HIP

Influence of patient activity on femoral osteolysis at five and ten years following hybrid total hip replacement

A. Lübbeke, G. Garavaglia, C. Barea, R. Stern, R. Peter, P. Hoffmeyer

From Geneva University Hospitals, Geneva, Switzerland

We conducted a longitudinal study including patients with the same type of primary hybrid total hip replacement and evaluated patient activity and femoral osteolysis at either five or ten years post-operatively. Activity was measured using the University of California, Los Angeles scale. The primary outcome was the radiological assessment of femoral osteolysis. Secondary outcomes were revision of the femoral component for aseptic loosening and the patients’ quality of life. Of 503 hip replacements in 433 patients with a mean age of 67.7 years (30 to 91), 241 (48%) were seen at five and 262 (52%) at ten years post-operatively. Osteolytic lesions were identified in nine of 166 total hip replacements (5.4%) in patients with low activity, 21 of 279 (7.5%) with moderate activity, and 14 of 58 (24.1%) patients with high activity. The risk of osteolysis increased with participation in a greater number of sporting activities. In multivariate logistic regression adjusting for age, gender, body mass index and the inclination angle of the acetabular component, the adjusted odds ratio for osteolysis comparing high vs moderate activity was 3.6 (95% confidence interval 1.6 to 8.3). Stratification for the cementing technique revealed that lower quality cementing increased the effect of high activity on osteolysis. Revision for aseptic loosening was most frequent with high activity. Patients with the highest activity had the best outcome and highest satisfaction.

In conclusion, of patients engaged in high activity, 24% had developed femoral osteolysis five to ten years post-operatively.

The wish to return to recreational or sporting activity is occasionally expressed by patients undergoing total hip replacement (THR), particularly among younger patients and the more athletic older patients. In two recent studies the proportion of patients who reported performing recreational or athletic activity following THR was found to be 61% and 83% at one to two years after surgery, respectively. In another report 52% of patients indicated that they participated in at least one sporting activity at five years post-operatively. In these reports the mean age of the study populations at the time of activity assessment was greater than 65 years.

Patient activity is thought to be one of the most important patient-related factors influencing survival of the implant. While there is much debate about the amount and type of activity that orthopaedic surgeons can safely recommend to their patients, there is little in the literature that specifically quantifies the influence of recreational and sporting activity on implant survival. In the past, authors have often used variables such as age, gender, Charnley disability grades or function scores as surrogate measures of activity. While the level of activity is difficult to measure because it varies, a validated physical activity assessment score has been developed which is considered an appropriate measure of activity in THR patients.

The primary objective of this study was to evaluate the influence of the level of the activity pursued by a patient upon femoral osteolysis five to ten years after THR. The secondary objectives were to assess the incidence of revision attributable to the level of activity and rates of polyethylene wear, patient satisfaction, residual pain and functional outcomes.

Patients and Methods

Since March 1996 all patients undergoing THR under our care are routinely enrolled into a prospective database and followed longitudinally. For this study we included all primary THR patients with a hybrid prosthesis, comprising an uncemented acetabular component and a cemented femoral component with a
28 mm diameter alumina ceramic modular head articulating with a polyethylene insert. The project was approved by our Ethics Committee. Patients who underwent THR as a result of trauma or metastatic disease were excluded. Since assessment of activity at follow-up was only performed routinely after April 2006, we included a cohort of patients operated on between 1996 and 1998 who had undergone their ten-year review, and a cohort of patients operated on between 2001 and 2003 who had attended their five-year review.22

All patients received a cemented Müller straight stem (Zimmer, Winterthur, Switzerland). This was manufactured in cobalt-chromium alloy with a satin surface finish and implanted with gentamicin-loaded cement employing a third generation technique with pulsed lavage and an intramedullary plug. Femoral components were inserted with a press-fit technique in which the femur was broached to the largest possible size and a component of the same size as the largest accepted broach was inserted into the cement-filled cavity, thus obtaining additional cement pressurisation. The acetabular component used was the Morscher press-fit implant (Zimmer). This was an uncedmented, non-modular, porous-coated component with a standard ultra-high molecular weight polyethylene (UHMWPE) insert. The acetabular components were sterilised by gamma irradiation in an inert atmosphere.

The level of activity was measured retrospectively at follow-up using the University of California, Los Angeles (UCLA) activity scale,23 which has ten points:

1) wholly inactive, dependent on others; 2) mostly inactive, restricted to minimal activities of daily living; 3) sometimes participate in mild activity such as walking, limited housework or shopping; 4) regularly participate in mild activities; 5) sometimes participate in moderate activity such as swimming and unlimited housework or shopping; 6) regularly participate in moderate activities; 7) regularly participate in active events such as bicycling; 8) regularly participate in very active events such as bowling or golf; 9) sometimes participate in impact sport such as jogging, tennis, skiing, heavy labour; 10) regularly participate in impact sport.

The scale is reliable and valid19,20,23 and is considered an appropriate measure of activity in THR patients.20 In addition, we questioned the patients more precisely on their participation in recreational and/or sporting activities. We considered activities such as exercise walking, gardening, social dancing and yoga as recreational pastimes. In contrast more intense activities such as swimming, cycling, gymnastics, tennis, golf, skiing, hiking and mountain climbing were considered as sports.

The main outcome of interest was the incidence of focal or linear osteolysis around the femoral component. Secondary outcomes were the amount of linear UHMWPE wear and the incidence of revision for aseptic loosening, whether of either or both components, five to ten years after the primary replacement, as well as the disease-specific quality of life and patient satisfaction evaluated with the Harris hip score (HHS),24 the Merle d’Aubigné and Postel score,25 and a visual analogue scale (VAS) to evaluate satisfaction (0, lowest satisfaction; 10, highest satisfaction).

In the estimation of the association between the level of activity and the outcomes of interest, the following potential confounders were assessed: (a) body mass index (BMI) evaluated as a continuous and categorical variable applying the categories of normal weight, overweight, and obese according to the definitions of the World Health Organisation.26 The BMI values for each patient were the mean of the pre-operative and follow-up BMIs; (b) age at operation; (c) gender; (d) Charnley disability grade; (e) American Society of Anesthesiologists27 (ASA) grade; (f) diagnosis of osteoarthritis; (g) acetabular inclination angle; (h) cementing quality;28 and (i) femoral cortical index.29

Information about pre-operative status and surgical intervention, including implant- and technique-related details, was routinely documented by the surgeon on specifically designed data collection forms. Pre-operative and immediate post-operative radiographs were systematically collected. Information about comorbidities was routinely retrieved from the anaesthetic record and the discharge summary. The treatment of any major complication or revision procedure performed at our hospital or reported at follow-up was included in the database. As part of our routine protocol at five and ten years post-operatively, all patients were contacted for clinical and radiological assessment. They also indicated their activity on the UCLA scale and the types of recreational and sports activities performed on a regular basis. They also rated their satisfaction with their THR.

Radiological analysis. Standardised anteroposterior (AP) pelvic and lateral radiographs of the replaced hip from the immediate post-operative period were compared with radiographs obtained at five or ten years post-operatively. They were examined by an experienced orthopaedic surgeon (GG) who was blinded to the patients’ level of activity. Evaluation was performed on digitised radiographs, and quantitative measurements were performed using specific templates and DICOMMeasure software (ViewTec, Maison-Alfort, France). The radiographs were calibrated using the known diameter of the femoral head.

Femoral osteolysis was defined as an area of endosteal, intracortical or cancellous bone loss that was scalloped or had the appearance of bone destruction rather than osteopenia.30,31 We recorded the presence of focal osteolysis or radiolucent lines greater than 1 mm in width at the bone-cement interface, noting their dimension and location according to the zones of Gruen, McNeice and Amstutz.32 However, radiolucent lines of ≤ 2 mm in the proximal 1 cm of Gruen zones 1 and 7 on the AP view, and 8 and 14 on the lateral view, were considered to be normal.30,31 The grading of the quality of cementing post-operatively was performed using the criteria described by Barrack et al.28 The cortical index was measured according to Gruen.29 Linear polyethylene wear was measured using a computer-assisted
semi-automated dual-circle technique based on vector analysis as described by Martell and Berdia.\textsuperscript{33} Inter- and intra-observer repeatability of this method have been assessed and described previously.\textsuperscript{34} The inclination of the acetabular component was determined on AP radiographs by measuring the angle formed by the intersection of the line joining the inferior aspect of the teardrops and the line joining the highest and the lowest points of the ellipse projected on the radiographs, as described by Sutherland et al.\textsuperscript{35} It was evaluated as a dichotomised variable (≤45° vs >45°).

**Statistical analysis.** The patients’ activity was evaluated in the ten categories of the UCLA scale, and in three categories defined as follows: low, UCLA 1 to 4; moderate, UCLA 5 to 7; and high, UCLA 8 to 10. The distribution of demographic and radiological related covariates was compared among these three levels of activity. We reported relative risks (RR) and 95% confidence intervals (CIs) for categorical variables, and we used univariate linear regression for continuous variables (dependent variables in the model) to estimate trends within the three levels of activity.

In order to assess the crude association between activity and risk of osteolysis we first calculated risk estimates according to the ten and the three activity categories. Then we performed univariate logistic regression analysis to obtain unadjusted odds ratios (OR). For the evaluation according to the three categories, the moderate activity group (UCLA 5 to 7) was chosen as the reference group. In order to assess the modification of effects and confounding we used stratification. Since the association between activity and osteolysis did not differ among the patients seen at five or ten years, they were analysed together. In order to adjust for the effect of activity on osteolysis for confounding variables we used multivariable logistic regression modelling. Activity was introduced as a continuous variable (for the ten categories) (model 1) and as a categorical variable with three categories (model 2).

The relationship between level of activity and revision was assessed using Pearson’s chi-squared linear-by-linear association. For the other secondary outcomes (all continuous variables) linear trends within the three levels of activity were estimated with use of univariate linear regression analysis. Statistical significance was set at a p-value < 0.05.

**Results**

Of 941 patients with 1048 THRs operated upon in the study period, 433 patients with 503 THRs had complete clinical and radiological information and were included in the final analysis. The details of patients operated upon during the inclusion period are shown in Figure 1. The mean age of those included in the study at the time of operation was 67.7 years (30 to 91); 292 (58%) were in women; their mean pre-operative BMI was 26.9 kg/m\(^2\) (17.7 to 41.5); 425 hips (84%) were in patients with an ASA grade of 1 or 2, and their Charnley disability grades were grade A in 195 hips (39%), grade B in 206 hips (41%) and grade C in 102 hips (20%).

Of the 503 THRs included, 241 hips (48%) operated upon between January 2001 and May 2003 were evaluated at five years post-operatively, and 262 hips (52%) operated upon between March 1996 and December 1998 at ten years post-operatively. The mean follow-up time was 94.5 months (50 to 146). According to their level of activity, 166 THRs (33%) were in patients who reported a low level of activity, 279 (55%) in patients with a moderate activity level, and 58 (12%) in patients with a high activity level. In comparison with the low and moderate activity groups, patients reporting high activity levels were younger, predominantly male, had lower mean BMI and ASA scores and higher mean Charnley disability grades (Table I).

---

**Fig. 1**

Flowchart of patients undergoing total hip replacement (THR).
Overall, five to ten years after operation, 258 THRs (51%) were implanted in patients (at a mean age of 75.5 years (36 to 99) at follow-up) who reported at least one recreational activity or sports activity. Of those, a total of 162 (32%) were in patients who reported a recreational activity only, and 96 (19%) in those who participated in one or more sports activities, mostly cycling, swimming, attending a gym and less often skiing, mountain hiking or golf.

**Primary outcome.** Focal or linear osteolytic lesions were found around 44 femoral components (8.7%) in 41 patients. The occurrence of femoral osteolysis according to all ten UCLA grades is presented in Figure 2. On nine occasions (9/166; 5.4%) the osteolysis had developed in patients with low activity, 21 (21/279; 7.5%) in patients with moderate activity, and 14 (14/58; 24.1%) had developed in patients with high activity. Compared with the moderate activity group used as the reference category, high activity was associated with a more than three times higher risk for developing femoral osteolysis (unadjusted OR 3.9, 95% CI 1.9 to 8.3). Stratification according to other possible risk factors for osteolysis such as cementing quality, gender, and follow-up time revealed the

| Table 1. Distribution of baseline characteristics in the patients in the University of California, Los Angeles (UCLA) low, moderate and high categories at 5- to 10-year follow-up |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| **Low activity (UCLA 1 to 4)   (n = 166 THRs*)** | **Moderate activity (UCLA 5 to 7) (n = 279 THRs)** | **High activity (UCLA 8 to 10) (n = 58 THRs)** | **High vs low/moderate RR (95% CI) p-value for linear trend** |
| Women (%)| 113 (68.1) | 166 (59.5) | 13 (22.4) | Reference |
| Men (%)| 53 (31.9) | 113 (40.5) | 45 (776) | 2.1 (1.7 to 2.5)† |
| Age at operation, mean (SD)| 72.1 (9.8) | 66.7 (8.7) | 59.7 (10.5) | < 0.001† |
| UCLA score, mean (SD)| 3.2 (1.0) | 5.8 (0.7) | 8.7 (0.7) | - |
| Weight, mean (SD)| 74.4 (14.7) | 73.9 (13.9) | 75.6 (12.8) | 0.825† |
| BMI§, mean (SD)| 27.5 (4.6) | 26.9 (4.1) | 25.6 (3.5) | 0.004‡ |
| Normal weight (%)| 51 (30.7) | 104 (37.3) | 26 (44.8) | 1.1 (0.8 to 1.5)† |
| Overweight (%)| 69 (41.6) | 112 (40.1) | 24 (41.4) | Reference |
| Obese (%)| 46 (27.7) | 63 (22.6) | 8 (13.8) | 0.7 (0.4 to 1.2)† |
| ASA¶ score (%)| 125 (75.3) | 242 (86.7) | 58 (100.0) | Reference |
| Diagnosis (%)| 34 (20.5) | 49 (17.6) | 10 (17.2) | 0.9 (0.5 to 1.7)† |
| Charnley disability grade (%)| A 132 (79.5) | 230 (82.4) | 48 (82.8) | Reference |
| B 34 (20.5) | 49 (17.6) | 10 (17.2) | 0.9 (0.7 to 1.3)† |
| C 58 (35.0) | 38 (13.8) | 6 (10.3) | 0.5 (0.2 to 1.0)† |
| Other hip operated (%)| 118 (71.1) | 205 (73.5) | 42 (72.4) | Reference |
| Yes 48 (28.9) | 74 (26.5) | 16 (27.6) | 1.0 (0.6 to 1.6)† |
| Cementing quality (Barrack27)(%)| A 131 (78.9) | 236 (84.6) | 45 (776) | Reference |
| B 28 (16.9) | 30 (10.8) | 10 (17.2) | 1.3 (0.7 to 2.5)† |
| Missing 7 (4.2) | 13 (4.7) | 3 (5.2) | - |
| Cortical index, mean (SD)| 46.1 (6.5) | 46.7 (6.5) | 48.0 (6.3) | 0.069‡ |
| Acetabular component inclination angle (%)| | | | |
| ≤ 45°| 141 (84.9) | 230 (82.4) | 50 (86.2) | Reference |
| > 45°| 25 (15.1) | 49 (17.6) | 8 (13.8) | 0.8 (0.4 to 1.6)† |

* THRs, total hip replacements
† for categorical variables relative risks (RR) are presented comparing high vs low and moderate activity taken together; CI, confidence intervals
‡ for continuous variables p-values obtained with use of univariate linear regression (activity in three levels as independent variable) are presented
§ BMI, body mass index
¶ ASA, American Society of Anesthesiologists
highest risk of osteolysis, at 50%, among patients with both reduced cementing quality (Barrack grade B) and high activity levels (Fig. 3). Furthermore, the probability of developing osteolytic lesions while maintaining a high activity level (UCLA 8 to 10) was only slightly greater among men (Fig. 4). The association between activity and osteolysis was not notably influenced by follow-up time (Fig. 5). The adjusted OR for the association between activity (high vs moderate) and osteolysis after adjustment for age, gender, BMI and inclination angle of the acetabular component was 3.6 (95% CI 1.6 to 8.3). In addition, evaluating the UCLA scale as a continuous variable we found a significant increase with increasing activity level (Table II).

Regarding the number of different sports or recreational activities performed and the occurrence of femoral osteolysis, there was a significant linear association with an OR of 1.6 (95% CI 1.2 to 2.1) per unit increase in the number of activities (Fig. 6).

**Secondary outcomes.** Of the 44 THRs with femoral osteolytic lesions, four (0.8%) in three men and one woman with a mean age of 55 years (31 to 68) were revised for aseptic loosening of the femoral component at a mean of 74.8 months (57 to 119) after the primary THR. Two patients (2 of 58, 3.4%) belonged to the high activity group and two (2 of 279, 0.7%) to the moderate activity group. No patient was revised in the low activity group. The risk of revision for aseptic loosening increased significantly with increasing level of activity (univariate linear regression, \( p = 0.023 \)). The mean annual linear UHMWPE wear was 0.11 mm (SD 0.06) in THRs of patients with low activity, 0.12 mm (SD 0.07) in those with moderate activity, and 0.13 mm (SD 0.08) in THRs of patients with high activity (univariate linear regression, \( p = 0.174 \)). The mean HHS and the Merle d’Aubigné scores\(^{25}\) as well as patient satisfaction increased significantly with increasing level of activity. This was the case for the pre-operative and follow-up evaluations (Table III). Patients in the highest activity group...
were the most satisfied, had the best functional outcome, and the least amount of pain.

**Discussion**

At five to ten years following primary THR we found substantially more osteolytic lesions around a cemented femoral component in patients with high activity levels. One in four patients participating in a high activity sport developed osteolysis. Furthermore, the rate of revision for aseptic loosening was also highest in this group.

With respect to the UCLA activity scale, more than half (55.5%) of the patients reported a moderate activity level, 33% low activity, and 11.5% a high activity level five to ten years after primary THR. Upon more specific questioning of the type of activity, we found that 51% of patients at a mean age of 75 years participated in sports or recreational activity. Taking into account the older age at the time of assessment in our study, this proportion of active persons seems to be comparable with the existing literature.

To the best of our knowledge no study has quantified the risk of osteolysis around cemented femoral components and implant failure according to different activity levels with use of the UCLA scale. However, it has been reported that younger age, male gender and Charnley A classification are associated with reduced survival of the prosthesis. This has been interpreted to mean that these variables are surrogate measures for activity. Studies attempting to quantify the influence of activity on implant survival using a specific measure of activity are rare. Kilgus et al compared the revision rate for aseptic loosening ten years after cemented THR among patients with high and low activities. Patients were classified as high activity when they regularly performed sports or heavy labour. The authors reported a revision rate of 28% in the high activity group compared with 6% in the low activity group. After adjusting for pre-operative diagnosis, the risk remained more than twice as high. Their study was conducted 20 years ago. While our revision rate was substantially lower (3.4% in high activity and 0.4% in low activity), the magnitude of the relative effect is comparable.

Another more recent cohort study specifically investigated the influence of skiing on implant survival. With respect to the femoral side the authors did not find a higher rate of aseptic loosening or femoral osteolysis at five and ten years post-operatively.

In addition to higher activity levels, the quality of cementing is another important risk factor for femoral osteolysis. We found that the risk of osteolysis was 50% among high activity patients in the presence of suboptimal cementing (Barrack grade B), compared with 20% among those with good cementing.

Polyethylene wear and the resulting UHMWPE particles are considered to be an important cause of osteolysis and aseptic loosening. However, wear is not present in all cases with osteolysis indicating a multifactorial origin. Other causes have been proposed, specifically related to

**Table II. Effect of University of California, Los Angeles (UCLA) activity (continuous variable and in three categories) on femoral osteolysis adjusted for relevant patient-related factors using multivariate logistic regression models**

<table>
<thead>
<tr>
<th>Model 1*</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity (UCLA) continuous</strong></td>
<td><strong>Activity continuous OR (95% CI)</strong></td>
</tr>
<tr>
<td>Activity continuous</td>
<td>1.28 (1.06 to 1.56)</td>
</tr>
<tr>
<td>Activity in 3 categories</td>
<td></td>
</tr>
<tr>
<td>UCLA 1 to 4</td>
<td>1.0 (Reference)</td>
</tr>
<tr>
<td>UCLA 5 to 7</td>
<td>3.59 (1.56 to 8.27)</td>
</tr>
<tr>
<td>UCLA 8 to 10</td>
<td>1.04 (0.52 to 2.08)</td>
</tr>
<tr>
<td>BMI † (continuous)</td>
<td>0.96 (0.89 to 1.04)</td>
</tr>
<tr>
<td>Age (continuous)</td>
<td>0.99 (0.96 to 1.02)</td>
</tr>
<tr>
<td>Sex (female = 1)</td>
<td>0.94 (0.48 to 1.84)</td>
</tr>
<tr>
<td>Acetabular component inclination (&gt; 45° = 1)</td>
<td>1.91 (0.91 to 4.02)</td>
</tr>
</tbody>
</table>

* OR, odds ratio; CI, confidence interval
† BMI, body mass index

![Bar chart showing risk of osteolysis as related to the number of different recreational/sports activities performed (OR, odds ratio; 95% CI, confidence interval).](chart.png)
patient characteristics, genetic factors, mechanisms of cell activation, micromotion, high fluid pressure, endotoxins and sealed interfaces. We found only a small increase in annual mean linear UHMWPE wear with increasing activity at a mean of 94.5 months (50 to 146). However, this may change with a longer follow-up. Similarly, two other studies, one at six years and one at ten years post-operatively, did not find a correlation between linear UHMWPE wear and level of activity. However, Prakash et al using a 22 mm diameter femoral head, reported a substantially higher rate of UHMWPE wear ten years after THR in active patients, and Gschwend et al found a particularly high rate of wear in very active patients at ten years, but not at five years post-operatively.

This study has several strengths. It is a cohort study including patients operated upon with the same implant and technique. Patient activity was assessed using a validated instrument that has recently been compared to others, and considered as the best among available activity scales. Moreover, a large number of potential confounding factors were considered, for which adjustment was made.

There are several limitations to our study. First, only 48% of the THR in patients operated upon during the inclusion period (corresponding to 64% of the THRs in patients who had not died or were lost to follow-up) had both a complete clinical examination including activity assessment and a complete high-quality radiological follow-up evaluation. Secondly, patient activity was assessed at only one point in time (five or ten years post-operatively), and levels of activity can change substantially over time. We approached this limitation by questioning the patients not only about their present level of activity, but also to indicate what corresponded to their most general level of activity over the follow-up period. In case of discrepancy, the most representative level was chosen by the physician. Thirdly, it is known that the UCLA scale does not capture differences in frequency, duration and intensity within a given level of activity. Fourthly, activity levels are self-reported and this may introduce bias as people tend to propose that they are more active than they really are. However, activity assessment using a score or questionnaire is the best available tool at present. Fifthly, wear was assessed on AP radiographs with use of a semi-automated computer-assisted technique based on vector analysis by Martell and Berdia, an appropriate and extensively used method for wear assessment in large cohorts but known to be less precise than radiostereometric analysis. And finally, even though our patients have been followed longitudinally, it is not possible to perform a survival analysis or to calculate incidence rates because the outcome of osteolysis cannot be associated with a specific date of appearance. Radiographs were taken at two points in time, post-operatively and at follow-up, and osteolysis was either present or not at five or ten years.

Our findings were obtained in patients with a specific type of THR comprising a press-fit acetabular component with standard UHMWPE articulating with a 28 mm ceramic head and cemented femoral component with satin-surfaced finish. The magnitude of the effect found in our study may be different with other types of implants.

Overall, 11.5% of the THRs in this cohort were in patients who engaged in high activity five to ten years after primary THR. Of those, 24% had developed osteolytic lesions around the cemented femoral component and 3.4%
had undergone revision for aseptic loosening. While these patients had an excellent clinical outcome and satisfaction, we feel it is important to inform patients participating in high activity about a possible reduction in the survival of their implant, and even more so in the presence of poorer quality cementing.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References