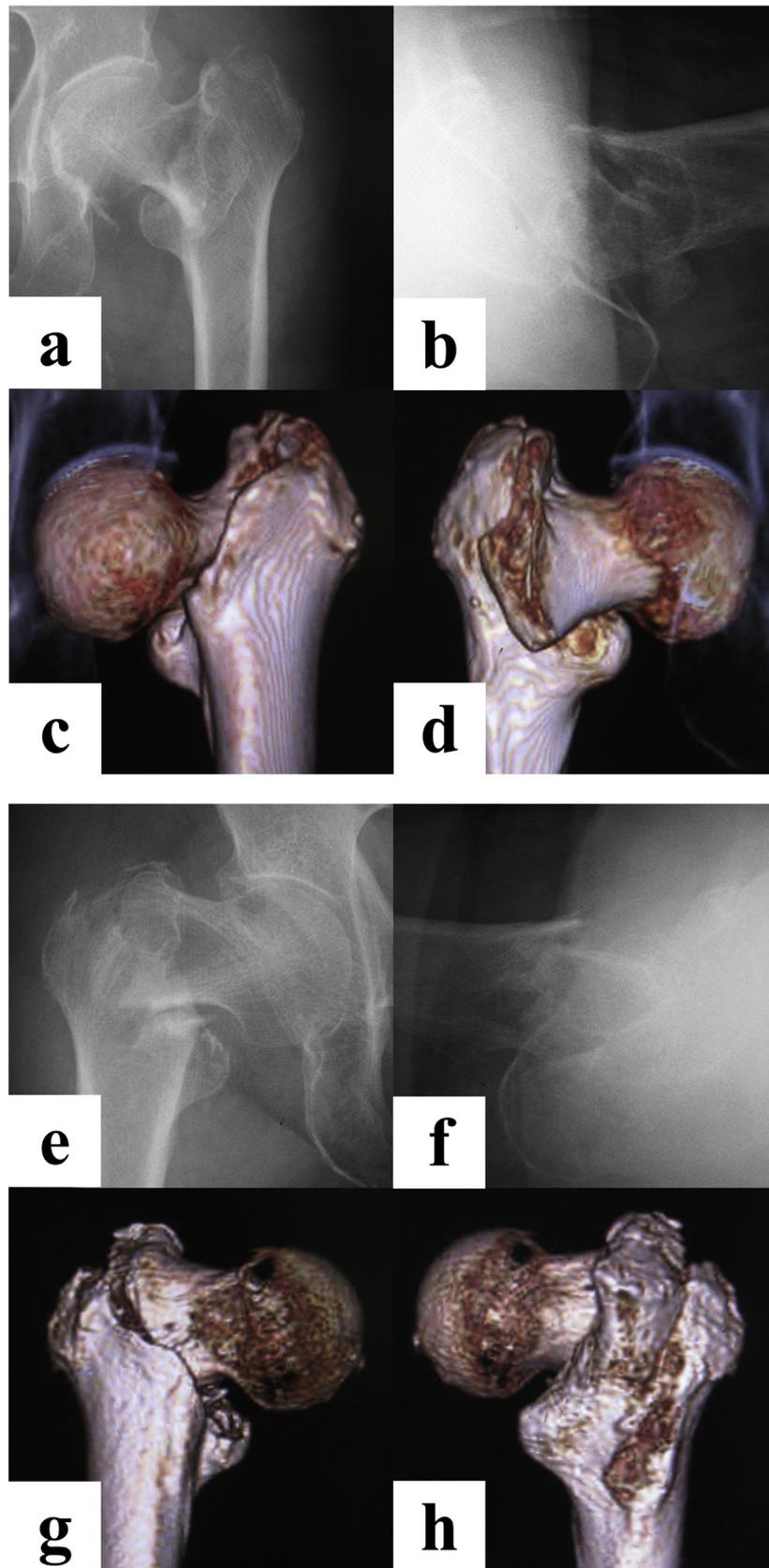
(a) Subtype-A: The head-neck fragment is located anterior to the shaft fragment.

(b) Subtype-N: The head-neck fragment is not displaced in both the anterior and posterior direction.

(c) Subtype-P: The head and neck fragment is located posterior to the shaft fragment.



**Fig. 3.** Representative images of irreducible fractures (Subtype-A). Case1 (a–d): Type 3 + 4, Subtype-A. Case2 (e–h): Type 5, Subtype-A. Plain radiograph: Anteroposterior view (a, e), lateral view (b, f). 3D-CT: anterior view (c, g), posterior view (d, h).



**Fig. 4.** Representative images of irreducible fractures (Subtype-P). Case3 (a–d): Type 2, Subtype-P. Case4 (e–h): Type 3, Subtype-P. Plain radiograph: Anteroposterior view (a, e), lateral view (b, f). 3D-CT: anterior view (c, g), posterior view (d, h).

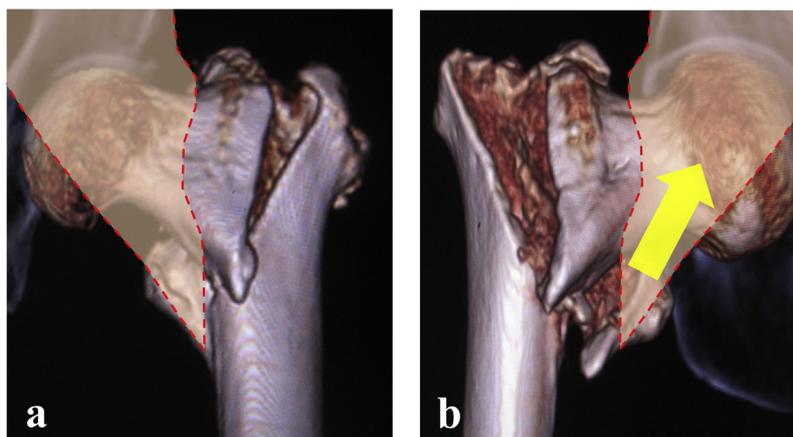
## Discussion

Quality of reduction determines the postoperative result. Anatomic reduction reestablishes bone contact with the medial anatomy, allowing it to perform its weight bearing function [6]. Meanwhile, subtype-P leads to excessive sliding [13]. Anatomic reduction has replaced nonanatomic methods such as the medial displacement osteotomy [6]. Traction, applied under fluoroscopy is normally used as the initial management of trochanteric fractures, with the rotation being dictated by the position of the proximal fragment of the fracture relative to the shaft [18]. Generally, neutral or slight internal rotation is used when the proximal segment consists of the head and neck, with slight external rotation being used when the proximal segment included the head-neck and the greater trochanter. External rotation during traction is also indicated for comminuted fractures. In their review of 154 closed reduction of trochanteric fractures, Bennister et al. reported that traction in neutral rotation provided the *best* reduction in most cases, with internal rotation enhancing reduction of fractures with 2 or 3 fragments, and external rotation being useful for fractures with 4 fragments [19]. Several studies have reported that closed reduction, performed on a fracture table, is unsuccessful in 5.8–17.6% of cases of femoral trochanteric fractures [20–22]. In our retrospective case series, 11.3% of cases were identified as irreducible by closed reduction. Based on preoperative lateral view radiographic images, we identified successful closed reduction for all subtype-N fractures. However, combination of the lateral view classification and Jensen's classification on 3D-CT images provided features predictive of irreducibility for subtype A and P fractures.

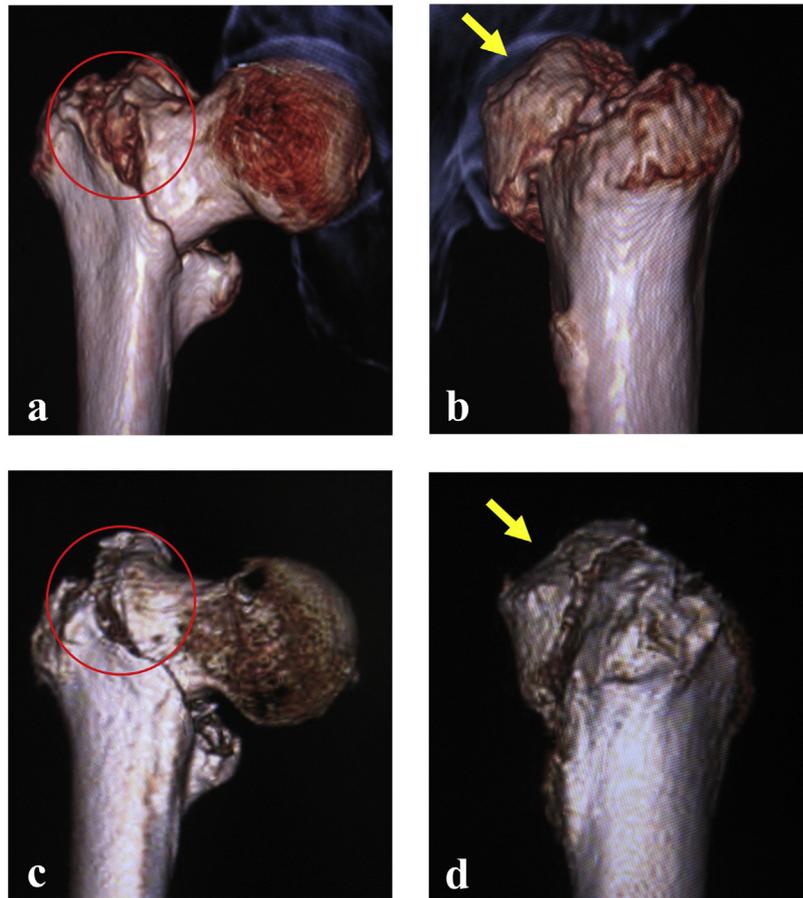
For subtype A fractures, closed reduction was successful when there was no displacement of the lesser trochanter, whereas fractures with a proximal displacement of the lesser trochanter were irreducible (Fig. 5). Therefore, the position of the lesser trochanter is an important factor contributing to the success/failure of closed reduction. The displacement of the head-neck fragment and the position of the lesser trochanter in subtype-A fractures (in which the anterior fracture line crosses distal to the inter-trochanteric line) are influenced by the effect of the iliofemoral ligament and iliopsoas tendon (IPT). The iliofemoral ligament is a major stabilizer of the hip joint [23], restricting hip extension. This ligament is divided into superior and inferior branches. The superior and inferior branches attach to the upper and lower part of the intertrochanteric line anterior to the hip joint, respectively [24]. Thus, the head-neck fragment can be displaced

anteriorly by the relative tension of both the superior and inferior branches of the ligament. Moreover, the IPT runs obliquely in front of the femoral head and neck due to varus deformity and shortening at the fracture site. Increased tension in the IPT is induced by traction applied to the lower limb in cases of fractures with an intact or undisplaced lesser trochanter, causing pressure to be applied against the anterior surface of the femoral neck that helps to reduce the head-neck fragment. However, when the lesser trochanter is fractured and medially displaced, which inhibits proximal fragment reduction, tension developed in the IPT by the applied traction would increase the anterior displacement of the proximal (head-neck) segment (Fig. 5). Of note, the successful closed reduction obtained in the 3 cases of subtype-A fracture included a displaced lesser trochanteric fragment in which the head-neck fragment included a long anterior spike, extending below the lesser trochanter. Considering that the vastus medialis originates from the inferior intertrochanteric line, the tension developed in this muscle during traction could exert a force on the anterior spike, preventing the head-neck fragment from being displaced anteriorly. Said et al. [25] however, reported on 5 cases of trochanteric fractures with a long anterior spike, in middle-aged men, in which open reduction was required due to failed closed reduction. In these cases, the lesser trochanter was included in the distal fragment of the fracture, being trapped between the iliopsoas tendon and the lesser trochanter. On lateral view, these fractures were classified as subtype-P fractures, with the femoral shaft being located anterior to the head-neck segment.

In our case series, for the subtype-P fractures that were successfully reduced, the tip of the greater trochanteric fragment was clearly displaced in the posterior direction. In contrast, cases in which the greater trochanter was either intact or was not clearly displaced were irreducible (Fig. 6). This reflects the mechanics of the fracture in which a shift of the head-neck segment in a proximal and valgus direction is needed to move the head-neck fragment off the interlocking area of the shaft fragment. Thus, sufficient lateral and proximal space at the fracture site is necessary for closed reduction of the head-neck fragment, with contact between the greater trochanter and the lateral base of the femoral neck making reduction difficult to achieve. The anterior and posterior fracture line in subtype-P fractures normally cross proximal to the intertrochanteric line and distal to the intertrochanteric crest, respectively. Thus, the head-neck fragment can be displaced in a posterior direction in these cases by the action of the external rotators of the hip and the gluteal muscles on the proximal portion of the greater trochanter. The resulting decrease



**Fig. 5.** Subtype-A fracture pattern, with the head-neck fragment located anterior to the shaft fragment. (a) Reducible cases, having an intact lesser trochanter. (b) Irreducible cases, with a proximal displacement of the lesser trochanter caused by pulling forces applied by the iliopsoas (yellow bold arrow). Red dotted line: Iliopsoas tendon and muscle. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).



**Fig. 6.** Subtype-P fracture pattern, with head-neck fragments located posterior to the shaft fragment. Reducible (a, b) and irreducible (c, d) fracture cases. Reducible cases had a wider bone defect space of the posterolateral fracture region (red circle; a), compared to irreducible cases (red circle; c). The greater trochanteric fragment (yellow bold arrow; b) was large and displaced posterior to the shaft in reducible cases. In irreducible cases, the greater trochanteric fragment was only slightly displaced (yellow bold arrow; d). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

in the contact area in the posterolateral region of the fracture in these cases can pull the head-neck fragment off the femoral shaft fragment. However, if the greater trochanter was intact or its fracture fragment small, the firm contact in the posterolateral region of the fracture would increase the difficulty of the closed reduction (Fig. 6).

Taken together, we identified the following 3 criteria as being necessary for successful closed reduction of a femoral trochanteric fracture. First, all subtype-N fractures can be reduced by traction applied with the patient on a fracture table. Second, subtype-A fractures with a displaced lesser trochanteric fragment are irreducible, except for those with a long anterior spike. Third, subtype-P fractures with an intact greater trochanter or small greater trochanteric fragment are also irreducible. These criteria predicted the success/failure of closed reduction in 140 of 141 fractures (99.3%) included in our analysis. The exception was one patient who had a subtype-A fracture with 2 fragments and an intact lesser trochanter. Review of the clinical history of this patient revealed that she had continued to walk, as usual, until the time of admission, 6 days after the injury. The consequent additional mechanical stress on the fracture site is likely to have contributed to the difficulty of the closed reduction in this case.

Our findings indicate that evaluation of both the fracture type and the direction of displacement of the fracture fragments are necessary to predict the outcome of closed reduction, preoperatively, and that 3D-CT can provide useful assistance in this respect. Identification of irreducible cases is clinically relevant to avoid

unnecessary procedures, as well as to shorten the in-operating room time and to protect the soft tissues around the fracture site by avoiding unnecessary manipulation.

The limitations of our study need to be acknowledged. First, we did not evaluate the rotational alignment of the fracture site postoperatively, as postoperative CT imaging was not performed. A previous study reported a rate of rotational malunion of about 40%, with internal over-rotation being induced during the reduction manoeuvre in the majority of cases [26]. Of note, because we evaluated reduction intraoperatively, we believe that our use of the anteromedial bone contact was appropriate as a standard to determine the success/failure of the closed reduction procedure. Second, we did not evaluate other factors that may have contributed to the failure of closed reduction, including soft tissue injury or tightness, periosteal status, and intercalation of the IPT at the fracture site. Our analysis did show, however, an implication of the tension of the IPT, and fracture/displacement of the lesser and greater trochanter in the irreducibility of trochanteric fractures. However, the causative effect of these factors on the success/failure of closed reduction remains to be clearly evaluated by direct confirmation of these factors in all cases. Third, our sample size was relatively small, with 141 fractures. Of note, Evans type II fractures (reverse obliquity fractures) were not observed in our case series. Moreover, the majority of our patients were elderly, with a mean age of 85.7 years at the time of surgery and, thus, it is possible that different features of the fracture pattern may influence the success/failure of closed reduction in young middle-aged patients.

## Conclusions

Although our criteria for predicting the success/failure of closed reduction for trochanteric fractures may not cover all patients or fracture types, our findings should be useful for identifying patients in whom closed reduction would be suitable and, thus, avoiding ineffectual manipulation in unsuitable patients.

## Declaration of Competing Interest

All authors declare that they have no conflict of interest.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.injury.2019.06.035>.

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