What is the lifetime risk of revision for patients undergoing total hip arthroplasty?

A 40-YEAR OBSERVATIONAL STUDY OF PATIENTS TREATED WITH THE CHARNLEY CEMENTED TOTAL HIP ARTHROPLASTY

Aims
The purpose of this study was to determine the lifetime risk of revision surgery for patients undergoing Charnley cemented total hip arthroplasty (THA), with 40-year follow up, using death as a competing risk.

Materials and Methods
We retrospectively reviewed 2000 cemented Charnley THAs, with 51 living hips available at 40 years.

Results
The cumulative risk of revision or removal for any reason was 13% (95% confidence interval (CI) 12 to 15). Patients aged under 50 years at the time of surgery had a 35% (95% CI 28 to 42) risk of revision or removal for any reason (Hazard Ratio (HR) 3.6; 95% CI 2.5 to 5.2; p < 0.001), patients 50 to 59 years old had a 20% risk (95% CI 16 to 24) (HR 2.1; 95% CI 1.5 to 2.8; p < 0.0001), patients aged 60 to 69 years had a 9% risk (95% CI 7 to 11) (reference point), and patients ≥ 70 years old had a 5% risk (95% CI 4 to 7) (HR 0.96; 95% CI 0.6 to 1.5; p = 0.86) during their lifetime. Men had a higher risk of revision or removal for any reason (HR 2.1; 95% CI 1.7 to 2.7; p < 0.001).

Conclusion
With almost all the patients in this series followed up till either death or revision, we have been able to develop a ‘rule of thumb’ for lifetime likelihood of revision or implant removal for the Charnley THA: one in three for patients < 50 years, one in five for patients 50 to 59 years, one in ten for patients 60 to 69 years, and one in 20 for patients ≥ 70 years. The results provide a benchmark for comparison of outcomes, for the newer designs of THA.

Understanding the risk that a total hip arthroplasty (THA) will need revision during a patient’s lifetime is important for both patients and orthopaedic surgeons. The Charnley cemented THA (DePuy International Ltd, Leeds, United Kingdom) has shown a 78% to 95% estimated survivorship in many series at 15 to 35 years after surgery.1-12 Our group previously reported on 2000 cemented Charnley prostheses at a mean of 25 years follow-up performed between 1969 and 1971.6 At the time of the previous study, 461 patients were still alive and the Kaplan-Meier survivorship calculated the chance of patients being free of revision for any cause to be 78% (95% confidence interval (CI) 75 to 80) at 25 years. A multi-variate survivorship analysis revealed a significant increase in the revision rate for each decade decrease in age at time of surgery (p < 0.001) and an increased risk of revision in men (p < 0.001). The purpose of the current study was to evaluate the outcome of a large series of patients treated by Charnley cemented THA, followed up in most cases for the lifetime of the patient, and estimate the lifetime risk of revision using a contemporary competing risk analysis method.

Patients and Methods
The original study6 consisted of 2000 consecutive primary Charnley cemented THAs in 1689 patients which were performed at a single academic institution from 1969 to 1971. Institutional Review Board (IRB) approval was obtained prior to initiation of the current study. Patients were identified from our joint replacement registry, which collects outcome data prospectively, on all patients who undergo a total joint arthroplasty at our institution, and has done so since 1969.13,14 Clinical and radiological follow-up data were recorded at one, two and five years, and every
lost to follow-up. The association of patient factors would be treated as a censor and considered the same as greater using Kaplan-Meier survival estimates, where death was accounted for as the competing risk, the cumulative incidence of revision or removal for any reason was 28% (95% CI 23 to 33) for the acetabular and/or femoral component (Table I). As such, the Kaplan-Meier survivorship estimated revision for any reason to be greater by 15%, or approximately two-fold.

Overall survival with Kaplan-Meier survivorship analysis. In this regard, the cumulative incidence of revision or removal for any reason at 40 years was 28% (95% CI 23 to 33) for the acetabular and/or femoral component (Fig. 1). As such, the Kaplan-Meier survivorship estimated revision for any reason to be greater by 15%, or approximately two-fold.

Stratification by age. With death as a competing risk accounted for in the model, the 30-year cumulative incidence of an acetabular and/or a femoral component revision or removal for any reason was 35% (95% CI 28 to 42) in patients < 50 years, 20% (95% CI 16 to 24) for patients 50 to 59 years, 9% (95% CI 7 to 11) for patients 60 to 69 years, and 5% (95% CI 4 to 7) for those 70 years or older (Fig. 2).

A multivariate analysis revealed that patients 50 years or younger at the time of surgery were 3.6 times (95% CI 2.5 to 5.2; p < 0.001) more likely than patients 60 to 69 years of age to require revision or removal of either component for any reason during their lifetime. Similarly, patients between the ages of 50 to 59 were 2.1 times (95% CI 1.5 to 2.8; p < 0.001) more likely to require revision or removal of either component for any reason when compared with those 60 to 69 years of age. Patients who were 70 years of age or older at their primary THA, had a non-statistically significant, slightly decreased risk of revision or removal of either component during their lifetime (Hazard Ratio (HR) 0.9; 95% CI 0.6 to 1.5; p = 0.8).

When revision or implant removal for any reason was analysed for the acetabular component only, the multivariate analysis revealed that patients less than 50 years of age at primary THA were at a 3.5-fold (95% CI 2.3 to 5.5; p < 0.001) increased risk. Patients 50 to 59 years of age were at a two-fold (95% CI 1.4 to 2.9; p < 0.001) increased risk, whereas patients 70 years of age or older had a HR of 0.7 (95% CI 0.4 to 1.3; p = 0.23).

When revision or implant removal for any reason was analysed for the femoral component only, the multivariate analysis indicated that patients less than 50 years of age at primary THA were at a 3.2-fold (95% CI 2.2 to 4.8;
p < 0.001) increased risk. Patients aged 50 to 59 years were at a 2.1-fold (95% CI 1.5 to 2.9; p < 0.001) increased risk, whereas patients 70 years of age or older had a HR of 0.8 (95% CI 0.5 to 1.3; p = 0.4).

The Kaplan-Meier survivorship analysis produced a higher estimate of the cumulative incidence of revision or implant removal for any reason for every age group (Table I). For patients less than 50 years of age at the time of surgery, the Kaplan-Meier estimate was 43% (95% CI 34 to 51), for patients 50 to 59 years of age it was 30% (95% CI 24 to 35), for patients 60 to 69 years of age it was 14% (95% CI 10 to 17) and for patients 70 years of age or older at primary surgery it was 13% (95% CI 2 to 22).

Stratification by gender and age. At 40 years, the cumulative incidence of acetabular and/or the femoral component revision or implant removal for any reason, with death accounted for as the competing risk, was 10% (95% CI 8 to 12) in female patients, and 17% (95% CI 14 to 19) in male patients (Fig. 3). In comparison with women, men were approximately twofold more likely to require revision of either component for any reason (HR = 2.1; 95% CI 1.7 to 2.7; p < 0.001). The cumulative incidence of revision or removal of any component for any reason was higher for all age groups in men than women (Table I). The effect of gender was most notable in younger age groups and young men had by far the highest risk of revision or removal (Table I).

Stratification by diagnosis. At 40 years in this multivariate analysis, a diagnosis of rheumatoid arthritis (when compared with a diagnosis of degenerative joint disease) was protective from revision or removal of either component for any reason (HR 0.43; 95% CI 0.25 to 0.73; p = 0.001). This difference was maintained when looking at the acetabular component in isolation (HR 0.47; 95% CI 0.25 to 0.87; p = 0.02) and the femoral component in isolation (HR 0.38; 95% CI 0.21 to 0.70; p = 0.002). With the competing risk model, developmental dysplasia of the hip (p = 0.56) and post-traumatic arthritis (p = 0.59) did not demonstrate a statistically significant effect on risk of revision for any reason.

### Table I. Comparison of the competing risk and Kaplan-Meier (K-M) methods of calculating cumulative incidence of revision or implant removal for any reason at 30 years

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Competing risk model</th>
<th>Male patients (%) (95% CI)</th>
<th>Female patients (%) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>Overall 13 (12 to 15)</td>
<td>K-M survivorship 28 (23 to 33)</td>
<td>Male patients 17 (14 to 19)</td>
</tr>
<tr>
<td></td>
<td>&lt; 50 35 (28 to 42)</td>
<td>Competing risk model 42 (34 to 51)</td>
<td>Female patients 44 (31 to 54)</td>
</tr>
<tr>
<td>50 to 59</td>
<td>20 (16 to 24)</td>
<td>50 (43 to 56)</td>
<td>10 (8 to 12)</td>
</tr>
<tr>
<td>60 to 69</td>
<td>9 (7 to 11)</td>
<td>14 (10 to 17)</td>
<td>14 (9 to 18)</td>
</tr>
<tr>
<td>≥ 70</td>
<td>5 (4 to 7)</td>
<td>13 (2 to 22)</td>
<td>13 (6 to 20)</td>
</tr>
</tbody>
</table>
| CI, confidence interval

![Graph showing the cumulative incidence of revision for any reason at 30 years stratified based upon age at index arthroplasty.](image-url)
WHAT IS THE LIFETIME RISK OF REVISION FOR PATIENTS UNDERGOING TOTAL HIP ARTHROPLASTY?

Revision for aseptic loosening, instability and infection. With death accounted for as a competing risk, the cumulative incidence of revision for aseptic loosening of either component at 40 years was 7.8% (95% CI 0.6 to 9). When stratified by age, the cumulative incidence of revision was 22% (95% CI 3.1 to 28.1) for patients < 50 years, 14% for patients 50 to 59 years (95% CI 1.6 to 17), 4.8% for patients 60 to 69 years (95% CI 3.3 to 6.3), and 1.8% (95% CI 0.6 to 3.1) for patients 70 years of age or greater. With death accounted for as a competing risk, the cumulative incidence of revision for loosening at 40 years was 1% (95% CI 0.22 to 1.45). With death accounted for as a competing risk, the cumulative incidence of revision for infection at 40 years was 0.86% (95% CI 0.21 to 1.26).

Discussion

THA ideally provides a durable treatment for the lifetime of a patient. However, there is a paucity of studies with large case numbers and very long-term follow-up approaching the life expectancy of most patients. Often patients wish to know the likelihood requiring revision during their lifetime. Unfortunately, the current literature does not allow for an accurate answer to this question. As such, we conducted a competing risk analysis for implant survival with death as a competing risk, in what we believe to be the largest study of patients undergoing Charnley low friction THAs with the longest follow-up. Based upon the competing risk model, patients undergoing Charnley THA have a lifetime cumulative risk of revision or implant removal for any reason of 13.5%. Recently, a study with similar follow-up by Callaghan et al7 found a Kaplan-Meier survivorship of 78% (95% CI 70 to 86) at a minimum of 35 years of follow-up in 314 hips.7 Lampropoulou-Adamidou et al3 found Kaplan-Meier survivorship of 68% (95% CI 61 to 76) at 25 years in young patients with a Charnley THA. Other publications at shorter follow-up intervals have found similar results, but were not analysed using a competing risk model.5-12 As shown by our study, the Kaplan-Meier survivorship analysis estimates the cumulative incidence of revision for any reason to be 15% higher, or nearly twofold. The greatest discrepancies between the competing risk model and the Kaplan-Meier models were seen in patients who have a higher annual mortality rate.

This study provides an answer to the question: “What is the chance my hip will need to be revised during my lifetime?” for patients, stratified by age, gender and diagnosis, at least for Charnley THAs. As a rule of thumb, patients less than 50 years of age at index arthroplasty have a one in three chance of requiring a revision during their lifetime, patients between 50 to 59 years of age have a one in five chance of requiring a revision during their lifetime, patients between 60 to 69 years of age have a one in ten chance of requiring a revision during their lifetime, and patients 70 years of age or older have a one in 20 chance of requiring a revision during their lifetime. This is in part likely due to the increased polyethylene wear and the effects of prolonged mechanical stress on implant and cement interfaces in younger more active patients.22 The polyethylene acetabular components used in this series were conventional polyethylene that were sterilised by gamma irradiation in air.8,23

Age and gender had strong effects on the risk of revision. Previous studies have also shown male gender to have an influence on implant survival rates.21,24,25 With this analysis, we are able to show that overall, men have a twofold increased risk of revision during their lifetime compared with women. The interaction between age and gender is important, with the greatest difference in implant survivorship between gender in younger patients. In patients less than 50 years of age, there is nearly a 20% difference in the cumulative risk of revision for any reason between men and women. This difference decreases to 12% in patients between 50 and 59 years of age and then disappears for patients 60 years of age or older. As such, male gender is a
disproportionally greater risk factor for patients who are less than 60 years of age.

There are limitations to the current study. First, the study cohort does not include a control group. At the time of implantation, the low friction arthroplasty was the standard of care and other therapeutic options/prostheses were hardly available. Our intention was not to compare the Charnley prosthesis with other THAs. Second, developments in implant design and fixation methods have largely resulted in the demise of cemented arthroplasty in the United States. However, the results of the present study can serve as a benchmark in assessing the survivorship of newer implants and designs, although this will of course mandate similar long-term follow-up investigations of the newer implant designs.

In conclusion, the Charnley cemented THA provided excellent long-term results at 40 years. Male gender and younger age increase the risk of revision. Our data show a twofold increase in the incidence of revision for men during their lifetime. In addition, we have developed rules of thumb for the risk of revision during a patient’s lifetime, based upon age at index arthroplasty: one in three for patients < 50 years, one in five for patients 50 to 59 years, one in ten for patients 60 to 69 years, and one in 20 for patients ≥ 70 years of age. Our results and analysis provide a benchmark for comparison by the subsequent changes in design of THAs.

Take home message:
Almost all patients in this series were followed until death or revision; this allowed development of ‘rules of thumb’ for lifetime likelihood of revision or implant removal for Charnley THA: one in three for patients < 50 years, one in five for patients 50 to 59 years, one in ten for patients 60 to 69 years, and one in 20 for patients ≥ 70 years.

Author contributions:
M. P. Abdel: Hypothesis generation, Data analysis, Manuscript preparation and editing.
R. von Roth: Data analysis and manuscript preparation.
W. S. Harmsen: Data analysis, Statistical analysis.
D. J. Berry: Hypothesis generation, Data analysis, Manuscript preparation.

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References