Radiographic risk factors for predicting failure of geriatric intertrochanteric fracture treatment with a cephalomedullary nail

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Abstract

Background: The cephalomedullary nail is the most common device used to treat unstable intertrochanteric fractures (ITFs) (AO/OTA 31-A2 and A3) in the geriatric population. However, there is lack of radiological parameter to evaluate the entry point; hence, this study reports a new radiological parameter to evaluate the entry point of the nail. Besides, other risk factors were also examined.

Methods: A retrospective study on the geriatric population with unstable ITFs was conducted from July 2011 to December 2014. A total of 136 patients were enrolled in this study; they received treatment with Gamma-3 nails (Stryker, Mahwah, NJ, USA) and were followed for at least 1 year. Demographic data, radiological parameters, and side-difference of the distance from the piriformis fossa to the greater trochanteric tubercle in the anteroposterior view (dPG) were compared between the union and failure groups. Student's *t* test, χ^2 test, and multiple logistic regression were used in the statistical analyses.

Results: The overall failure rate was 13.23% (18 patients). Sex, tip-apex distance (TAD), and dPG were significantly different between the failure and union groups in multivariate analyses. Using a dPG > 6 mm as a reference, patients with a dPG > 6 mm had an odds ratio of 7.64 for failure relative to a dPG < 6 mm.

Conclusion: This study provides additional evidence demonstrating that sex and TAD have significant effects on the outcomes of unstable ITFs after nailing. Moreover, the newly reported radiological parameter, dPG, can be used to predict the failure of ITFs treated using cephalomedullary nails.

Keywords: Bone malposition; Intertrochanteric fractures; Intramedullary nailing; Treatment failure

1. INTRODUCTION

Geriatric intertrochanteric fracture (ITF) remains as one of the leading burdens on the health care system. In United States, it accounts for nearly 30% of all fracture-related hospitalizations.[1] Dynamic hip screw (DHS) and cephalomedullary nailing are the two main fixation methods for surgical treatment that aim to achieve stable fixation. Although the most suitable fixation method for treating this fracture is still debated, the cephalomedullary nail, which is characterized by a shorter moment arm and sound lateral support, is believed to be theoretically more stable than the DHS.[2]

However, the failure rate of ITF after nailing remains high (6.5% to 16.5%).[3,4] The failure patterns of ITF after nailing are commonly subsidence of the proximal fragment or lag screw cut-out.[5] Reported risk factors for failure after nailing are inadequate tip-apex distance (TAD), improper position of the lag screw, and female sex.[6] Besides, improper entry point selection is also considered to be associated with a high failure rate after nailing.[7]

Because few studies have evaluated radiologic parameters of the cephalomedullary nail and geometry of its entry point, we proposed a new radiological parameter, the side-difference of the distance from the piriformis fossa to the greater trochanteric tubercle in the anteroposterior view (dPG), to evaluate the radiological characteristic of improper entry point. In addition, other radiological and clinical risk factors were also evaluated in this study.

2. METHODS

2.1. Materials

In this study, patients were consecutively included from July 2011 to December 2014. The inclusion criteria were geriatric patients (older than 65 years), patients who received cephalomedullary nailing as treatment for unstable ITF, and patients with follow up of at least 1 year. Patients who presented with pathologic fractures, nonambulation, previous contralateral or ipsilateral hip orthopedic surgeries; those in whom we were unable to identify the radiological landmarks; and those who were lost to follow-up were all excluded.

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Unstable ITF was defined as an ITF with an insufficient lateral wall, inadequate medial support (involvement of the lesser trochanter), or a reverse oblique fracture line.[8,9] Unstable ITFs were classified as AO/OTA 31-A2 or 31-A3 based on whether they were lateral wall fractures or reverse oblique fractures, respectively.[10] We used Gamma-3 nails (Stryker, Mahwah, NJ, USA) to treat unstable ITFs, and the procedures were performed by four trauma surgeons or senior residents under supervision.

All patients underwent clinical follow-up and radiography with pelvic anteroposterior (AP) and hip lateral views at 4 weeks, 8 weeks, 3 months, 6 months, and 12 months after the operation. The outcome was classified into union or failure according to the final radiological reports. Lag screw cut-out, nonunion, and osteonecrosis were defined as failure outcomes.

Patients' demographics including age, sex, side of injury, and American Society of Anesthesiologists' Physical Status Classification (ASA classification) were compared between the union and failure groups. Radiological parameters including reduction quality on AP and lateral views, TAD, and AO/OTA classification were also compared between the groups.[10]

In addition, the newly proposed radiological parameter dPG was evaluated for its reliability and its ability to predict failure. All radiographs were reviewed independently by two orthopedic trauma surgeons using smartIRIS version 13.0 (Taiwan Electronic Data Processing Corporation, New Taipei City, Taiwan).

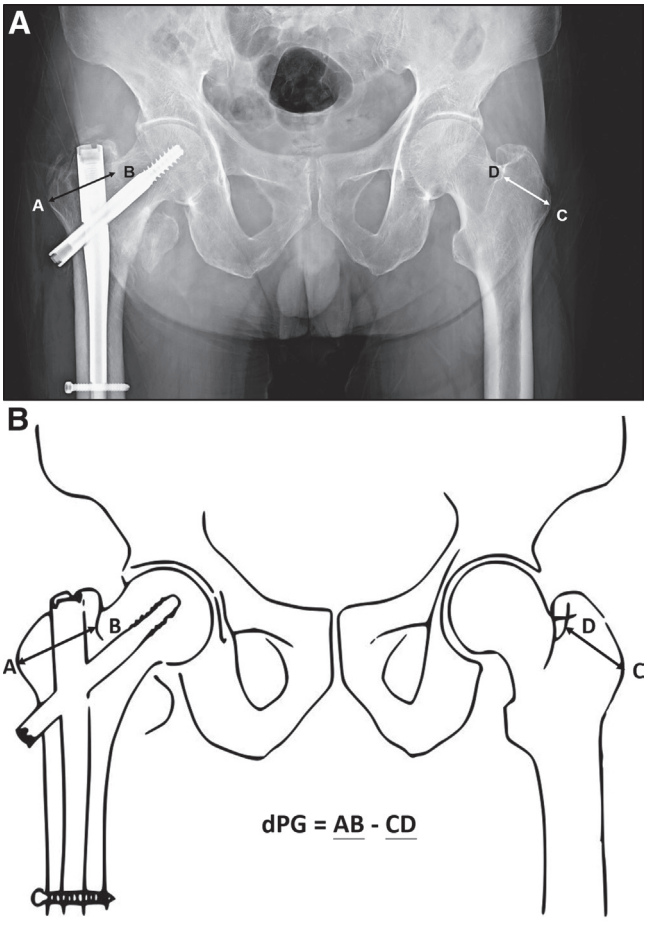

Fig. 1 a, Measurement of dPG. Distance A to B was the distance from the piriformis fossa to the greater trochanteric tubercle of the injured side, and distance C to D was the distance from the piriformis fossa to the greater trochanteric tubercle of the healthy side. The difference between the two distances was dPG. b, Illustration of the dPG measurement. dPG, side-difference of the distance from the piriformis fossa to the greater trochanteric tubercle in the anteroposterior view.

2.2 Radiological measurements

Reduction quality was categorized as good, acceptable, or poor based on the radiographs obtained postoperatively; this classification was originally reported by Baumgaertner et al. and subsequently modified by Kashigar et al.[11,12] There were two criteria for classifying the reduction quality. The first criterion was a neck shaft angle in AP view between 120° and 135° and lateral angulation at <20°. The second criterion was <4 mm displacement in AP and lateral views. Reduction was categorized as good if both criteria were met or acceptable if only one criterion was met. If neither criterion was met, the reduction quality was categorized as poor.

In the lateral view, reduction was examined and categorized into three groups based on Tsukada et al.'s classification.[13] Reduction without displacement in the lateral view was considered as type 1, reduction with anterior displacement of the head and neck fragment as type 2, and reduction with the posterior displacement of the head and neck fragment as type 3.

TAD was measured based on Baumgaertner et al.'s method and classified into >25 mm or ≤25 mm.[12] dPG was measured on pelvic AP views obtained on postoperative day 1. We measured the distance from the deepest point of the piriformis fossa to the tip of the greater trochanteric tubercle, and the difference between each side was defined as dPG (Fig. 1a, b). We excluded

Table 1

Demographic data and radiological parameters categorized by the outcome

Factors	Union (n = 118)	Failure (n = 18)	*p*
Gender			
Female	60	16	0.002*
Male	58	2	
Age, y	83.82 ± 6.20	81.50 ± 8.52	0.162**
ASA classification			
I	2	0	0.603*
II	44	5	
III	72	13	
Injury side			
Right	50	10	0.294*
Left	68	8	
AO/OTA classification			
31-A2 (n = 103)	86	17	0.047*
31-A3 (n = 33)	32	1	
TAD			
>25 mm	110	12	0.004*
≤25 mm	8	6	
dPG (mean ± SD), mm	4.68 ± 4.58	9.10 ± 4.35	0.001**
(range), mm	(−4.10 to 17.50)	(2.20 to 17.70)	
Reduction quality			0.047*
Good	68	5	
Acceptable	42	10	
Poor	8	3	
Displacement in lateral view			0.027*
Type 1	103	12	
Type 2	6	4	
Type 3	9	2	

*χ^2 test.
**Two-sample *t* test.
dPG = side difference from piriformis fossa to greater trochanteric tubercle; TAD = tip-apex distance.

Table 2

Logistic regression analysis for multiple variants

Factors	Odds ratio (95% CI)	*p*
Gender	8.66 (1.91-39.28)	0.002*
AO/OTA classification		0.140
TAD	5.75 (1.77-18.59)	0.011*
dPG	7.64 (2.33-24.99)	0.002*
Reduction quality		0.099
Displacement on lateral view		0.108

*$p < 0.05$.

dPG = side difference from the piriformis fossa to greater trochanteric tubercle; TAD = tip-apex distance.

patients with extensive comminuted fracture with unclear landmarks from our study.

2.3. Statistical analysis

Continuous variables were analyzed using Student's *t* test, and categorical variables were analyzed with the χ^2 test. We regarded $p < 0.05$ as statistically significant. For factors with statistical significance, further analysis using multiple logistic regression was performed. The interobserver reliability was evaluated using the intraclass correlation coefficient with a 95% CI for continuous data. The receiver operating characteristic curve (ROC) was used to calculate the discrimination ability of the test. Besides, we used the Youden index to determine the optimal cutoff point. Statistical analyses were performed using SPSS 17.0 (IBM Corp., Armonk, NY, USA).

3. RESULTS

From July 2011 to December 2014, 193 consecutive geriatric patients with unstable ITFs were screened, and 53 patients were excluded. Among the excluded patients, eight had previous hip operations, five had pathological fractures, 21 had complications or mortality due to medical comorbidities, four had inadequate radiological landmarks, and 19 were lost to follow-up. Finally, 136 subjects were included in this study.

Overall, there were 60 men and 76 women. One hundred three patients had an AO/OTA classification 31-A2, and 33 patients had an AO/OTA classification 31-A3. At the final follow-up, 18 (13.23%) patients had treatment failure. Except for one patient with osteonecrosis, the other cases of failure were due to varus change of the proximal fragment with screw cut-out.

In univariate analysis, female sex ($p = 0.002$), AO/OTA classification ($p = 0.047$), TAD ($p = 0.004$), dPG ($p = 0.001$), reduction quality ($p = 0.047$), and displacement in the lateral view ($p = 0.027$) were significantly associated with treatment failure. Age, the ASA classification, and side of injury were not significantly different between the two groups (Table 1). In further multivariate analysis, female sex, TAD, and dPG remained statistically significant (Table 2).

In the union group, the mean dPG was 4.68 ± 4.58 mm, and the range of the lower to upper limit was –4.1 to 17.5 mm. In the failure group, the mean dPG was 9.10 ± 4.35 mm, and the range of the lower to upper limit was 2.2 to 17.7 mm. Cases with increased dPG were shown in Fig. 2. In this study, four patients had comminuted fractures, which make it impossible to identify the trochanteric tubercle or piriformis fossa. In cases with lateral wall breakage and greater trochanteric fracture, the fracture lines were generally below the greater trochanteric tubercle, and the landmark was easily identified in the AP view after reduction. In cases with greater trochanter displacement, the avulsed fragment was usually above the landmark, and we did not observe any case in which the fracture involved the greater trochanteric tubercle.

To assess the interobserver reliability of dPG, the intraclass correlation coefficient was calculated. The single-measure intraclass correlation coefficient was 0.70 (95% CI, 0.60 to 0.77), and the average-measure intraclass correlation coefficient was

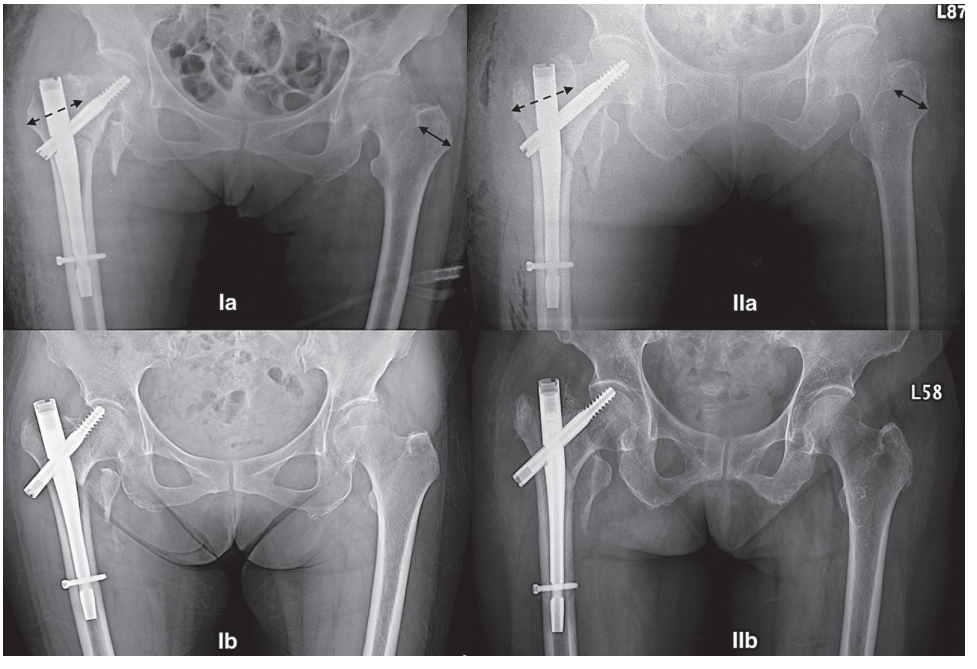

Fig. 2 Cases of increased dPG. Ia: An 86-year-old woman with increased dPG after Gamma-3 nail treatment. Ib: Follow-up at 1 month demonstrating screw cut-out. IIa: A 79-year-old woman with increased dPG after Gamma-3 nail treatment. IIb: Follow-up at 2 months revealing screw cut-out. dPG, side-difference of the distance from the piriformis fossa to the greater trochanteric tubercle in the anteroposterior view.

Table 3

Reliability between the two observers for dPG

Variable	Intraclass correlation coefficient or weighted kappa	95% CI
dPG		
Single measure	0.700	0.603-0.777
Average measure	0.824	0.752-0.874

dPG = side-difference of the distance from the piriformis fossa to the greater trochanteric tubercle in the anteroposterior view.

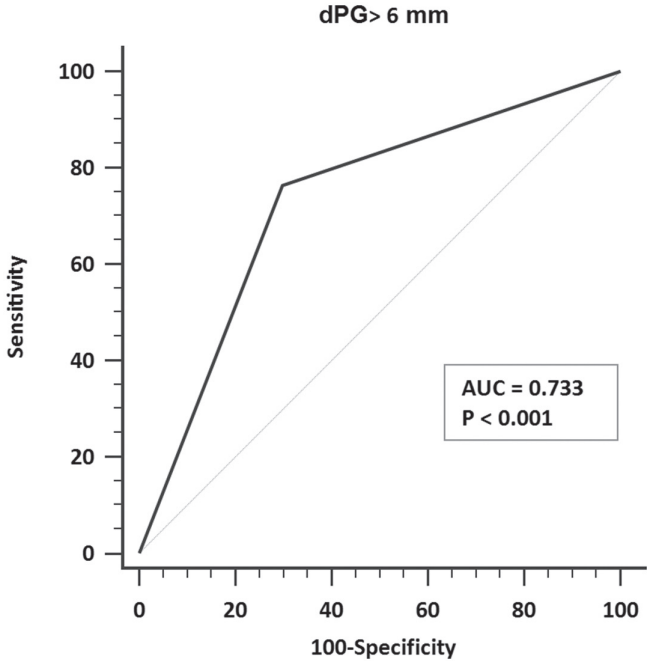

Fig. 3 ROC for dPG. AUC, area under the ROC curve; dPG, side-difference of the distance from the piriformis fossa to the greater trochanteric tubercle in the anteroposterior view; ROC, receiver operating characteristic curve.

0.82 (95% CI, 0.75 to 0.88), both of which corresponded with good reliability (Table 3).

Based on the ROC curve, the optimal cutoff value for dPG was 6 mm, and the area under ROC curve value was 0.796 (Fig. 3). When dPG > 6 mm was used as a reference, the specificity and sensitivity were 76.47% and 70.16%, respectively. Patients with dPG > 6 mm had an odds ratio of 7.64 (95% CI, 2.33 to 24.99).

4. DISCUSSION

This study demonstrated that female sex, TAD > 25 mm, and dPG > 6 mm increased the risk of failure after nailing in unstable ITF. Additionally, dPG was a reliable measurement, and it was a significant predictor of failure.

Although accumulated evidence currently suggests no difference in outcome for unstable fractures treated with either the DHS or cephalomedullary nail, the cephalomedullary nail is considered advantageous in preventing anatomic deformities.[7,14] More recently, use of the cephalomedullary nail has become common in clinical practice for treating unstable ITFs. From 1999 to 2006, the usage rate of the intramedullary nail has been reportedly increased from 3% to 67%.[15]

The failure pattern of sliding hip screws and their risk factors have been well studied;[16] however, the failure pattern of the cephalomedullary nail and risk factors of failure need further exploration. A previous study demonstrated that the most typical failure pattern associated with the intramedullary nail is varus change of the reduction and cut-out of the screw.[5] In our study, we also demonstrated this failure pattern.

Sex was a risk factor for failure of ITFs treated using cephalomedullary nails in the current study and the finding was consistent with the previous study.[6] We think that the relatively worse osteoporosis and small bone architecture of women in our study may explain this finding.

A 31-A3 fracture according to the AO/OTA classification has been recognized as a risk factor for poor outcomes when the sliding hip screw is used as treatment,[7,9] whereas this risk is low when an intramedullary device is used as treatment.[11,17,18] In the current study, we observed the phenomenon in univariate analysis. The cephalomedullary nail provides firm lateral support, which could have prevented displacement in 31-A3 fractures and, hence, decrease the risk of failure in our study.

Multiple studies have demonstrated that TAD can not only affect the failure rate of DHS but it is also a significant predictor of outcomes after intramedullary nailing.[11,19,20] In the present study, we also observed that TAD is a strong predictor of failure, which adds to the existing evidence.

Reduction quality in the AP view has significant effects on outcomes in multiple studies.[11,19] On the contrary, some studies reported that the reduction quality did not affect the outcome according to multivariate analysis.[17,18] In the current study, the reduction quality was a significant factor in univariate analysis but not in multivariate analysis, which is comparable to a previous study finding.[17] Regarding displacement in the lateral view, Tsukada et al. and Ito et al. reported that posterior displacement of the head and neck fragment predicted significant sliding of the fracture.[13,18] In our study, we also found that displacement in the lateral view was a significant factor in univariate analysis; however, we failed to demonstrate the result in multivariate analysis, as we had a limited number of cases with displacement in the lateral view.

Numerous studies have demonstrated that the entry point of the intramedullary nail is crucial to avoid fracture malreduction in ITF.[21,22] However, to the best of our knowledge, no radiologic parameter has been reported for this geographic change related to selection of the entry point. In the present study, dPG was intentionally designed to measure the geographic change around the trochanteric area after nail insertion. Postoperatively, in the AP view, the trochanteric tubercle can be easily defined as the lateral tip of the greater trochanter. The piriformis fossa was also obviously identifiable after nail insertion. The current study showed that an increased dPG bears a higher failure rate in both univariate and multivariate analyses. In addition, we demonstrated that the interobserver reliability of the dPG measurement was good and consistent. The increase in dPG can be explained by the movement of the piriformis fossa and proximal fragment away from the distal fragment during nailing, which could be attributed to inadequate nail preparation or inappropriate entry point selection. Using dPG > 6 mm as a reference, the odds ratio for dPG > 6 mm is larger than TAD > 25 mm (7.64 vs 5.75); in addition the sensitivity and specificity were also satisfied.

Although this study has presented solid preliminary results, it has some limitations. First, the retrospective design of the study has its own confounding factor and bias. Second, the radiographic measurement is sometimes impossible to measure; nevertheless, we demonstrated that the interobserver correlation is good and the number for this condition is low. Finally,

considering the relatively low incidence of failure after nailing, more subjects are needed in future studies to strengthen the conclusions of our study.

In conclusion, this study proposed a new radiological parameter, dPG, to reflect the geometry of the greater trochanter after nailing. We found that increased dPG is highly associated with failure and indicates varus change of the proximal fragment or lateralization of the distal fragment, which is closely related to entry point selection and canal preparation.

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