

Patient-Relevant Outcomes Following First Revision Total Knee Arthroplasty, by Diagnosis

An Analysis of Implant Survivorship, Mortality, Serious Medical Complications, and Patient-Reported Outcome Measures Utilizing the National Joint Registry Data Set

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Background: The purpose of this study was to investigate patient-relevant outcomes following first revision total knee arthroplasties (rTKAs) performed for different indications.

Methods: This population-based cohort study utilized data from the United Kingdom National Joint Registry, Hospital Episode Statistics Admitted Patient Care, National Health Service Patient-Reported Outcome Measures, and the Civil Registrations of Death. Patients undergoing a first rTKA between January 1, 2009, and June 30, 2019, were included in our data set. Patient-relevant outcomes included implant survivorship (up to 11 years postoperatively), mortality and serious medical complications (up to 90 days postoperatively), and patient-reported outcome measures (at 6 months postoperatively).

Results: A total of 24,540 first rTKAs were analyzed. The patient population was 54% female and 62% White, with a mean age at the first rTKA of 69 years. At 2 years postoperatively, the cumulative incidence of re-revision surgery ranged from 2.7% (95% confidence interval [CI], 1.9% to 3.4%) following rTKA for progressive arthritis to 16.3% (95% CI, 15.2% to 17.4%) following rTKA for infection. The mortality rate at 90 days was highest following rTKA for fracture (3.6% [95% CI, 2.5% to 5.1%]) and for infection (1.8% [95% CI, 1.5% to 2.2%]) but was <0.5% for other indications. The rate of serious medical complications requiring hospital admission within 90 days was highest for patients treated for fracture (21.8% [95% CI, 17.9% to 26.3%]) or infection (12.5% [95% CI, 11.2% to 13.9%]) and was lowest for those treated for progressive arthritis (4.3% [95% CI, 3.3% to 5.5%]). Patients who underwent rTKA for stiffness or unexplained pain had some of the poorest postoperative joint function (mean Oxford Knee Score, 24 and 25 points, respectively) and had the lowest proportion of responders (48% and 55%, respectively).

Conclusions: This study found large differences in patient-relevant outcomes among different indications for first rTKA. The rate of complications was highest following rTKA for fracture or infection. Although rTKA resulted in large improvements in joint function for most patients, those who underwent surgery for stiffness and unexplained pain had worse outcomes.

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

Primary total knee arthroplasty (pTKA) is highly clinically effective. Nearly all procedures are performed for the treatment of osteoarthritis¹, and it has been reported

that most patients experience predictable and large improvements in terms of pain and joint function², usually for the rest of their lives^{3,4}. However, research has shown that around 4% of

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (<http://links.lww.com/JBJS/H645>).

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pTKAs are revised within 10 years¹ and that the need for revision total knee arthroplasty (rTKA) is steadily increasing^{5,6}. This trend reflects aging populations and an increasing number of joint replacements among younger patients⁴.

Research has demonstrated that rTKA produces less improvement in joint function and health-related quality of life than that produced by pTKA^{7,8}. Previous work has highlighted clinically important differences in patient outcomes associated with the indication for surgery^{9,10}. rTKA for infection or other urgent indications has been shown to incur greater costs and higher rates of complications than elective rTKA performed for other indications¹⁰⁻¹³. Researchers have also reported that fewer than half of patients who underwent rTKA for stiffness were satisfied with the outcome, compared with two-thirds of patients who underwent surgery for a worn component⁹.

We previously identified the domains of outcome that are important to patients undergoing joint replacement: implant survival, joint function, health-related quality of life, medical complications, and the impact of hospital admission¹⁴. Information on these outcomes in the context of different indications for rTKA is lacking and is needed to support shared decision-making.

The aim of the present study was to investigate patient-relevant outcomes following first rTKA performed for different indications. Utilizing routinely collected national data from the United Kingdom (U.K.), we investigated the rate of repeat revision surgery (re-revision) at 2 and 5 years postoperatively, the rate of mortality and serious medical complications up to 90 days postoperatively, patient-reported outcome measures at 6 months postoperatively, and the length of the hospital admission for the index procedure.

Materials and Methods

This study was reported according to the RECORD (Reporting of studies Conducted using Observational Routinely-collected health Data) checklist¹⁵. Ethical approval was obtained.

Study Data Sets

Routinely collected national data were analyzed from the National Joint Registry (NJR) for England, Wales, Northern Ireland, the Isle of Man, and Guernsey; Hospital Episode Statistics Admitted Patient Care (HES APC); National Health Service (NHS) Patient-Reported Outcome Measures (PROMs)¹⁶; and the Civil Registrations of Death.

NJR

The NJR is a prospective register of rTKA procedures. Submission is mandatory for public and private health-care providers¹⁷. The NJR originally defined rTKA as “an operation performed to remove and replace one or more components of a total joint prosthesis, for whatever reason.”¹⁸ The instructions on procedures to be reported changed over the study period, with the addition of secondary patellar resurfacing procedures on December 1, 2013, and the addition of debridement, antibiotics, and implant retention procedures with or without modular exchange on June 25, 2018¹⁹.

HES APC

HES APC includes NHS-funded secondary care episodes in England. Data are entered by trained clerks. Submission is mandatory in order for health-care providers to receive financial remuneration. Diagnoses are coded using World Health Organization International Classification of Diseases, 10th revision, codes²⁰. Procedures are coded using the Office of Population Censuses and Surveys' Classification of Surgical Operations and Procedures, version 4, codes²¹.

PROMs

Patients completed a questionnaire preoperatively and at 6 months postoperatively¹⁶ (see the section entitled “Outcome Measures,” below).

Civil Registrations of Death

Date and cause of death are recorded from death certificates.

Inclusion and Exclusion Criteria

Patients undergoing a first rTKA between January 1, 2009, and June 30, 2019, were included. Cases were censored on December 31, 2019 (or earlier if an event was observed). We excluded early NJR data (for poor compliance^{22,23}) and data during the COVID-19 pandemic (the data were not representative of usual practice). Adult patients (≥18 years old) were eligible for inclusion following a first rTKA recorded in the NJR. rTKAs with no linked pTKA were excluded because we could not determine the sequence of events. For patients who underwent rTKA for both knees, only the first procedure was included to fulfill the assumption of independence of observations. Partial knee arthroplasty procedures (for example, unicompartamental and patellofemoral arthroplasties) were excluded. For the analysis of medical complications and the length of hospital stay (LOS), first-linked rTKAs were joined to corresponding episodes on HES APC. For the analysis of PROMs, preoperative PROM questionnaires needed to be returned within 90 days prior to rTKA and postoperative questionnaires needed to be returned 180 days to 1 year following rTKA.

Data Cleaning and Linkage

The statistical code is provided on GitHub²⁴. The preparation of HES APC data followed the principles of HES Pipeline R²⁵. Records in each dataset were de-duplicated, and variables were checked for out-of-range, missing, and invalid entries.

The NJR was used as the master data set for record linkage. The NNNid field was assigned a study_id and represented 1 patient. Patient identifiers stored within the NJR (NHS number, family name, given name, gender, date of birth, and postcode) were supplied to NHS Digital to create an HES patient cohort. NJR records were joined to the Civil Registrations of Death on study_id where available. For the analysis of complications and that of LOS, the index NJR procedures were joined to HES APC on study_id and date of surgery (±7 days). PROM data were linked indirectly to NJR on epikey with use of HES APC¹⁶.

Groups

Patients were grouped by the indication for revision surgery. Each procedure was assigned a single, dominant diagnosis: infection, malalignment, aseptic loosening, instability, fracture, progressive arthritis (in the case of secondary patellar resurfacing), stiffness, unexplained pain, or other^{25,26} (see Appendix A).

Outcome Measures

Implant Survivorship

The cumulative incidence of re-revision surgery at up to 11 years was analyzed postoperatively. We have reported survival estimates at 2 and 5 years.

Mortality and Serious Medical Complications in the Hospital within 90 Days After Surgery

Deaths that occurred within 90 days following rTKA were identified from the Civil Registrations of Death. The following serious medical complications were recorded from HES APC: acute kidney injury, lower respiratory tract infection, myocardial infarction, deep-vein thrombosis, pulmonary embolism, stroke, and urinary tract infection.

PROMs

A total of 5 domains were measured: postoperative joint function, responder analysis, postoperative health-related quality of life, satisfaction, and perceived success.

1. *Postoperative joint function*: This outcome was measured with use of the Oxford Knee Score (OKS)²⁷. The OKS is a 12-item Likert instrument with good measurement properties for the assessment of pain and function following rTKA^{28,29}. For each item, the best response is assigned a score of 4 points, whereas the worst response is assigned a score of 0 points. The total possible score ranges from 0 points (worst) to 48 points (best)³⁰.
2. *Responder analysis*: Patients were dichotomized into responders (postoperative OKS – preoperative OKS ≥ 6 points [i.e., a minimal important change]) or nonresponders (postoperative OKS – preoperative OKS < 6 points)⁷.
3. *Postoperative health-related quality of life*: This outcome was measured with use of the EuroQol-5 Dimensions-3 Levels (EQ-5D-3L)³¹. Each response set was converted to a utility score scaled for the U.K. population from -0.594 (worst) to 1 (best). A utility score of 0 represented a health state equivalent to being dead.
4. *Satisfaction*: Patients were asked, “How would you describe the results of your operation?” The answer options were “Excellent,” “Very good,” “Good,” “Fair,” or “Poor.” We considered patients who responded “Good” or better as satisfied.
5. *Perceived success*: Patients were asked, “Overall, how are the problems now in the hip/knee on which you had surgery, compared to before your operation?” The answer options were “Much better,” “A little better,”

“About the same,” “A little worse,” or “Much worse.” We considered patients who responded “Much better” or “A little better” to have considered the surgery a success.

LOS

We calculated the duration in days of the single Continuous Inpatient Spell (CIPS) within HES APC that corresponded most closely with a first rTKA record in the NJR. One CIPS refers to 1 uninterrupted period within NHS secondary care. CIPs were constructed in accordance with published methods³². Supplementary analyses were performed for finished consultant episodes and provider spells³³.

Statistical Analysis

Patient characteristics (age, gender, American Society of Anesthesiologists [ASA] classification, modified Charlson Comorbidity Index [Summary Hospital-level Mortality Indicator Specification]³⁴, body mass index [BMI], index of multiple deprivation, ethnicity, year of surgery) and the aforementioned outcome measures were grouped by indication. Continuous variables were described with use of means and standard deviations (SDs) or medians and interquartile ranges (IQRs) after the inspection of data distributions. Binary and categorical data were described with use of counts and percentages. The cumulative incidence of re-revision surgery was calculated from the complement of net implant survival (1 minus Kaplan-Meier). All procedures were censored at the time of a patient's death or at the end of the study (December 31, 2019). Kaplan-Meier survival curves were presented with 95% confidence intervals (CIs) and risk tables. Mortality and serious complications were presented as percentage frequencies with 95% CIs, with a normal approximation to a Poisson distribution having been assumed. The PROM linkage rate was defined as the total of knees with a completed preoperative questionnaire linked to an rTKA divided by the total of rTKAs in the NJR. Missing data were summarized descriptively for each variable. Since the missingness mechanism was unknown, data were assumed to be missing not at random and imputation was not performed (i.e., all analyses were performed with use of available data only). Statistical analyses were performed with use of R version 4.2.1 (R Foundation for Statistical Computing). An R Shiny application is available for readers to interact with the study results (<https://shiraz-sabah.shinyapps.io/rKA-app/>).

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This study was funded by a National Institute for Health and Care Research doctoral research fellowship.

Results

A total of 24,540 first-linked rTKAs (24,540 patients) were identified. Data cleaning and linkage are illustrated in Figure 1. Baseline patient characteristics are summarized in Table I. The mean age (and SD) at the first rTKA was 69 ± 10 years. More rTKAs were performed in female patients than in male patients overall (54%; 13,332 of 24,540 rTKAs), and the

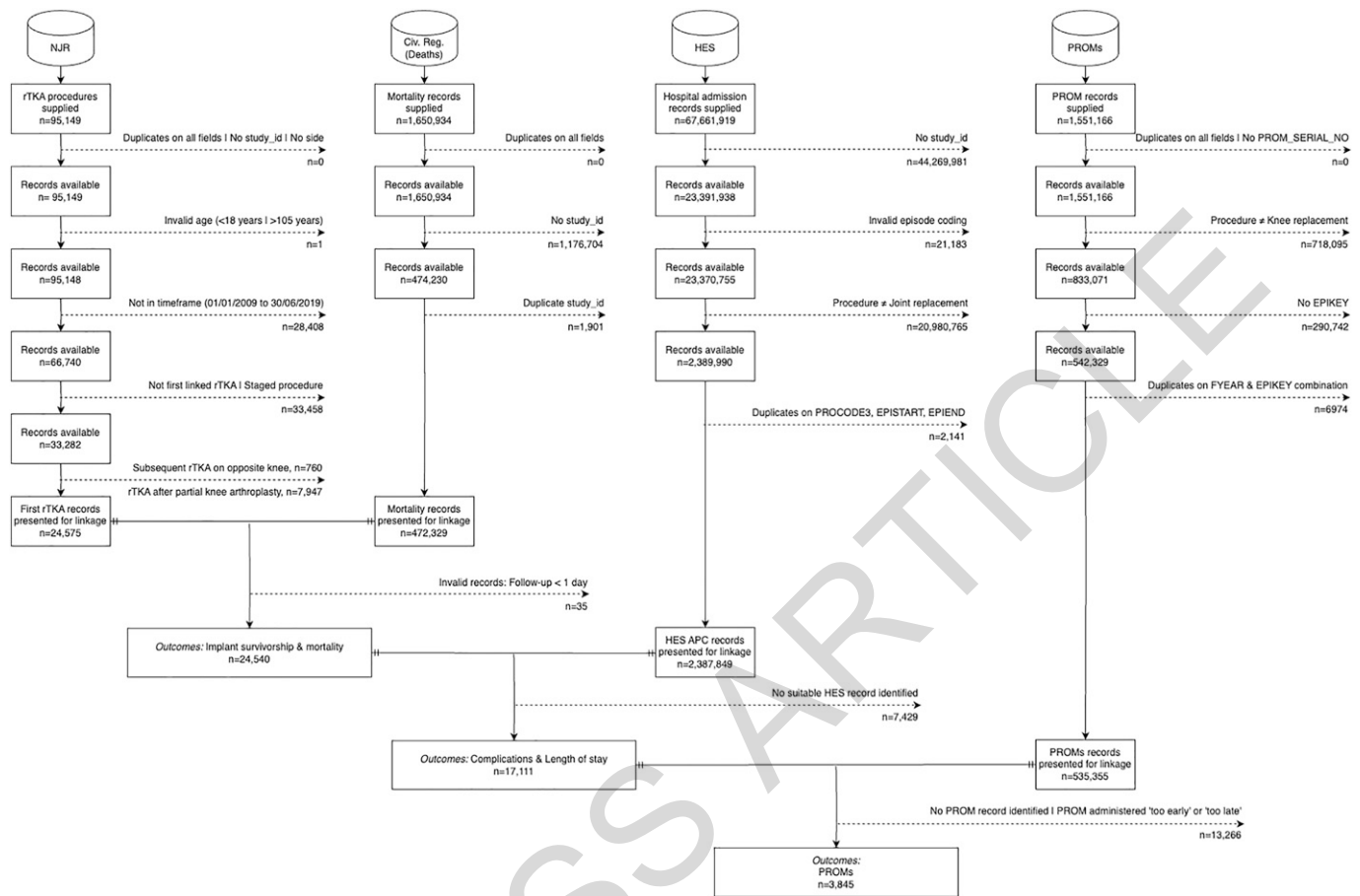


Fig. 1
Flowchart demonstrating the attrition of study records during data preparation and record linkage. Where 2 tables are joined, the attrition of records is reported for the upper left table only (NJR records). Further information on HES APC fields (EPIEND, EPIKEY, EPISTART, FYEAR, PROCODE 3) is available within a data dictionary from NHS Digital⁴².

percentages of female patients were higher for all indications except infection (42%; 2,098 of 4,937) and stiffness (47%; 599 of 1,279). Patients who underwent rTKA for fracture or infection had more severe comorbidity than those who underwent rTKA for other diagnoses. A total of 495 (53%) of 938 rTKAs that were performed for fracture and 1,983 (40%) of 4,937 rTKAs that were performed for infection were done in patients who were ASA Class 3 or higher, compared with approximately 25% of rTKAs for the other indications.

Implant Survivorship

The cumulative incidence of re-revision surgery was 7.8% (95% CI, 7.5% to 8.2%) at 2 years and 13.2% (95% CI, 12.7% to 13.7%) at 5 years postoperatively. The cumulative incidence of re-revision surgery is presented in Figure 2. Survival plots with 95% CIs and risk tables are presented for each indication individually in Appendix B. A first rTKA for infection had the highest cumulative incidence of re-revision at 2 years (16.3% [95% CI, 15.2% to 17.4%]) and 5 years (22.6% [95% CI, 21.2% to 23.9%]). A first rTKA for progressive arthritis had the lowest cumulative incidence of re-

revision at 2 years (2.7% [95% CI, 1.9% to 3.4%]) and 5 years (6.3% [95% CI, 4.9% to 7.7%]).

Mortality and Serious Medical Complications

Mortality and serious medical complications requiring hospital admission are summarized in Table II. Overall, 175 of 24,540 patients died within 90 days after rTKA (mortality rate, 0.7% [95% CI, 0.6% to 0.8%]). The highest mortality rates were observed in the fracture group (3.6% [95% CI, 2.5% to 5.1%]) and infection group (1.8% [95% CI, 1.5% to 2.2%]). Among the remaining groups, estimated mortality rates ranged from 0.0% to 0.4%.

Serious medical complications were common, with 1,286 of 17,111 patients developing ≥ 1 complication within 90 days after surgery (complication rate, 7.5% [95% CI, 7.1% to 7.9%]). The highest complication rates were found among patients who underwent rTKA for fracture (21.8% [95% CI, 17.9% to 26.3%]) or infection (12.5% [95% CI, 11.2% to 13.9%]). Acute kidney injury was the most frequent complication (469 of 17,111 patients; 2.7% [95% CI, 2.5% to 3.0%]). Lower respiratory tract infection was the second most frequent complication (429 of 17,111 patients; 2.5% [95% CI, 2.3% to 2.8%]).

TABLE I Baseline Characteristics of Patients Undergoing First rTKA by Indication for Revision

Characteristic	Overall (N = 24,540)	Infection (N = 4,937)	Malalignment (N = 603)	Loosening/ Osteolysis (N = 5,198)	Instability (N = 3,768)	Fracture (N = 938)	Progressive Arthritis (N = 2,004)	Stiffness (N = 1,279)	Unexplained Pain (N = 3,295)	Other (N = 2,518)
Age at first rTKA										
Mean and SD (yr)	69.2 ± 9.7	70.4 ± 9.7	68.8 ± 9.1	69.1 ± 9.0	68.3 ± 10.1	75.8 ± 10.5	70.2 ± 9.3	66.4 ± 9.5	67.6 ± 9.5	69.2 ± 9.7
Data missing (no. of patients)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Gender (no. of patients)										
Female	13,332 (54%)	2,098 (42%)	401 (67%)	2,772 (53%)	2,252 (60%)	752 (80%)	1,201 (60%)	599 (47%)	1,817 (55%)	1,440 (57%)
Male	11,208 (46%)	2,839 (58%)	202 (33%)	2,426 (47%)	1,516 (40%)	186 (20%)	803 (40%)	680 (53%)	1,478 (45%)	1,078 (43%)
ASA class (no. of patients)										
ASA 1	1,477 (6%)	186 (4%)	32 (5%)	324 (6%)	261 (7%)	21 (2%)	88 (4%)	118 (9%)	275 (8%)	172 (7%)
ASA 2	16,128 (66%)	2,768 (56%)	432 (72%)	3,591 (69%)	2,513 (67%)	422 (45%)	1,467 (73%)	885 (69%)	2,309 (70%)	1,741 (69%)
ASA ≥3	6,935 (28%)	1,983 (40%)	139 (23%)	1,283 (25%)	994 (26%)	495 (53%)	449 (22%)	276 (22%)	711 (22%)	605 (24%)
Charlson Comorbidity Index (no. of patients)										
0	8,066 (33%)	1,040 (21%)	241 (40%)	2,014 (39%)	1,367 (36%)	195 (21%)	701 (35%)	513 (40%)	1,180 (36%)	815 (32%)
≥1	9,045 (37%)	1,682 (34%)	248 (41%)	1,976 (38%)	1,441 (38%)	304 (32%)	770 (38%)	473 (37%)	1,288 (39%)	863 (34%)
Not specified	7,429 (30%)	2,215 (45%)	114 (19%)	1,208 (23%)	960 (25%)	439 (47%)	533 (27%)	293 (23%)	827 (25%)	840 (33%)
Body mass index										
Mean and SD (kg/m ²)	31.7 ± 6.0	31.3 ± 6.4	31.7 ± 6.3	32.2 ± 6.1	31.8 ± 6.0	31.4 ± 7.5	31.6 ± 5.4	31.2 ± 5.3	31.6 ± 5.7	31.2 ± 5.8
Data missing (no. of patients)	8,932 (36%)	2,502 (51%)	177 (29%)	1,614 (31%)	1,153 (31%)	499 (53%)	544 (27%)	384 (30%)	1,114 (34%)	945 (38%)
Ethnicity (no. of patients)										
Asian/Asian British	380 (2%)	83 (2%)	8 (1%)	84 (2%)	78 (2%)	4 (0%)	25 (1%)	16 (1%)	47 (1%)	35 (1%)
Black/Black British	259 (1%)	36 (1%)	4 (1%)	100 (2%)	55 (1%)	4 (0%)	6 (0%)	19 (1%)	19 (1%)	16 (1%)
Chinese/other	74 (0%)	13 (0%)	2 (0%)	17 (0%)	15 (0%)	2 (0%)	5 (0%)	7 (1%)	8 (0%)	5 (0%)
Mixed	61 (0%)	11 (0%)	2 (0%)	15 (0%)	13 (0%)	0 (0%)	2 (0%)	7 (1%)	7 (0%)	4 (0%)
White	15,314 (62%)	2,422 (49%)	437 (72%)	3,553 (68%)	2,466 (65%)	463 (49%)	1,347 (67%)	861 (67%)	2,250 (68%)	1,515 (60%)
Not specified	8,452 (34%)	2,372 (48%)	150 (25%)	1,429 (27%)	1,141 (30%)	465 (50%)	619 (31%)	369 (29%)	964 (29%)	943 (37%)
Index of multiple deprivation (no. of patients)										
Most deprived 20%	3,155 (13%)	508 (10%)	90 (15%)	701 (13%)	537 (14%)	94 (10%)	264 (13%)	183 (14%)	477 (14%)	301 (12%)
More deprived 20%-40%	3,232 (13%)	482 (9.8%)	95 (16%)	745 (14%)	508 (13%)	93 (10%)	266 (13%)	204 (16%)	496 (15%)	343 (14%)
Middle group	3,331 (14%)	530 (11%)	84 (14%)	783 (15%)	564 (15%)	101 (11%)	277 (14%)	196 (15%)	476 (14%)	320 (13%)
Less deprived 20%-40%	3,740 (15%)	620 (13%)	102 (17%)	894 (17%)	614 (16%)	106 (11%)	336 (17%)	200 (16%)	524 (16%)	344 (14%)
Least deprived 20%	3,386 (14%)	553 (11%)	109 (18%)	813 (16%)	523 (14%)	94 (10%)	303 (15%)	180 (14%)	466 (14%)	345 (14%)
Not specified	7,696 (31%)	2,244 (45%)	123 (20%)	1,262 (24%)	1,022 (27%)	450 (48%)	558 (28%)	316 (25%)	856 (26%)	865 (34%)
Year of surgery (no. of patients)										
2009	1,450 (6%)	253 (5%)	51 (8%)	309 (6%)	200 (5%)	29 (3%)	35 (2%)	76 (6%)	263 (8%)	234 (9%)
2010	1,681 (7%)	336 (7%)	44 (7%)	369 (7%)	236 (6%)	43 (5%)	59 (3%)	64 (5%)	318 (10%)	212 (8%)
2011	1,765 (7%)	353 (7%)	43 (7%)	382 (7%)	243 (6%)	35 (4%)	82 (4%)	94 (7%)	336 (10%)	197 (8%)
2012	2,209 (9%)	423 (9%)	54 (9%)	460 (9%)	331 (9%)	52 (6%)	141 (7%)	114 (9%)	386 (12%)	248 (10%)
2013	2,121 (9%)	403 (8%)	65 (11%)	443 (9%)	349 (9%)	56 (6%)	138 (7%)	115 (9%)	347 (11%)	205 (8%)
2014	2,415 (10%)	500 (10%)	56 (9%)	470 (9%)	363 (10%)	97 (10%)	213 (11%)	109 (9%)	341 (10%)	266 (11%)
2015	2,614 (11%)	522 (11%)	76 (13%)	542 (10%)	407 (11%)	115 (12%)	254 (13%)	129 (10%)	279 (8%)	290 (12%)
2016	2,793 (11%)	555 (11%)	52 (9%)	628 (12%)	393 (10%)	133 (14%)	306 (15%)	143 (11%)	319 (10%)	264 (10%)
2017	2,941 (12%)	611 (12%)	72 (12%)	647 (12%)	476 (13%)	126 (13%)	303 (15%)	158 (12%)	290 (9%)	258 (10%)
2018	3,009 (12%)	648 (13%)	50 (8%)	643 (12%)	481 (13%)	169 (18%)	315 (16%)	201 (16%)	272 (8%)	230 (9%)
2019	1,542 (6%)	333 (7%)	40 (7%)	305 (6%)	289 (8%)	83 (9%)	158 (8%)	76 (6%)	144 (4%)	114 (5%)

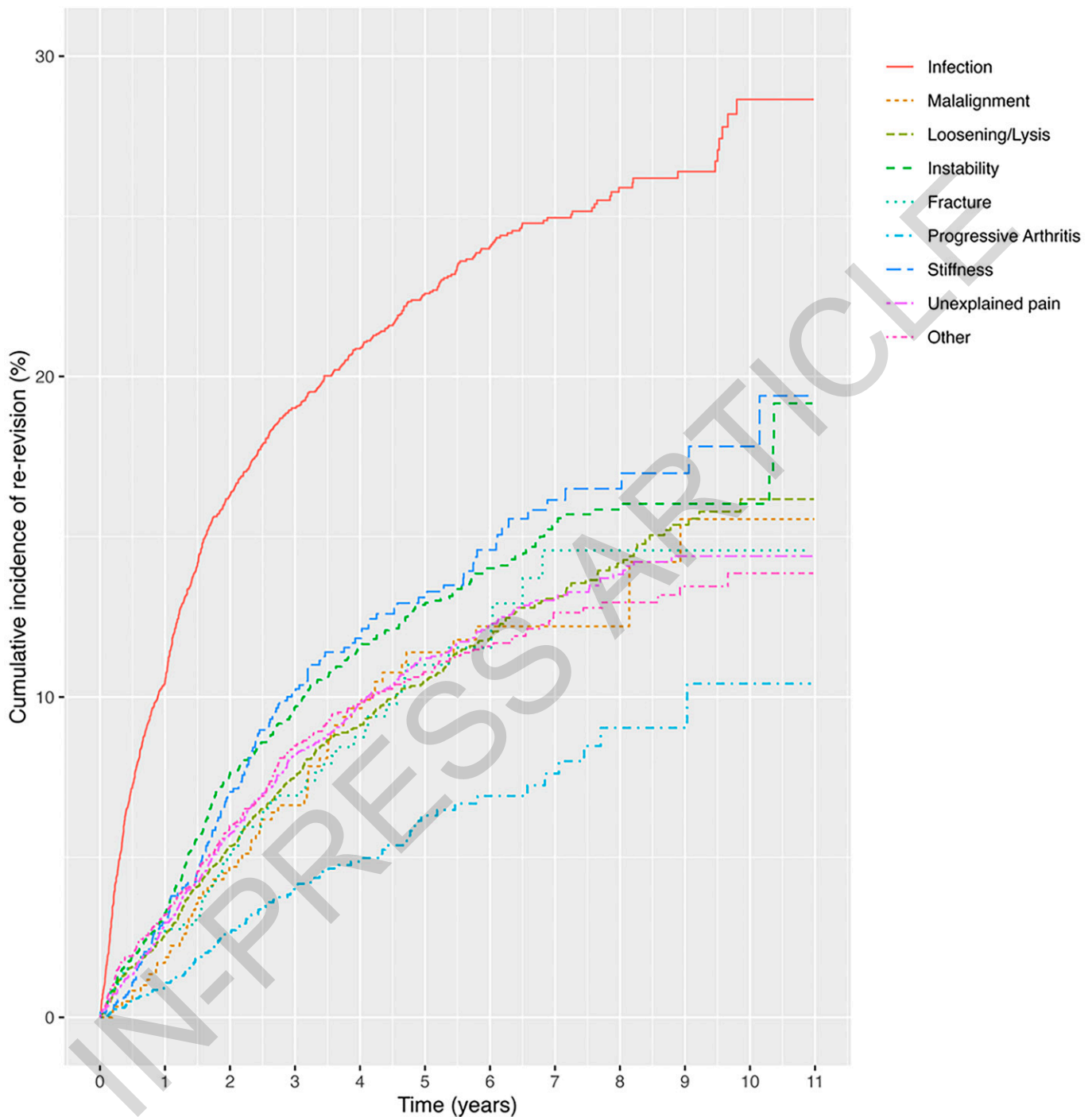


Fig. 2
The cumulative incidence of re-revision TKA by indication for first-linked rTKA. Risk tables and 95% CIs are provided in the Appendix.

PROMs

PROM data were available for 3,845 (16%) of 24,540 rTKAs (Table III, Appendix C). The infection, fracture, and progressive arthritis groups had the lowest proportions of PROM data available (~8% to 9% of rTKAs) whereas malalignment (23%) and aseptic loosening (23%) had the highest proportions. Patients who underwent rTKA for infection or fracture had the

poorest preoperative function (mean OKS, 14 ± 8 for each indication). Patients with progressive arthritis had the highest preoperative function (mean OKS, 19 ± 8). At 6 months post-rTKA, patients with progressive arthritis had the best function (mean OKS, 31 ± 10), whereas patients who underwent rTKA for malalignment (mean OKS, 24 ± 10), stiffness (mean OKS, 24 ± 11), or unexplained pain (mean OKS, 25 ± 11) had the poorest

TABLE II Multimodal Outcomes Following First rTKA by Indication for Revision

Characteristic	Indication for Revision									
	Overall	Infection	Malalignment	Loosening/ Osteolysis	Instability	Fracture	Progressive Arthritis	Stiffness	Unexplained Pain	Other
Cumulative incidence of re-revision* (%)										
2 yr postop.	7.8 (7.5 to 8.2)	16.3 (15.2 to 17.4)	4.7 (2.9 to 6.5)	5.3 (4.7 to 6.0)	7.6 (6.7 to 8.5)	5.1 (3.5 to 6.6)	2.7 (1.9 to 3.4)	7 (5.5 to 8.5)	5.7 (4.9 to 6.5)	6 (5 to 6.9)
5 yr postop.	13.2 (12.7 to 13.7)	22.6 (21.2 to 23.9)	11.4 (8.4 to 14.3)	10.5 (9.5 to 11.5)	12.9 (11.6 to 14.1)	11 (8.1 to 13.8)	6.3 (4.9 to 7.7)	13.1 (10.9 to 15.3)	11.2 (10 to 12.4)	10.8 (9.4 to 12.1)
Death within 90 d postop.										
No. of patients	175/24,540	90/4,937	2/603	20/5,198	15/3,768	34/938	1/2,004	0/1,279	6/3,295	7/2,518
Rate* (%)	0.7 (0.6 to 0.8)	1.8 (1.5 to 2.2)	0.3 (0.0 to 1.2)	0.4 (0.2 to 0.6)	0.4 (0.2 to 0.7)	3.6 (2.5 to 5.1)	0.0 (0.0 to 0.3)	0.0 (0.0 to 0.3)	0.2 (0.1 to 0.4)	0.3 (0.1 to 0.6)
Complications										
Any serious medical complication										
No. of patients	1,286/17,111	340/2,722	30/489	270/3,990	206/2,808	109/499	63/1,471	46/986	134/2,468	88/1,678
Rate* (%)	7.5 (7.1 to 7.9)	12.5 (11.2 to 13.9)	6.1 (4.1 to 8.8)	6.8 (6.0 to 7.6)	7.3 (6.4 to 8.4)	21.8 (17.9 to 26.3)	4.3 (3.3 to 5.5)	4.7 (3.4 to 6.2)	5.4 (4.5 to 6.4)	5.2 (4.2 to 6.5)
Acute kidney injury										
No. of patients	469/17,111	171/2,722	9/489	90/3,990	62/2,808	35/499	22/1,471	9/986	42/2,468	29/1,678
Rate* (%)	2.7 (2.5 to 3.0)	6.3 (5.4 to 7.3)	1.8 (0.8 to 3.5)	2.3 (1.8 to 2.8)	2.2 (1.7 to 2.8)	7.0 (4.9 to 9.8)	1.5 (0.9 to 2.3)	0.9 (0.4 to 1.7)	1.7 (1.2 to 2.3)	1.7 (1.2 to 2.5)
Deep vein thrombosis										
No. of patients	84/17,111	21/2,722	2/489	16/3,990	11/2,808	6/499	4/1,471	9/986	9/2,468	6/1,678
Rate* (%)	0.5 (0.4 to 0.6)	0.8 (0.5 to 1.2)	0.4 (0.0 to 1.5)	0.4 (0.2 to 0.7)	0.4 (0.2 to 0.7)	1.2 (0.4 to 2.6)	0.3 (0.1 to 0.7)	0.9 (0.4 to 1.7)	0.4 (0.2 to 0.7)	0.4 (0.1 to 0.8)
Lower respiratory tract infection										
No. of patients	429/17,111	92/2,722	9/489	93/3,990	73/2,808	46/499	22/1,471	12/986	50/2,468	32/1,678
Rate* (%)	2.5 (2.3 to 2.8)	3.4 (2.7 to 4.1)	1.8 (0.8 to 3.5)	2.3 (1.9 to 2.9)	2.6 (2.0 to 3.3)	9.2 (6.7 to 12.3)	1.5 (0.9 to 2.3)	1.2 (0.6 to 2.1)	2.0 (1.5 to 2.7)	1.9 (1.3 to 2.7)
Myocardial infarction										
No. of patients	38/17,111	10/2,722	0/489	14/3,990	4/2,808	1/499	4/1,471	0/986	2/2,468	3/1,678
Rate* (%)	0.2 (0.2 to 0.3)	0.4 (0.2 to 0.7)	0.0 (0.0 to 0.8)	0.4 (0.2 to 0.6)	0.1 (0.0 to 0.4)	0.2 (0.0 to 1.1)	0.3 (0.1 to 0.7)	0.0 (0.0 to 0.4)	0.1 (0.0 to 0.3)	0.2 (0.0 to 0.5)
Pulmonary embolism										
No. of patients	142/17,111	32/2,722	2/489	31/3,990	23/2,808	18/499	3/1,471	8/986	17/2,468	8/1,678
Rate* (%)	0.8 (0.7 to 1.0)	1.2 (0.8 to 1.7)	0.4 (0.0 to 1.5)	0.8 (0.5 to 1.1)	0.8 (0.5 to 1.2)	3.6 (2.1 to 5.7)	0.2 (0.0 to 0.6)	0.8 (0.4 to 1.6)	0.7 (0.4 to 1.1)	0.5 (0.2 to 0.9)
Stroke										
No. of patients	42/17,111	9/2,722	1/489	8/3,990	5/2,808	3/499	3/1,471	3/986	8/2,468	2/1,678
Rate* (%)	0.2 (0.2 to 0.3)	0.3 (0.2 to 0.6)	0.2 (0.0 to 1.1)	0.2 (0.1 to 0.4)	0.2 (0.1 to 0.4)	0.6 (0.1 to 1.8)	0.2 (0.0 to 0.6)	0.3 (0.1 to 0.9)	0.3 (0.1 to 0.6)	0.1 (0.0 to 0.4)
Urinary tract infection										
No. of patients	374/17,111	92/2,722	8/489	68/3,990	71/2,808	50/499	20/1,471	13/986	26/2,468	26/1,678
Rate* (%)	2.2 (2.0 to 2.4)	3.4 (2.7 to 4.1)	1.6 (0.7 to 3.2)	1.7 (1.3 to 2.2)	2.5 (2.0 to 3.2)	10.0 (7.4 to 13.2)	1.4 (0.8 to 2.1)	1.3 (0.7 to 2.3)	1.1 (0.7 to 1.5)	1.5 (1.0 to 2.3)
Length of stay† (days)	5 (3 to 8)	13 (8 to 20)	4 (3 to 7)	5 (3 to 7)	5 (3 to 7)	9 (4 to 19)	3 (2 to 4)	5 (3 to 7)	4 (3 to 6)	4 (3 to 6)

*The 95% CI is shown in parentheses. †The values are given as the median, with the first and third quartiles in parentheses.

TABLE III Patient-Reported Outcome Measures Following First rTKA by Indication for Revision*

Characteristic	Indication for Revision									
	Overall	Infection	Malalignment	Loosening/ Osteolysis	Instability	Fracture	Progressive Arthritis	Stiffness	Unexplained Pain	Other
PROM records linked† (no. of patients)	3,845/24,540 (16%)	432/4,937 (9%)	137/603 (23%)	1,200/5,198 (23%)	753/3,768 (20%)	71/938 (8%)	176/2,004 (9%)	252/1,279 (20%)	539/3,295 (16%)	285/2,518 (11%)
OKS										
Preop.										
Score‡ (points)	16.5 ± 8.0	14.4 ± 8.2	15.5 ± 7.3	16.9 ± 8.0	16.5 ± 7.9	13.8 ± 7.9	19.1 ± 8.2	16.8 ± 7.8	16.5 ± 7.6	17.6 ± 8.3
Data missing (no. of patients)	59 (2%)	7 (2%)	1 (1%)	21 (2%)	13 (2%)	2 (3%)	5 (3%)	1 (0%)	5 (1%)	4 (1%)
Postop.										
Score‡ (points)	27.6 ± 11.4	26.0 ± 11.7	24.0 ± 10.3	30.3 ± 11.0	26.6 ± 11.2	29.5 ± 10.8	31.2 ± 10.5	24.2 ± 11.3	25.0 ± 11.2	28.4 ± 11.8
Data missing (no. of patients)	83 (2%)	11 (3%)	0 (0%)	25 (2%)	16 (2%)	2 (3%)	2 (1%)	9 (4%)	12 (2%)	6 (2%)
Change										
Score‡ (points)	11.0 ± 10.6	11.4 ± 11.0	8.6 ± 9.5	13.3 ± 10.4	10.1 ± 10.1	15.9 ± 11.7	11.8 ± 9.9	7.4 ± 10.2	8.6 ± 10.1	10.8 ± 11.0
Data missing (no. of patients)	132 (3%)	18 (4%)	1 (1%)	41 (3%)	25 (3%)	3 (4%)	7 (4%)	10 (4%)	17 (3%)	10 (4%)
Responder (no. of patients)										
Yes	2,477 (64%)	282 (65%)	84 (61%)	861 (72%)	478 (63%)	52 (73%)	117 (66%)	121 (48%)	299 (55%)	183 (64%)
No	1,207 (31%)	125 (29%)	49 (36%)	291 (24%)	245 (33%)	16 (23%)	50 (28%)	121 (48%)	220 (41%)	90 (32%)
Data missing	161 (4%)	25 (6%)	4 (3%)	48 (4%)	30 (4%)	3 (4%)	9 (5%)	10 (4%)	20 (4%)	12 (4%)
EQ-5D utility										
Preop.										
Utility§ (points)	0.189 (0.030, 0.620)	0.159 (−0.016, 0.620)	0.159 (0.030, 0.620)	0.159 (0.055, 0.656)	0.293 (0.042, 0.656)	0.159 (−0.070, 0.569)	0.587 (0.101, 0.691)	0.293 (0.011, 0.620)	0.159 (−0.003, 0.620)	0.208 (0.055, 0.691)
Data missing (no. of patients)	227 (6%)	27 (6%)	8 (6%)	61 (5%)	46 (6%)	5 (7%)	15 (9%)	9 (4%)	34 (6%)	22 (8%)
Postop.										
Utility§ (points)	0.691 (0.516, 0.760)	0.620 (0.293, 0.760)	0.620 (0.159, 0.691)	0.691 (0.587, 0.796)	0.620 (0.516, 0.743)	0.689 (0.516, 0.691)	0.691 (0.587, 0.796)	0.620 (0.293, 0.726)	0.620 (0.186, 0.691)	0.691 (0.478, 0.796)
Data missing (no. of patients)	225 (6%)	22 (5%)	5 (4%)	71 (6%)	53 (7%)	6 (8%)	9 (5%)	16 (6%)	30 (6%)	13 (5%)
Change										
Utility§ (points)	0.194 (0.000, 0.532)	0.263 (0.000, 0.554)	0.058 (0.000, 0.472)	0.275 (0.000, 0.601)	0.140 (0.000, 0.532)	0.431 (0.156, 0.626)	0.140 (0.000, 0.450)	0.104 (−0.008, 0.532)	0.123 (0.000, 0.532)	0.150 (0.000, 0.532)
Data missing (no. of patients)	428 (11%)	47 (11%)	13 (9%)	125 (10%)	90 (12%)	10 (14%)	23 (13%)	24 (10%)	61 (11%)	35 (12%)
Patient satisfaction (no. of patients)										
Excellent	483 (13%)	46 (11%)	13 (9%)	172 (14%)	97 (13%)	10 (14%)	26 (15%)	26 (10%)	43 (8%)	50 (18%)
Very good	948 (25%)	94 (22%)	28 (20%)	363 (30%)	174 (23%)	20 (28%)	62 (35%)	47 (19%)	101 (19%)	59 (21%)
Good	1,031 (27%)	129 (30%)	36 (26%)	354 (30%)	192 (25%)	29 (41%)	34 (19%)	54 (21%)	134 (25%)	69 (24%)
Fair	852 (22%)	95 (22%)	41 (30%)	191 (16%)	187 (25%)	8 (11%)	38 (22%)	63 (25%)	162 (30%)	67 (24%)
Poor	458 (12%)	58 (13%)	17 (12%)	95 (8%)	92 (12%)	3 (4%)	15 (9%)	55 (22%)	87 (16%)	36 (13%)
Missing	73 (2%)	10 (2%)	2 (1%)	25 (2%)	11 (1%)	1 (1%)	1 (1%)	7 (3%)	12 (2%)	4 (1%)
Perceived success (no. of patients)										
Much better	1,825 (47%)	201 (47%)	51 (37%)	687 (57%)	329 (44%)	41 (58%)	96 (55%)	88 (35%)	202 (37%)	130 (46%)
A little better	864 (22%)	87 (20%)	40 (29%)	244 (20%)	178 (24%)	16 (23%)	34 (19%)	60 (24%)	139 (26%)	66 (23%)
About the same	432 (11%)	36 (8%)	17 (12%)	98 (8%)	97 (13%)	8 (11%)	19 (11%)	43 (17%)	80 (15%)	34 (12%)
A little worse	342 (9%)	53 (12%)	16 (12%)	88 (7%)	70 (9%)	3 (4%)	13 (7%)	19 (8%)	57 (11%)	23 (8%)
Much worse	314 (8%)	44 (10%)	10 (7%)	63 (5%)	67 (9%)	2 (3%)	12 (7%)	37 (15%)	52 (10%)	27 (9%)
Missing	68 (2%)	11 (3%)	3 (2%)	20 (2%)	12 (2%)	1 (1%)	2 (1%)	5 (2%)	9 (2%)	5 (2%)

*Except where specified, counts and percentages are based on the total number of linked PROM records for that category (not the total number of first rTKAs in the NJR). †Counts and percentages are based on the total number of first rTKAs in the NJR. ‡The values are given as the mean and the standard deviation. §The values are given as the median, with the first and third quartiles in parentheses.

function. The group that underwent rTKA for fracture had the highest proportion of responders (52 of 71 patients, including those with missing data; 73% [95% CI, 62% to 82%]), whereas the stiffness group (121 of 252 patients, including those with missing data; 48% [95% CI, 42% to 54%]) and unexplained-pain group (299 of 539 patients, including those with missing data; 55% [95% CI, 51% to 60%]) had the lowest proportions.

LOS

The LOS is summarized as the CIPS in Table II. Additional data on Finished Consultant Episodes and provider spells are provided in Appendix D. The median LOS was 5 days (first quartile to third quartile [Q1 to Q3], 3 to 8 days). The longest LOS was in the infection group (median, 13 days; Q1 to Q3, 8 to 20 days), followed by that in the fracture group (median, 9 days; Q1 to Q3, 4 to 19 days).

Discussion

Patients undergoing a first rTKA for infection were at a high risk for re-revision surgery (~1 in 6 at 2 years postoperatively; ~1 in 4 at 5 years postoperatively). The rate of re-revision surgery at 2 years was much lower for patients undergoing rTKA for other indications, ranging from 1 in 13 for instability to 1 in 37 for progressive arthritis. The rate of death within 90 days was high for patients undergoing surgery for fracture (~1 in 28) and infection (~1 in 56) but was ≤1 in 250 for patients treated for any of the other diagnoses. The rate of a serious medical complication requiring admission to a hospital was highest following rTKA for fracture (~1 in 5) and infection (~1 in 8) but was ≤1 in 14 for the other indications. Acute kidney injury (1 in 37) and lower respiratory tract infection (1 in 40) were the most frequently observed complications.

Deere et al.³⁵ recently investigated implant survivorship for first and re-revision rTKAs utilizing the NJR. Their reported rates of revision following first rTKAs (~7% at 2 years and ~12% at 5 years) were similar to ours and they found high rates of additional surgery following second and third rTKA procedures. We previously reported that the rates of mortality and serious complications following first rTKAs for elective indications were comparable with those following pTKAs, whereas rTKAs for urgent indications (such as infection and fracture) had poorer outcomes than both elective rTKAs and pTKAs¹⁰. We reproduced these findings in the present study with use of more contemporary data, describing patient subgroups in greater detail by utilizing surgeon-coded diagnoses recorded in the NJR. We also included additional domains of outcome (joint function, quality of life) in the present study through record linkage to NHS PROMs. This approach revealed differences in outcomes among elective, aseptic indications for rTKA. For example, approximately half of the patients who underwent rTKA for stiffness (48%) and unexplained pain (55%) reported a clinically meaningful improvement in joint function, compared with 73% of those who underwent rTKA for fracture and 72% of those who underwent rTKA for aseptic loosening.

In the present study, we analyzed routinely collected data from the NHS and private providers of rTKA in the U.K. over a 10-year study period. The NJR is a mature registry and has been


shown to have excellent data quality^{22,23}, and HES APC and the Civil Registrations of Death provide near universal coverage of emergency hospital admissions and deaths in the U.K. The present study had limitations common to other observational research, including the limited information available within each data set. We stratified rTKAs by indication for surgery but did not control for confounding by indication. As such, the outcomes observed may be a result of differences in patient characteristics among the groups. The analysis was not exhaustive, and there may be other sources of heterogeneity that could be investigated in the future, such as differences in outcomes related to the type of components revised or between acute and chronic infection. The rates of serious medical complications are an underestimate of the true rates as they represent only patients admitted to secondary care. There may be large discrepancies in complication rates for conditions commonly managed in primary care or in outpatient departments. A gold standard for estimating postoperative complications does not exist, but recent studies have utilized a similar methodology to our own^{36,37}. A high record attrition impacted the analysis of PROMs, such that PROM data were available for only ~1 in 6 rTKAs. This attrition was exacerbated by the requirement to link PROMs indirectly to the NJR via HES APC. Less record attrition may be possible in the future when the Master Person Service identifier is available from NHS Digital³⁸. The rate of PROM attrition was particularly high for the infection and fracture groups. Although the PROM questionnaires returned by these groups demonstrated that a high proportion of patients responded to treatment and that there were large improvements in health-related quality of life, there is clear selection bias: patients who died within 6 months after surgery would not have returned a PROM questionnaire, and those who experienced a serious complication may have been less likely to have returned a PROM questionnaire.

The information from this study can be utilized to support the informed consent of patients undergoing rTKA and to set expectations for those patients. Patients with infection or fracture experienced high rates of adverse events (re-revision surgery, death, and serious medical complications). A priority for future research is to investigate the risk factors that can be modified to improve outcomes. The data analyzed here predate the extension of the Best Practice Tariff in the U.K. to include distal femoral and periprosthetic fractures³⁹. Patients with stiffness and unexplained pain accounted for approximately one-fifth of first rTKAs performed during the study period. For approximately half of these patients, the observed improvements in PROM scores were small and clinically unimportant, whereas serious medical complications were comparable to those associated with other elective, aseptic indications. From the perspective of the NHS, it is important to establish the patient groups for whom these procedures are (or are not) cost-effective. Recent evidence suggests that more attention may need to be given to nonoperative treatment. The Support and Treatment After Replacement (STAR) care pathway was found to be more clinically effective and cost-effective than usual care for patients with persistent pain at 3 months following pTKA⁴⁰. The natural history of pain following pTKA also appears to be one of improvement over time, with 1 study demonstrating that two-thirds of patients recovered

during the first 4 years postoperatively⁴¹. As such, we caution against early rTKA for unexplained pain.

In conclusion, this study demonstrated large differences in patient-relevant outcomes among different indications for first rTKAs. This information can be used to support the informed consent of, and to help set expectations for, patients undergoing a first rTKA.

Appendix

 Supporting material provided by the authors is posted with the online version of this article as a data supplement at [jbjs.org \(http://links.lww.com/JBJS/H646\)](http://links.lww.com/JBJS/H646). ■

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