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Anterior Malreduction is Associated With Lag Screw Cutout After Internal Fixation of Intertrochanteric Fractures

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Abstract

Background Lag screw cutout is a devastating complication after internal fixation of an intertrochanteric fracture. Although the tip-apex distance (TAD) is known to be associated with this complication, another factor we thought was potentially important—fracture reduction on an oblique lateral view—has not, to our knowledge, been explored.

Questions/purposes (1) Is a well-reduced fracture position on an oblique lateral view after internal fixation of intertrochanteric fracture associated with a lower odds of postoperative cutout, independently of the TAD? (2) Is postoperative sliding of the lag screw after fixation associated with postoperative cutout?

Methods Patients with intertrochanteric fractures who were at least 65 years old and who had been treated with internal fixation in one of six facilities between July 2011 and December 2017 were included. All patients in the study group had lag screw cutout, and controls were selected by risk-set sampling of age-matched and sex-matched patients using a ratio of 4:1 for patients from each hospital. Of the 2327 intertrochanteric fractures, there were 36 patients (0.02 per person-year), with a mean age of 85 years; 89% (32) were women. In the control group, there were 135 controls. There was no difference in age or sex between the two groups. Sagittal reduction was evaluated using an immediate postoperative oblique lateral radiograph (anterior malreduction versus anatomic reduction or posterior malreduction). The association between anterior malreduction and the odds of cutout was estimated by conditional logistic regression analysis with the TAD and interaction between the TAD and the reduced position as covariates. As a sensitivity analysis, we estimated whether sliding within 2 weeks postoperatively was associated with cutout.

Results After controlling for the potentially confounding variables of age and sex, we found that anterior malreduction was independently associated with a higher odds of cutout compared with anatomic reduction or posterior malreduction (adjusted OR 4.2 [95% CI 1.5 to 12]; p = 0.006). There was also an independent association between cutout and larger TAD (≥ 20 mm) (adjusted OR 4.4 [95%

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The work was performed at Teikyo University Hospital, Tokyo, Japan.

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CI 1.4 to 14]; p = 0.01). However, the association between cutout and reduction was not modified by the TAD (adjusted OR of interaction term 0.6 [95% CI 0.08 to 4]; p = 0.54). Postoperative sliding ≥ 6 mm within 2 weeks was associated with higher odds of cutout after adjusting for age and sex (adjusted OR 11 [95% CI 3 to 40]; p < 0.001).
Conclusion In patients older than 65 years with intertrochanteric fractures, anterior malreduction on a lateral oblique view was associated with much greater odds of postoperative cutout than anatomic reduction or posterior malreduction. Because anterior malreduction is within the surgeon's control, our findings may help surgeons focus on intraoperative reduction on an oblique lateral view to prevent cutouts. Although this factor is a reliable indicator, the results should be applied to cephalomedullary nails, because there was only one patient with cutout among those with sliding hip screws. Because this study was conducted in a homogenous Japanese population, future studies should focus on the association between anterior malreduction and cutout in people of different ethnicities, adjusting for confounding factors such as implant type and surgeon level.
Level of Evidence Level III, therapeutic study.

Introduction

Proximal femoral fractures are among the most common fragility fractures seen by orthopaedic surgeons in daily practice. Although osteoporosis treatment has reduced the incidence of this fracture in some countries, the number of fractures worldwide is expected to increase as the absolute number of older people increases [8, 10, 14, 30]. Two major problems associated with this fracture are mortality and walking impairment after injury [18, 26]. An increase in the number of people with walking impairments increases the need for social care and contributes to social burden [8]. Therefore, finding methods to prevent postoperative complications of this fracture, which worsen treatment outcomes, is of great interest to both orthopaedic surgeons and health policymakers.

Approximately half of proximal femoral fractures are intertrochanteric fractures, and internal fixation with a fixed-angle device that allows compression, such as a sliding hip screw or cephalomedullary nail, is the standard treatment [31, 32]. Internal fixation with a sliding hip screw or cephalomedullary nail has been reported to result in a similar likelihood of bone healing because of compression between the neck and diaphyseal fragments [31]. One of the most severe postoperative complications of this procedure is lag screw cutout, which is the intra-articular penetration of cephalic fixation through the femoral head (Fig. 1). If cutout occurs, it typically results in conversion to arthroplasty, with a high risk of complications [5, 12]. Although the frequency of cutout is not high (range 1.0% to 6.9%) [24], the absolute number of patients experiencing this complication is high because intertrochanteric fractures are so common. Therefore, it is crucial to identify factors within a surgeon's control that can reduce the likelihood of cutout.

Previous observational studies have reported that older age, greater tip-apex distance (TAD), and poor reduction are associated with a higher likelihood of cutout [2, 4, 15, 25, 29, 39]. An observational study among Japanese women suggested that TAD was the most influential factor in cutout [11]. On the other hand, recent studies have reported that anteromedial cortex contact between the neck and diaphyseal fragment affects postoperative instability [6, 19, 22]. In the past decade, a method for evaluating anteromedial cortex contact using radiographs in the sagittal plane has been reported in East Asia [7, 17, 19, 21, 28, 38, 40]. Reduction as seen on oblique lateral radiographs was classified into three categories according to the relationship between the anterior cortex of the neck fragment and the anterior cortex of the diaphyseal fragment (Fig. 2). In anatomic reduction and posterior malreduction, during weightbearing, the distal edge of the anterolateral cortex of the neck fragment contacts the proximal anteromedial cortex of the diaphyseal fragment, thus causing load sharing between the fragments. In contrast, in anterior malreduction,

Fig. 1 This radiograph shows the cutout of a lag screw.

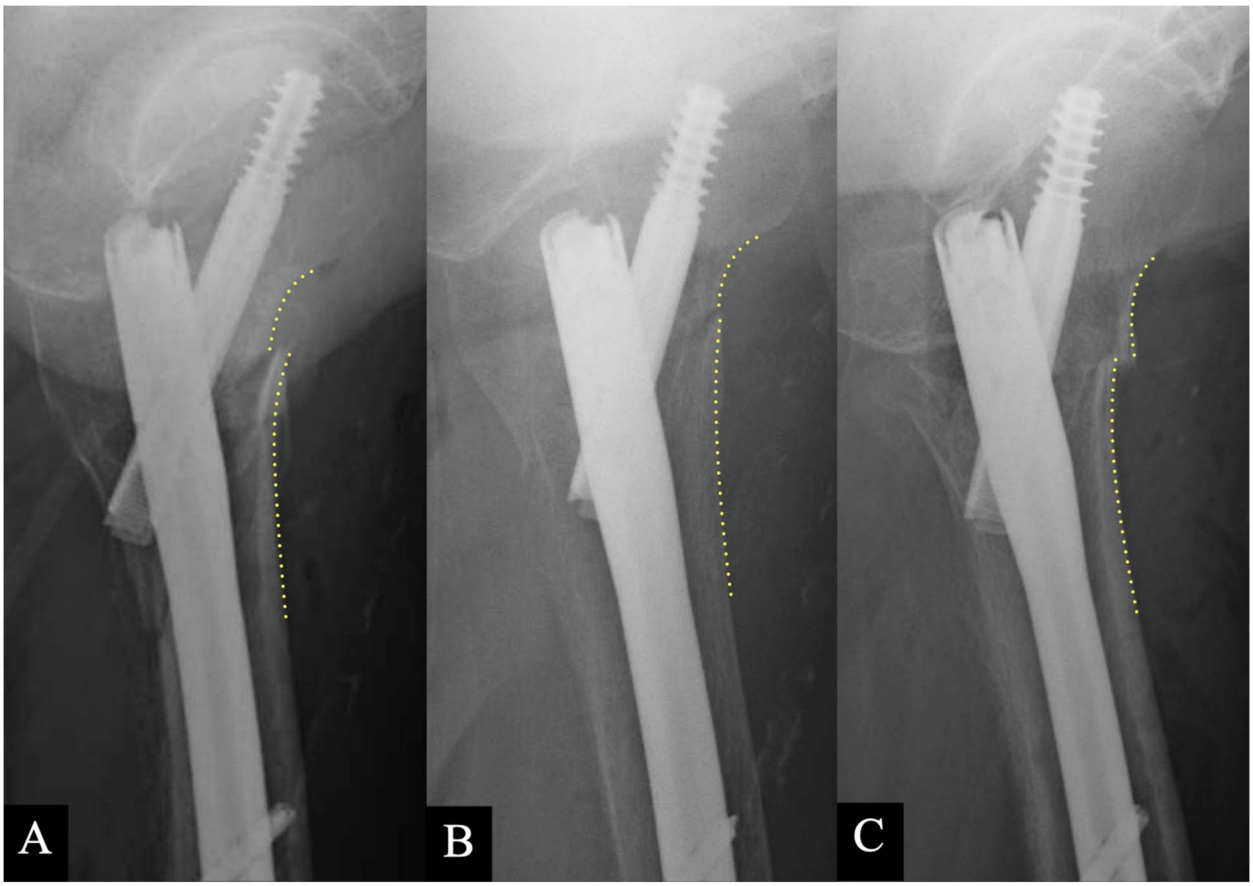

Fig. 2 These oblique radiographs show the sagittal reduced positions. (**A**) Anterior malreduction is shown here. (**B**) Anatomic reduction is shown. (**C**) Posterior malreduction is shown. The dotted line indicates the anterior cortex of the neck and diaphyseal fragment.

the distal edge of the anterolateral cortex of the neck fragment slides into the canal of the diaphyseal fragment without load sharing [19, 40]. Consequently, anterior reduction results in greater postoperative sliding and instability than anatomic reduction or posterior malreduction [17, 28, 36, 38]. Although a recent meta-analysis of observational studies suggested that anterior malreduction is associated with cutout, the result of the pooled analysis was low in its certainty of evidence [42]. Therefore, it is still unclear whether anterior malreduction is associated with cutout, which is a more clinically important outcome of intertrochanteric fractures than the amount of sliding. In addition, no studies have adequately estimated whether other factors, including confounding and interaction effects, are independently associated with cutout.

We therefore asked: (1) Is a well-reduced fracture position on an oblique lateral view after internal fixation of intertrochanteric fracture associated with a lower odds of postoperative cutout, independently of the TAD? (2) Is postoperative sliding of the lag screw after fixation associated with postoperative cutout?

Patients and Methods

Study Design and Setting

This was a case-control study nested in a multicenter cohort of patients with intertrochanteric fractures repaired with a cephalomedullary nail or sliding hip screw. The cohort comprised patients from a university trauma center and five referral hospitals in Japan.

Patients

We identified eligible patients 65 years or older who had undergone internal fixation for intertrochanteric fractures between July 2011 and December 2017 from the surgical list of each hospital. We collected data on the patients' age, sex, diagnosis, surgical procedure, date of surgery, last postoperative hip radiographs, and other radiographs. We excluded patients with subtrochanteric fractures, pathologic fractures associated with malignancy, and

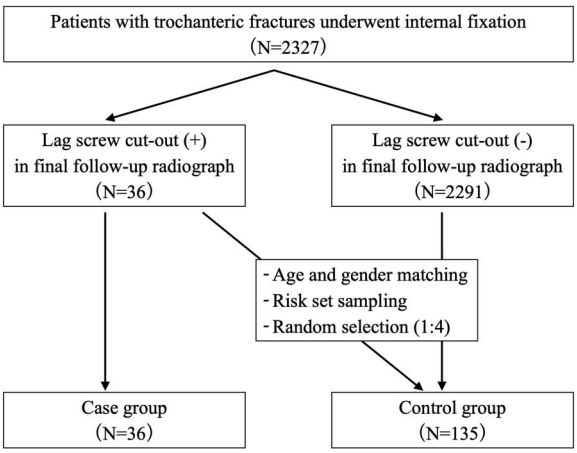

Fig. 3 This flow diagram shows the patients included in this study.

patients for whom follow-up radiographs had not been taken.

Selection of Cases and Controls

We identified the case group as patients whose final follow-up radiographs showed lag screw cutout and reviewed their postoperative radiographs during the follow-up period. We used the date of the first observation of lag screw cutout on postoperative radiographs and calculated its duration from the surgery date. Other than those in the case group, we considered all patients as candidates for the control group, and we calculated the observational duration from the date of the last radiograph and surgery date. We performed risk-set sampling to choose the control group at each hospital using the duration between surgery and cutout in the case group and using the observational duration in the control group. After matching sex and age (difference within 3 years of age) as confounding factors, we randomly selected the control group in a 4:1 ratio to the case group without allowing duplication within the matched strata [20, 37] (Fig. 3).

During the study period, there were 2327 patients with intertrochanteric fractures in all facilities. The total incidence rate of cutout was 0.02 per person-year. A retrospective assessment of postoperative radiographs identified 36 lag screw cutouts for inclusion in the case group. Matching and risk-set sampling identified 135 patients for inclusion in the control group. In the case group, 11% were male (four patients) and 89% were female (32), and the mean age was 85 ± 8 years. On the other hand, in the control group, 9% were male (12) and 91% were female (123), and the mean age was 85 ± 7 years (Table 1). Among all patients with cutout, three underwent internal fixation again, 30 underwent conversion to arthroplasty, and the remaining three declined any further surgical procedures. There were no cases of cutout with signs suggestive of infection. The mean duration between surgery and the first observation of lag screw cutout on postoperative radiographs was 99 ± 88 days. The initial surgeries were performed or supervised by a board-certificated orthopaedic surgeon of the Japanese Orthopaedic Association. In those with fixation with cephalomedullary nails, all nails were interlocked.

Main Exposure

Based on an oblique lateral radiograph [7] of the proximal femur taken in the operating room immediately after surgery, sagittal reduction of the anteromedial cortex contact between the neck and diaphyseal fragment was classified into three categories: anterior malreduction, which was the anterior cortex of the neck fragment posterior to the anterior cortex of the diaphyseal fragment; anatomic reduction, in which both fragments were located anatomically; and posterior malreduction, which was the position of the two fragments opposite from the anterior malreduction [17, 36, 38, 40] (Fig. 2). Because anatomic reduction and posterior malreduction have positive contact with the anteromedial cortex [19, 40], they were combined. In this study, these three classifications were divided into two groups according to the anteromedial cortex contact (anterior malreduction or other reduction) as the main exposure. In all facilities, postoperative oblique-view lateral radiographs were taken in a patella-forward position to control rotation of the lower extremity. Three examiners (two expert trauma surgeons [TS, KM] and one fellowship-level trauma surgeon [TI]) evaluated the sagittally reduced position of 20 randomly selected postoperative oblique lateral radiographs and calculated the Fleiss kappa coefficient to measure the interrater agreement of the exposure. A kappa coefficient of 0.2 or less was considered poor agreement, 0.21 to 0.40 was considered fair agreement, 0.41 to 0.60 was considered moderate agreement, 0.61 to 0.80 was considered substantial agreement, and 0.81 or more was considered almost perfect agreement [23]. As a result, Fleiss kappa as the interrater agreement for classifying the sagittally reduced position was 0.86, interpreted as almost perfect agreement.

Variables

After matching, we extracted the patients' demographic, surgical, and treatment information from the medical records. The measured variables were age, sex, injured side (left or right), BMI (< 18.5 kg/m^2, 18.5 to 25.0 kg/m^2, or > 25.0 kg/m^2) [41], American Society of Anesthesiologists

Table 1. Demographic, surgical, and treatment data of the patients

Variable	Case group (n = 36)	Control group (n = 135)	p value
Age in years	85 ± 8	85 ± 7	0.87
Sex, female	89 (32)	91 (123)	0.68
Injured side, left	53 (19)	54 (73)	0.89
BMI in kg/m^2			
< 18.5	26 (9 of 35)	31 (40 of 128)	0.75
18.5 to 25.0	60 (21 of 35)	58 (74 of 128)	
≥ 25.0	14 (5 of 35)	11 (14 of 128)	
ASA-PS			
1	3 (1 of 33)	2 (3 of 130)	0.96
2	49 (16 of 33)	50 (65 of 130)	
3	49 (16 of 33)	48 (62 of 130)	
Walking ability before injury, no aid or with a cane	71 (25 of 35)	58 (78 of 134)	0.15
Living condition before injury, own home	78 (28)	67 (91)	0.23
AO/OTA classification			
AO31-A1	42 (15)	58 (78)	0.06
AO31-A2	44 (16)	38 (51)	
AO31-A3	14 (5)	4 (6)	
History of contralateral hip fracture	14 (5)	11 (15)	0.64
Waiting period for surgery			
< 3 days	61 (22)	79 (106)	0.054
3 to 7 days	31 (11)	19 (26)	
> 7 days	8 (3)	2 (3)	
Operative time in minutes	55 ± 23	49 ±20	0.17
Blood loss during surgery			
< 20 mL	44 (16)	47 (63)	0.94
20 to 100 mL	42 (15)	42 (56)	
> 100 mL	14 (5)	12 (16)	
Reduction maneuver, closed	50 (18)	67 (90)	0.07
Type of implant, CMN	97 (35)	92 (124)	0.26
Nail length, short nail	89 (31 of 35)	94 (116 of 124)	0.32
TAD, ≥ 20 mm	33 (12)	14 (19)	0.008
Postoperative neck-shaft angle as continuous variable	131 ± 8	129 ± 5	0.04
Postoperative neck-shaft angle as categorical variable, < 130°	50 (18)	61 (83)	0.21
Medial cortex support on AP view, positive	78 (28)	85 (115)	0.29
Sagittal reduction in oblique lateral view, anterior malreduction	42 (15)	19 (25)	0.004
Length of hospital stay			
< 15 days	8 (3)	9 (12)	0.12
15 to 30 days	19 (7)	37 (50)	
> 30 days	72 (26)	54 (73)	
Postoperative sliding of lag screw within 2 weeks as continuous variable	8 ± 5	3 ± 3	< 0.001

Table 1. continued

Variable	Case group (n = 36)	Control group (n = 135)	p value
Postoperative sliding of lag screw within 2 weeks as categorical variable, ≥ 6 mm	52 (14 of 27)	13 (15 of 112)	< 0.001

Data presented as mean ± SD or % (n); ASA-PS = American Society of Anesthesiologists physical status; SHS = sliding hip screw; CMN = cephalomedullary nail; TAD = tip-apex distance.

physical status [1], walking ability before injury (walking with a cane or without any aid or other) [16], living condition before injury (own home or institution), AO/OTA classification [27], history of contralateral hip fracture, waiting period for surgery (< 3 days, 3 to 7 days, or > 7 days), operative time, amount of blood loss during surgery (< 20 mL, 20 to 100 mL, or > 100 mL), reduction maneuver (closed, percutaneous, or open), type of implant (sliding hip screw or cephalomedullary nail), TAD (< 20 mm or ≥ 20 mm) [11], postoperative neck-shaft angle (continuous variable, < 130° or ≥ 130°) [37], postoperative medial cortex support on an AP view (positive or negative) [6], and length of hospital stay (< 15 days, 15 to 30 days, or > 30 days). The TAD measured on the postoperative radiograph was calibrated using the known diameter of the lag screw [2]. We measured the amount of lag screw sliding within 2 weeks according to the change in the distance between the tip of the lag screw and intersection with the center of the nail after calibrating the rotational difference using the known length of the lag screw from the surgical record (continuous variable, < 6 mm or ≥ 6 mm) [9].

Patients in the case group had a higher proportion of TAD ≥ 20 mm, anterior malreduction, and postoperative sliding of lag screw within 2 weeks ≥ 6 mm than patients in the control group (Table 1). The proportion of TAD ≥ 20 mm was 33% (12) in the case group versus 14% (19) in the control group (p = 0.008), the proportion of anterior malreduction was 42% (15) in the case group versus 19% (25) in the control group (p = 0.004), and the proportion of postoperative sliding ≥ 6 mm was 52% (14 of 27) in the case group versus 13% (15 of 112) in the control group (p < 0.001).

Primary and Secondary Study Outcomes

Our primary study goal was to quantify the magnitude of the association between anterior malreduction and postoperative cutout compared with other reductions. After case and control selection, we calculated the adjusted odds of anterior malreduction by adjusting for age, sex, and TAD with its interaction between sagittal reduction a priori.

Our secondary study goal was to quantify the magnitude of the association between early postoperative sliding and postoperative cutout. We calculated the adjusted odds of postoperative sliding amount after adjusting for age and sex.

Ethical Approval

This retrospective observational study was approved by the institutional review board of Teikyo University. Because the study was retrospective, we obtained informed consent via the opt-out method. All procedures involving human participants were performed in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Statistical Analysis

We designed the analytical method before data collection for the primary outcome of this study. Demographic, surgical, and treatment data were compared between the case and control groups using a t-test for continuous variables and the chi-square test for categorical variables to describe the balance between the two groups. We did not use these data for variable selection in the primary multivariate analysis. Missing variables were analyzed using pairwise deletions. As the primary multivariate analysis, the association between sagittal reduction and cutout was estimated with a conditional logistic regression analysis to adjust for the confounding effects of matching variables, such as age and sex [33], and we adjusted for the covariates of TAD and the interaction between sagittal reduction and TAD, which are known to have a strong association with postoperative cutout [2, 11, 15, 29, 39]. Because this variable selection was determined before data collection, we did not use the results of univariate analyses. The adjusted OR, acquired from density sampling and conditional logistic regression analysis is mathematically consistent with the incidence rate ratio of cutout, different from general case-control studies [20, 35].

The sample size was calculated based on a target OR of 3, a matching ratio of 4, an anterior malreduction of 0.3 [17, 38], an alpha error probability of 0.05, and a power of 0.80. Thus, this study required at least 33 patients.

As a post hoc analysis for the secondary outcome of this study, we evaluated the association between the amount of postoperative sliding within 2 weeks of surgery and cutout. The amount of postoperative sliding was divided into two categories: less than 6 mm and 6 mm or more. The effect of sliding on cutout was estimated using a conditional logistic regression analysis adjusted for age and sex.

For all analyses, including sample size calculation, we used STATA version 16.0 (Stata Corp LLC). Statistical significance was defined as a two-sided p value less than 0.05.

In the primary and sensitivity analyses, the adjusted OR, 95% CI, and p values were determined.

Results

After controlling for potential confounding variables, such as age and sex, we found that anterior malreduction and TAD ≥ 20 mm were independently associated with increased odds of postoperative cutout (Table 2). If we considered that anatomic reduction or posterior malreduction and TAD < 20 mm were the base combination, the adjusted odds of cutout combined with anterior malreduction and TAD < 20 mm was four times higher than that of the base combination (adjusted OR 4.2 [95% CI 1.5 to 12]; p = 0.006). The adjusted odds of cutout in combination with anatomic reduction or posterior malreduction and TAD ≥ 20 mm was also four times higher than that of the base combination (adjusted OR 4.4 [95% CI 1.4 to 14]; p = 0.01). The adjusted odds of cutout in combination with anterior malreduction and TAD ≥ 20 mm was 10 times higher than that of the base combination (adjusted OR 10 [95% CI 2.0 to 50]; p = 0.005); however, no differences were observed in the interaction term (adjusted OR 0.6 [95% CI 0.08 to 4]; p = 0.54).

After controlling for potential confounding variables, such as age and sex, we found that early postoperative sliding of the lag screw ≥ 6 mm within 2 weeks was independently associated with increased odds of cutout, compared with sliding < 6 mm in the post hoc analysis (adjusted OR 11 [95% CI 3 to 40]; p < 0.001).

Table 2. Factors independently associated with postoperative cutout

Variable	Adjusted OR (95% CI)	p value
Anatomic reduction or posterior malreduction and TAD < 20 mm	1 (Base)	
Anterior malreduction and TAD < 20 mm	4.2 (1.5 to 12)	0.006
Anatomic reduction or posterior malreduction and TAD ≥ 20 mm	4.4 (1.4 to 14)	0.01
Anterior malreduction and TAD ≥ 20 mm	10 (2.0 to 50)	0.005
Interaction term	0.6 (0.08 to 4)	0.54

Conditional logistic regression analysis adjusted for age and sex. TAD = tip-apex distance.

Discussion

Cutout after internal fixation of intertrochanteric fractures is a severe complication, and several factors are associated with cutout, such as older age, poor reduction, and greater TAD [2, 4, 15, 29, 39]. It is crucial to identify factors within a surgeon's control to reduce the likelihood of cutout. Anterior malreduction on an oblique lateral view has been associated with a greater amount of postoperative sliding [17, 28, 36, 38], but it was unclear whether anterior malreduction was associated with cutout. The results of this retrospective observational study showed that the association between anterior malreduction and cutout was as large as that with TAD after adjusting for the confounding factors of age and sex. This suggests that anterior malreduction should be avoided during internal fixation to lower the odds of postoperative cutout.

Limitations

First, it would be unwise to apply the results of this study to SHS implants because of potential selection bias. To avoid an arbitrary analysis of the acquired data, the methodology for the primary analysis of this study was determined before data collection. After the analysis, only one patient among those with cutout underwent fixation with SHS. SHS may have been used more frequently in patients with stable fractures with a low risk of cutout, resulting in fewer cutouts. When the post hoc analysis was limited to patients undergoing fixation with cephalomedullary nailing, although the matched controls were theoretically different from those who would have been selected if matching was performed only in the patients with cephalomedullary nail implants, the results of univariate (Supplemental Table 1; http://links.lww.com/CORR/B232) and multivariate analyses (Supplemental Table 2; http://links.lww.com/CORR/B233) were almost the same as those in the primary analysis. This was a study of homogeneous Japanese people with low BMI. Additional research in other populations is needed to determine whether the results can be generalized.

Second, some of the previously reported mixed assessment methods of the reduction quality were not used [29, 39]. It is important to make a comprehensive assessment based on the location between bone fragments and the implant. On the other hand, we believe that a simple index such as the TAD is better than an index that combines several variables to identify the high-likelihood area of cutout. Therefore, we chose an

index that could be considered an oversimplification. Surprisingly, a single index had a magnitude of association with cutout comparable to that of the TAD. Nevertheless, this index should not be used alone to evaluate the appropriateness of reduction in actual surgery, and comparisons with other indices are desirable in the future.

Third, some data were missing because this was a retrospective study (Table 1). The necessary variables for the primary analysis that was planned before data collection, including age, sex, reduction on an oblique lateral radiograph, and TAD, were unlikely to be missing or misclassified when data were extracted from medical records. Therefore, the quality of the data is unlikely to have affected the results of the primary analysis. However, the missing outcomes owing to loss to follow-up and competing outcomes such as death and bone union were problematic. This study used a survival analysis approach that included censoring to address the missing outcomes as much as possible [20, 34]. However, because limiting missing data would be ideal, it would be beneficial to see future studies with prospective data collection.

Fourth, this study was a nested case-control study, and selection bias and the influence of unmeasured confounding might have occurred [34]. Variables possibly related to cutout, such as surgeon experience level, fracture type, implant manufacturer, and osteoporosis, could not be adjusted in the multivariate analysis because of the retrospective nature of the study and sample size. Randomized controlled trials should be conducted to address this problem; however, these studies are impractical for estimating the risk of rare complications [3], and they are challenging to validate because of the uncertainty about whether fractures may be reduced as randomized. From this perspective, high-quality, prospective, observational studies are desirable.

Discussion of Key Findings

This study demonstrated that anterior malreduction as seen on oblique lateral radiographs was associated with a higher likelihood of postoperative cutout. Because the interrater agreement of this sagittal reduction was almost perfect (kappa = 0.86) [23], the reduction quality as seen on an oblique lateral image can be reliably confirmed by an image intensifier during surgery. Therefore, we consider this method to be a valuable and easy index for evaluating intraoperative fracture reduction. Malreduction is a risk factor for cutout, which was evaluated based on factors such as varus reduction on an AP radiograph, angular deformity on a lateral radiograph, and a residual gap between the fragments—alone or in combination [2, 4, 29, 39]. Observational studies have shown that anterior malreduction, which evaluates the reduction quality of contact of the anteromedial cortex using oblique lateral radiographs, increased the amount of postoperative sliding [17, 28, 36, 38]. Although the classification of reduction on an oblique lateral radiograph is only a one-plane evaluation, three-dimensional CT analysis has shown that the anteromedial cortex contact between the neck and diaphyseal fragments is not only present in only 4% of patients with anterior malreduction, but also is more correctly determined than on a lateral radiograph [7]. Therefore, in patients with anterior malreduction, insufficient bony contact between the proximal and distal segments leads to a greater amount of postoperative sliding before load sharing can occur between the implant and fracture site [19, 40]. However, previous studies have not shown that anterior malreduction directly increases cutout [15, 28, 39]. This might have been due to insufficient statistical power owing to small samples and inappropriate multivariable analyses. Because our study included more than 2000 patients and met the number of cutout events in the sample size calculation, we consider the results of this study to be more statistically powerful than those of previous studies.

The result of the post hoc analysis for our secondary study goal clarified that a large amount of sliding in the early postoperative period was associated with substantially greater adjusted odds of cutout (adjusted OR 11). In addition to anterior malreduction [17, 28, 36, 38], several variables, such as fracture type [36], age, and TAD [28], were associated with a greater amount of postoperative sliding. If the postoperative fixation is unstable, excessive sliding may occur, and the stability between the lag screw and head weakens, resulting in a cutout. Although there have been studies on the amount of postoperative sliding [6, 17, 21, 22, 28, 36, 38], no studies that we know of have directly demonstrated that increased sliding is associated with greater odds of cutout. Therefore, according to the results of the present study, identifying factors associated with the amount of postoperative sliding would help identify factors associated with cutout. Because cutout is a rare complication [24], it would be difficult to conduct a study to directly identify the associated factors, as in this study. However, it would be easy to conduct a study using the amount of postoperative sliding as an outcome. The results of this study would be useful for determining the cutoff values for future studies (> 6 mm within 2 weeks after surgery).

Sagittal reduction on an oblique lateral view was also associated with postoperative cutout independent of TAD. Although several factors have been reported to be associated with cutout [2, 4, 11, 15, 29, 39], no study has examined the interactions between identified factors. Because prior studies have suggested that TAD has a larger impact on the odds of cutout than any other factor [2, 11], the association with TAD should be examined when evaluating the association of any new factors. When an interaction exists, the association of anterior malreduction changes for a particular TAD [13]. For example, if there is a negative interaction, a smaller TAD may decrease or eliminate the association between

anterior malreduction and cutout. However, the results showed no association with the interaction term, indicating there is an effect of anterior malreduction regardless of the TAD value (Table 2). We believe this is because TAD and sagittal malreduction are independent concepts: TAD is the position of the lag screw within the head of the bone [2], and anterior malreduction is the position of the bone fragments between the neck and diaphyseal fragments [40]. Furthermore, no association was noted between the TAD and the reduced position on an oblique lateral radiograph [21]. Hence, we believe well-performed surgical treatment of an intertrochanteric fracture will achieve two requirements: reduce the TAD and avoid anterior malreduction.

Conclusion

In patients older than 65 years with intertrochanteric fractures, anterior malreduction on a lateral oblique view was associated with much greater adjusted odds of postoperative cutout than either anatomic reduction or posterior malreduction. This effect was similar to the odds of cutout associated with a larger TAD. Because avoiding anterior malreduction is within the surgeon's control, our findings might help surgeons focus on intraoperative reduction from an oblique lateral view to prevent cutouts. Although this factor is a reliable indicator, the results should only be applied for cephalomedullary nailing, because there was only one patient with cutout among those with sliding hip screws. Because this study was conducted in a homogenous Japanese population, future studies should focus on the association between anterior malreduction and cutout, adjusting for other confounding factors such as implant type, surgeon experience level, and heterogeneous ethnicities.

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