eC **A commentary by Geoffrey F. Dervin, MD, MSc, FRCSC,** is linked to the online version of this article at jbjs.org.

Outcomes of Unicompartmental Knee Arthroplasty After Aseptic Revision to Total Knee Arthroplasty

A Comparative Study of 768 TKAs and 578 UKAs Revised to TKAs from the Norwegian Arthroplasty Register (1994 to 2011)

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Background: The general recommendation for a failed primary unicompartmental knee arthroplasty (UKA) is revision to a total knee arthroplasty (TKA). The purpose of the present study was to compare the outcomes, intraoperative data, and mode of failure of primary UKAs and primary TKAs revised to TKAs.

Methods: The study was based on 768 failed primary TKAs revised to TKAs (TKA→TKA) and 578 failed primary UKAs revised to TKAs (UKA→TKA) reported to the Norwegian Arthroplasty Register between 1994 and 2011. Patient-reported outcome measures (PROMs) including the EuroQol EQ-5D, the Knee Injury and Osteoarthritis Outcome Score (KOOS), and visual analog scales assessing satisfaction and pain were used. We performed Kaplan-Meier and Cox regression analyses adjusting for propensity score to assess the survival rate and the risk of re-revision and multiple linear regression analyses to estimate the differences between the two groups in mean PROM scores.

Results: Overall, 12% in the UKA→TKA group and 13% in the TKA→TKA group underwent re-revision between 1994 and 2011. The ten-year survival percentage of UKA→TKA versus TKA→TKA was 82% versus 81%, respectively (p = 0.63). There was no difference in the overall risk of re-revision for UKA→TKA versus TKA→TKA (relative risk [RR] = 1.2; p = 0.19), or in the PROM scores. However, the risk of re-revision was two times higher for TKA→TKA patients who were greater than seventy years of age at the time of revision (RR = 2.1; p = 0.05). A loose tibial component (28% versus 17%), pain alone (22% versus 12%), instability (19% versus 19%), and deep infection (16% versus 31%) were major causes of re-revision for UKA→TKA versus TKA→TKA, respectively, but the observed differences were not significant, with the exception of deep infection, which was significantly greater in the TKA→TKA group (RR = 2.2; p = 0.03). The surgical procedure of TKA→TKA took a longer time (mean of 150 versus 114 minutes) and more of the procedures required stems (58% versus 19%) and stabilization (27% versus 9%) compared with UKA→TKA.

Conclusions: Despite TKA→TKA seeming to be a technically more difficult surgical procedure, with a higher percentage of re-revisions due to deep infection compared with UKA→TKA, the overall outcomes of UKA→TKA and TKA→TKA were similar.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Peer Review: This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. It was also reviewed by an expert in methodology and statistics. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

Disclosure: During this study, the corresponding author (T.H.L.) received a grant from the Department of Orthopedic Surgery at Haukeland University Hospital. No external funding was received in support of this work. The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article.

Unicompartmental knee arthroplasty (UKA) is an alternative to total knee arthroplasty (TKA) for patients with unicompartmental knee osteoarthritis[1,2]. There is some evidence that functional outcome after primary UKA is somewhat better than after primary TKA[3]. However, the risk of revision of primary UKA is higher than for primary TKA[4-8]. Furthermore, some surgeons claim that revision of a primary UKA to TKA (UKA→TKA) yields the same results as a primary TKA[6,7].

A comparison of UKA→TKA and primary TKA revised to TKA (TKA→TKA) has been made by only a few authors, and the results have varied[4,9-11]. Hang et al. reported that UKA→TKA demonstrated the same risk of re-revision as TKA→TKA[4]. Sierra et al. concluded that survival was substantially better for UKA→TKA than for TKA→TKA[10]. Pearse et al. reported that the functional results of UKA→TKA were not significantly better than those of TKA→TKA[9]. There are also varying reports as to the technical challenge associated with the surgical procedure for UKA→TKA in terms of operative time and the need for bone-grafting, stems, and/or augmentation[4,7,9,11-22]. Additionally, we found no previous studies presenting comparisons between UKA→TKA and TKA→TKA in terms of patient-reported outcome measures (PROMs): the EuroQol EQ-5D, the Knee Injury and Osteoarthritis Outcome Score (KOOS), and visual analog scale (VAS) scores assessing satisfaction and pain. Furthermore, many surgeons prefer to use UKA for younger patients and to postpone TKA, believing that the results of UKA→TKA are equal to those of primary TKA and better than those of TKA→TKA[9,23]. For this to be true, UKA→TKA should outperform TKA→TKA.

Our aim was to compare prosthesis survival, functional outcome, level of pain, patient satisfaction, and health-related quality of life after UKA→TKA and TKA→TKA using data from a national registry. We also aimed to compare the mode of failure and technical difficulty of the surgical procedure of these two revision groups.

TABLE I Demographic Data

	TKA→TKA			UKA→TKA		
Variable	1994-2011, N = 768*	1994-2005, N = 150†	P Value‡	1994-2011, N = 578*	1994-2005, N = 127†	P Value‡
Age at revision *(no. [%])*			0.74			0.74
>70 years	383 (50)	80 (53)		197 (34)	44 (35)	
60-70 years	222 (29)	40 (27)		188 (33)	41 (32)	
<60 years	163 (21)	30 (20)		193 (33)	42 (33)	
Sex *(no. [%])*			0.17			0.89
Female	552 (72)	116 (77)		354 (61)	78 (61)	
Male	216 (28)	34 (23)		224 (39)	49 (39)	
Primary diagnosis *(no. [%])*			0.97			0.14
Osteoarthritis	593 (77)	116 (77)		510 (88)	106 (83)	
Other	175 (23)	34 (23)		68 (12)	21 (17)	
Time since revision *(no. [%])*			<0.001			<0.001
≤5 years	468 (61)	6 (4)		364 (63)	8 (6)	
>5 years	300 (39)	144 (96)		214 (37)	119 (94)	
Type of fixation *(no. [%])*						
Cemented	661 (86)	130 (87)	0.55	485 (84)	101 (80)	0.23
Hybrid	99 (13)	17 (11)		93 (16)	26 (20)	
Uncemented	8 (1)	3 (2)		0	0	
Charnley category§ *(no. [%])*						
A		18 (13)			22 (18)	
B		19 (13)			24 (20)	
C		105 (74)			75 (62)	
EQ-5D index score#						
Preop.		0.44 ± 0.23			0.41 ± 0.21	
Postop.		0.63 ± 0.24			0.63 ± 0.24	

*Refers to the whole study cohort (Fig. 1). †Refers to the study cohort with PROM data in addition to the NAR data (Fig. 1). ‡Chi-square test. §Missing Charnley category: n = 8 for TKA→TKA, and n = 6 for UKA→TKA. A = involvement of the actual knee only, B = additional involvement of the contralateral knee, and C = additional involvement of other joints or systematic problems limiting activity. #The EQ-5D index scores ranges from 0 (indicating the worse possible health status) to 1 (indicating the best possible health status). The values are presented as the mean and SD.

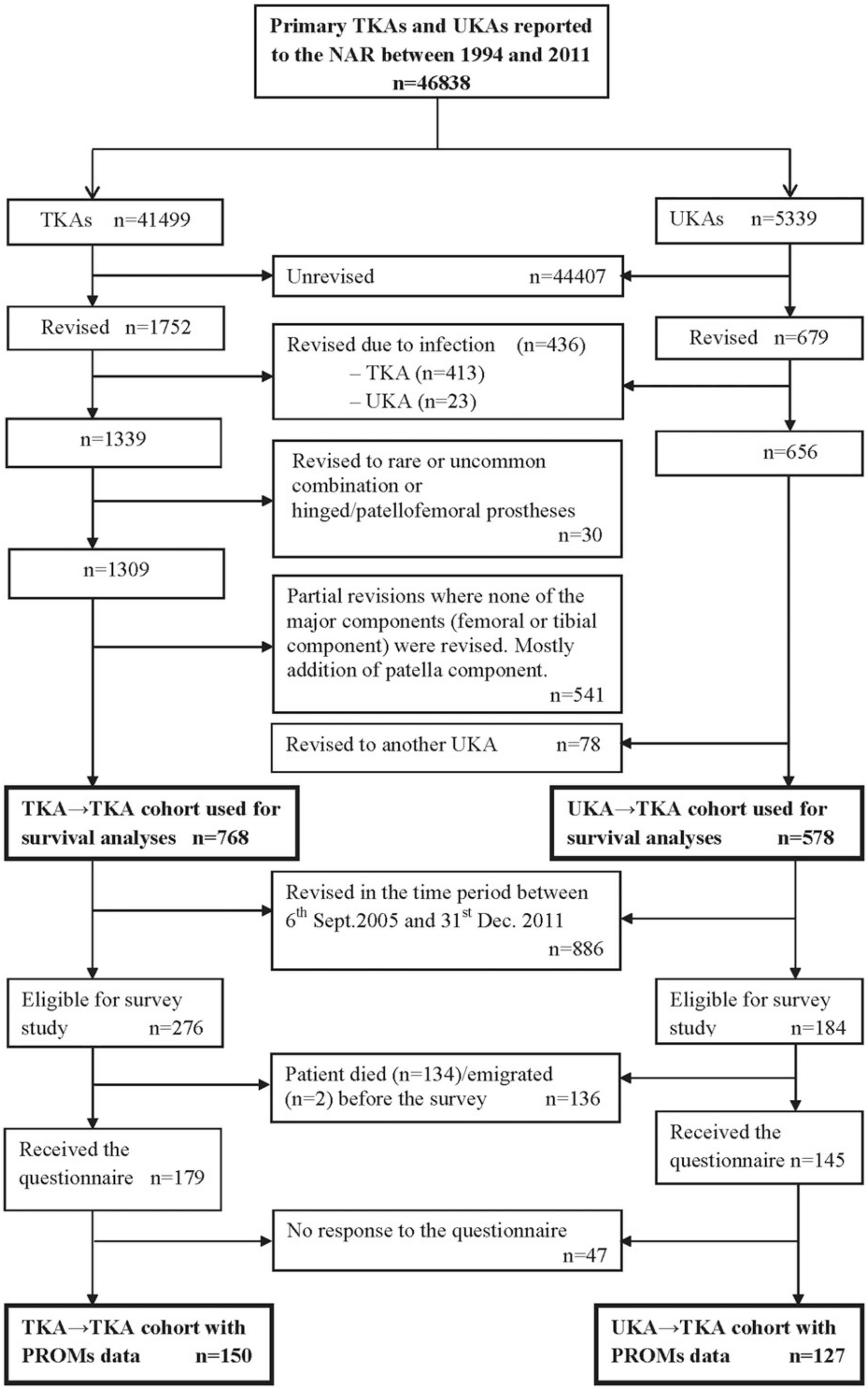

Fig. 1

The study population.

Materials and Methods

Study Population

Patients who underwent TKA→TKA or UKA→TKA and who had both primary and revision procedures reported to the Norwegian Arthroplasty Register (NAR) between 1994 and 2011 were eligible for this study. During this period, 3.4% of the revisions of primary UKA and 24% of the revisions of primary TKA were due to infection. To make the material more homogenous; only aseptic TKA→TKA procedures that had involved an exchange of the femoral and/or the tibial component and aseptic UKA→TKA procedures were included in the study. In total, 1346 knee arthroplasties (768 TKA→TKA and 578 UKA→TKA procedures) were included in the analyses of survival and re-revision risk (Fig. 1).

TABLE II Reasons for Revision and Cox Relative Risk of TKA→TKA Versus UKA→TKA by Reason for Re-Revision (Norwegian Arthroplasty Register, 1994 to 2011)*

Indication (Reason)	Revision: TKA→TKA, N = 768 No. (%)	Revision: UKA→TKA, N = 578 No. (%)	Re-Revision: TKA→TKA, N = 96 (12.5%) No. (%)	Re-Revision: TKA→TKA, N = 96 (12.5%) Duration of Follow-up§ *(yr)*	Re-Revision: UKA→TKA, N = 67 (11.6%) No. (%)	Re-Revision: UKA→TKA, N = 67 (11.6%) Duration of Follow-up§ *(yr)*	RR (95% CI)† Crude	RR (95% CI)† Adjusted	P Value‡
Loose femoral component	149 (19.4)	116 (20.1)	9 (9.4)	4.1 ± 3.2	4 (6.0)	2.8 ± 1.8	1.6 (0.5-5.3)	2.3 (0.7-7.6)	0.19
Loose tibial component	391 (50.9)	132 (22.8)	16 (16.7)	3.5 ± 2.9	19 (28.4)	3.5 ± 3.3	0.6 (0.3-1.2)	0.7 (0.4-1.4)	0.32
Loose patellar component	12 (1.6)	0	1 (1.0)	8.3	0				
Dislocation of patella	17 (2.2)	0	4 (4.2)	4.0 ± 2.0	0				
Dislocation other than patella	9 (1.2)	7 (1.2)	1 (1.0)	1.1	0				
Instability	144 (18.8)	41 (7.1)	18 (18.8)	2.2 ± 2.0	13 (19.4)	3.2 ± 3.9	1.1 (0.5-2.2)	1.3 (0.6-2.7)	0.49
Malalignment	143 (18.6)	42 (7.3)	6 (6.3)	3.7 ± 2.4	9 (13.4)	4.2 ± 4.1	0.5 (0.2-1.5)	0.6 (0.2-1.7)	0.31
Deep infection	#	#	30 (31.3)	1.3 ± 1.3	11 (16.4)	2.0 ± 1.3	2.1 (1.04-4.1)	2.2 (1.1-4.5)	0.03
Periprosthetic fracture	58 (7.6)	24 (4.2)	4 (4.2)	0.7 ± 0.6	0				
Defect or wear of polyethylene inserts	62 (8.1)	33 (5.7)	4 (4.2)	6.6 ± 4.1	1 (1.5)	1.4	2.7 (0.3-24.5)	4.2 (0.4-40.3)	0.21
Pain alone	50 (6.5)	187 (32.4)	11 (11.5)	2.9 ± 2.1	15 (22.4)	2.1 ± 1.1	0.6 (0.3-1.2)	0.7 (0.3-1.6)	0.38
Progression of arthritis	2 (0.3)	58 (10.0)	1 (1.0)	0.3	0				
Arthrofibrosis and stiff knee	21 (2.7)	1 (0.2)	5 (5.2)	2.4 ± 2.9	1 (1.5)	2.6	3.7 (0.4-31.5)	5.0 (0.6-44.5)	0.15
Other reason	20 (2.6)	22 (3.8)	1 (1.0)	0.4	3 (4.5)	3.2 ± 4.3	0.2 (0.03-2.3)	0.3 (0.03-2.8)	0.27

*More than one reason for revision and/or re-revision was reported for some patients. †Relative risk (RR) for re-revision in the Cox regression analysis, where UKA→TKAs were used as the reference group and adjustment was made for propensity-score covariates of sex, age at revision, duration of time since revision, primary diagnosis, and type of fixation. ‡P value for the adjusted RR. §The values are presented as the mean and the standard deviation. #Not included in the analysis (see Fig. 1).

Sources of Data

Patients were identified in the NAR database (Fig. 1). As of the time of this study, the NAR does not prospectively record any PROMs related to knee arthroplasty procedures. Such information, however, was collected through a mailed self-administered questionnaire in 2006 as a part of one earlier PhD study from the NAR[24-26]. Only patients who had a minimum of one year of postoperative follow-up were included in the survey because it takes one year to achieve maximum pain relief and functional outcome after revision TKA[27]. Of the 1346 knees included in this study, 277 knees (150 in the TKA→TKA cohort and 127 in the UKA→TKA cohort) had PROM data in addition to the NAR data (Fig. 1).

The PROM data used in the study were quality of life according to the EQ-5D[28,29], functional outcome as measured by the KOOS[30-33], satisfaction and pain according to the VAS[34-36], and responses to questions related to musculoskeletal comorbidity (Charnley category)[37,38].

Definitions

A *revision* is defined as the removal, addition, or exchange of a part or the whole implant. A *re-revision* is defined as the revision of a previously revised knee arthroplasty. Re-revision for any reason was the outcome in the survival analyses. Multiple reasons could be reported for each case. However, infection was considered as the primary cause of failure if reported in combination with other causes. Pain was only considered a primary reason if not combined with other causes of failure. The duration of operative time and the need for bone impaction, stems, and/or stabilization of the knee (posterior-cruciate stabilizing [PCS] or fully stabilized knee/constrained condylar knee [CCK]) served as proxies for the technical difficulty of the surgical procedure.

Statistical Power

For PROMs, clinical importance was assessed relative to a stated minimal perceptible clinical difference (MPCD) of 8 to 10 units for the KOOS subscales[31] and 9 to 12 units for outcomes measured on a VAS[39], and the minimum important difference to be detected was 0.06 to 0.08 for the EQ-5D index score[40,41]. To have an 80% chance of detecting a significant difference (at the two-sided, 5% level) of 10 units in mean outcome score for the KOOS and VAS between the treatment groups, with an assumed standard deviation (SD) of 20, sixty-four individuals in each group were required. Questionnaires were mailed to 324 patients; of those, 277 patients (150 TKA→TKA and 127 UKA→TKA) responded to the questionnaire, yielding a response rate of 85.5% (Fig. 1). For the survival analyses, a power analysis indicated that a total of 938 prostheses (469 in each group) was required to detect a relative risk (RR) of 2 as significant (two-sided test; alpha = 0.05, 1 − beta = 0.80) with a difference in cumulative survival at fifteen years of 9% (90% and 81%).

Statistical Analysis

Kaplan-Meier and Cox regression analyses were used, respectively, to compare the survival rate and the RR of re-revision between TKA→TKA and UKA→TKA, with any reason for re-revision as the end point. The reverse Kaplan-Meier method was used to calculate the median duration of follow-up[42]. Survival analyses were undertaken separately for TKA→TKA and UKA→TKA, according to age at revision (less than sixty, sixty to seventy, or greater than seventy years) and the period of the revision operation (1994 to 2002 or 2003 to 2011). Cox regression analyses were first performed with

TABLE III Intraoperative Data: Operative Time, Stems, Bone Impaction, and Implant Stability (Norwegian Arthroplasty Register, 1994 to 2011)

Proxies	TKA→TKA, N = 768	UKA→TKA, N = 578
Stems *(no. [%])*	446 (58%)	112 (19%)
Stabilized (PCS or CCK)* *(no. [%])*	205 (27%)	50 (9%)
Stems and PSC or CCK* *(no. [%])*	169 (22%)	24 (4%)
Bone impaction† *(no. [%])*	125 (24%)	82 (19%)
Operative time‡ *(min)*	150 ± 52	114 ± 35

*PCS = posterior-cruciate stabilizing, and CCK = constrained condylar knee. †Registration of bone impaction in the Norwegian Arthroplasty Register (NAR) database started in 2005, and the percentage was calculated according to the number of revision knee prostheses reported to the NAR between 2005 and 2011. ‡The values are presented as the mean and SD.

adjustments for propensity score. The covariates included in the propensity score model were age at revision (less than sixty, sixty to seventy, or greater than seventy years), sex, type of fixation (cemented, hybrid, or uncemented), primary diagnosis (osteoarthritis or other), and duration of time since the revision operation (five years or less or greater than five years). The proportional hazard assumption (PHA) of the Cox regression model was assessed by graphical examination (log-log plot). If the conditions for the assumption were not fulfilled during the total time period, additional time-dependent survival analyses were performed by dividing the follow-up into two time periods.

Independent-sample Student t test and multiple linear regression with adjustment for sex, age at revision, type of fixation, preoperative EQ-5D index score except in the case of the change in EQ-5D index score (i.e., the postoperative minus the preoperative EQ-5D index score), duration of time since the revision operation, primary diagnosis, and Charnley category (A, B, or C) were used to estimate the differences in mean PROM scores between the TKA→TKA and UKA→TKA groups.

Crude and adjusted results are presented with the 95% confidence interval (CI), and p values of <0.05 were considered significant. The statistical analyses were performed using SPSS statistical software (IBM) version 22, and the survival curves with 95% CI shading were calculated using R software version 3.1.1.

Ethics Clearance

The Regional Committee for Research Ethics in Western Norway (REK Vest) approved the survey study (registration number 2012/1692/REK Vest).

Results

Demographic Characteristics

The UKA→TKA group underwent revision at a younger age, had a greater percentage of male patients and patients with a primary diagnosis of osteoarthritis, and had a lower percentage of patients with comorbidity compared with the TKA→TKA group. The study cohort with PROM data (NAR 1994 to 2005) and the full study cohort (NAR 1994 to 2011) of both revision groups did not differ significantly in any of the baseline characteristics, with the exception of the duration of follow-up (Table I). Profix (Smith & Nephew) and LCS Complete (DePuy Synthes) prostheses were the two most frequently used prosthesis brands in both revision groups (NAR 1994 to 2011) (see Appendix).

Survival and Re-Revision Rates

The five, ten, and fifteen-year Kaplan-Meier survival percentages for UKA→TKA were 85% (95% CI = 82% to 88%), 82% (95%

TABLE IV Mean Differences in KOOS Subscales Scores, VAS for Satisfaction and Pain, and EQ-5D Index Scores (Norwegian Arthroplasty Register, 1994 to 2005)

Outcome Measure	TKA→TKA*	UKA→TKA*	Mean Difference (95% CI)†		P Value‡
			Unadjusted§	Adjusted#	
KOOS subscale**					
Pain	55 ± 19	52 ± 17	−2.8 (−7.2 to 1.6)	−2.3 (−7.6 to 3.0)	0.39
Symptoms	47 ± 14	47 ± 16	0.2 (−3.5 to 3.9)	0.4 (−4.2 to 4.9)	0.87
ADL	57 ± 17	55 ± 18	−2.2 (−6.3 to 1.9)	−2.3 (−7.3 to 2.7)	0.37
Sport/rec.	35 ± 31	38 ± 31	3.3 (−4.2 to 10.7)	4.7 (−4.2 to 13.6)	0.30
QOL	61 ± 27	60 ± 25	−0.8 (−7.1 to 5.4)	−2.0 (−9.5 to 5.6)	0.61
VAS for satisfaction	58 ± 26	57 ± 27	−1.7 (−8.1 to 4.8)	−0.8 (−8.7 to 7.0)	0.84
VAS for pain	62 ± 23	61 ± 23	−0.9 (−6.4 to 4.6)	−2.9 (−9.4 to 3.7)	0.39
Change in EQ-5D index score††	0.19 ± 0.27	0.23 ± 0.26	0.03 (−0.03 to 0.09)	0.03 (−0.04 to 0.1)	0.36

*The values are presented as the mean and SD †The difference is equal to the mean score among UKA→TKAs minus the mean score among TKA→TKAs. A positive value is in favor of UKA→TKA. ‡P values refer to the adjusted mean difference. §Independent-sample Student t test. #Adjustment was done for age at revision, sex, Charnley category, duration of time since revision operation, diagnosis at primary operation, type of fixation, and preoperative EQ-5D index score (except for the change in EQ-5D index score) in a multiple linear regression model. **The KOOS subscale scores and the VAS scores range from 0 to 100, with 0 indicating the worst possible state and 100 indicating the best possible state. ††The EQ-5D index score ranges from 0 (indicating the worst possible health status) to 1 (indicating the best possible health status). ADL = activities of daily living (function in daily life), sport/rec. = function in sports and recreation, QOL = knee-related quality of life, and the change in EQ-5D index score = the postoperative minus the preoperative EQ-5D index score.

CI = 77% to 87%), and 76% (95% CI = 63% to 88%), respectively, and the corresponding percentages for TKA→TKA were 87% (95% CI = 84% to 89%), 81% (95% CI = 77% to 85%), and 80% (95% CI = 76% to 84%), respectively. There was no significant difference in the overall survival percentage between the two groups (p = 0.63) or in the adjusted risk of re-revision (RR = 1.2; 95% CI = 0.9 to 1.7; p = 0.19). In the age-stratified analysis, however, the risk of re-revision among the patients who underwent revision at an age of greater than seventy years was double for those in the TKA→TKA group compared with the UKA→TKA group (RR = 2.1; 95% CI = 1.01 to 4.2; p = 0.05) (Fig. 2). The median duration of follow-up for UKA→TKA was 4.1 years (95% CI = 3.6 to 4.6 years) and for TKA→TKA was 4.6 years (95% CI = 4.1 to 5.1 years). To check for the effect of time-dependent differences on the revision outcome, we performed a subanalysis according to time periods of revision operations. We found significant differences in the survival rate or risk of re-revision between UKA→TKA and TKA→TKA in the period 1994 to 2002, with the risk of re-revision being two times higher for TKA→TKA (RR = 2.0; 95% CI = 1.03 to 3.8; p = 0.04) (see Appendix).

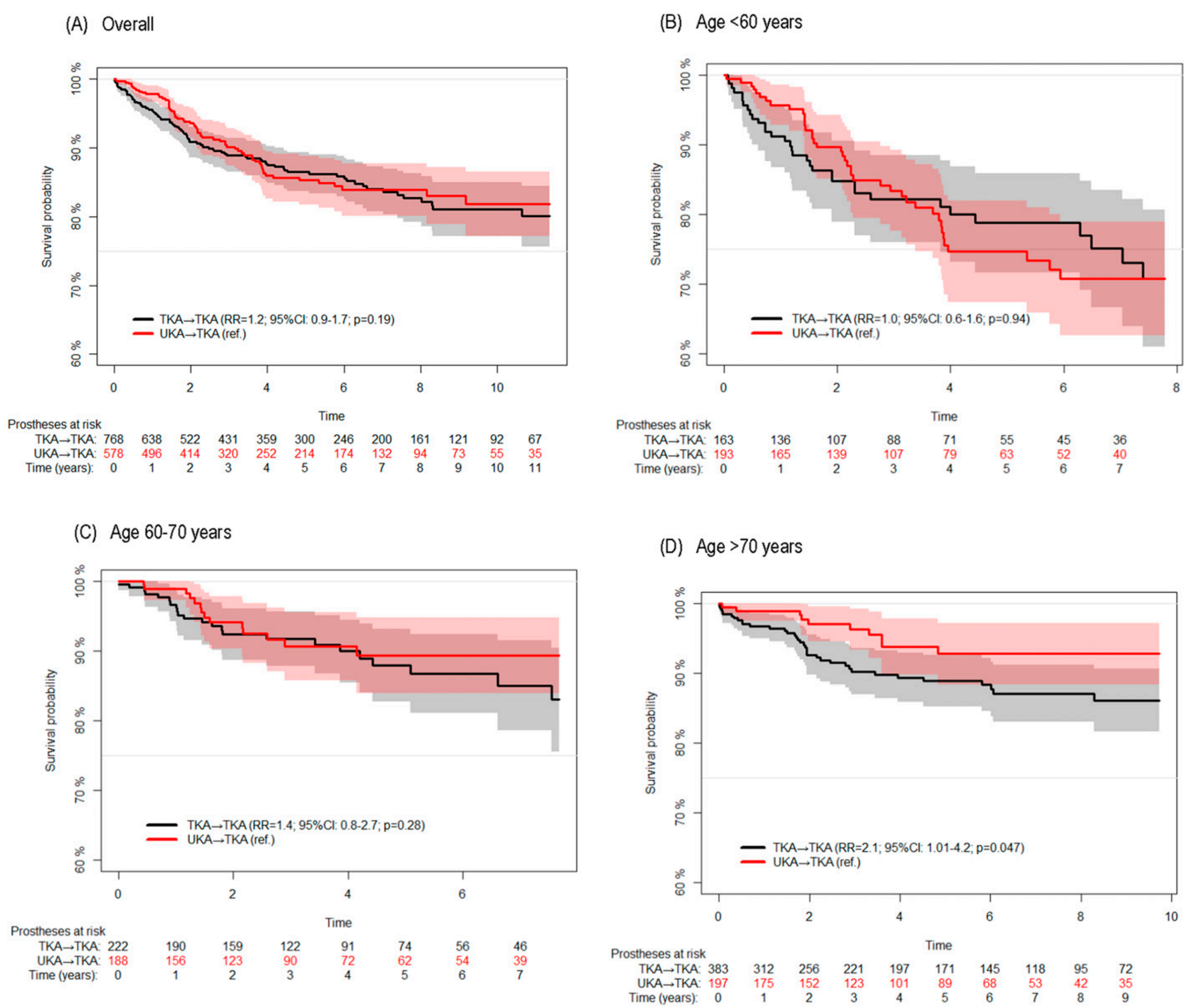

Fig. 2

Figs. 2-A through 2-D Survival curves (Kaplan-Meier) and Cox regression analyses for failed primary TKAs revised to TKA (TKA→TKA) versus failed primary UKAs revised to TKA (UKA→TKA) from the Norwegian Arthroplasty Register, 1994 to 2011. **Fig. 2-A** Overall survival probability and risk of re-revision. **Figs. 2-B, 2-C, and 2-D** Survival probability and risk of re-revision according to age at revision. RR = relative risk of re-revision in the Cox regression analysis, where UKA→TKA was used as the reference group and adjusting for the propensity-score covariates of sex, age at revision (for the overall analysis but not for the age-stratified analyses), duration of time since the revision operation, primary diagnosis, and type of fixation. CI = confidence interval, and time = duration of follow-up in years. The Kaplan-Meier survival curves were terminated when fewer than thirty knees remained at risk.

The graphical examination of the PHA revealed that the assumption was not met for the revision groups (UKA→TKA and TKA→TKA), two of the age groups (less than sixty years and sixty to seventy years) (Fig. 2), and the period of the revision operation (2003 to 2011) (see Appendix). Thus, we performed additional time-dependent adjusted Cox regression analyses by dividing the follow-up into two time periods (zero to three years and greater than three years) for each of those variables. Still, we found no significant differences in the risk of re-revision between UKA→TKA and TKA→TKA.

Overall, sixty-seven (11.6%) of the UKA→TKAs and ninety-six (12.5%) of the TKA→TKAs were re-revised between 1994 and 2011. A loose tibial component (28% versus 17% in the two groups, respectively), pain alone (22% versus 12%), instability (19% versus 19%), and deep infection (16% versus 31%) were the major causes of re-revision. However, the observed differences in the overall proportions of the reason for re-revision of UKA→TKA versus TKA→TKA were not significant except for deep infection, which was significantly greater in the TKA→TKA group (RR = 2.2; 95% CI = 1.1 to 4.5; p = 0.03) (Table II). Significant differences in the proportions of the reason for re-revision (deep infection, pain alone, and arthrofibrosis and stiff knee) were observed between TKA→TKA and UKA→TKA among the patients who underwent revision at an age of less than sixty years (see Appendix).

Intraoperative Data

The mean operative time (and SD) was greater for TKA→TKA than for UKA→TKA (150 ± 52 versus 114 ± 35 minutes, respectively). A greater number of the TKA→TKA procedures required stems (58% versus 19%), bone impaction (24% versus 19%), and stabilization (27% versus 9%) (Table III).

EQ-5D Index Score and Level of Pain Relief (NAR 1994 to 2005)

The mean EQ-5D index score (and SD) increased from 0.41 ± 0.21 preoperatively to 0.63 ± 0.24 postoperatively for the UKA→TKA group and from 0.44 ± 0.23 preoperatively to 0.63 ± 0.24 postoperatively for the TKA→TKA group (Table I). There was no

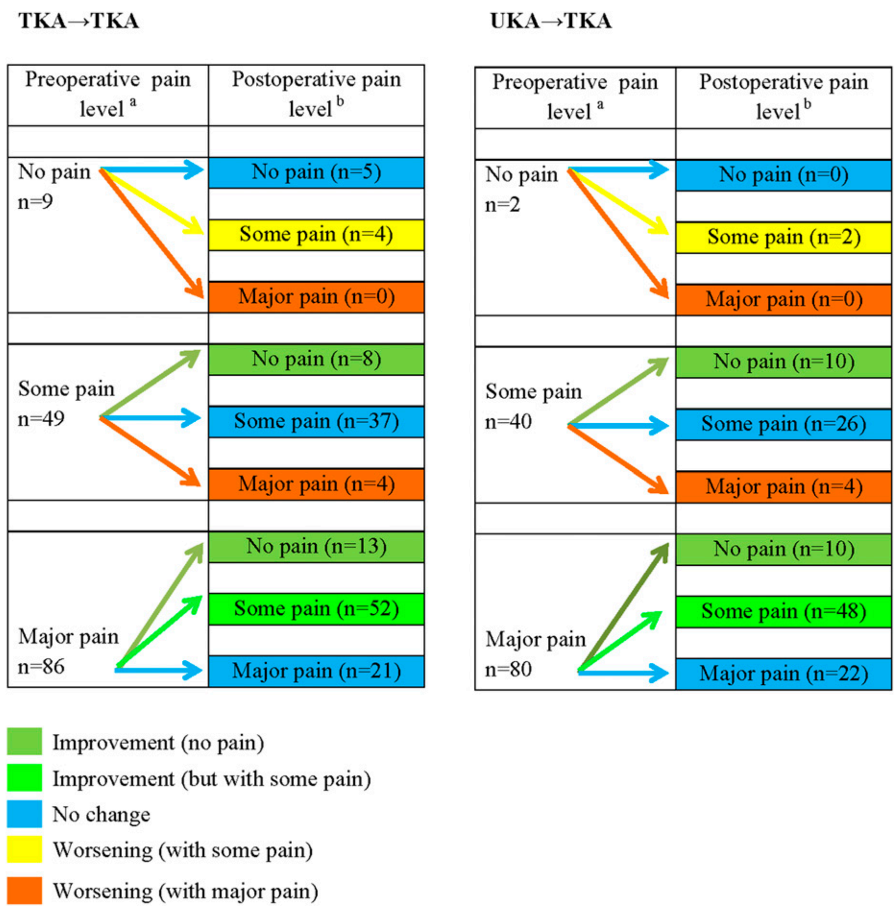

Fig. 3

Preoperative pain level (a) and postoperative change in pain level (b) according to the EQ-5D pain/discomfort domain among patients with a failed primary TKA revised to TKA (TKA→TKA) or a failed primary UKA revised to TKA (UKA→TKA) at a minimum postoperative follow-up of one year (Norwegian Arthroplasty Register, 1994 to 2005). Six of the 150 patients with PROMs in the TKA→TKA group and five of the 127 in the UKA→TKA group did not report either the preoperative or postoperative EQ-5D level of pain/discomfort. Therefore, only the remaining patients (144 TKA→TKAs versus 122 UKA→TKAs) who reported both preoperative and postoperative pain level were considered in the assessment of the changes in the severity of pain.

significant difference in the change in EQ-5D index score between the two groups, nor did we observe a significant minimum important difference (p = 0.36) (Table IV). Seventy-three percent of eighty UKA→TKA patients and 76% of eighty-six TKA→TKA patients with severe preoperative pain or discomfort according to the EQ-5D reported improvement postoperatively (Fig. 3; see Appendix).

KOOS Subscales and VAS Scores (NAR 1994 to 2005)

Seventeen percent of the 127 UKA→TKA patients and 14% of the 150 TKA→TKA patients reported severe to extreme or intolerable pain (VAS for pain of <40 points) postoperatively. Twenty-five percent of the 127 UKA→TKA patients and 22% of the 150 TKA→TKA patients were dissatisfied with the revision surgery (VAS for satisfaction of <40 points). There were no significant differences in mean postoperative KOOS subscale scores or in the VAS scores between the two groups (Table IV).

Discussion

We found no significant difference between UKA→TKA and TKA→TKA in the overall survival rate or risk of re-revision, and no significant difference in the reason for failure (with the exception of deep infection, which was significantly greater in the TKA→TKA group) or in PROM scores. The surgical procedure of TKA→TKA took a longer time (mean of 150 minutes versus 114 minutes for UKA→TKA) and required more stems (58% versus 19%) and/or stabilization (27% versus 9%).

Our finding of no significant difference between UKA→TKA and TKA→TKA in the survival rate or risk of re-revision is consistent with the findings of some previous studies[4,10,11,43]. However, Cross et al. reported a higher re-revision rate for TKA→TKA (19%) compared with UKA→TKA (8%)[43]. Data from the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) indicated that the risk of re-revision following TKA→TKA was 1.4 times higher than that following UKA→TKA (RR = 1.41; 95% CI = 1.2 to 1.7; p < 0.001)[44]. The power of our study was also somewhat lower, with risk estimates similar to the AOANJRR data (RR = 1.2, p = 0.2) but not significant. In the present study, the risk of re-revision of TKA→TKA was 2.1 times higher than that for UKA→TKA in the patients who underwent revision at an age of greater than seventy years (p = 0.05). We also found that the risk of re-revision for TKA→TKA was two times higher than that for UKA→TKA performed in the period between 1994 and 2002.

In the present study, UKA→TKAs were more often re-revised because of a loose tibial component and pain alone, whereas TKA→TKAs were more often re-revised because of deep infection. Similar descriptive findings were also reported in earlier studies[4,8-10,13,45-47]. Relatively, the greatest proportion of those re-revisions were performed because of pain alone and loosening following UKA→TKA, whereas most were performed because of infection following TKA→TKA. One possible explanation might be the presence of occult low-grade infection and unrecognized aseptic loosening that were not detected preoperatively by the available detection modalities. Additionally UKA→TKA patients were younger and might have greater activity levels and higher expectations regarding their postoperative status. Furthermore, the increased risk of infection following TKA→TKA could be attributed to the poorly vascularized tissue often encountered after multiple operations, the longer operative time for revision surgery, the larger implants used, comorbidity, and the greater average age of the patient population[45,48,49]. Given the low numbers of available re-revisions, the results in Table II should be interpreted with caution.

Some authors have reported technical difficulties during UKA→TKA, namely substantial bone loss requiring grafting and the need for stems or custom implants in 50% to 76% of the knees[13,16,17]. Others, however, have reported that the surgical procedure of UKA→TKA is less technically demanding than TKA→TKA[7,9,11,15,18-22]. Cross et al. reported fewer technical difficulties of the surgical procedure of UKA→TKA in terms of operative time (mean of 120 versus 163 minutes) and less use of stems, augments, and/or constrained bearings (34% versus 100% of knees) compared with the performance of TKA→TKA[43], which is consistent with our finding. A possible explanation for conflicting reports on difficulties of the surgical procedure is differences in hospital and surgeon volume and experience in performing the primary UKA surgery. Some experienced surgeons might have a more conservative policy toward bone cuts. Sierra et al., however, reported that the use of stems did not correlate with difficulty but more often correlated with the surgeon's need to protect damaged bone[10]. Châtain et al. also concluded that the surgical procedure of UKA→TKA is not technically difficult but requires precision and skill[12].

We found no significant differences in functional outcome, level of pain, satisfaction, and change in health-related quality of life between UKA→TKA and TKA→TKA. Pearse et al. found similar functional outcomes (according to mean Oxford Knee Score results) between UKA→TKA and TKA→TKA at six months of follow-up[9]. Cross et al., however, reported better improvement in Knee Society Scores (mean improvement, 34 versus 29) and Knee Society function scores (mean improvement, 31 versus 21) for patients who underwent UKA→TKA compared with TKA→TKA[43]. Robertsson et al. reported that the proportion of dissatisfied patients was higher for TKA→TKA than UKA→TKA among patients with osteoarthritis. However, the overall proportion of satisfied patients was equal between the two revision groups[50], which is in accordance with our findings.

The strength of this study is its relatively large sample size. We had a long duration of follow-up (zero to seventeen years), and used national registry data with high (95% to 97%) registration completeness[51,52]. Most previous studies assessed the outcomes of UKA→TKA and TKA→TKA in terms of prosthesis survival, but to present a complete and accurate picture of joint replacement outcomes, reporting prosthesis survival as well as PROMs is recommended[53], and so we did in the present study.

Our study also had limitations. First, the preoperative EQ-5D was assessed retrospectively; it may be difficult for patients to recall the exact level of preoperative symptoms. Accordingly, the

EQ-5D answer may be biased[54]. On the other hand, earlier studies have reported moderate to good correlation between prospectively collected data and recalled data regarding preoperative status[55,56]. Moreover, Blome and Augustin concluded that "in studies aiming to determine treatment benefit as perceived by the patient (instead of 'true effect'), retrospective QOL assessment should even be more appropriate."[57] Second, we had no information on preoperative KOOS and VAS for pain, so we could not evaluate the effect of the revision procedure on those outcomes. Third, the NAR does not record any information on surgeon volume and experience as of the time of this writing. Thus, we lack data on surgeon volume as a proxy for surgical experience and technical performance.

In conclusion, the outcomes of UKA→TKA and TKA→TKA in terms of survival, functional outcome, level of pain, patient satisfaction, and change in health-related quality of life were similar. Similarly, the two revision groups had no significant differences in reasons for re-revision, with the exception of a greater percentage of revisions due to deep infection in the TKA→TKA group. However, the surgical procedure of TKA→TKA seems to be more technically complex than UKA→TKA.

Appendix

eA Figures presenting survival curves for revised knees according to year of operation (1994 to 2002 and 2003 to 2011) and showing the changes in the severity of problems according the domains of the EQ-5D, and tables showing the types of prosthesis brands used and the reasons for re-revision according to age at revision are available with the online version of this article as a data supplement at jbjs.org. ■

NOTE: The authors thank the Norwegian Arthroplasty Register (NAR) for allowing access to the registry dataset. The authors also thank Norwegian orthopaedic surgeons in all Norwegian hospitals for reporting their surgical cases to the NAR and all patients who gave consent for their data to be entered into the NAR database as well as for their willingness to participate and respond to the survey on which this study was based.

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