Epidemiology of periprosthetic femoral fractures in 5417 revision total hip arthroplasties

A 40-YEAR EXPERIENCE

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Aims
The goals of this study were to define the risk factors, characteristics, and chronology of fractures in 5417 revision total hip arthroplasties (THAs).

Patients and Methods
From our hospital’s prospectively collected database we identified all patients who had undergone a revision THA between 1969 and 2011 which involved the femoral stem. The patients’ medical records and radiographs were examined and the relevant data extracted. Post-operative periprosthetic fractures were classified using the Vancouver system. A total of 5417 revision THAs were identified.

Results
There were 668 intra-operative fractures, giving an incidence of 12%. Fractures were three times more common with uncemented stems (19%) than with cemented stems (6%) (p < 0.001). The incidence of intra-operative femoral fracture varied by uncemented stem type: fully-coated (20%); proximally-coated (19%); modular fluted tapered (16%) (p < 0.05). Most fractures occurred during the insertion of the femoral component (35%). One-third involved the diaphysis and 26% were of the calcar: 69% were undisplaced.

There were 281 post-operative fractures of the femur (20-year probability = 11%). There was no difference in risk for cemented and uncemented stems. Post-operative fractures were more common in men < 70 years (p = 0.02). Periprosthetic fractures occurred earlier after uncemented revision of the femoral component, but later after a cemented revision. The most common fracture type was a Vancouver B1 (31%). Of all post-operative fractures, 24% underwent open reduction and internal fixation and 15% revision arthroplasty.

Conclusion
In revision THA, intra-operative fractures occurred three times more often with an uncemented stem. Many were undisplaced diaphyseal fractures treated with cerclage fixation.

While the risk of post-operative fracture is similar between uncemented and cemented components, they occur at notably different times depending on the type of stem fixation.

Take home message: In revision THA, intra-operative periprosthetic femoral fractures occur three times more often with uncemented stems. Many are non-displaced diaphyseal fractures treated with cerclage fixation. While postoperative fracture risks are equivalent between uncemented and cemented components, they occur at notably different time periods based on stem fixation type.

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Unlike periprosthetic fractures around a primary THA, relatively little is known about fractures around revision THAs. Most series consist of a small number of patients, or focus on a specific implant.

The primary purpose of this study was to define the demographic and operative risk factors and chronology of fractures in a large cohort of patients who had undergone THA. Our secondary goals were to determine the clinically relevant nature of the fractures and their subsequent treatment.

**Patients and Methods**

Institutional Review Board (IRB) approval was given before the study started.

We retrospectively reviewed the entire total joint registry (TJR) at the Mayo Clinic from 1969 to 2011. All revision THAs which involved the femoral component were included. Periprosthetic femoral fractures were studied for demographics (age, gender), timing (intra-operative or post-operative), type of fixation (cemented or uncemented) and type of uncemented stem (proximally coated; fully coated; or modular fluted tapered). Intra-operative fractures of the femur were studied with respect to timing of occurrence during the procedure, anatomical site, displacement, treatment modification, and the need for additional surgical intervention. Post-operative fractures of the femur were studied for mechanism of injury, Vancouver classification, anatomical site, displacement, subsequent treatment modification, and the need for additional surgical intervention.

Patients were identified through the TJR that is used to follow all patients who have undergone total joint arthroplasty at our institution since 1969. The medical records and radiographs of all patients with a periprosthetic fracture at our institution since 1969. The medical records follow all patients who have undergone total joint arthroplasty. Most series consist of a small number of patients, or focus on a specific implant.

The incidence of intra-operative periprosthetic fractures was assessed using logistic regression, adjusting for within patient correlation (bilateral THA). Results are reported as odds ratios (OR) or hazard ratios (HR) with 95% confidence intervals (CI). The cumulative probability of post-operative periprosthetic fracture was estimated using the Kaplan–Meier method. The association of a variable with the risk of a post-operative periprosthetic fracture was assessed using Cox proportional hazards regression, adjusting for within patient correlation (bilateral THA). The α-level was set at 0.05 for statistical significance.

**Results**

**Intra-operative fractures.** The incidence of intra-operative periprosthetic fractures of the femur was 12.3% (668 of 5417) (Table I). Female patients had a statistically significant slightly higher likelihood of intra-operative fracture than male patients (13.7% versus 11.3%, respectively; \( p = 0.007; \) OR = 1.25 with 95% CI 1.06 to 1.47). Age ≥ 70 years at revision was not a significant risk factor when compared with age < 70 years (12.5% versus 12.1%, respectively; \( p = 0.68; \) OR = 1.04 with 95% CI of 0.88 to 1.22).

While not an aim of this study, there was a trend towards fewer intra-operative fractures in those patients who had an extended femoral osteotomy for exposure than for those without an osteotomy (\( p = 0.07; \) OR = 1.3 with 95% CI of 0.98 to 1.54).

In total, 516 (18.6%) of the 2781 hips revised to an uncemented femoral component had an intra-operative fracture, compared with only 152 (5.8%) of the 2636 hips.

**Statistical analysis.** Descriptive statistics are reported as numbers (percentage) or medians (absolute range) as appropriate. The association of a variable with the odds of an intra-operative periprosthetic fracture was assessed using logistic regression, adjusting for within patient correlation (bilateral THA). Results are reported as odds ratios (OR) or hazard ratios (HR) with 95% confidence intervals (CI). The cumulative probability of post-operative periprosthetic fracture was estimated using the Kaplan–Meier method. The association of a variable with the risk of a post-operative periprosthetic fracture was assessed using Cox proportional hazards regression, adjusting for within patient correlation (bilateral THA). The α-level was set at 0.05 for statistical significance.

**Table I. Risk of intra-operative periprosthetic fracture of the femur by cement status and type of uncemented stem**

<table>
<thead>
<tr>
<th>Variables</th>
<th>No. of fractures/No. of revision THAs (%)</th>
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<tbody>
<tr>
<td>Intra-operative (all)</td>
<td>668 / 5417 (12.3)</td>
</tr>
<tr>
<td>Uncemented</td>
<td>516 / 2781 (18.6)</td>
</tr>
<tr>
<td>Proximally coated</td>
<td>161 / 848 (19.0)</td>
</tr>
<tr>
<td>Fully coated</td>
<td>242 / 1213 (20.0)</td>
</tr>
<tr>
<td>Modular fluted tapered</td>
<td>113 / 720 (15.7)</td>
</tr>
<tr>
<td>Cemented</td>
<td>152 / 2636 (5.8)</td>
</tr>
</tbody>
</table>

THA, total hip arthroplasty
revised to a cemented femoral component (p < 0.001; OR = 3.72; 95% CI 3.08 to 4.50). When stratified by un cemented stem type, there was a 19.0% (161 of 848) risk of intra-operative fracture with a proximally coated stem, 20.0% (242 of 1213) risk with a fully-coated stem, and 15.7% (113 of 720) risk with a modular fluted tapered stem (Table I). There were statistically increased odds of an intra-operative fracture with a fully-coated stem when compared with a modular fluted tapered stem (p = 0.02; OR = 1.34 with 95% CI 1.05 to 1.71). Of note, 43 of 668 patients (0.06%) with an intra-operative fracture also suffered a post-operative fracture during the follow-up period.

Of the 668 intra-operative fractures, 626 had appropriate radiographs and sufficient details in their medical records for in-depth review (94%). Most intra-operative fractures of the femur occurred at one of three times during the revision procedure: during placement of the femoral component (216 fractures; 34.5%), removal of the previous prosthesis (192 fractures; 30.7%) or trial reduction (141 fractures; 22.5%; table available in supplementary material). About one third of fractures involved the diaphysis (209 fractures; 33.4%), one quarter the medial femoral neck region (~calcane~) (160 fractures; 25.5%), and one fifth each of the subtrochanteric regions (129 fractures; 20.6%) and greater trochanter regions (128 fractures; 20.4%).

The most common time for a fracture of the greater trochanter was during removal of the old component (42.6%) followed by trial reduction (27.5%) and final implant insertion (19.8%) (Table II). A little over half were undisplaced (57%). Fractures of the medial aspect of the femoral neck occurred most commonly during preparation of the femur (46.5%) or trial reduction (26.8%), and were often undisplaced linear cracks (60.6%). Most were treated with cerclage wires or cables with or without a cortical strut allograft (83.1%) (Table II). Subtrochanteric fractures occur nearly equally during preparation of the femoral canal (34.1%), trial reduction (30.2%), or insertion of the femoral component (26.4%). Most were undisplaced linear cracks (76%): 74% were treated with cerclage wires or cables with or without a cortical strut allograft (89.9%).

**Post-operative fractures.** After revision THA, the cumulative probability of a post-operative periprosthetic fracture of the femur was 1.9% at one year, 3.8% at five years, 6.4% at ten years, and 11.4% at 20 years (Table III). Of the 281 post-operative periprosthetic femoral fractures, 135 occurred after 2781 uncemented femoral revision THAs and 146 after 2636 cemented femoral revision THAs. The risk of post-operative periprosthetic fracture did not differ significantly between cemented and uncemented femoral stems (p = 0.17; HR = 1.2; 95% CI 0.9 to 1.5) (Fig. 1). The 20-year cumulative probability of fracture for a cemented stem was 10.2% (95% CI 8.4 to 13.3) and 12.1% (95% CI 8.2 to 6.3) for an uncemented stem.

In distinction to intra-operative fractures, men were at a higher risk of post-operative fracture with a hazard ratio of 1.48 (95% CI 1.16 to 1.89). Surprisingly, patients ≥ 70 years of age at operation had a significantly lower risk of post-operative fracture of the femur than patients < 70 years of age (p = 0.02; HR = 0.74; 95% CI 0.57 to 0.96).

When stratified by uncemented stem type at 15 years, there was a 7.1% (4.8 to 9.4) probability of post-operative fracture with a proximally-coated stem, an 11.4% (6.9 to 17.8) probability with a fully-coated stem, and an 8.4% (3.2 to 23.8) probability with a modular fluted tapered stem (p = 0.12) (Table IV and Fig. 2).

Of the 281 post-operative fractures, 237 had appropriate radiographs and medical records for in-depth review (84%). Most (82.7%; 196 of 237) were treated at the Mayo Clinic. Of note, 107 fractures were intentionally not

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**Table II. Summary of Vancouver A2 fractures (n = 49)**

<table>
<thead>
<tr>
<th>Mean time to fracture</th>
<th>Mechanism of injury (%)</th>
<th>Nature (%)</th>
<th>Treatment (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>47 mths</td>
<td>Fall from standing height (28.6)</td>
<td>Transverse (51.2)</td>
<td>Non-operative (83.7)</td>
</tr>
<tr>
<td></td>
<td>No known trauma (53.1)</td>
<td>Non-displaced linear (32.6)</td>
<td>ORIF (6.1)</td>
</tr>
<tr>
<td></td>
<td>Progressive osteolysis (6.1)</td>
<td>Oblique (6.1)</td>
<td>Revision THA (10.2)</td>
</tr>
<tr>
<td></td>
<td>Stress fracture (4.1)</td>
<td>Avulsion (6.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intra-operative propagation (4.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dislocation (4.1)</td>
<td></td>
<td></td>
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</table>

**Table III. Risk of post-operative periprosthetic fracture of the femur by cement status**

<table>
<thead>
<tr>
<th></th>
<th>Cumulative probability of fracture estimate, (95% CI)</th>
<th>Cox proportional hazards</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Yr</td>
<td>5 Yrs</td>
<td>10 Yrs</td>
</tr>
<tr>
<td>Overall</td>
<td>1.9 (1.5 to 2.3)</td>
<td>3.8 (3.3 to 4.4)</td>
<td>6.4 (5.5 to 72)</td>
</tr>
<tr>
<td>Uncemented</td>
<td>2.5 (1.9 to 3.1)</td>
<td>4.2 (3.3 to 5.0)</td>
<td>6.4 (5.2 to 76)</td>
</tr>
<tr>
<td>Cemented</td>
<td>1.3 (0.8 to 1.7)</td>
<td>3.4 (2.7 to 4.2)</td>
<td>6.1 (5.0 to 72)</td>
</tr>
</tbody>
</table>

CI, confidence interval.
classified because they were a combination of Vancouver fractures (as opposed to a simple fracture pattern), not treated at our institution, or did not have adequate radiographs. Of the fractures that could be classified, the most common were Vancouver B₁ fractures (53; 30.5%), followed by Vancouver A₂ G fractures (49; 28.1%) (Table V). There was a similar incidence of Vancouver B₁ fractures with cemented and uncemented stems. By contrast, Vancouver B₂ and B₃ fractures (those with a loose stem) occurred more commonly with a cemented stem.
Vancouver AG and AL fractures occurred more commonly with an uncemented stem (p < 0.001). When analysing the Vancouver AG fractures, just over half occurred without any known injury (53.1%) (Table II). Another quarter of the fractures occurred as the result of a fall from standing height. Only 32.6% were undisplaced. Most were treated non-operatively (83.7%). Vancouver B1 fractures occurred for many reasons, the three most common being a fall from standing height (28.6%), a low-energy injury (16.7%), and without a known injury (16.7%) (Table VI). The fracture pattern was oblique in 41.7%, spiral in 33.3%, non-displaced linear cracks in 19.4% and comminuted in 5.6%. While 61.1% were treated by ORIF, 38.9% were treated non-operatively. Vancouver B2 and B3 fractures most commonly occurred after a fall from standing height (55.6%) (Table VII). Most had an oblique fracture pattern (48.9%): 80% were treated by revision THA.

At 20 years, the cumulative probability of a post-operative fracture of the femur was 11.4% (95% CI 9.3 to 13.5).

Of the 146 post-operative periprosthetic fractures around a cemented femoral revision, 2.7% (n = 4) occurred within 30 days, 22% (n = 32) during the first year, 32% (n = 46) during years one to five, and 47% (n = 68) after five years. Of the 135 post-operative periprosthetic fractures around an uncemented femoral revision, 13.3% (n = 18) occurred within 30 days, 47% (n = 64) during the first year, 23% (n = 31) during years one to five, and 30% (n = 40) after five years. Fracture within the first year was
implant, and trial reduction. The frequency of fracture removal of the old implant, trialling or insertion of the new implants. The frequency of fracture and represented the early experience with uncemented implants. Morrey et al reported an 18% rate of intra-operative periprosthetic fracture of the femur at revision, compared with a rate of 3.5% for primary procedures. Morrey et al reported an 18% rate of intra-operative periprosthetic fractures with an uncemented stem, compared with 3% with a cemented stem. Likewise, Berry reported a 20.9% (322 of 1536) rate of intra-operative fracture for uncemented femoral revisions, compared with 3.6% (175 of 4813) for cemented femoral revisions. Of note, these reports were derived from the same database, and represented the early experience with uncemented implants.

Intra-operative fractures occur most commonly during removal of the old implant, trialling or insertion of the new implant, and trial reduction. The frequency of fracture during trialling of implants and reduction of an uncemented implant has not previously been reported and deserves attention as precautions can be taken to mitigate these risks. Furthermore, this paper provides practical information about the specific parts of the operation that are most likely to be associated with a specific type of fracture. For example, almost half of the fractures of the greater trochanter occurred during removal of the failed implant. In 1981, Johansson et al reported 22 intra-operative fractures that occurred during revision procedures. Most (11/22) followed removal of the cement and may have been related to the lack of sophisticated methods of cement removal at that time. On the other hand, Christensen et al reported ten intra-operative fractures during 159 revision THAs, half of which occurred when dislocating the hip.

While others have reported intra-operative periprosthetic fractures associated with uncemented implants during revision THA, this is the first report to identify and describe the risk factors and fracture patterns in detail. For example, our series shows a statistically increased risk of intra-operative fracture when using a fully-coated stem rather than a modular fluted tapered stem.

Not all intra-operative fractures are benign. Many required further intervention, making the procedure more complex. In addition, 21% of patients with an intra-operative periprosthetic fracture of the femur eventually need further surgical intervention for reasons directly related to their fracture.

We found that while the risk of post-operative fracture is similar for uncemented and cemented femoral components, fractures occur at a different rate at different times depending on the method of fixation: there are many more early fractures with uncemented components than with cemented components. This is likely to be the result of unrecognised intra-operative fracture or weakening of the bone when preparing the femur. From an epidemiological perspective, Berry previously reported a post-operative fracture rate of 4.0% in 6349 revision stems. Lindahl et al similarly noted a post-operative periprosthetic fracture rate of 2.1% with revision stems. Kavanagh estimated the frequency of post-operative periprosthetic fracture of the femur to be 4.2% after revision THA. These numbers are prevalence figures and hence are subject to bias by duration of follow-up. In this, the largest series to date with the longest follow-up, we used cumulative probability calculations which account for time of follow-up, and found that the cumulative probability of post-operative periprosthetic fracture of the femur was 1.9% at one year, 3.8% at five years, 6.4% at ten years, and 11.4% at 20 years.

Differing results have been reported for the effect of age on periprosthetic fractures after revision THA. Cook et al noted that patients over 70 years of age had a 2.9 times greater risk of sustaining a periprosthetic fracture of the femur but found no association between fracture and gender. By contrast, Lindahl et al found a statistically significant increase in the risk of periprosthetic fractures in younger patients. They hypothesised that the increased activity led to increased loosening thereby increasing risk of fracture. Our data, unlike those of Lindahl et al, showed that men, and patients less than 70 years of age had a higher risk of post-operative fracture. This may be because younger patients are usually more active.

We identified Vancouver B3 fractures as the most common pattern of post-operative fracture, followed by Vancouver A3. Vancouver B3 fractures occurred for many reasons, the two most common being a fall from standing height and no known injury. Approximately half the Vancouver A3 fractures occurred without any identifiable injury and one third were undisplaced. Most were treated non-operatively.

There are limitations to the current study. Foremost, the data are minimum figures for the incidence of post-operative fracture given that fractures treated elsewhere may not have been identified in our registry, despite the fact that patients are seen and contacted at regular intervals (one, two, five, ten, and every five years, thereafter). In addition, the fractures in this series occurred over a 40-year period, during which surgical techniques and implants changed and improved. However, this is the most comprehensive analysis of periprosthetic fractures of the femur...
after revision THA and reports a very large cohort of patients. Finally, while we noted a trend towards fewer intra-operative fractures when an extended femoral osteotomy was used, there is an inherent risk of bias in this observation as osteotomy was only undertaken for the most difficult cases.

Periprosthetic fractures around hip arthroplasties are increasing in prevalence for several reasons. By 20 years, nearly 12% of surviving patients will have experienced a post-operative periprosthetic fracture of the femur after revision THA.

Supplementary material
A table showing a summary of intra-operative fractures is available alongside the online version of this article at www.bjj.boneandjoint.org.uk

Author contributions:
M. P. Abdel: Hypothesis generation, data collection, data analysis, writing manuscript, editing manuscript.
M. T. Houdek: Data collection, data analysis.
C. D. Watts: Performed surgeries, reviewed manuscript.
D. G. Lewallen: Hypothesis generation, performed surgeries, reviewed manuscript.

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References