Patient reported function and quality of life following revision total knee arthroplasty: Analysis of 10,727 patients from the NHS PROMs programme

1. Shiraz A. Sabah, 0000-0003-2401-1372 – shiraz.sabah@ndorms.ox.ac.uk
2. Abtin Alvand, 0000-0001-6069-978X – abtin.alvand@ndorms.ox.ac.uk
3. Ruth Knight, 0000-0001-6810-2845 - ruth.knight@csm.ox.ac.uk
4. David J. Beard, 0000-0001-7884-6389 – david.beard@ndorms.ox.ac.uk
5. Andrew J. Price, 0000-0002-4258-5866 – andrew.price@ndorms.ox.ac.uk

Institutions

1. Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford
2. Nuffield Orthopaedic Centre, Oxford
3. Oxford Clinical Trials Research Unit, Centre for Statistics in Medicine, Nuffield Department of Orthopaedics Rheumatology and Musculoskeletal Sciences, University of Oxford

Initials, surnames, appointments, and highest academic degree

SA Sabah: DPhil Student, BSc FRCS(Orth) 1
A Alvand: Consultant Orthopaedic Surgeon, DPhil FRCS(Orth) 1,2
R Knight: Senior Medical Statistician, MMath, PhD 3
DJ Beard: Professor of Musculoskeletal and Surgical Science, DPhil, FRCS (hon) 1
AJ Price: Professor of Orthopaedics, DPhil FRCS(Orth) 1,2

Correspondence address

Mr Shiraz Sabah (shiraz.sabah@ndorms.ox.ac.uk)
Price Knee Research Group, Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences (NDORMS)
Botnar Research Centre, Oxford, OX3 7LD

Author contributions

All authors made substantial contributions to the work:

SAS: Conception and design, Analysis and interpretation, Drafting, Final approval, Obtaining funding
AA: Conception and design, Drafting, Final approval
RK: Analysis and interpretation, Statistical expertise, Drafting, Final approval
DJB: Analysis and interpretation, Statistical expertise, Drafting, Final approval
AJP: Conception and design, Analysis and interpretation, Drafting, Final approval, Obtaining funding

Role of the funding source

Mr. Shiraz Sabah has received funding from the Royal College of Surgeons One-Year Fellowship and Rosetrees Trust. Neither funding source had any role in the design or conduct of the study.

Competing interests statement

There are no conflicts of interest related to this work. AA and AJP have received speaker bureau fees from Zimmer-Biomet and DePuy Synthes outside of the submitted work.

Data statement

All data for this study is available within the public domain on the NHS Digital PROMS website and is regularly updated (11). Statistical code is available on request.

Acknowledgements

We would like to acknowledge all of the patients who contributed data to the NHS PROMs programme over the study period.

Word count = 3428 words

Patient reported function and quality of life following revision total knee arthroplasty: Analysis of 10,727 patients from the NHS PROMs programme

Abstract

Aims

To investigate changes in patient-reported outcomes measures (PROMs) following revision total knee arthroplasty (rTKA).

Patients and Methods

10,727 patients undergoing elective rTKA were recruited from the UK NHS PROMs dataset from 2013 to 2019. PROMs were collected at baseline and six months to assess joint function (Oxford Knee Score, OKS) and quality of life (EQ-5D). Associations to change in OKS (COKS) were investigated through multiple linear regression.

Results

The mean COKS was 12.4 (SD 10.7) points. 6776/10329 (65.6%) patients demonstrated increase in OKS above the minimal important change (MIC) of 7.5 points. The median change in EQ-5D utility was 0.227 (interquartile range 0.000 to 0.554). 4917/9279 (53.0%) patients achieved a composite endpoint of improvement greater than MIC for joint function and 'better' QoL according to Paretian analysis. 7477/10727 (69.7%) patients reported satisfaction with rTKA. 7947/10727 (74.1%) patients felt surgery was a success. 4888/10632 (46.0%) patients reported one or more adverse events. Higher pre-operative OKS was

associated with lower COKS (coefficient -0.63 [95% CI -0.67 to -0.60]). Other factors associated with lower COKS were post-operative complication(s), age under 60 years, longer duration of knee problems, patients who identified as disabled, problems in anxiety/depression and self-care dimensions of EQ-5D, comorbid conditions (circulatory problems, diabetes and depression) and earlier year of procedure in dataset.

Conclusion

Two-thirds of patients experienced a meaningful improvement in joint function after rTKA. However, there was a high frequency of patient-reported complications. These findings may enable better informed discussion of the risks and benefits of discretionary rTKA.

Key words

Total knee arthroplasty

Reoperation

Patient reported outcome measures

Health-related quality of life

Introduction

A revision total knee arthroplasty (rTKA) is a procedure to replace, modify or washout a joint arthroplasty that is no longer functioning correctly (1). In the United Kingdom, around 6000 rTKAs are performed each year (1). These are among the most expensive (2) and high-risk procedures performed in elective orthopaedics. The requirement for rTKA is expected to rise sharply over the next decade (3). Whilst some rTKA procedures are urgent and non-discretional, such as those performed for prosthetic joint infection or fracture, the majority of procedures are elective, where the goal of surgery is to improve pain, function and quality of life (1).

The National Health Service (NHS) Patient Reported Outcome Measures (PROMs) programme has routinely collected data on elective, primary and revision knee arthroplasty procedures since April 2009 (4). Pain and function related to the knee joint during activities of daily living are recorded using the Oxford Knee Score (OKS) (5), whilst general health is evaluated with the EuroQol 5-dimension score (EQ-5D-3L) (6). These data have been used to provide detailed information on the patterns of clinical improvement following primary knee arthroplasty (7–9). However, few studies have investigated these patterns for revision procedures. As a result, the information available to patients to weigh up the risks and benefits of rTKA as part of a shared decision-making process is limited (10). In addition, this restricts the ability to use PROM data for secondary purposes – such as clinical effectiveness or management of health care providers (11).

The aims of this study were: (i) to investigate changes in joint-specific function following revision knee arthroplasty, (ii) to characterise pre- and post-operative factors associated to change in joint-specific function and (iii) to investigate the proportion of patients achieving a clinically meaningful improvement in joint function following revision knee arthroplasty.

Patients and Methods

Ethical approval was not required as this study analysed de-identified, patient-level data available within the public domain. Study reporting follows the RECORD statement (12).

Study dataset

Participants were recruited from the NHS PROMs programme from 1st April 2013 to 31st March 2019. This dataset records information from PROM questionnaires administered pre-operatively and at six months following surgery. Revision knee arthroplasty procedures were identified from the 'Revision Flag' field. This field is linked to a list of Office of Population Censuses and Surveys Classification of Surgical Operations and Procedures (OPCS-4) codes identifying revision knee arthroplasty procedures in the Hospital Episodes Statistics (HES) dataset (Appendix Table 1). This linkage is performed centrally by NHS Digital and detailed diagnostic and procedure codes or other routine care data (such as length of stay) are not available from this extract. The study dataset included only patients who returned both pre- and post-operative PROM questionnaires, and provided informed consent. The PROM participation rate for this sample is estimated at 34.2% (13).

Outcome measures

The NHS PROMs questionnaires were originally designed to investigate a priori hypotheses on risk factors for good and bad outcome after joint arthroplasty. In addition to patient demographics, the pre-operative questionnaire collects data on the need for assistance to complete the questionnaire, living arrangements, duration of knee problems, self-report

comorbidities and perceived disability. Joint-specific function is recorded using the Oxford Knee Score (OKS) (5), which is a validated, twelve Likert item, self-report instrument that reports knee pain and function over the preceding four weeks. The best score is 48, and the worst score is zero. Health-related quality of life is recorded using the EQ-5D 3-level score (6), which analyses five dimensions (mobility, self-care, usual activities, pain/discomfort and anxiety/depression) each rated from 1 (no problems) to 3 (severe problems). The EQ-5D profile is converted to a utility for the UK population, where best health is represented by 1 and worst health by -0.59. A health state of zero is considered to be equivalent to death. Patients also completed a visual analogue scale to rate their overall health, ranging from 100 (best) to 0 (worst). The post-operative questionnaire includes OKS and EQ-5D instruments, together with questions on complications, satisfaction and perceived success of surgery. To assess satisfaction, patients were asked: *"How would you describe the results of your operation?" Response: Excellent/Very Good/Good/Fair/Poor*. We defined dissatisfaction by responses of 'Fair' or 'Poor'. To investigate the perceived success of surgery, patients were asked*: "Overall, how are the problems now in the knee on which you had surgery, compared to before your operation?" Response: Much better/A little better/About the same/A little worse/Much worse*. We defined perceived success by responses of 'Much better' and 'A little better'.

Statistical analysis

Baseline demographics and other categorical data were described using counts with percentage frequency. Continuous variables were described using means and standard deviations or medians and interquartile ranges after visual examination of data distributions.

The primary outcome measure was the change in the Oxford Knee Score (COKS) which was calculated as the difference between the OKS at six months and the OKS at baseline. Kernel density plots were used to graphically summarise pre- and post-operative OKS and EQ-5D using the *ggplot2* package in R. Patients were classified as having achieved a minimal important change (MIC) in the OKS if they demonstrated an improvement of 7.5 points or more (13). The change in health-related quality of life was evaluated using the EQ-5D. This was calculated as the difference between the EQ-5D utility at six months and the EQ-5D utility at baseline. This had a non-normal distribution, so was summarised using medians and IQRs. Since interpretation of the change in utility can be limited by the need to compare across health care dimensions, a Paretian Classification of Health Change is also presented (14). This system classifies patients as better off, worse off, the same or non-comparable. A health profile was 'better off' if it improved in at least one dimension and was no worse in any other dimension; 'worse off' if it worsened in one dimension and was no better in any other dimension; 'the same' if there was no change in any dimension; and 'non-comparable' if there was mixed change for improvement and deterioration among dimensions (14). Finally, a composite endpoint was defined to calculate the proportion of patients who reported a meaningful improvement in joint-specific function (defined as a COKS greater than the MIC) and QoL (defined as Pareto 'better off').

The relationship between change in the Oxford Knee Score (COKS) at six months, pre-operative patient factors and early post-operative complications was explored. The factors explored were: (i) age (<60/ 60-69/ 70-79/ ≥80); (ii) gender (male/ female); (iii) year of surgery (2013-4/ 2014-5/ 2015-6/ 2016-7/2017-8/ 2018-9); (iv) symptom period (<1 year/ 1-5 years/ 6-10 years/ >10 years); (v) living arrangements (with partner, spouse, family or friends/ alone/

nursing home or facility/ other); (vi) perceived disability (yes/ no); (vii) self-reported comorbidities - arthritis, cancer, circulation, depression, diabetes, heart disease, high blood pressure, kidney disease, liver disease, lung disease, nervous system disorder, stroke (yes/ no, for each comorbidity); (viii) total number of comorbidities (0/1/2/3+); (ix) each dimension of EQ-5D-3L (mobility, self-care, usual activities, pain/discomfort, anxiety/depression); (x) baseline OKS; (xi) self-reported complications - further surgery, hospital readmission, wound healing problems, urinary tract infection, drug reaction, bleeding problems (yes/ no, for each complication). These variables all met with a priori hypotheses or existing evidence from primary or revision knee arthroplasty. Pairwise correlations between each predictor showed no evidence for collinearity. A backwards stepwise selection approach with a probability for removal of 0.05 was used to investigate the appropriate linear regression model. Coefficients from the selected model are presented with 95% confidence intervals and associated p-values. The analysis was performed for complete cases only, with missing data presented descriptively, since the missingness mechanism was unknown. Statistical analyses were performed using Stata (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.) and R version 3.6.2.

Results

Study population

10,727 patients (49.6% female, 44.3% male, 6.0% gender not specified) were available for analysis. Patient demographics and other baseline information are summarised in Table 1. The most frequent age-band was 70-79 years (37.3% of patients). 87.2% of patients reported at least one comorbidity, with 25.0% reporting 3 or more comorbidities. The most frequent self-reported comorbidities were arthritis (70.6%), high blood pressure (43.8%), diabetes (14.3%), and depression (12.0%). 66.0% of patients reported that they considered themselves to be disabled prior to revision surgery.

Patient-reported outcome measures

PROM data are summarised in Table 2. Complete Oxford Knee Scores were available for 10,329 patients. The OKS prior to revision surgery was relatively normally distributed, with a slight right skew (Figure 1). The mean pre-revision OKS was 16.6 (SD 8.1) points. The post-revision OKS had a left skew, with mean score 29.0 (SD 11.4) points. The mean change in OKS (COKS) was 12.4 (SD 10.7) points. 6776/10329 (65.6%) patients demonstrated increase in OKS above the minimal important change of 7.5 points.

Complete EQ-5D measurements were available for 9,549 patients. The EQ-5D utility was not normally distributed pre- or post-revision (Figure 2). The median EQ-5D utility was 0.260 (IQR 0.055 to 0.691) pre-revision and 0.691 (IQR 0.516 to 0.796) post-revision, with the median change in EQ-5D 0.227 (IQR 0.000 to 0.554). Paretian analysis found that 6033 (63.2%) of

patients were ‘better off’, 1233 (12.9%) were ‘worse off’, 1276 (13.4%) were ‘the same’, and 1007 (10.5%) were ‘non-comparable’. Complete EQ-VAS measurements were present for 9143 patients, with mean pre-revision score 63.8 (SD 22.1) and post-revision score 67.0 (SD 21.2), giving a change score of 3.2 (SD 23.7).

Data for the composite endpoint, meaningful change in joint function and QoL, was available for 9279 patients. 4917 (53.0%) patients reported improvement in OKS greater than the MIC and were also classified as ‘better off’ on Paretian analysis.

Success and Satisfaction

7477 (69.7%) patients reported that they were satisfied with revision knee arthroplasty at six months (rating the results of the operation as ‘Good’, ‘Very good’ or ‘Excellent’). 3067 (28.6%) patients were dissatisfied and 1.7% of responses were missing.

7947 (74.1%) patients reported that revision knee arthroplasty was a success (rating the problems in their knee now as ‘Much better’ or ‘A little better’ compared to before surgery). 1072 (10.0%) patients reported the problems were ‘About the same’. 1531 (14.3%) patients reported that problems with their knee were worse following revision surgery, and 1.7% of responses were missing.

Post-operative complications

4888/10632 (46.0%) patients reported experiencing at least one adverse event after surgery. The reported complications in order of frequency were wound problems (18.7%), hospital

readmission (13.8%), bleeding (13.7%), urinary problems (13.0%), drug reaction (12.3%), and further surgery (11.7%).

Multiple linear regression

A multiple linear regression model is presented in Table 3 and Figure 3. 7220 patients had complete data and were included in the final model, whilst 3507 patients were excluded. The population included in the model appeared to be representative of population as a whole at baseline. However, we did note that baseline EQ-5D utility was higher for patients with complete data than for excluded patients. Characteristics of patients included or excluded from the final regression model are provided for reference in a supplemental table (Appendix Table 2). Higher pre-operative OKS was a significant predictor of lower COKS. For each 1-point increase in pre-operative OKS, COKS was -0.63 (95% CI -0.67 to -0.60) points lower. Each year of surgery after 2013-4, except for 2016-7 ($p=0.06$), was associated with higher COKS compared with 2013-4. All age groups demonstrated significantly better COKS than patients aged less than 60 years (all $p<0.001$). The association for patients aged over 80 years had greatest magnitude (coefficient 3.86 [95% CI 2.99 to 4.73]). Self-reported disability (coefficient -3.01 [-3.53 to -2.50]) was associated with lower COKS ($p<0.001$). Patients who reported comorbidities of circulatory problems ($p<0.001$), depression ($p=0.002$) and/or diabetes ($p=0.004$) experienced lower COKS than those without each comorbidity. EQ-5D Anxiety/Depression and Self-Care dimensions were associated with COKS with increasing severity of pre-operative problems related to lower COKS (all $p<0.001$). All complications except post-operative bleeding were included in the final model and were associated to lower COKS, with the largest association for further surgery (coefficient -4.38 [-5.22 to -3.53]).

Discussion

Main findings

This study found that two-thirds of patients (65.6%) achieved a clinically meaningful improvement in joint function after elective revision total knee arthroplasty. However, only half of all patients (53.0%) achieved a composite endpoint of a clinically meaningful improvement in joint function following surgery and 'better' health-related quality of life according to Paretian analysis. Revision surgery had a high patient-reported complication rate of 46.0%, with the presence of a complication independently associated to a lower change in joint function. The most important predictor of a lower COKS was a higher pre-operative OKS. A patient starting with an OKS 10-points higher than her peer is predicted to improve by 6.3 points fewer following rTKA assuming that all other factors remained unchanged. Other factors associated to lower COKS were age under 60 years, longer duration of knee problems, patients who self-identified as disabled, patients reporting more problems in EQ-5D dimensions of anxiety/depression and self-care, comorbid conditions (circulatory problems, diabetes and depression) and earlier year of procedure in the dataset.

Secondary findings and reference to other studies

The mean pre-operative OKS in this study was 16.6 (SD 8.1) points. Baker et al (15) performed an early analysis of patient-reported outcomes following revision using the NHS PROMs dataset. They reported on 797 aseptic revision knee arthroplasties and found a similar baseline score, with their estimate of change score of 10.4 points slightly lower than our estimate. For primary knee arthroplasty, Liddle et al (16) estimated baseline OKS to be 19.6

points and COKS 15.5 points. This indicates that the average patient awaiting primary knee arthroplasty starts with better baseline patient-reported joint function than in revision and improves more in absolute terms. We recently reported that the OKS was responsive for use in revision knee arthroplasty and defined a minimal important change in OKS of ≥7.5 points (13). Here, we found that one-third of patients (34.4%) did not achieve this threshold. Few studies have used clinically relevant thresholds to evaluate functional changes after revision. Baker et al (15) reported that 17% of patients reported 'no improvement' after revision surgery, but did not relate this to the minimal important change, limiting the interpretability of this finding. Our study found that around one-quarter of patients were dissatisfied (28.6%) or felt that surgery did not make their knee problem better (24.3%). Both figures are worse than for primary knee arthroplasty and similar to other estimates following revision (15).

We found that nearly half of all patients experienced at least one complication after revision knee arthroplasty. The rate of patient-reported complications is around ten times higher than estimates for primary knee arthroplasty (17). Unsurprisingly, these were significant predictors of worse change scores. Identification of potentially avoidable complications and strategies to meet patient expectations when complications do arise should be prioritised. We found a high burden of comorbidity in patients undergoing revision knee arthroplasty, with exactly one-quarter of patients reporting three or more comorbidities. This estimate is around twice that for patients undergoing primary knee arthroplasty (17). A recent meta-analysis in primary knee arthroplasty (18) concluded that higher comorbidity was associated with early mortality and hospital readmission, but found little evidence for worse PROMs. In contrast, our linear regression model found that circulatory problems, depression and diabetes were significantly associated with worse change scores. The baseline prevalence of depression in

our population was 12%, which compares to 5% in primary knee arthroplasty (17). We found that younger age was associated with worse change score and therefore these patients should be counselled appropriately. In contrast, Williams et al (19) found the opposite trend for primary surgery, with greater improvements in joint function seen for younger patients at up to two year follow-up. However, they also noted that younger patients reported the lowest rates of satisfaction with the surgical outcome. Finally, we observed that year of surgery was a predictor of change in joint function, with more recent surgeries associated to greater improvements. This reasons for this should be explored. This finding is consistent with recent evidence that quality measure public reporting was associated with improved outcomes (20).

Strengths and Limitations

This is the largest study of PROMs in rTKA and the first to encompass a validated OKS for this population. However, there are a number of limitations that should be considered. First, this study has investigated patient-reported outcomes at 6-month follow-up and it is important to appreciate that some patients may experience gains beyond this time point. Second, we have concentrated on patient-reported outcomes, rather than other outcome measures that might also be considered to be important (such as mortality and length of stay). Our analyses were based on elective rTKA enrolled in the NHS PROMs programme and probably cannot be generalised to urgent cases (such as for periprosthetic fracture). In addition, we did not investigate the outcomes from rTKA by diagnosis as this data was not available to us. This research question may be addressed in the future through record linkage of NHS PROMs to the National Joint Registry. This process is currently associated to very high record attrition; however, solutions to this may become available in the near future (24). The National PROMs dataset included a small amount of suppressed data to prevent patient reidentification (4).

This means that outcomes for very low volume centres may be under-represented as well as patients with less common demographic characteristics (e.g. the very young or old). However, our analyses do represent the vast majority of patients undergoing rTKA and one of the principles of regression modelling involves removal of outlying observations. Our regression model used patient-reported comorbidity, which has recently been shown to have good validity compared to administrative coding (21,22). The reporting of patient-reported complications may even be regarded as advantageous since it both captures the patient perspective and is able to detect complications occurring in primary and secondary care. A final limitation that should be considered is that some of the complications may have occurred during the four-week period over which patients are asked to rate their joint function and the effect of this on OKS scores is unknown.

Context

This is an important study, given the increasing use of PROM data to manage health care providers (11) and to feedback performance to surgeons (23). We have shown that high proportions of patients do not achieve meaningful clinical benefits from revision surgery, whilst entertaining high complication rates. This information should be shared with patients in order to support the decision of whether to choose discretionary revision knee arthroplasty. However, it is important to acknowledge that there is very limited comparative data on alternative management options (for example, the effect of revision surgery versus supportive treatment [such as pain management or physiotherapy]). We believe that this is a deficit in the evidence-base that should be prioritised for future research. In addition, whilst the indication for primary TKA is almost always to treat pain and poor function, discretionary revision knee arthroplasty has varied indications (such as aseptic loosening, component wear,

stiffness or unexplained pain). This dataset did not provide outcomes by indication for revision, which may be important for more individualised communication of risks and benefits to patients. This is particularly true for indications where the main goal of surgery is not necessarily to improve joint function, but rather to treat a pre-defined problem (such as infection), and it is not known whether PROM instruments are appropriate for use in this setting.

Conclusion

In conclusion, this study found that two-thirds of patients (65.6%) achieved a clinically meaningful improvement in joint function after elective revision total knee arthroplasty. However, only half of all patients (53.0%) achieved a composite endpoint of a clinically meaningful improvement in joint function following surgery and 'better' health-related quality of life. Patients undergoing revision knee arthroplasty had a high burden of comorbidities and nearly half reported a post-operative complication. Higher baseline joint-function was the most important predictor associated with lower change in joint function. Other significant predictors of lower change in joint function were a longer duration of knee problems, earlier year of knee surgery, the presence of a post-operative complication, pre-operative problems with anxiety/depression, self-care or perceived disability, younger age, and comorbidities of diabetes, depression and circulatory problems. These findings may be useful to provide more informed discussion of the risks and benefits of discretionary rTKA.

References

1. National Joint Registry for England Wales Northern Ireland and the Isle of Man. NJR 17th Annual Report. 2020;(December 2019).
2. Briggs T. A national review of adult elective orthopaedic services in England: GETTING IT RIGHT FIRST TIME. Br Orthop Assoc [Internet]. 2015;(March):68. Available from: https://www.boa.ac.uk/wp-content/uploads/2015/03/GIRFT-National-Report-Mar15..pdf
3. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of Primary and Revision Hip and Knee Arthroplasty in the United States from 2005 to 2030. J Bone Jt Surg. 2007 Apr 1;89(4):780.
4. NHS Digital. Patient Reported Outcome Measure (PROMs) in England: A guide to PROMs methodology [Internet]. 2017. Available from: http://content.digital.nhs.uk/media/1537/A-Guide-to-PROMs-Methodology/pdf/PROMs_Guide_V8.pdf
5. Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Jt Surg Br. 1998 Jan;80(1):63–9.
6. EuroQol - a new facility for the measurement of health-related quality of life. Health Policy (New York). 1990;16(3):199–208.
7. Kiran A, Beard D, Javaid MK, Field RE, Murray D, Price A, et al. Interpretation of patient-reported outcomes for hip and knee replacement surgery. J Bone Joint Surg Br. 2012;94-B(3):412–8.
8. Judge A, Arden NK, Cooper C, Javaid MK, Carr AJ, Field RE, et al. Predictors of outcomes of total knee replacement surgery. Rheumatol (United Kingdom). 2012 Oct;51(10):1804–13.
9. Arden N, Altman D, Beard D, Carr A, Clarke N, Collins G, et al. Lower limb arthroplasty: can we produce a tool to predict outcome and failure, and is it cost-effective? An epidemiological study. Program Grants Appl Res. 2017;5(12):1–246.
10. National Joint Registry for England, Wales NI and the I of M. Patient Decision Support Tool for Joint Replacement [Internet]. [cited 2020 Apr 28]. Available from: https://jointcalc.shef.ac.uk/
11. NHS Digital. Patient Reported Outcome Measures (PROMs) [Internet]. [cited 2020 Apr 16]. Available from: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/patient-reported-outcome-measures-proms
12. Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, et al. The REporting of studies

Conducted using Observational Routinely-collected health Data (RECORD) Statement. PLOS Med [Internet]. 2015 Oct 6 [cited 2021 Jan 25];12(10):e1001885. Available from: https://dx.plos.org/10.1371/journal.pmed.1001885

13. Sabah SA, Alvand A, Beard DJ, Price AJ. Evidence for the validity of a patient-based instrument for assessment of outcome after revision knee replacement: Evaluation of the Oxford Knee Score using the UK National PROMS Dataset. Bone Joint J. 2021;(in press).
14. Devlin NJ, Parkin D, Browne J. Patient-reported outcome measures in the NHS: New methods for analysing and reporting EQ-5D data. Health Econ. 2010;19(8):886–905.
15. Baker P, Cowling P, Kurtz S, Jameson S, Gregg P, Deehan D. Reason for revision influences early patient outcomes after aseptic knee revision. Clin Orthop Relat Res. 2012 Aug 22;470(8):2244–52.
16. Liddle AD, Pandit H, Judge A, Murray DW. Patient-reported outcomes after total and unicompartmental knee arthroplasty. Bone Joint J. 2015;97(6):793–801.
17. Podmore B, Hutchings A, Konan S, Van Der Meulen J. Impact of comorbidities on adverse outcomes after hip and knee arthroplasty: a study of 640 832 patients in England. LSHTM PhD Thesis. 2018;
18. Podmore B, Hutchings A, Van Der Meulen J, Aggarwal A, Konan S. Impact of comorbid conditions on outcomes of hip and knee replacement surgery: A systematic review and meta-analysis. BMJ Open. 2018;8(7):1–12.
19. Williams DP, Price AJ, Beard DJ, Hadfield SG, Arden NK, Murray DW, et al. The effects of age on patient-reported outcome measures in total knee replacements. J Bone Jt Surg - Ser B. 2013 Jan;95 B(1):38–44.
20. Bozic K, Yu H, Zywiel MG, Li L, Lin Z, Simoes JL, et al. Quality Measure Public Reporting Is Associated with Improved Outcomes Following Hip and Knee Replacement. J Bone Joint Surg Am. 2020 Oct;102(20):1799–806.
21. Podmore B, Hutchings A, Konan S, van der Meulen J. The agreement between chronic diseases reported by patients and derived from administrative data in patients undergoing joint arthroplasty. BMC Med Res Methodol. 2019 Apr 24;19(1):87.
22. Dang KLT, Badge H, Harris IA. Validity of patient-reported complications after total hip and knee arthroplasty. J Orthop Surg. 2018 Sep 1;26(3):2309499018802493.
23. National Joint Registry for England, Wales NI and the I of M. NJR Clinician Feedback - Surgeon PROMs

Reports [Internet]. [cited 2020 Apr 28]. Available from: https://clinicianfeedback.njrcentre.org.uk/SurgeonPromsReports.aspx

24. NHS Digital. Master Person Service (MPS) [Internet]. [cited 2021 Mar 9]. Available from: https://digital.nhs.uk/services/master-person-service

Tables & Figures

Table 1. Baseline patient demographics

	Count	Percentage
	N=10727	
Age-band		
Under 60	1207	11.3
60 to 69	3546	33.1
70 to 79	3997	37.3
80 to 89	1330	12.4
Not specified	647	6.0
Gender		
Male	4760	44.4
Female	5320	49.6
Not specified	647	6.0
Year of surgery*		
2013-4	2036	19.0
2014-5	1859	17.3
2015-6	1761	16.4
2016-7	1726	16.1
2017-8	1733	16.2
2018-9	1612	15.0
Duration of knee problems		
Less than 1 year	1185	11.0
1 to 5 years	4655	43.4
6 to 10 years	1952	18.2
More than 10 years	2737	25.5
Missing	198	1.8
Need for assistance completing questionnaire		
Yes	1816	16.9
No	8822	82.2
Missing	89	0.8
Self-report disability		
Yes	7080	66.0
No	3126	29.1
Missing	521	4.9
Self-Report Comorbidity**		
Arthritis	7571	70.6
Cancer	553	5.2
Circulation	810	7.6
Depression	1289	12.0
Diabetes	1529	14.3
Heart disease	1217	11.3
High blood pressure	4703	43.8
Kidney disease	253	2.4
Liver disease	68	0.6
Lung disease	1047	9.8
Nervous system disorder	140	1.3
Stroke	197	1.8
Number of Comorbidities		
0	1373	12.8
1	3331	31.1
2	3345	31.2
3 or more	2678	25.0
Living arrangements		
With partner/spouse/family/friends	8146	75.9
Alone	2304	21.5
Nursing home/Facility	17	0.2
Other	36	0.3
Not specified	224	2.1

**Each year of the PROMs dataset runs from 1st April to 31st March of the following year.*
***Patients were able to report none or as many comorbidities as were applicable*

Table 2. Patient reported outcome measures and complications

Outcome	Summary
Oxford Knee Score	
Baseline	16.6 (8.1), 10329
Six months	29.0 (11.4), 10329
Change from baseline to six months	12.4 (10.7), 10329
Change greater than MIC (7.5 points)	
Yes	6776/10329 (65.6%)
No	3553/10329 (34.4%)
EQ-5D utility score	
Baseline	0.260 (0.055, 0.691), 9549
Six months	0.691 (0.516, 0.796), 9549
Change from baseline to six months	0.227 (0.000, 0.554), 9549
Paretian analysis	
Better off	6033/9549 (63.2%)
Worse off	1233/9549 (12.9%)
The same	1276/9549 (13.4%)
Non-comparable	1007/9549 (10.5%)
EQ-5D VAS score	
Baseline	63.8 (22.1), 9143
Six months	67.0 (21.2), 9143
Change from baseline to six months	3.2 (23.7)
Success transition	
Much better	5674/10727 (52.9%)
A little better	2273/10727 (21.2%)
About the same	1072/10727 (10.0%)
A little worse	801/10727 (7.5%)
Much worse	730/10727 (6.8%)
Missing	177/10727 (1.7%)
Patient satisfaction	
Excellent	1713/10727 (16.0%)
Very good	2919/10727 (27.2%)
Good	2845/10727 (26.5%)
Fair	2029/10727 (18.9%)
Poor	1038/10727 (9.7%)
Missing	183/10727 (1.7%)
Complications*	
Bleeding	1275/9323 (13.7%)
Drug reaction	1167/9486 (12.3%)
Hospital readmission	1455/10542 (13.8%)
Further surgery	1221/10479 (11.7%)
Urinary problems	1208/9277 (13.0%)
Wound problems	1798/9627 (18.7%)
Number of complications per patient	
0	5744/10727 (53.5%)
1	2766/10727 (25.8%)
2	1332/10727 (12.4%)
3	535/10727 (5.0)
4 or more	255/10727 (2.4%)
*Missing***	95/10727 (0.9%)

**Patients were able to report none or as many different complications as were applicable. For each complication, the proportion of patients who experienced it was calculated out of the number who answered either yes or no.*

*** Patients were counted as missing data if they had not answered any of the complications questions. If they had answered at least one complication question, it was assumed that any missing answers were no (i.e. that the patient did not have that complication)*

Table 3. Multivariable linear regression analysis to Change in Oxford Knee Score (COKS) at 6 months.

	Coefficient	95% CI	p value
Constant	28.55	[27.28, 29.82]	<0.001
	Continuous predictor[1]		
Pre-operative OKS	-0.63	[-0.67, -0.60]	<0.001
	Binary and Categorical predictors		
Age[2]			
Under 60 years	Reference		
60 to 69 years	2.37	[1.67 ,3.07]	<0.001
70 to 79 years	3.47	[2.77, 4.18]	<0.001
Over 80 years	3.86	[2.99, 4.73]	<0.001
Year of surgery[2]			
2013-4	Reference		
2014-5	1.08	[0.37, 1.79]	0.003
2015-6	0.96	[0.24, 1.68]	0.01
2016-7	0.69	[-0.03, 1.42]	0.06
2017-8	1.34	[0.62, 2.06]	<0.001
2018-9	1.56	[0.83, 2.30]	<0.001
Self-report disability[3]	-3.01	[-3.53, -2.50]	<0.001
Self-report comorbidities[3]			
Circulation	-3.13	[-3.99, -2.27]	<0.001
Depression	-1.19	[-1.94, -0.45]	0.002
Diabetes	-0.91	[-1.52, -0.29]	0.004
Duration of knee problems[2]			
Less than 1 year	Reference		
1 to 5 years	-2.99	[-3.70, -2.28]	<0.001
6 to 10 years	-4.89	[-5.70, -4.07]	<0.001
More than 10 years	-3.51	[-4.28, -2.74]	<0.001
Pre-operative EQ-5D dimensions			
Anxiety/Depression[2]			
No problems	Reference		
Some problems	-1.08	[-1.58, -0.58]	<0.001
Severe problems	-2.09	[-3.13, -1.05]	<0.001
Self-care[2]			
No problems	Reference		
Some problems	-2.01	[-2.52, -1.50]	<0.001
Severe problems	-3.56	[-5.30, -1.83]	<0.001
Complications[3]			
Further surgery	-4.38	[-5.22, -3.53]	<0.001
Hospital readmission	-2.74	[-3.52, -1.95]	<0.001
Wound problems	-2.49	[-3.14, -1.83]	<0.001
Urinary tract infection	-1.24	[-1.98, -0.50]	0.001
Drug reaction	-1.09	[-1.87, -0.31]	0.01
Observations	7220		
R-squared	0.235		
AIC	522619		

[1] the estimate describes the effect on the change in score if the predictor variable is increased by one point.

[2] the estimate describes the difference with respect to the first category.

[3] the estimate describes the difference with respect to the reference category which was 'no'.

Figure 1. Kernel density plot demonstrating Oxford Knee Score before revision and at six months post-surgery

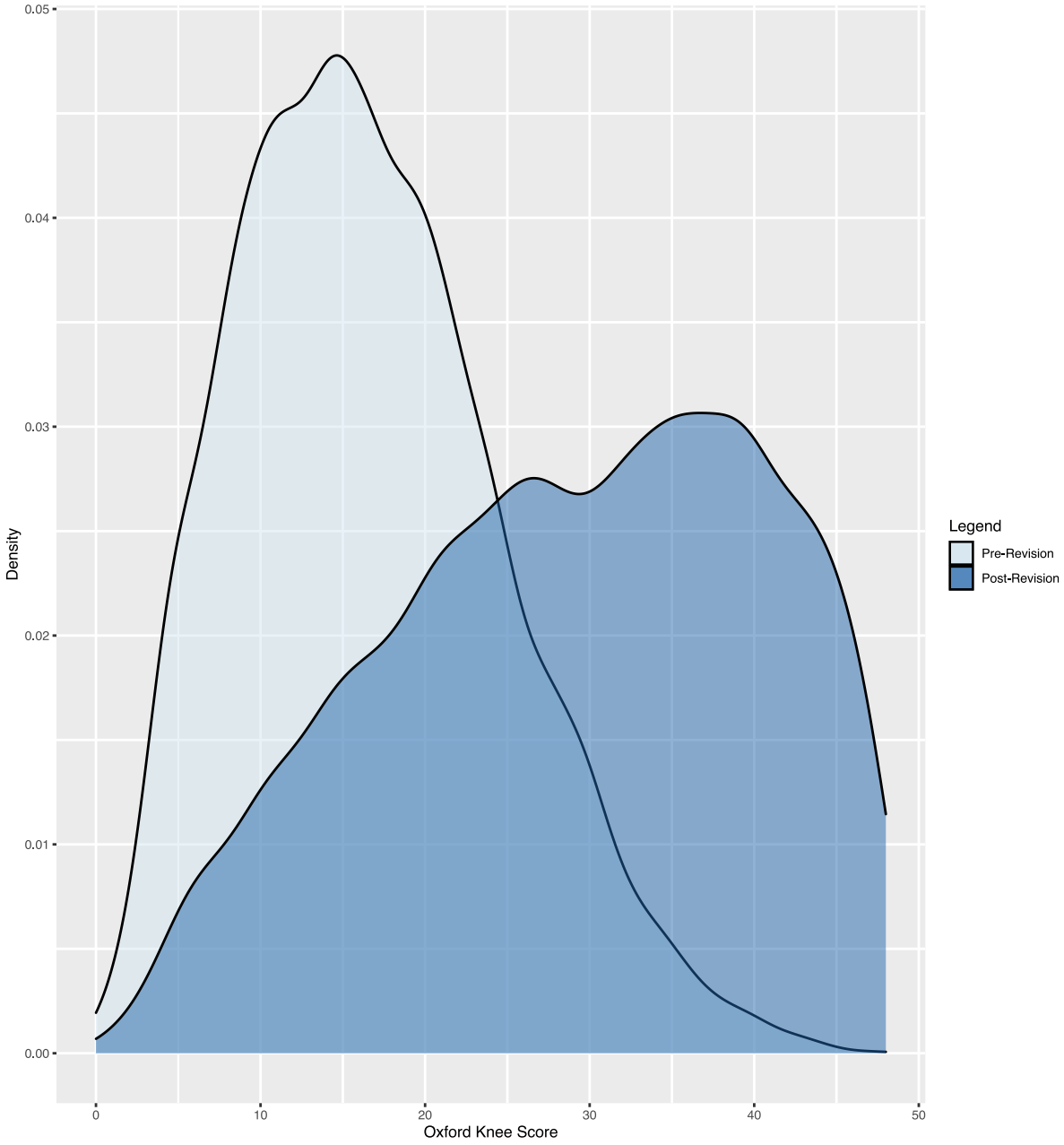


Figure 2. Kernel density plots demonstrating EQ-5D utility before revision and at six months post-surgery

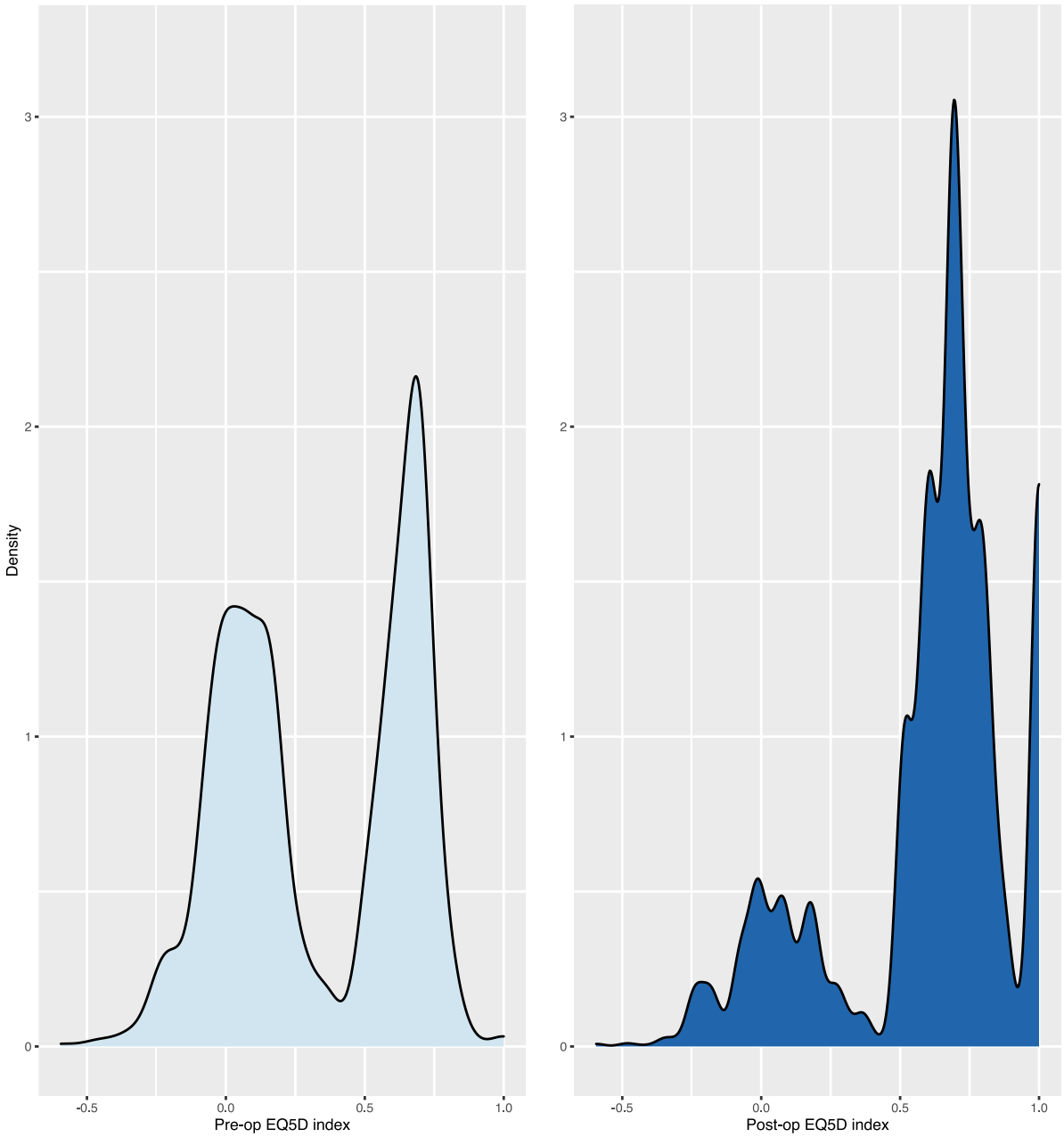
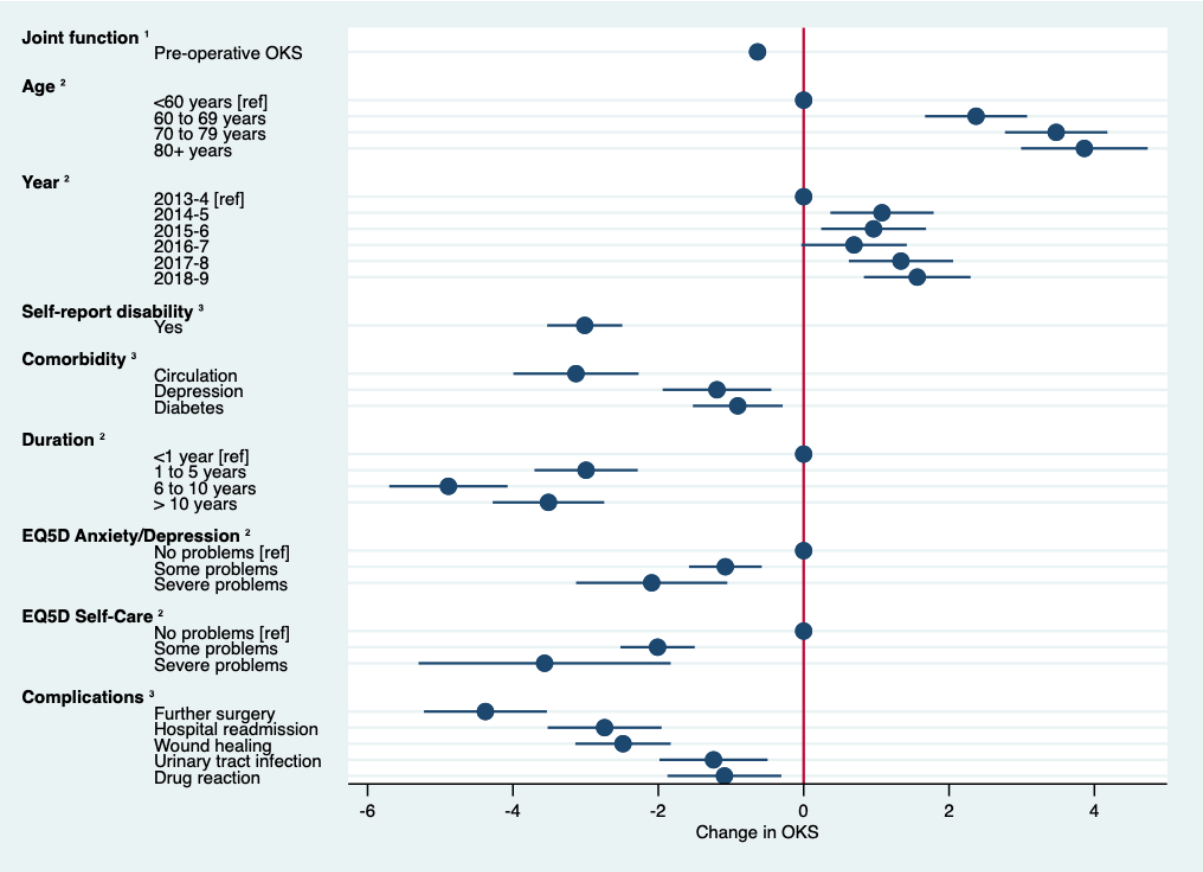


Figure 3: Multivariable linear regression model: Coefficient plot to demonstrate associations to Change in Oxford Knee Score at six months.



[1] *the estimate describes the effect on the change in score if the predictor variable is increased by one point.*
[2] *the estimate describes the difference with respect to the first category.*
[3] *the estimate describes the difference with respect to the reference category which was 'no'.*

Appendix Table 1. NHS PROMs OPCS Codes for Revision Knee Replacement (reproduced from (12)*)*

OPCS Code	*Note(s)*	*Code Description*
O180		Conversion from previous hybrid prosthetic replacement of knee joint using cement
O182		Conversion to hybrid prosthetic replacement of knee joint using cement
O183		Revision of hybrid prosthetic replacement of knee joint using cement
O184		Attention to hybrid prosthetic replacement of knee joint using cement
W400		Conversion from previous cemented total prosthetic replacement of knee joint
W402		Conversion to total prosthetic replacement of knee joint using cement
W403		Revision of total prosthetic replacement of knee joint using cement
W404		Revision of one component of total prosthetic replacement of knee joint using cement
W410		Conversion from previous uncemented total prosthetic replacement of knee joint
W412		Conversion to total prosthetic replacement of knee joint not using cement
W413		Revision of total prosthetic replacement of knee joint not using cement
W414		Revision of one component of total prosthetic replacement of knee joint not using cement
W420		Conversion from previous total prosthetic replacement of knee joint NEC
W422		Conversion to total prosthetic replacement of knee joint NEC
W423		Revision of total prosthetic replacement of knee joint NEC
W424	A	Attention to total prosthetic replacement of knee joint NEC
W425		Revision of one component of total prosthetic replacement of knee joint NEC
W426		Arthrolysis of total prosthetic replacement of knee joint
W520	K	Conversion from previous cemented prosthetic replacement of articulation of bone NEC
W522	K	Conversion to prosthetic replacement of articulation of bone using cement NEC
W523	K	Revision of prosthetic replacement of articulation of bone using cement NEC
W530	K	Conversion from previous uncemented prosthetic replacement of articulation of bone NEC
W532	K	Conversion to prosthetic replacement of articulation of bone not using cement NEC
W533	K	Revision of prosthetic replacement of articulation of bone not using cement NEC
W540	K	Conversion from previous prosthetic replacement of articulation of bone NEC
W542	K	Conversion to prosthetic replacement of articulation of bone NEC
W543	K	Revision of prosthetic replacement of articulation of bone NEC
W544	K, A	Attention to prosthetic replacement of articulation of bone NEC
W582	K	Revision of resurfacing arthroplasty of joint

K Must be combined with knee body part codes (Z846 Or Z765 Or Z845 or Z844 Or Z774 Or Z787)

A Must be combined with action codes (Y032 Or Y037)

OPCS - Office of Population Censuses and Surveys Classification of Surgical Operations and Procedures (OPCS-4) codes used in Hospital Episode Statistics Admitted Patient Care
PROMS - Patient Reported Outcome Measures

Appendix Table 2. Characteristics of patients included in regression model compared to those excluded due to missing data

	Excluded	**Included**
	N=3,507	N=7,220
Age-band[1]		
Under 60	291 (8.3%)	916 (12.7%)
60 to 69	977 (27.9%)	2,569 (35.6%)
70 to 79	1,166 (33.2%)	2,831 (39.2%)
80 to 89	426 (12.1%)	904 (12.5%)
Not specified	647 (18.4%)	NA
Gender[1]		
Male	1,323 (37.7%)	3,437 (47.6%)
Female	1,537 (43.8%)	3,783 (52.4%)
Not specified	647 (18.4%)	NA
Year of surgery[1,4]		
2013-4	654 (18.6%)	1,382 (19.1%)
2014-5	629 (17.9%)	1,230 (17.0%)
2015-6	595 (17.0%)	1,166 (16.1%)
2016-7	581 (16.6%)	1,145 (15.9%)
2017-8	536 (15.3%)	1,197 (16.6%)
2018-9	512 (14.6%)	1,100 (15.2%)
Duration of knee problems[1]		
Less than 1 year	359 (10.2%)	826 (11.4%)
1 to 5 years	1,435 (40.9%)	3,220 (44.6%)
6 to 10 years	642 (18.3%)	1,310 (18.1%)
More than 10 years	873 (24.9%)	1,864 (25.8%)
Missing	198 (5.6%)	NA
Self-report disability[1]		
Yes	2173 (62.0%)	4907 (68.0%)
No	813 (23.2%)	2313 (32.0%)
Missing	521 (14.9%)	
Self-Report Comorbidity[1,5]		
Arthritis	2,328 (66.4%)	5,243 (72.6%)
Cancer	169 (4.8%)	384 (5.3%)
Depression	422 (12.0%)	867 (12.0%)
Diabetes	516 (14.7%)	1,013 (14.0%)
Heart disease	395 (11.3%)	822 (11.4%)
High blood pressure	1,400 (39.9%)	3,303 (45.7%)
Kidney disease	82 (2.3%)	171 (2.4%)
Liver disease	18 (0.5%)	50 (0.7%)
Lung disease	343 (9.8%)	704 (9.8%)
Nervous system disorder	44 (1.3%)	96 (1.3%)
Stroke	68 (1.9%)	129 (1.8%)
Number of Comorbidities[1]		
0	607 (17.3%)	766 (10.6%)
1	1021 (29.1%)	2310 (32.0%)
2	1027 (29.3%)	2318 (32.1%)
3 or more	852 (24.3%)	1826 (25.3%)
Oxford Knee Score[2]		
Baseline	16.0 (8.2), 3326	16.8 (8.0), 7220
Six months	26.7 (11.8), 3275	30.0 (11.1), 7220
Change from baseline to six months	10.6 (10.9), 3109	13.2 (10.5), 7220
EQ-5D utility score[3]		
Baseline	0.189 (-0.003, 0.620), 2944	0.264 (0.055, 0.691), 7095

Six months	0.639 (0.364, 0.760), 3235	0.691 (0.587, 0.796) , 6933
Change from baseline to six months	0.159 (0.000, 0.532), 2732	0.263 (0.000, 0.590) , 6817
EQ-5D VAS score[2]		
Baseline	62.1 (22.6), 2871	64.3 (21.9), 6740
Six months	64.1 (22.2), 3281	68.4 (20.5), 6873
Change from baseline to six months	1.6 (24.7), 2708	3.9 (23.2), 6435
Success transition[1]		
Much better	1,574 (44.9%)	4,100 (56.8%)
A little better	745 (21.2%)	1,528 (21.2%)
About the same	389 (11.1%)	683 (9.5%)
A little worse	321 (9.2%)	480 (6.6%)
Much worse	336 (9.6%)	394 (5.5%)
Missing	142 (4.0%)	35 (0.5%)
Patient satisfaction[1]		
Excellent	465 (13.3%)	1,248 (17.3%)
Very good	793 (22.6%)	2,126 (29.4%)
Good	893 (25.5%)	1,952 (27.0%)
Fair	755 (21.5%)	1,274 (17.6%)
Poor	459 (13.1%)	579 (8.0%)
Missing	142 (4.0%)	41 (0.6%)
Complications[1]		
Urinary problems		
No	1,521 (43.4%)	6,548 (90.7%)
Yes	536 (15.3%)	672 (9.3%)
Missing	1,450 (41.3%)	NA
Wound problems		
No	1,527 (43.5%)	6,302 (87.3%)
Yes	880 (25.1%)	918 (12.7%)
Missing	1,100 (31.4%)	NA
Hospital readmission		
No	2,690 (76.7%)	6,397 (88.6%)
Yes	632 (18.0%)	823 (11.4%)
Missing	185 (5.3%)	NA
Further surgery		
No	2,736 (78.0%)	6,522 (90.3%)
Yes	523 (14.9%)	698 (9.7%)
Missing	248 (7.1%)	NA
Drug reaction		
No	1,697 (48.4%)	6,622 (91.7%)
Yes	569 (16.2%)	598 (8.3%)
Missing	1,241 (35.4%)	NA
Bleeding		
No	1,551 (44.2%)	6,497 (90.0%)
Yes	592 (16.9%)	683 (9.5%)
Missing	1,364 (38.9%)	40 (0.6%)

[1] Summaries are n (%)

[2] Summaries are mean (SD), N

[3] Summaries are median (IQR), N

[4] Each year of the PROMs dataset runs from 1st April to 31st March of the following year.

[5] Patients were able to report none or as many comorbidities as were applicable