Revision Total Knee Arthroplasty: 1990 Through 2002

A Review of the Finnish Arthroplasty Registry

By Pu-Yi Sheng, MD, Liisa Konttinen, MSc, Matti Lehto, MD, Daisuke Ogino, PhD, Esa Jämsen, Juha Nevalainen, MD, Jorma Pajamäki, MD, Pekka Halonen, MD, and Yrjö T. Konttinen, MD, PhD

Investigation performed at COXA Hospital for Joint Replacement, Tampere; ORTON Orthopaedic Hospital, Invalid Foundation, Helsinki; National Agency for Medicines, Helsinki; and Department of Medicine, Helsinki University Central Hospital, Helsinki, Finland

Background: National and regional arthroplasty registries have been used to study the results of primary total knee arthroplasties. The purpose of this paper was to present the results of revision total knee replacements and describe predictors of survival of those replacements, with repeat revision as the end point.

Methods: The nationwide Finnish Arthroplasty Registry included 2637 revision total knee arthroplasties from 1990 through 2002. Survivorship of the revision total knee arthroplasties was analyzed, with repeat revision as the end point. The survivorship analyses comprised evaluations of the proportional hazards assumption followed by calculations of univariate and multivariate statistics and model diagnostics as appropriate.

Results: The survival rate following the revision total knee arthroplasties was 95% (95% confidence interval, 94% to 96%) at two years (1874 knees), 89% (95% confidence interval, 88% to 90%) at five years (944 knees), and 79% (95% confidence interval, 78% to 81%) at ten years (141 knees). Multivariate regression analysis showed the most significant predictors of prosthetic survival to be the age of the patient and the life in service of the primary total knee replacement (that is, the time between the primary total knee replacement and the revision). Survivorship was also significantly predicted by the year of the first revision total knee arthroplasty and the reason for the revision.

Conclusions: An age greater than seventy years, revision five years or more after the primary arthroplasty, and absence of patellar subluxation are positive indicators of survival of a revision total knee replacement. We believe that normal aging as well as the deconditioning effect of disease (osteoarthritis and rheumatoid arthritis) and its treatment (primary total knee replacement) may lead to a reduced activity level, which, together with a presumed reluctance to operate on elderly patients, protects against repeat revisions.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

Despite improvements in joint replacement surgery, the number of revision total knee replacements continues to increase[1]. This has heightened interest in the factors that affect the outcome of revision total knee arthroplasties. National and regional arthroplasty registries have been used to study the results of primary operations[2,3], but to our knowledge no large-scale reports on the results of revision total knee replacements have been published. The Finnish Orthopaedic Association began to register arthroplasty operations in 1980; at present, the registry is run by the National Agency for Medicines. Registration of joint replacements was initially voluntary, but since 1996 it has been statutory, meaning that institutions and orthopaedic units are obliged to provide the National Agency for Medicines with information on a special form. The arthroplasty registry is linked and matched with other national data registries, which allows detection of death of the patient and repeat revision operations in all Finnish hospital districts. In the present study, data from the Finnish Arthroplasty Registry were used to analyze the results of revision total knee arthroplasties performed from 1990 through 2002 and to attempt to determine which factors affect these results.

The goal of this study was to determine the effect of age at the time of the revision operation, gender, diagnosis (rheumatoid arthritis compared with primary or secondary osteoarthritis), year of the first revision operation, time between the previous operation and the revision, reason for the revision, type of prosthesis (hinged compared with condylar), brand of prosthesis, fixation method (cemented, hybrid, or uncemented), use of bone grafts, presence of primary complications, and type of hospital where the operation was performed (university, central, regional, or other) on the outcome of revision total knee arthroplasty, with repeat revision as the end point.

Materials and Methods

Patients

The database maintained by the Finnish Arthroplasty Registry was used as a source for records. Only records on first total knee revisions were included; repeat revisions were excluded.

The Finnish Arthroplasty Registry contained information on 2845 revision total knee replacements performed from 1990 through 2002. Two hundred and eight of those procedures were repeat revisions, which were excluded from the study. The final number of knees analyzed was thus 2637.

The mean age of the patients at the time of revision was sixty-nine years (range, seventeen to ninety-one years). The most common reasons for revision were loosening of the tibial component, the femoral component, or both components (33%) and patellar complications (32%) (see Appendix).

Statistical Analyses

Data were analyzed with SPSS statistical software (version 12.0.1; SPSS, Chicago, Illinois). The factors included in the statistical analyses are presented in the Appendix. Variable descriptives were checked to find any extreme values or errors in data input. Categorical variables were dummy-coded. For the survival analyses, the original data file from the National Implant Registry was organized so that each row represented one knee. The steps in the analysis included checking the adequacy of the proportional hazards (the probability of an end event) assumption[4] by graphical examination of the partial residuals and, more formally, by testing the significance of time dependency (a trend in the partial residuals with time and significance of the time-dependent covariate [that is, an interaction term between the covariate and time] were taken as evidence against the assumption), testing for significant differences in survival with use of Kaplan-Meier survivorship analysis and log-rank tests, calculating univariate statistics for each variable, entering significant variables into a multivariate Cox model, and using Cox regression model diagnostics in order to determine whether the model adequately described the data. In addition to the analysis of the proportional hazards assumption, as detailed above, model diagnostics included checking for influential observations[5]. In order to detect any exceptionally influential observations or outliers, dfbeta values, which estimate the changes in the regression coefficients on deletion of each observation in turn, were calculated.

The significance level (p value) was set at 0.05 for all statistical testing. However, weakly significant variables ($p < 0.1$) were also included in the multivariate Cox model.

Results are given as the mean and 95% confidence interval if not otherwise indicated. Binomial confidence intervals were calculated for the survival figures with use of Clinstat (Kingston, Ontario, Canada)[4].

Results

Proportional Hazards Assumption

The proportional hazards assumption was met for age group, gender, diagnosis, time-interval between the primary and revision operations, year of first revision, reason for revision, type of implanted prosthesis, brand of prosthesis, use of bone grafts, primary complications, and fixation method. In other words, the hazards (the risks of repeat revision) associated with these variables did not depend on time. The proportional hazards assumption was not met for the type of hospital (university, central, regional, or other); the hazards associated with different types of hospitals varied over time.

Kaplan-Meier Survival Analysis and Log-Rank Tests

The log-rank tests indicated that the diagnosis, type of implanted prosthesis, primary complications, and type of hospital did not affect the survival of the revision total knee replacements. These variables were excluded from the multivariate Cox analysis. Age group, year of first revision operation, time between the primary and the revision operation, reason for revision, brand of prosthesis, fixation method, use of bone grafts, and to a lesser degree gender ($p = 0.07$) were

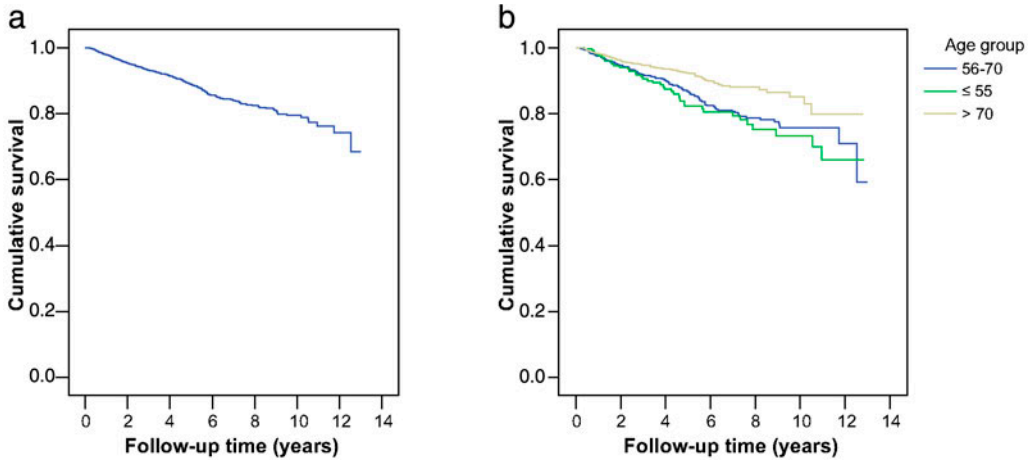

Fig. 1

a: Overall survival of revision prostheses, with repeat revision as the end point. *b:* Survival of revision prostheses in the different age groups. (See text for confidence intervals.)

found to significantly affect the survival of the revision total knee replacements. These variables were included in the multivariate Cox analysis.

Univariate Analyses

Prosthetic survival was estimated with use of the Kaplan-Meier technique, and hazard ratios were estimated with use of univariate Cox analyses (see Appendix). The overall survival of the revision prostheses, with repeat revision as the end point, was 95% (95% confidence interval, 94% to 96%) at two years (1874 knees), 89% (95% confidence interval, 88% to 90%) at five years (944 knees), and 79% (95% confidence interval, 78% to 81%) at ten years (141 knees) (Fig. 1, *a*).

Prosthetic survival at five years, with repeat revision as the end point, was 82% (95% confidence interval, 78% to 87%) for patients younger than fifty-six years of age, 87% (95% confidence interval, 84% to 89%) for those between the ages of fifty-six and seventy years, and 92% (95% confidence interval, 90% to 94%) for those older than the age of seventy years. Prosthetic survival was significantly better for the patients who were older than seventy years than it was for the patients who were younger than seventy years ($p < 0.005$). However, it was not better for the patients between the ages of fifty-six and seventy years than it was for those younger than fifty-six years (Fig. 1, *b*).

Prosthetic survival at five years, with repeat revision as the end point, was 84% (95% confidence interval, 81% to 87%) for men and 90% (95% confidence interval, 88% to 91%) for women ($p = 0.07$). The five-year survival rate was significantly worse ($p < 0.0005$) for patients who had had their first revision operation between 1990 and 1995 (85%; 95% confidence interval, 84% to 87%) than it was for patients who had had their first revision between 1996 and 2002 (92%; 95% confidence interval, 91% to 94%) (Fig. 2). Similarly, the survival rate following the revision arthroplasties performed less than five years after the primary operation (85%; 95% confidence interval, 83% to 87%) was significantly lower ($p < 0.0005$) than the rate following the revisions performed five years or more after the primary operation (92%; 95% confidence interval, 91% to 94%) (Fig. 3).

The survival of revisions done in patients with patellar subluxation was worse ($p < 0.005$) than the overall survival of revisions performed for other reasons (Fig. 4). Pairwise comparisons with use of the log-rank test indicated that the survival of revisions done because of subluxation differed significantly from that of revisions performed because of a fracture of the prosthesis ($p < 0.005$) but did not differ significantly from the survival of revisions due to loosening, malposition, infection, or other patellar complications.

The five-year survival rate, with repeat revision as the end point, was 93% (95% confidence interval, 88% to 95%) for the AGC Dual Articular prosthesis (Biomet, Warsaw, Indiana), 90% (95% confidence interval, 84% to 93%) for the AGC V2 prosthesis (Biomet), 87% (95% confidence interval, 83% to 90%) for the Duracon prosthesis (Stryker Howmedica Osteonics, Allendale, New Jersey), 98% (95% confidence interval, 96% to 99%) for the Duracon Modular prosthesis (Stryker Howmedica Osteonics), 89% (95% confidence interval, 85% to 93%) for the LINK Endo-Modell prosthesis (Waldemar Link, Hamburg, Germany), and 98% (95% confidence interval, 94% to 100%) for the NexGen prosthesis (Zimmer, Warsaw, Indiana). No patient in the registry had had a P.F.C. Sigma prosthesis (DePuy Orthopaedics, Warsaw, Indiana) for five years, but the survival rate of that prosthesis at 4.5 years was 98% (95% confidence interval, 93% to 99%). The NexGen and Duracon Modular pros-

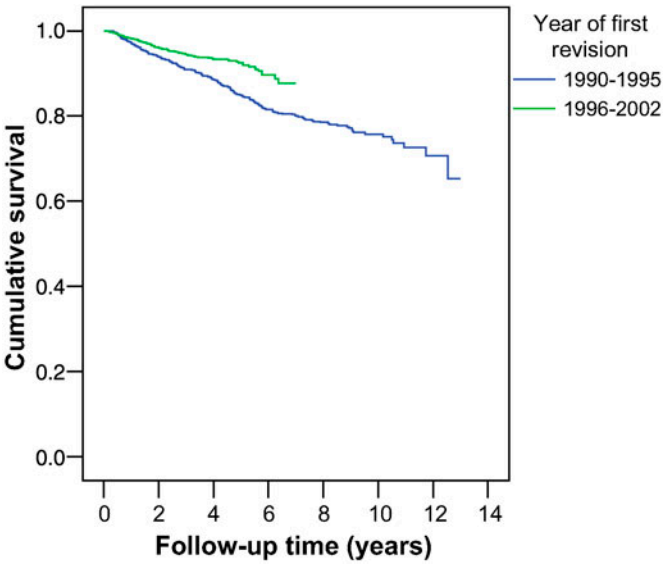

Fig. 2

Survival of revision prostheses according to the year of the first revision, with repeat revision as the end point. (See text for confidence intervals.)

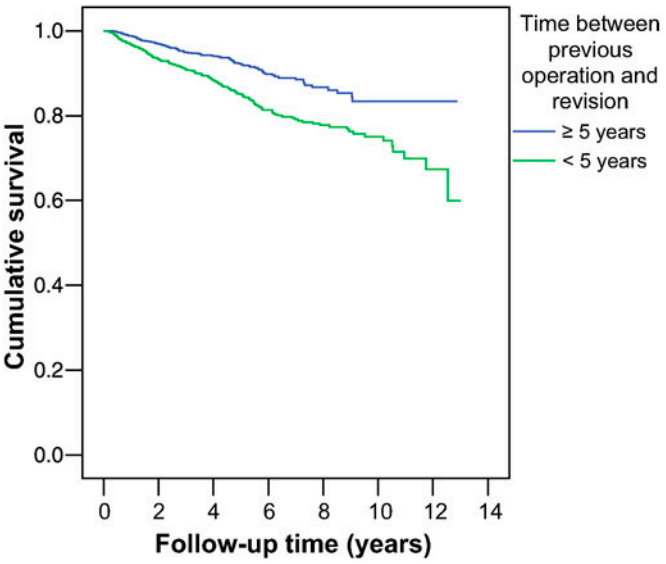

Fig. 3

Survival of revision prostheses according to the time between the previous operation and the revision, with repeat revision as the end point. (See text for confidence intervals.)

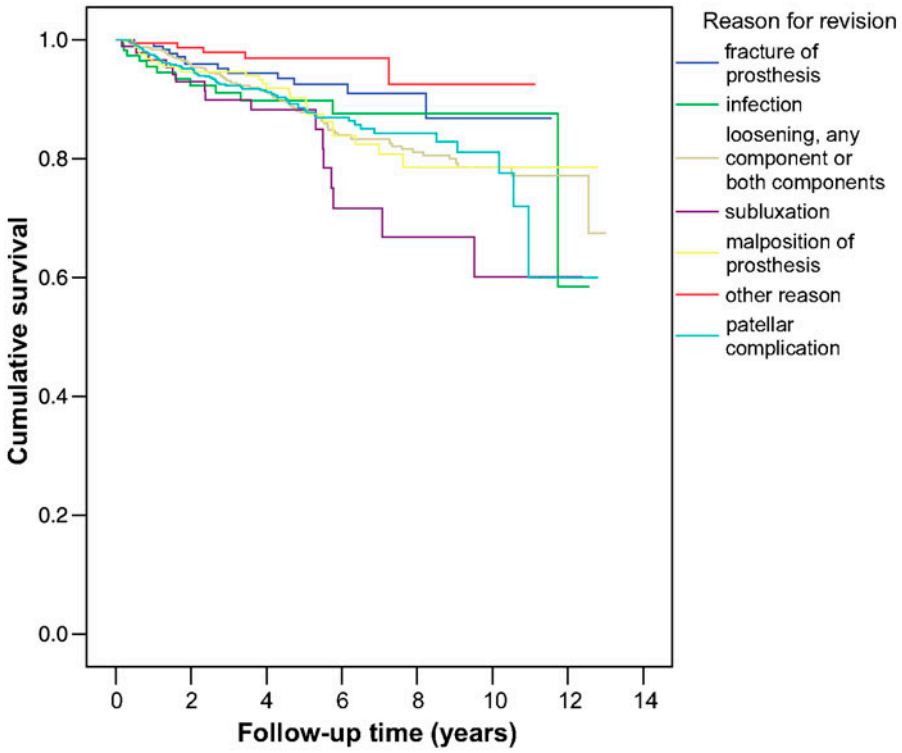

Fig. 4

Survival of revision prostheses according to the reason for revision. The survival following the arthroplasties performed because of patellar subluxation was worse ($p < 0.005$) than the overall survival following the revision arthroplasties performed for other reasons. (See text for confidence intervals.)

theses had better survival rates ($p < 0.05$) than the Duracon implant, which had the shortest time-to-event survival.

Cement fixation ($p < 0.005$) and bone-grafting ($p = 0.05$) improved prosthetic survival, whereas hybrid fixation did not differ significantly from cementless fixation with regard to prosthetic survival (Fig. 5).

The diagnosis, type of prosthesis, primary complications, and type of hospital did not significantly affect the prosthetic survival.

Multivariate Cox Regression Analysis

Significant variables were included in the multivariate Cox analysis. Only age group was significant ($p < 0.005$) in the initial multivariate analysis, which included all of the variables that were found to be significant in the univariate analyses—that is, age group, year of the first revision operation, time between the primary and revision operations, reason for revision, brand of prosthesis, fixation, use of bone grafts, and gender. However, 57% (1514) of the 2637 knees were missing from the analysis, mainly because of missing information regarding the brand of prosthesis and the fixation method. While our statistical software package can include cases with missing values, this was not considered appropriate[6], and a subanalysis was done without those variables (that is, after omission of the brand of prosthesis and fixation method). In this analysis, an age of more than seventy years, having the first operation after 1996, five years or more of service of the primary prosthesis prior to the revision, and absence of patellar subluxation were all found to be significantly associated with improved survival of the revision.

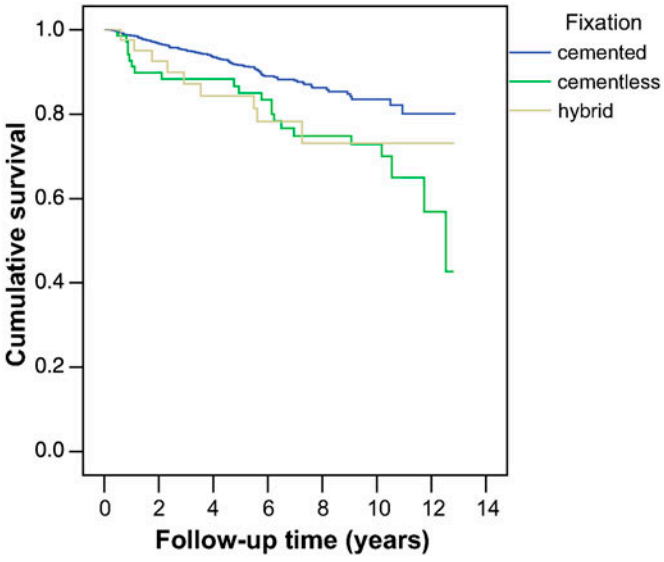

Fig. 5

Survival of revision prostheses according to fixation method. (See text for confidence intervals.)

Model Diagnostics

We found no extreme values or outlier observations that would have dominated the model individually and resulted in a misrepresentative model.

Discussion

One of the assumptions in the Cox regression analysis is that the observations are independent of each other. In reality, the two knees of one patient are not independent of each other, and this must be considered when both knees are operated on. It has, however, been reported that the effect of not accounting for bilateral prostheses is minute, and that the risk of revision of knee prostheses can be analyzed without consideration of the dependency[3]. In the present study, a relatively small proportion (11.3%, 297) of the 2637 knees were in a patient with a bilateral revision, and the survival analyses were carried out without taking bilaterality into account. A subanalysis indicated that bilateral knee revision was associated with better survival than was unilateral knee revision. This finding is in accordance with the finding of better survival of bilateral primary total knee replacements compared with unilateral primary total knee replacements[2].

Age group was a significant predictor of prosthetic survival, with an age of greater than seventy years being associated with better survival ($p < 0.005$). The quality of bone declines with age as a result of senile osteoporosis. However, the reduced physical activity of elderly people diminishes cyclic loading and micromotion. A reduced activity level and low body weight may explain why a long interval between the primary and revision operations predicts a long survival of the revision replacement, but this cannot be proven because physical activity and weight are not recorded in the Finnish Arthroplasty Registry. To some extent, the effect of the patient's age may reflect surgeons' reluctance to perform repeat revisions in elderly and frail patients. Age in itself cannot be considered as a contraindication for revision knee arthroplasty. On the contrary, it seems that revision knee prostheses can be expected to have a long service life in elderly patients.

The outcomes of primary arthroplasties have been relatively good in patients with rheumatoid arthritis[2], although this disease is characterized by destruction of cartilage and bone, ligamentous laxity, and juxta-articular and generalized osteoporosis. The differences in prosthetic survival between knees with a diagnosis of osteoarthritis and those with rheumatoid arthritis, and between men and women, were significant in the study of primary knee replacements ($p < 0.001$ and <0.0001, respectively)[2]. This was not the case in our study of revision knee replacements. This difference may be due to the fact that patients who had already been treated with primary knee arthroplasty had adapted to a reduced activity level so that any pre-existing differences were diminished.

The type of hospital where the patient had undergone the revision arthroplasty (that is, at a university, central, regional, or other type of hospital) was not a significant predictor of prosthetic survival in our analyses. However, it should be noted that, during the follow-up period, specialization in the different fields of orthopaedics very often had not yet developed, even in large units, in Finland[7]. Therefore, some orthopaedic surgeons performed only a few arthroplasties in a year. On the other hand, large hospitals that had achieved a good reputation in a certain field may have attracted more patients with more difficult cases, and this may have worsened the results in those hospitals. Concurrently, the high number of revision operations needed and the long waiting times sometimes led to a revision being performed only when it could no longer be avoided[7]. This may have improved the prosthetic survival figures for individual units. However, the registry provides the nationwide mean for the outcome of revision total knee arthroplasty in Finland, which can be considered to be one of its major advantages.

Patellar subluxation seems to adversely affect the outcome of revision knee replacement, indicating that surgeon-related factors are in part responsible for the failure of some of these procedures. This finding is consistent with those of our previous studies, which demonstrated an excellent or good result in 82% (fifty-eight) of seventy-one patients, a high (94%) eight-year survival rate combined with a low (8.5%) complication rate (six of seventy-one), and very few and asymptomatic radiolucent lines around Total Condylar III revision total knee prostheses (Johnson and Johnson, Braintree, Massachusetts) when these operations were performed by a few experienced revision surgeons[8,9]. Furthermore, only 5% (115) of the 2443 revisions in the present study for which the reason for revision was known resulted from infection. This might to some extent represent underreporting, but that seems unlikely considering the wide coverage of the registry, which was estimated to be 90% to 95% even in the early 1990s, when registration was still voluntary[10].

To improve feedback and quality control, the Finnish Arthroplasty Registry is being further developed so that it will, perhaps in the near future, be possible for individual surgeons to confidentially check online their personal performance in relation to the nationwide norm. The surgeon is responsible for the selection of the brand of prosthesis, the fixation method, and the use of bone grafts, which may affect the survival of revision total knee replacements. Many different brands have been used in Finland, and only the most commonly implanted ones were included in our analyses. Many of the new brands had been used in very small numbers of knees, so more observations are needed before reliable survivorship analyses of those brands in a clinical setting can be performed.

Rand et al. found that primary total knee arthroplasty can be expected to have the most durable results in women who are more than seventy years of age, have inflammatory arthritis, and are treated with certain types of prostheses[2]. They also reported that the cruciate-retaining design was better than the cruciate-sacrificing design in primary total knee arthroplasty. Detailed information about the status of the cruciate ligament was not available in the Finnish Arthroplasty Registry. On the basis of the results of the present study, it can be concluded that revision total knee arthroplasty can be expected to have the most durable results in patients who are

older than seventy years of age and in whom the primary implant had been in service for a long period of time. Absence of patellar subluxation is also a positive indicator.

Gender and diagnosis did not predict the survival of the revised total knee replacements, perhaps because the patients had adapted to a reduced activity level after the primary total knee arthroplasty. Recent advances in implant materials, designs, and operative and fixation techniques presumably have improved implant survival. Indeed, the results of revision total knee surgery in Finland have improved since the early 1990s.

Appendix

eA Tables showing demographic data, factors included in the analyses, and the estimated hazard ratios for the factors are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

Pu-Yi Sheng, MD
Department of Orthopaedics, the First Affiliated Hospital, Sun Yat-sen University, 510080 Guangzhou, People's Republic of China

Liisa Konttinen, MSc
Daisuke Ogino, PhD
ORTON Orthopaedic Hospital, Invalid Foundation, Tenholantie 10, Helsinki FIN-00280, Finland

Matti Lehto, MD
Esa Jämsen
Jorma Pajamäki, MD
Pekka Halonen, MD
COXA Hospital for Joint Replacement, Biokatu 6 b, P.O. Box 652, 33101 Tampere, Finland

Juha Nevalainen, MD
National Agency for Medicines, Finnish Arthroplasty Registry, Mannerheimintie 1036, P.O. Box 55, 00301, Helsinki, Finland

Yrjö T. Konttinen, MD, PhD
Department of Medicine/Invärtes Medicin, Biomedicum Helsinki, P.O. Box 700 (Haartmaninkatu 8), 00029 HUS, Finland. E-mail address: yrjo.konttinen@helsinki.fi

In support of their research for or preparation of this manuscript, one or more of the authors received the Academy of Finland Center of Excellence Grant. None of the authors received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

doi:10.2106/JBJS.E.00737

References

1. Nevalainen J, Keinonen A, Mäkelä A, Pentti A. The 2002-2003 implant yearbook on orthopaedic endoprostheses: Finnish Arthroplasty Register. Helsinki, Finland: National Agency for Medicines; 2003. www.nam.fi/uploads/julkaisut/Orthopaedic_Endoprostheses_2003_v.pdf

2. Rand JA, Trousdale RT, Ilstrup DM, Harmsen WS. Factors affecting the durability of primary total knee prostheses. J Bone Joint Surg Am. 2003;85:259-65.

3. Robertsson O, Ranstam J. No bias of ignored bilaterality when analysing the revision risk of knee prostheses: analysis of a population based sample of 44,590 patients with 55,298 knee prostheses from the national Swedish Knee Arthroplasty Register. BMC Musculoskelet Disord. 2003;4:1.

4. Bland M. An introduction to medical statistics. 3rd ed. Oxford: Oxford University Press; 2000.

5. Fox J. Cox proportional-hazards regression for survival data. Appendix to an R and S-PLUS companion to applied regression. cran.r-project.org/doc/contrib/Fox-Companion/appendix-cox-regression.pdf. February 2002.

6. Pelz CJ, Klein JP. Analysis of survival data: a comparison of three major statistical packages (SAS, SPSS, BMDP). Medical College of Wisconsin. www.biostat.mcw.edu/tech/tr017.pdf. September 1996.

7. Nevalainen J, Hirvonen A, Pulkkinen P. A study of the outcome of arthroplasty surgery in Finland, commissioned by the Ministry of Social Affairs and Health. Appendix to the 1998 implant yearbook on orthopaedic endoprostheses. Helsinki, Finland: National Agency for Medicines; 2000. www.nam.fi/uploads/english/Publications/H-publ_3.2000.pdf

8. Sheng PY, Jämsen E, Lehto M, Konttinen YT, Pajamäki J, Halonen P. Revision total knee arthroplasty with Total Condylar III system in inflammatory arthritis. J Bone Joint Surg Br. 2005;87:1222-4.

9. Sheng PY, Jämsen E, Lehto M, Pajamäki J, Halonen P, Konttinen YT. Revision total knee arthroplasty with the Total Condylar III system: a comparative analysis of 71 consecutive cases in patients with osteoarthritis or inflammatory arthritis. Acta Orthop. In press.

10. Nevalainen J, Hirvonen A, Pulkkinen P. The 1996 implant yearbook on orthopaedic endoprostheses: Helsinki, Finland: National Agency for Medicines; 1997.