ORIGINAL ARTICLE

Antirotation proximal femoral nail versus dynamic hip screw for intertrochanteric fractures: A meta-analysis of randomized controlled studies

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KEYWORDS
Peritrochanteric fractures; Proximal femoral nail antirotation; Dynamic hip screw; Meta-analysis

Summary
Background: Previous studies comparing proximal femoral nail antirotation (PFNA) with dynamic hip screw (DHS) for peritrochanteric fractures reported conflicting findings. The objective of this meta-analysis was to compare the efficacy and safety of PFNA and DHS for peritrochanteric fractures.

Hypothesis: PFNA achieves better efficacy for peritrochanteric fractures compared with DHS.

Materials and methods: Relevant randomized controlled trials comparing PFNA with DHS for peritrochanteric fractures were assessed for eligibility and included into this meta-analysis. Data were extracted independently and methodological quality was further assessed. The inclusion criteria of this meta-analysis were: randomized controlled trials comparing PFNA with DHS for peritrochanteric fractures and reporting at least one of these main outcomes, including operating time, blood loss, all causes mortality, and complications.

Results: Five randomized controlled trials were finally included into this meta-analysis. Pooled results showed there were less blood loss (weighted mean difference Blood loss = −249.75 ml, 95%CI −303.83 to −195.67, \(P < 0.0001\)) and fewer complications (Odds ratio = 0.40, 95%CI 0.23 to 0.70, \(P = 0.001\)) in the PFNA group compared with the DHS group. However, there was no difference in term of mortality between those two groups (Odds ratio mortality = 1.13, 95%CI 0.47 to 2.69, \(P = 0.79\)). Sensitivity analysis by sequential omission of individual studies showed that the significance of pooled odds ratios was robust, which suggested this outcome was credible.

Discussion: PFNA can benefit peritrochanteric fractures patients with less blood loss and fewer complications compared with DHS. The significant heterogeneity among the included trials for intraoperative blood loss, and operation time may be attributable to variation in the skills of the surgeons and the different types of peritrochanteric fractures. In addition, more powered...
randomized studies are needed to identify the findings from this meta-analysis, and the effects of long-term follow-up also need further study, especially the impact on the mortality.

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Introduction
Peritrochanteric fractures are becoming increasingly common as our population ages. These fractures typically occur in elderly patients and often result in the end of the patient's functional independence [1,2]. Treatment of peritrochanteric fracture is based on patient medical condition, bone quality and the biomechanics of the fracture configuration. Effective treatment strategies resulting in high rates of union of these fractures and low rates of complications are important. Generally, dynamic hip screw (DHS) internal fixation is one of the most primary options [3,4]. For stable or minimally displaced peritrochanteric fractures, the DHS fixation produces reproducibly reliable results. However, in unstable fractures, the DHS device performs less well with a relatively higher incidence of internal fixation failure [3,4]. The proximal femoral nail antitrotation (PFNA) is an intramedullary device with a helical blade rather than a screw for better purchase in the femoral head and has been adopted for patients with unstable peritrochanteric fractures [5–7]. There were many studies comparing the outcomes of the PFNA and DHS for peritrochanteric fractures, but there was obvious inconsistency of effects across those studies and the optimal management of peritrochanteric fractures remained controversial [8–10]. Single studies with small sample size have various designs, different methodologies and insufficient power, and fail to get a precise estimate, while combining data from all eligible studies by meta-analysis has the advantage of reducing random error and obtaining precise estimates for clinical interventions. Thus, to provide the most comprehensive assessment of the PFNA and DHS for peritrochanteric fractures, we performed this meta-analysis based on all relevant randomized controlled trials comparing PFNA with DHS for peritrochanteric fractures. The hypothesis of present study was that PFNA achieved better efficacy for peritrochanteric fractures compared with DHS.

Methods
Search strategy and eligibility criteria
We searched PubMed, Embase, and China National Knowledge Infrastructure (CNKI) databases for randomized controlled trials comparing PFNA with DHS for peritrochanteric fractures (last update October 2011). We used the following search terms: (“PFNA” or “proximal femoral nail antitrotation”) and (“DHS” or “dynamic hip screw”) and (“peritrochanteric fractures” or “intertrochanteric fractures” or “subtrochanteric fractures” or “pergrochanteric fractures” or “extracapsular hip fractures”). The references of the retrieved articles were also confirmed.

Language restriction was not imposed in our search. The inclusion criteria of this meta-analysis were: randomized controlled trials comparing PFNA with DHS for peritrochanteric fractures and reporting at least one of the main outcomes, including operating time, blood loss, all causes mortality, and complications. The major reasons for exclusion from the study were:

- case series that investigated either PFNA or DHS for treating peritrochanteric fractures;
- data were duplicated;
- demographic background of the patients and preoperative conditions were not similar;
- and usable data were not reported. Inconsistencies were resolved by reaching a consensus between all authors after discussion.

Data extraction and quality assessment
The following information was extracted from each study: year of publication, study design, number of patients, fracture classification, average follow-up time, operating time, blood loss, all causes mortality, and complications. We also did some contacts with the authors of the retained papers to improve data extraction. The complications mainly included the postoperative complications. The quality of randomized controlled trials included into this meta-analysis was assessed by the Jadad score [11]. The Jadad score system was as follows:

- was the study described as randomized?
- was the study described as double blind?
- was there a description of withdrawals and dropouts? [11].

Randomized controlled trials with scores no less than three points were defined as high quality randomized controlled trials, while randomized controlled trials with scores less than three points were defined as lesser quality randomized controlled trials [11]. However, we did not undertake a subgroup analysis for different fracture types because few included studies described the subgroup data by fracture types.

Statistical analysis
In each study the pooled odds ratio (OR) with a 95% confidence interval (CI) was calculated for dichotomous outcomes, and weighted mean difference (WMD) with a 95% confidence interval (CI) was calculated for continuous outcomes. To assess the between-study heterogeneity more precisely, both the Chi² based Q statistic test (Cochran’s Q statistic) [12] to test for heterogeneity and the I² statistic
to quantify the proportion of the total variation attributable to heterogeneity were calculated [13]. A significance level of less than 0.10 for the Chi² test was interpreted as evidence of heterogeneity. When there was no statistical evidence of heterogeneity, a fixed effect model was adopted [14]; otherwise, a random effect model was chosen [15]. Besides, to validate the credibility of outcomes in this meta-analysis, a sensitivity analysis was performed by sequential omission of individual studies [16]. Publication bias was investigated by funnel plot and an asymmetric plot suggested possible publication bias [17]. Statistical analyses were performed with the software program RevMan (Version 5.0, Copenhagen: The Nordic Cochrane Centre, the Cochrane Collaboration). All P-values were two-sided and a P-value of less than 0.05 was deemed statistically significant.

Results

Study characteristics

There were 76 initial records identified (Fig. 1). A total of 61 of these records were excluded, leaving 15 potentially relevant studies [8—10,18—29]. We then excluded seven non-random studies [20—26], two irrelevant studies [18,19] and one study for no available data [27]. Finally, five randomized controlled trials were included into this meta-analysis (Fig. 1, Table 1) [8—10,28,29]. Table 1 summarized the main characteristics of the included studies. Table 2 showed the methodological quality of included studies in this meta-analysis (Table 2). The quality of randomized controlled trials included was assessed using the Jadad scoring system, and three trials were high quality randomized controlled trials with scores no less than three points.

**Figure 1** Flow chart demonstrating selection of studies for inclusion in the meta-analysis.

**Operation time and blood loss**

Data for operation time were reported in 4 trials (Table 3, Fig. 2A). There was significant heterogeneity among these trials (I² = 99%, P < 0.001), and the random effects model was used to pool the results. Meta-analyses showed that PFNA was marginally associated with shorter operation time compared with DHS (WMD<sub>Operation time</sub> = −29.53 minutes, 95%CI −62.53 to 3.46, P = 0.08) (Fig. 2A). Besides, sensitivity analysis by sequential omission of individual studies showed the significance of WMD<sub>Operation time</sub> was not robust, which suggested this outcome was not credible.

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**Table 1** Main characteristics of the studies included into the meta-analysis.

<table>
<thead>
<tr>
<th>Study [Reference]</th>
<th>Study design</th>
<th>Indication</th>
<th>DFNA group (Mean age, sex distribution)</th>
<th>DHS group (Mean age, sex distribution)</th>
<th>Follow-up (Mean duration, months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garg et al. [10]</td>
<td>RCT</td>
<td>Unstable trochanteric fractures (31A2-3)</td>
<td>42 patients (60.2 years, 32 males)</td>
<td>39 patients (64.3 years, 27 males)</td>
<td>40 months (36 to 48 months)</td>
</tr>
<tr>
<td>Wang et al. [28]</td>
<td>RCT</td>
<td>Intertrochanteric fractures (Evans I-IV)</td>
<td>66 patients (80.0 years, 21 males)</td>
<td>71 patients (80.8 years, 25 males)</td>
<td>18 months</td>
</tr>
<tr>
<td>Xu et al. [9]</td>
<td>RCT</td>
<td>Unstable pertrochanteric fractures (31A2-3)</td>
<td>51 patients (69.9 years, 18 males)</td>
<td>55 patients (68.6 years, 15 males)</td>
<td>15 months (12 to 24 months)</td>
</tr>
<tr>
<td>Zou et al. [8]</td>
<td>RCT</td>
<td>Trochanteric Fractures (31A1-3)</td>
<td>58 patients (65 years, 12 males)</td>
<td>63 patients (65 years, 15 males)</td>
<td>12 months</td>
</tr>
<tr>
<td>Zuo et al. [29]</td>
<td>RCT</td>
<td>Intertrochanteric fractures (Evans I-IV)</td>
<td>26 patients (68 years, 10 males)</td>
<td>63 patients (66 years, 11 males)</td>
<td>18 months (12 to 24 months)</td>
</tr>
</tbody>
</table>

DFNA: proximal femoral nail antirotation; DHS: dynamic hip screw. *RCT was for randomized controlled trial.*
Table 2 Methodological quality of included studies in this meta-analysis.

<table>
<thead>
<tr>
<th>Study [Reference]</th>
<th>Randomization</th>
<th>Allocation concealment</th>
<th>Blinding</th>
<th>Loss to follow-up</th>
<th>Jadad score</th>
<th>Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garg et al. [10]</td>
<td>Adequate</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>4</td>
<td>Comparable</td>
</tr>
<tr>
<td>Wang et al. [28]</td>
<td>Inadequate</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>2</td>
<td>Comparable</td>
</tr>
<tr>
<td>Xu et al. [9]</td>
<td>Adequate</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>4</td>
<td>Comparable</td>
</tr>
<tr>
<td>Zou et al. [8]</td>
<td>Inadequate</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>2</td>
<td>Comparable</td>
</tr>
<tr>
<td>Zuo et al. [29]</td>
<td>Adequate</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>4</td>
<td>Comparable</td>
</tr>
</tbody>
</table>

Table 3 Summary of meta-analysis of comparing PFNA with DHS for peritrochanteric fractures.

<table>
<thead>
<tr>
<th>Comparison items</th>
<th>Number of included studies</th>
<th>WMD or odds ratio</th>
<th>Heterogeneity</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WMD/OR (95%CI)</td>
<td>P-value</td>
<td>I² (%)</td>
</tr>
<tr>
<td>Operating time</td>
<td>4</td>
<td>−29.53 (−62.53 to 3.46)</td>
<td>0.08</td>
<td>99</td>
</tr>
<tr>
<td>Blood loss</td>
<td>4</td>
<td>−249.75 (−303.83 to −195.67)</td>
<td>&lt; 0.001</td>
<td>89</td>
</tr>
<tr>
<td>Complications</td>
<td>5</td>
<td>0.50 (0.33 to 0.76)</td>
<td>0.001</td>
<td>23</td>
</tr>
<tr>
<td>Mortality</td>
<td>3</td>
<td>1.13 (0.47 to 2.69)</td>
<td>0.79</td>
<td>0</td>
</tr>
</tbody>
</table>

P_H: the P-value of heterogeneity analysis; WMD correspond to the average of PFNA minus the average of DHS; P-value: the value of the pooled estimates; OR: odds ratio; 95%CI: 95% confidence interval; I²: the value of I² statistic.

Data for blood loss were reported in 4 trials (Table 3, Fig. 2B). There was also significant heterogeneity among these trials (I² = 96%, P < 0.0001), and the random effects model was used to pool the results. Meta-analyses showed that there was obvious less blood loss in the PRFA group (WMDBlood loss = −249.75 ml, 95%CI −303.83 to −195.67, P < 0.0001) (Fig. 2B). Besides, sensitivity analysis by sequential omission of individual studies showed the significance of WMDBlood loss was robust, which suggested this outcome was also credible.

Figure 2 Forest plot of pooled WMD with 95% CI for comparing PFNA with DHS for peritrochanteric fractures on the assessment of operating outcomes. A. Forest plot of pooled WMD with 95% CI on the assessment of operation time. B. Forest plot of pooled WMD with 95% CI on the assessment of blood loss (The size of the data marker corresponds to the weight of the study. The diamond and vertical broken line represent the summary estimate).
Figure 3  Forest plot of pooled OR with 95% CI for comparing PFNA with DHS for peritrochanteric fractures on the assessment of complications (The size of the data marker corresponds to the weight of the study. The diamond and vertical broken line represent the summary estimate).

Figure 4  Forest plot of pooled OR with 95% CI for comparing PFNA with DHS for peritrochanteric fractures on the assessment of mortality (The size of the data marker corresponds to the weight of the study. The diamond and vertical broken line represent the summary estimate).

Complications evaluation

Data for complications were reported in all 5 trials (Table 3, Fig. 3). There was no significant heterogeneity between the trials ($I^2 = 23\%$, $P = 0.27$), and the fixed effects model was used to pool the results. Meta-analyses showed that there was fewer complications in the PFNA group compared with the DHS group (OR = 0.40, 95%CI 0.23 to 0.70, $P = 0.001$) (Fig. 3). Sensitivity analysis by sequential omission of individual studies showed the significance of OR was robust, which suggested this outcome was also credible.

Mortality evaluation

Data for mortality for any cause were reported in only three trials (Fig. 4). We noted no significant heterogeneity between the trials ($I^2 = 0\%$, $P = 0.57$), and the fixed effects model was used to pool the results. Meta-analysis showed that there was no difference in term of the prognosis between those two groups (OR$_{\text{Mortality}}$ = 1.13, 95%CI 0.47 to 2.69, $P = 0.79$) (Fig. 4). Sensitivity analysis by sequential omission of individual studies showed the significance of OR was robust, which suggested this outcome was credible.

Assessment of publication bias

Funnel plot was performed to assess the publication bias in this meta-analysis. The symmetry of Funnel plots’ shape did not find obvious evidence of publication bias risk (Fig. 5).

Discussion

There are many studies comparing the outcomes of the PFNA and DHS for peritrochanteric fractures, but there is obvious inconsistency of effects across those studies and the optimal management of peritrochanteric fractures remained
controversial [8–10,18–31]. Thus, to provide the most comprehensive assessment of the PFNA and DHS for peritrochanteric fractures, we performed this meta-analysis by including five randomized controlled trials. The results from our meta-analysis showed there were less blood loss (WMD Blood loss = −249.75 mL, 95% CI −203.83 to −195.67, P < 0.0001) and fewer complications (OR = 0.40, 95% CI 0.23 to 0.70, P = 0.001) in the PFNA group compared with the DHS group. However, there was no difference in term of the prognosis between those two groups (OR Mortality = 1.13, 95% CI 0.47 to 2.69, P = 0.79).

Significant heterogeneity was observed between the included trials for intraoperative blood loss, and operation time. This heterogeneity may be attributable to variation in the skills of the surgeons and the different types of peritrochanteric fractures. The eligibility criteria for inclusion of patients with peritrochanteric fractures were different from each other, which might influence the obvious consistency of effects across those included studies and cause the between-study heterogeneity (Table 1). To ensure uniformity in both defining patients’ characteristics for peritrochanteric fractures and defining outcome measures, an individual patient data meta-analysis is needed [32]. Besides, we did not undertake a subgroup analysis for different fracture types to identify the possible source of heterogeneity because not all of the included studies described data according to the different fracture types. Besides, the effects might differ as the different fracture types, and this different effect need further study.

The clinical outcomes of different DHS were different [33], but we did perform subgroup analyses by DHS type owing to the limited studies reported in original papers (Table 1). Thus, further studies can compare PFNA and DHS on account of the different type of DHS independently. Besides, one main outcome in this meta-analysis were analyzed to assess the efficacy of PFNA was mortality. As to the mortality, the outcome from this meta-analysis showed there was no difference in term of the prognosis between those two group (OR Mortality = 1.13, 95% CI 0.47 to 2.69, P = 0.79). Besides, most of the mean durations of follow-up were no more than 24 months, which was too shorter to assess the effects of long-term period effectively (Table 1). Thus, the effects of long-term period need further study, especially the effect on the mortality.

Established surgical options for peritrochanteric fractures mainly include DHS, Gamma nail, and proximal femoral nail, but the optimal treatment choice continues to be highly debated [30,31,33–36]. The PFNA is an intramedullary device with a helical blade rather than a screw for better purchase in the femoral head and has been adopted for patients with unstable peritrochanteric fractures [5–7]. Our meta-analysis suggests PFNA can benefit peritrochanteric fractures patients with less blood loss and fewer complications compared with DHS, thus PFNA can achieve better efficacy for peritrochanteric fractures compared with DHS. In addition, there are several established surgical options for peritrochanteric fractures, but which is the most optimal treatment choice continues to be unclear. Because the number of trials directly comparing different surgical options is limited, a network meta-analysis for indirect comparisons needs performing to provide a comprehensive assessment of different surgical options for peritrochanteric fractures [37].

In conclusion, PFNA can benefit peritrochanteric fractures patients with less blood loss and fewer complications compared with DHS. However, in addition, more powered randomized studies are needed to identify the findings from this meta-analysis, and the effects of long-term period also need further study, especially the effect on the mortality.

Disclosure of interest
The authors declare that they have no conflicts of interest concerning this article.

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Proximal femoral antirotation nail for peritrochanteric fractures


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