The use of intramedullary (IM) nailing is currently the gold standard treatment for the vast majority of femoral shaft fractures.\(^1\)\(^-\)\(^3\) Despite major advances in the design and engineering of these devices, there remains significant debate regarding the ideal entry point for antegrade nailing.\(^4\)\(^-\)\(^5\) Kuntscher’s original IM nail was straight and introduced in antegrade fashion through the tip of the greater trochanter (GT) to minimize the risk of intracapsular infections, osteonecrosis of the femoral head, and iatrogenic femoral neck fractures.\(^6\)\(^-\)\(^7\) However, because the tip of the GT is not colinear with the anatomic axis of the medullary canal, the insertion of a straight nail was reported to occasionally result in varus malreduction of the proximal fracture fragment, eccentric reaming of the medial cortex, and fracture comminution.\(^8\) As a result, Hansen and Winquist\(^9\) recommended using an entry point more medial to the GT at the junction of the femoral neck and the GT. At the same time, McMaster\(^10\) introduced the piriformis fossa (PF) entry, which is colinear with the medullary canal, as the ideal entry point for antegrade nailing of femoral shaft fractures.

The optimal entry point for antegrade intramedullary nailing of femoral shaft fractures remains controversial. The purpose of this systematic review was to determine whether there is a difference in operative parameters, healing, and functional outcome when comparing the greater trochanter (GT) and piriformis fossa (PF) entry points. A systematic search of multiple databases and 3 major orthopedic meetings (American Academy of Orthopaedic Surgeons, Canadian Orthopaedic Association, and Orthopaedic Trauma Association) was conducted. Four studies (570 patients) met the inclusion criteria. Mean patient age was 34.5 years, and 60.4% were male. The GT entry point was associated with significantly shorter operative (mean difference [MD], -20.05 minutes [95% confidence interval (CI), -23.09 to -17.02]; \(P<.0001\)) and fluoroscopy times (MD, -24.55 seconds [95% CI, -43.23 to -5.86]; \(P=.01\)). There was no significant difference in nonunion (risk ratio [RR], 0.74 [95% CI, 0.35 to 1.58]; \(P=.44\)) and delayed union rates (RR, 0.94 [95% CI, 0.41 to 2.14]; \(P=.88\)) between the 2 entry points. Heterogeneity in outcome measures reported prevented pooled analysis of functional outcomes. This review supports the use of the GT entry point during antegrade nailing of femoral shaft fractures over the PF entry point, with regard to shorter operative and fluoroscopy times. Healing and complication rates were not related to the entry point. Further study is required to determine the effect of each entry point on the surrounding soft tissue structures and ultimately its impact on postoperative function. [Orthopedics. 2016; 39(1):e43-e50.]
entry point for antegrade nailing. In the following years, the PF became the starting point of choice, due to its favorable biomechanical results.11-13

The debate surrounding the optimal entry point was revived with the advent of the IM nail featuring a proximal valgus bend. These nails were specifically designed to address the pitfalls associated with inserting a straight nail through the GT.4-7 Ricci et al.14 were the first to directly compare the GT and PF entry points during antegrade nailing of femoral shaft fractures.15 Results from their study demonstrated no difference in union rate and complications between the 2 entry points.14 However, they reported significantly shorter operative and fluoroscopy times with the GT entry point.14 Furthermore, other investigators have advocated the use of GT entry in obese patients, citing increased ease of use in that patient population.16 Since the study by Ricci et al.,14 there have been a number of randomized, controlled trials (RCTs) and cohort studies comparing the efficacy of the 2 entry points on various patient- and procedure-related outcomes.17-20 To the current authors’ knowledge, there has been no systematic review of the literature on optimal entry point during antegrade nailing of femoral shaft fractures.

The primary objective of the current systematic review was to compare the operative and fluoroscopic time required for IM nail fixation of femoral shaft fractures using the GT vs the PF entry point. A secondary objective was to determine whether there were any differences in complications (nonunion and delayed union) and functional outcomes between the 2 entry points.

**MATERIALS AND METHODS**

**Eligibility Criteria**

The authors identified all RCTs, prospective cohort studies (PCSs), and retrospective cohort studies (RCSs) that compared GT and PF entry points for antegrade IM nail fixation of femoral shaft fractures in adults. Case series, reviews, and technique and basic science articles that did not report patient-specific data were excluded. There were no language restrictions.

**Literature Search**

To identify eligible studies for inclusion, a systematic search of the electronic databases Medline, Embase, PubMed, Cochrane Central Register of Controlled Trials, and clinicaltrials.gov (for ongoing registered RCTs) was performed independently by 2 authors (U.S., C.G.). The search was conducted during the week of October 6, 2014, and articles were retrieved from database inception to the search date. Complete Embase and Medline search strategies can be found in Table 1 and Table 2, respectively. Titles of podium and poster presentations in programs of 3 major orthopedic meetings (American Academy of Orthopaedic Surgeons, Canadian Orthopaedic Association, and Orthopaedic Trauma Association) from 2011 to 2013 were reviewed for any relevant unpublished studies. Additional studies were detected by searching the bibliographies of eligible studies. The “related articles” feature of PubMed was used to identify similar relevant articles.

**Study Selection**

Article titles and abstracts were reviewed independently by 2 authors (U.S., C.G.) to determine whether they met inclusion criteria. If any ambiguity was encountered, the study was included until full-text review could be performed. The 2 independent reviewers assessed each full-text article for eligibility. Any disagreements were discussed between the reviewers and, if required, a third reviewer (J.C.) until consensus was reached.

**Data Extraction**

Data were abstracted by 2 independent reviewers (U.S., C.G.) into a standardized collection form using Microsoft Excel 2013 (Microsoft, Redmond, Washington).
Data collected included general study information (author, year of publication, study design, sample size, level of evidence), demographic data (mean or median age, sex), IM nail entry point (GT vs PF), IM nail characteristics (manufacturer), patient positioning (supine or lateral), follow-up data (mean duration, rate), and outcome measures used.

Methodological Quality Assessment
The quality of eligible studies was assessed independently by 2 authors (U.S., C.G.). The checklist to evaluate a report of a nonpharmacological trial (CLEAR-NPT) was used to assess the quality of RCTs. The CLEAR-NPT is a validated checklist used to assess the adequacy of 10 key elements of an RCT. The Newcastle-Ottawa Scale (NOS) was used to assess quality of the nonrandomized studies. The NOS uses a star system (0 to 9) to evaluate nonrandomized studies on 3 domains: selection, comparability, and outcome/exposure. Higher scores on the NOS represent higher study quality. A consensus agreement was achieved between reviewers.

Statistical Analysis
Data were pooled across studies; the weighted mean difference (MD) was calculated for continuous outcomes, and the risk ratio (RR) was calculated for binary outcomes. Point estimates for all outcomes were calculated with their corresponding 95% confidence intervals (CIs). All tests of significance (2-tailed) were performed with an $\alpha$ value of 0.05. In situations where studies only reported a median and interquartile range (IQR), established statistical methods were used to obtain converted mean and SD values to allow for pooling of data across studies.

A random-effects model was used to account for any heterogeneity, and the Cochran chi-square test of homogeneity was used to test for significance (ie, Q test, $P<.10$). An $I^2$ statistic value of greater than 75% was considered high. The authors could not assess for publication bias because the number of eligible studies was too small. A sensitivity analysis was planned to test the robustness of the pooled results by sequential removal of studies one by one. Subgroup analyses that were planned a priori included analyzing the primary outcomes (operative and fluoroscopy time) based on study randomization.

RESULTS
General Study Characteristics
The search resulted in 4 studies that met the eligibility criteria, providing a total of 570 patients for analysis. Included were 2 level I RCTs, 1 level II PCS, and 1 level III RCS. All of the studies were published in peer-reviewed journals. Of the 4 studies, 3 were written in English and 1 required translation (Korean to English) by a bilingual Korean-English medical student. Mean age of participants across all eligible studies was 34.5 years. Mean clinical follow-up across the 4 studies ranged from 10 to 48 months. Data pertaining to sex were available for 3 studies, and 278 (60.4%) of the 460 patients were male. Patients were placed supine for antegrade IM nailing in all of the eligible studies. Information on body mass index (BMI) was available for 3 of the 4 included studies. The frequency-weighted mean BMI across these studies was 25.0 kg/m² and 24.6 kg/m² in the GT-entry and PF-entry groups, respectively. Table 3 depicts the baseline characteristics of all eligible studies.

Fracture Type
All of the eligible studies comprised adults with isolated femoral shaft fractures (defined by the Orthopaedic

Figure 1: Flow diagram summarizing the search strategy and screening and selection process.
Table 3

Baseline Characteristics of Eligible Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>Inclusion Criteria</th>
<th>GT-Entry IM Nail</th>
<th>PF-Entry IM Nail</th>
<th>Operative Patient Position</th>
<th>GT-Entry Group</th>
<th>PF-Entry Group</th>
<th>Sample Size (% Male)</th>
<th>Mean Age, y</th>
<th>Follow-up Rate</th>
<th>Mean Follow-up, mo</th>
<th>Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricci et al</td>
<td>Level II, PCS</td>
<td>Femoral shaft or subtrochanteric fracture⁴</td>
<td>Trigen TAN Nail (Smith &amp; Nephew, Memphis, Tennessee)</td>
<td>Trigen FAN Nail</td>
<td>Supine</td>
<td>24</td>
<td>24</td>
<td>91 (59.3)</td>
<td>28.6</td>
<td>85.7%</td>
<td>10</td>
<td>Operative and fluoroscopy time, union time, fracture alignment, LEM</td>
</tr>
<tr>
<td>Stannard et al</td>
<td>Level I, RCT</td>
<td>Isolated femoral shaft fractures</td>
<td>Trigen TAN Nail</td>
<td>Trigen FAN Nail</td>
<td>Supine</td>
<td>28.1</td>
<td>27.8</td>
<td>110 (NR)</td>
<td>34</td>
<td>81%</td>
<td>16</td>
<td>Operative and fluoroscopy time, incision length, blood loss, WOMAC, VAS, union time, muscle strength, functional testing (chair stand test, timed up and go test)</td>
</tr>
<tr>
<td>Moein et al</td>
<td>Level I, RCT</td>
<td>Isolated femoral shaft fractures</td>
<td>Antegrade Femoral Nail (Synthes, Solothurn, Switzerland)</td>
<td>Unreamed Femoral Nail (Synthes)</td>
<td>Supine</td>
<td>NR</td>
<td>NR</td>
<td>19 (94.7)</td>
<td>28.9</td>
<td>90.5%</td>
<td>48</td>
<td>VAS, gait analysis, muscle strength, EMG, MRI</td>
</tr>
<tr>
<td>Ha et al</td>
<td>Level III, RCS</td>
<td>Isolated femoral shaft fractures</td>
<td>Sirius Femoral Nail (Zimmer, Cowpens, South Carolina)</td>
<td>M/DN Femoral Nail (Zimmer, Warsaw, Indiana)</td>
<td>Supine</td>
<td>24.3</td>
<td>23.7</td>
<td>350 (58.9)</td>
<td>36.4</td>
<td>81%</td>
<td>24</td>
<td>Operative and fluoroscopy time, blood loss, union time, HHS, complications (LLD, nonunion, delayed union, iatrogenic fracture, broken screw)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; EMG, electromyography; FAN, femoral antegrade nail; GT, greater trochanter; HHS, Harris Hip Score; IM, intramedullary; LEM, lower extremity measure; LLD, limb-length discrepancy; MRI, magnetic resonance imaging; NR, not reported; PCS, prospective cohort study; PF, piriformis fossa; RCS, retrospective cohort study; RCT, randomized, controlled trial; TAN, trochanteric antegrade nail; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

⁴No patients with subtrochanteric fractures were part of the study.

Study Quality

A summary of the methodological quality assessment of included studies using the CLEAR-NPT Odontological quality assessment tool and its published guidelines is provided in Table 5 and Table 6, respectively. In general, both of the RCTs were of moderate methodological quality. One study did not provide sufficient methodological quality information, and the remaining studies were of low methodological quality. The remaining studies were of low methodological quality.

One study did not provide information on the classification of the fractures, and the remaining studies were of low methodological quality. The remaining studies were of low methodological quality.

In 2 of the 4 studies, the TRICEN trochanteric antegrade nail (Smith & Nephew, Memphis, Tennessee) was used. In another study, the Medtronic Getinge module (Getinge, Sweden) was used. In another study, the Medtronic Getinge module (Getinge, Sweden) was used. In another study, the Medtronic Getinge module (Getinge, Sweden) was used. In another study, the Medtronic Getinge module (Getinge, Sweden) was used.

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The remaining studies were of low methodological quality. The remaining studies were of low methodological quality.

These results are summarized in Table 4.
enough information to determine whether generation of allocation sequence and surgeon experience was adequate. The other study failed to use the intention-to-treat principle for analysis. The nonrandomized studies had study populations that were well matched on important demographic and prognostic variables (e.g., mechanism of injury, fracture classification, and BMI). One study failed to mention how outcomes were collected. Overall, these cohort studies were found to be of high methodological quality and were noted to have NOS scores of 9 and 7, respectively, of a possible 9 stars.

**Primary Outcomes**

**Operative Time.** Data on operative time were available for 3 of the 4 included studies. The pooled mean difference (MD) in operative time across all studies significantly favored the GT-entry IM nail by approximately 20 minutes (3 studies [551 patients]; MD, -20.05 [95% CI, -23.09 to -17.02]; P<.00001) (Figure 2). Subgroup analysis using data from RCTs alone also demonstrated a significant difference in operative time favoring the GT entry IM nail by approximately 25 seconds (3 studies [551 patients]; MD, -24.55 [95% CI, -43.23 to -5.86]; P=.01) (Figure 2). A similar result was found during subgroup analysis using only data from RCTs (2 studies [201 patients]; MD, -36.36 [95% CI, -59.46 to -13.26]; P=.002).

**Secondary Outcomes**

**Nonunion.** The pooled nonunion rate among all patients in this study was 4.6% (26 of 570). The overall pooled nonunion rate was 3.9% (11 of 283) and 5.2% (15 of 287) for patients treated with GT-entry and PF-entry IM nails, respectively. A pooled summary of all 4 studies demonstrated no statistically significant difference in the overall risk of nonunion between patients treated with a GT-entry vs PF-entry IM nail (4 studies [570 patients]; RR, 0.74 [95% CI, 0.35 to 1.58]; P=.44) (Figure 2).

**Delayed Union.** The number of delayed unions was reported in 3 of 4 studies. The pooled delayed union rate among all patients in the current review was 4.2% (23 of 551). The overall pooled delayed union rate was 3.6% (10 of 274) and 4.7% (13 of 277) for patients treated with GT-entry and PF-entry IM nails, respectively. A pooled analysis of the 3 studies showed no statistically significant difference in the overall

### Table 4

<table>
<thead>
<tr>
<th>OTA Classification of Treated Fractures*</th>
<th>No. (%) of Fractures Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>With GT-Entry IM Nail</td>
<td>With PF-Entry IM Nail</td>
</tr>
<tr>
<td>32-A</td>
<td>137 (50)</td>
</tr>
<tr>
<td>32-B</td>
<td>70 (25)</td>
</tr>
<tr>
<td>32-C</td>
<td>70 (25)</td>
</tr>
<tr>
<td>Total</td>
<td>277 (100)</td>
</tr>
</tbody>
</table>

*Note: Only 3 of the 4 included studies provided data on fracture classification.

### Table 5

**Methodological Quality Assessment for 2 Eligible RCTs Using CLEAR-NPT Guidelines**

<table>
<thead>
<tr>
<th>CLEAR-NPT Criterion*</th>
<th>Study</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stannard et al17</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>U</td>
<td>1. U</td>
<td>1. U</td>
<td>Y</td>
<td>Y</td>
<td>U</td>
<td>4. Primary surgeon was senior resident; similar in each arm but may not have had same level of expertise as experienced surgeon. 5. Not applicable to surgical intervention. 7. Not feasible. 10. No mention of analysis for missing data.</td>
</tr>
<tr>
<td></td>
<td>Moein et al18</td>
<td>U</td>
<td>Y</td>
<td>Y</td>
<td>U</td>
<td>U</td>
<td>1. N</td>
<td>1. U</td>
<td>1. U</td>
<td>Y</td>
<td>Y</td>
<td>1. Patients randomized through envelopes. No information given whether envelopes introduced bias (e.g., no mention of sealed opaque, etc) 4. No mention of surgeons’ expertise. 5. Not applicable to surgical intervention. 7. Not feasible. 8. No mention of who outcome assessors were.</td>
</tr>
</tbody>
</table>

*Abbreviations: N, no; RCTs, randomized, controlled trials; U, unclear; Y, yes.

*1. Adequate generation of allocation sequence; 2. Treatment allocation concealed; 3. Details of each intervention available; 4. Expertise similar in each arm; 5. Participant adherence assessed; 6. Adequate participant blinding; 7. Care providers blinded; 8. Outcome assessors adequately blinded; 9. Similar follow-up between groups; 10. Used intention-to-treat analysis.
risk of delayed union among patients treated with a GT-entry vs a PF-entry IM nail (3 studies [551 patients]; RR, 0.94 [95% CI, 0.41 to 2.14]; P=.88) (Figure 2).

**Malunion.** Malunion or malalignment was reported in 2 of the eligible studies.\(^{14,17}\) One study defined malalignment as greater than 10° of angulation, greater than 15° of malrotation, and/or a leg-length discrepancy greater than 2 cm.\(^ {14}\) This study did not report any cases of malalignment in either group; however, 1 patient in the GT-entry group healed with 12° of external rotation.\(^ {14}\) The other study had a total of 9 fractures that healed with 5° to 8° of malalignment.\(^ {17}\) Six patients in the PF-entry group had a malunion; 4 healed in varus and 2 healed with femoral recurvatum. Two patients in the GT-entry group healed in varus, and one healed in slight procurvatum.\(^ {17}\)

**Functional Outcomes.** Due to the heterogeneity in outcome measures used among the included studies, data on functional outcomes could not be pooled. Although each study used a different outcome measure (Harris Hip Score [HHS],\(^ {19}\) customized functional outcome questionnaire,\(^ {18}\) Lower Extremity Measure [LEM],\(^ {14}\) and Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC]\(^ {17}\)), it is important to note that there were no differences in function and patient-reported outcomes between patients who received GT- and PF-entry nailing.

**DISCUSSION**

The current systematic review of comparative studies evaluating the optimal entry point (GT vs PF) for antegrade nailing of femoral shaft fractures found the following: (1) using the GT entry point leads to significantly reduced operative times compared with the PF entry point; (2) fluoroscopy time is significantly less when using the GT entry point compared with the PF entry point; and (3) nonunion and delayed union rates are not significantly different among patients undergoing antegrade nailing via the GT and PF entry points.

The observed MD in operative time of approximately 20 minutes favoring the GT entry point is a clinically significant finding. A decrease in operative time re-
roduces the potential morbidity associated with a longer anesthetic time and could potentially reduce intraoperative blood loss. It also reduces the economic costs associated with the surgical procedure (e.g., resource use and nursing). The cost of operating room time in the United States (as per 2005 data) has been estimated to range from $22 to $133 per minute. These figures do not include surgeon and anesthetist fees. Thus, the potential cost savings may be substantial. Furthermore, evidence from the literature suggests that the decrease in operative time associated with use of the GT entry point is even more pronounced when considering obese patients. However, it is important to note that future conversion to a total hip arthroplasty (THA) may be more difficult after use of a GT entry nail. Although no studies have reported on conversion to THA after GT-entry IM nailing for femoral fractures, literature pertaining to THA conversion following cephalomedullary nailing for hip fractures has found operative times and blood loss to be significantly greater with the GT entry point.

The current review’s finding that the time exposed to fluoroscopy is significantly less (approximately 25 seconds) when using the GT entry point is another clinically relevant finding. Previous work has found that the average fluoroscopy time for antegrade femoral nailing can range from 0.56 minutes (31.2 seconds) to 4.60 minutes (276 seconds). The current results suggest that there can be a significant reduction in radiation exposure to both the surgical team and the patient through the use of the GT entry point.

The pooled nonunion rate among all patients in this study was 4.6%, which may seem higher than the rates reported in the literature. However, nonunion rates have been found to range from 0.9% in simple femoral shaft fractures to 10% in cases of severe comminution and bone loss. With pooling of all fracture types (OTA 32-A/B/C) in the study, the overall nonunion rate reported here likely reflects this varying degree of severity in fractures treated. The finding of no difference in nonunion and delayed union rates between the GT and PF entry points is an important finding because it suggests that the biological healing process is not influenced by entry point.

The heterogeneity in outcome measures used to assess postoperative function in the eligible studies prevented any pooled analysis. Although no universal functional outcome measure was used, each eligible study in this review reported no significant difference in patient function (as per the outcome measure used in each study) when comparing the 2 entry points. However, whether PF-entry nailing has a detrimental effect on the soft tissue structures around the hip is an area of controversy. In fact, Archdeacon et al compared hip abductor function in patients who were treated for femoral shaft fractures with antegrade IM nailing using the GT or PF entry point. They found the PF-entry group had significantly less internal hip abduction moment at terminal stance or push-off compared with the GT-entry group. In a cadaver study, Dora et al found that the PF entry portal was associated with significant damage to the external rotators and medial circumflex artery when compared with the GT entry portal. Ansari Moein et al reported similar findings in their study of cadavers, noting that nailing through the GT would limit any surgical injury to the tendinous aspect of the hip abductor complex. However, in another cadaver study by McConnell et al, the GT entry point was reported to cause an average of 27% damage to the gluteus medius tendon insertion. Considering the current authors’ finding of no significant difference in functional outcome between the 2 entry points, postoperative function may be independent of the entry point.

The entry site may be a more critical element in the management of subtrochanteric fractures, which have demonstrated a propensity toward varus deformity with

CONCLUSION
The current systematic review demonstrates that use of the GT entry point during antegrade IM nailing is associated with decreased operative and fluoroscopy times, with no difference in nonunion and delayed union rates when compared with the PF entry point. Further research is required to determine the effect of each entry point on the surrounding soft tissue structures and functional outcomes.
References


