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Original article

Predictors of outcomes of total knee replacement surgery

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Abstract

Objective. To identify pre-operative predictors of patient-reported outcomes of primary total knee replacement (TKR) surgery.

Methods. The Elective Orthopaedic Centre database is a large prospective cohort of 1991 patients receiving primary TKR in south-west London from 2005 to 2008. The primary outcome is the 6-month post-operative Oxford Knee Score (OKS). To classify whether patients had a clinically important outcome, we calculated a patient acceptable symptom state (PASS) for the 6-month OKS related to satisfaction with surgery. Potential predictor variables were pre-operative OKS, age, sex, BMI, deprivation, surgical side, diagnosis, operation type, American Society of Anesthesiologists grade and EQ5D anxiety/depression. Regression modelling was used to identify predictors of outcome.

Results. The strongest determinants of outcome include pre-operative pain/function—those with less severe pre-operative disease obtain the best outcomes; diagnosis in relation to pain outcome—patients with RA did better than those with OA; deprivation—those living in poorer areas had worse outcomes; and anxiety/depression—worse pre-operative anxiety/depression led to worse pain. Differences were observed between predictors of pain and functional outcomes. Diagnosis of RA and anxiety/depression were associated with pain, whereas age and gender were specifically associated with function. BMI was not a clinically important predictor of outcome.

Conclusion. This study identified clinically important predictors of attained pain/function post-TKR. Predictors of pain were not necessarily the same as functional outcomes, which may be important in the context of a patient's expectations of surgery. Other predictive factors need to be identified to improve our ability to recognize patients at risk of poor TKR outcomes.

Key words: epidemiology, osteoarthritis, rheumatoid arthritis, knee replacement, patient-reported outcome, expectation, decision-making.

CLINICAL SCIENCE

Introduction

Total knee replacement (TKR) surgery is one of the most common and successful surgical interventions, providing substantial relief from pain and improvement in functional disability in patients with knee arthritis [1]. Attention is currently focused on the use of patient-reported outcome measures (PROMs) and assessments of satisfaction to see whether surgery has been successful from the patient's perspective [1, 2]. Although on average the majority of patients receive symptomatic improvement following surgery, it has emerged that an important minority of patients have no improvement or their symptoms get worse, with estimates up to 30% [3–9]. Not all patients are satisfied with the outcomes of surgery, where national joint registries suggest that 82% of patients were satisfied with their TKR [10–13]. It is important to identify patients at risk of poor patient-reported outcomes, such that clinicians and patients can evaluate the risks and benefits of surgery on an individual basis [14].

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Relatively little work has been done to establish the predictors of good or bad patient-reported outcomes after TKR [14]. A limitation of most studies is that they report such data treating the outcome as a continuous variable. Using a continuous outcome, we may find good evidence that a predictor is statistically important, however, it is not clear if this is clinically important [7]. Clinicians may find it difficult to communicate the results of a continuous outcome to patients. For a patient to know that, based on their pre-operative characteristics, having TKR will change your score by *x* points is not informative to either patients or clinicians. It is preferable to categorize patients according to whether or not they have had a clinically important improvement (responded) with surgery, so that as part of patient–clinician decision-making a patient will know the likely improvement in pain and function they can expect as a percentage.

The primary aim of this study was to identify whether patients' pre-operative characteristics can predict patient-reported outcomes [as measured by the Oxford Knee Score (OKS)] 6 months after surgery in a large prospective cohort of patients receiving primary TKR in the UK National Health Service (NHS). We address this in two ways by identifying predictors of (i) statistically important outcomes using the 6-month OKS; and (ii) clinically important outcomes by identifying a cut-point for the 6-month OKS related to satisfaction with surgery.

Methods

We obtained information from the database at the Elective Orthopaedic Centre (EOC), which is a purpose-built orthopaedic treatment centre opened in 2004. It performs TKR for four acute NHS Trusts in the UK: Kingston, St George's, Mayday, Epsom and St Heliers, covering a population of 1.5 million people in south-west London. Patients were included if they received primary unilateral (unicompartmental or total) knee replacement. Revision operations, a second primary knee replacement on the other side, and bilateral operations were excluded. Pre-operative information was collected on age, gender, height and weight (from which BMI was calculated), side of surgery, primary diagnosis, type of operation and the American Society of Anesthesiologists (ASA) status—a standard measure of fitness for surgery, scored from 1 (normal, healthy) to 4 (life-threatening systemic disease) [15]. We used the Index of Multiple Deprivation (IMD) [16] 2004 as a measure of social deprivation, linked to the lower-level super output area (SOA) the patient lives in (SOAs are geographical areas of consistent size with a minimum population of 1000 and mean of 1500). The index was constructed by the Social Disadvantage Research Centre at the University of Oxford through combining seven domain indices of deprivation using the following weights: income (22.5%), employment (22.5%), health deprivation and disability (13.5%), education, skills and training (13.5%), barriers to housing and services (9.3%), crime (9.3%) and living environment (9.3%). A higher deprivation score implies that the area has higher levels of deprivation (poorer), whereas lower scores represent more affluent areas.

Before surgery patients complete a pre-operative OKS [17, 18] and European Quality of life-5 dimensions (EQ5D) questionnaire [19] with a follow-up questionnaire at 6-month post-surgery. The OKS consists of 12 questions asking patients to describe their knee pain and function during the past 4 weeks. Each question is on a Likert scale taking values from 0–4, with 4 being the best outcome. An overall score is created by summing the responses to each of the 12 questions, ranging from 0 to 48, where 0 is the worst possible score (most severe symptoms) and 48 the best score (least symptoms). We considered the questions on the OKS relating to pain and function separately [10] (see supplementary data, available at *Rheumatology* Online), where scores for the five questions on pain were added together, as were the seven questions on function, to create total pain and function scores. The EQ5D contains information from five questions asking about a patient's health state today, covering mobility, self-care, usual activities, pain and anxiety/depression. Each question is on a Likert scale taking values: 1 (none), 2 (moderate) and 3 (severe).

Six months after their operation, patients were asked about their overall satisfaction with the outcome of surgery measured on a visual analogue scale from 0 to 100 using the following question: 'We would like you to indicate on this scale your overall satisfaction with the outcome of your operation. Please do this by circling whichever point on the scale best indicates your satisfaction. Zero means not satisfied and 100 means very satisfied.' We used a cut-off of $\geqslant$50/100 as being satisfied with TKR. Further, the proportion identified as satisfied using this cut-off (89%) is consistent with those reported elsewhere [10, 11]. As a sensitivity analysis, we repeated analyses using higher and lower cut-offs of $\geqslant$60 and $\geqslant$40, respectively.

Statistical methods

Stata version 11.1 (Stata, College Station, TX, USA) was used for all statistical analyses. Predictor variables were age, sex, BMI, IMD 2004, side of surgery, primary diagnosis (OA, RA, other), operation type (TKR, unicompartmental), ASA grade (1, 2, 3 and 4), pre-operative OKS, pre-operative EQ5D anxiety/depression question and year of surgery.

We used two methods to identify predictors of (i) statistically important outcomes using the 6-month OKS, and (ii) clinically important outcomes by identifying a cut-point for the 6-month OKS related to satisfaction with surgery. The results of complete case analyses can be biased [20]. The cumulative effect of missing data in several variables often leads to exclusion of a substantial proportion of the original sample, causing a loss of precision and power. This bias can be overcome by using multiple imputation methods. We have done this using the Imputation by Chained Equations procedure in Stata [21–23] (full details of the multiple imputation methods are described in the supplementary data, available at *Rheumatology* Online).

Continuous outcome

Analysis of covariance (ANCOVA) was used to identify predictors of the 6-month follow-up OKS, adjusting for pre-operative OKS. Univariable models examine the association between each predictor and the outcome, adjusting for pre-operative OKS. A multivariable model was fitted including all predictor variables. Analyses were repeated for the total OKS, pain and function scores separately. Regression diagnostics were checked to ensure that the assumptions underlying the linear regression model (ANCOVA) were met. As there was evidence of heteroscedasticity (variance of the residuals is non-constant), robust standard errors were used with the sandwich variance estimator [24]. Performance of the predictive model was assessed in terms of calibration and discrimination [25, 26]. Calibration measures how closely the predicted 6-month OKS agrees with the observed score. This was assessed for each tenth of predicted risk using 10 equally sized groups. Discrimination was assessed using the R^2-statistic as a measure of explained variation.

Binary outcome

Receiver operating characteristic (ROC) curve analyses were used to identify cut-points for the 6-month follow-up OKS associated with satisfaction with surgery. The area under the ROC curve is the probability of correctly identifying whether or not patients were satisfied based on their 6-month OKS. The area ranges from 0.5 (a test with no accuracy in distinguishing satisfied from not satisfied) to 1.0 (perfect accuracy). This can be interpreted as a patient acceptable symptom state (PASS) for the 6-month OKS related to satisfaction with surgery [27].

The outcome is a binary variable of whether or not the patient achieved a PASS at 6 months. Logistic regression modelling was used to identify predictors of the 6-month PASS score. Calibration was assessed using a Hosmer–Lemeshow goodness of fit test. Discrimination was assessed by calculating the area under the ROC curve [25]. Regression diagnostics were checked to ensure the assumptions underlying the logistic regression model were met.

Results

The EOC database contains information on 3608 patients who had a primary TKR operation between 2005 and 2008. Patients were aged between 17 and 96 years (mean age 71.3 years). Of these patients, 1991 (55.2%) completed both a pre-operative and 6-month post-operative OKS and these patients form the cohort used for the analysis of statistically important outcomes. Baseline demographic details are described in Table 1. There were small differences between patients that did and did not respond to the 6-month questionnaire, where those who responded were older, had a lower BMI and were less likely to suffer from anxiety/depression. Importantly, there were no differences in baseline pain and function as assessed by the OKS, nor for other baseline predictors. Of the 1991 patients that completed pre- and post-operative OKS, 1784 (89.6%) also completed the 6-month satisfaction question, forming the cohort used for analysis of clinically important outcomes. There were no differences in the 6-month OKS of patients who did and did not complete the satisfaction question ($P = 0.14$).

Histograms of the distribution of OKS at baseline, 6-months and the absolute difference in scores (Fig. 1) highlight that at 6 months the score is negatively skewed to the left, suggesting the majority of patients achieve improvement in pain and function. However, the histogram of the difference in scores highlights that whereas some patients get better, others get worse or receive no improvement. Using ROC curve analyses, we identified a cut-point of $\geqslant 30$ (95% CI 29.0, 31.0) for the 6-month OKS associated with satisfaction with surgery. The area under the ROC curve was 0.85 (95% CI 0.83, 0.88), indicating good predictive accuracy in using the 6-month OKS to distinguish between patients who are satisfied and not satisfied. This classified 71.7% of patients as achieving a PASS at 6 months following TKR.

A number of variables were identified as statistically important predictors of attained 6-month OKS (Table 2). Increasing baseline OKS (better pre-operative pain/function) was associated with increasing 6-month follow-up OKS (better post-operative pain/function). People living in more deprived areas (poorer) had worse 6-month pain/function. Interestingly, predictors of functional outcomes were not necessarily the same as for pain outcomes. Older people, women and those with higher BMI had worse functional outcomes, but not pain. Patients with RA had better pain outcomes, but no association was observed for function. Patients who were anxious/depressed at the time of surgery had worse pain at follow-up, with a weaker effect observed for functional outcome. Assessing the discriminatory ability of the models, the total OKS model explained 14.6% of the variability in outcome, whereas the model for function explained 18.9% and pain only 8.2%. Assessing the size of the regression coefficients, the strongest predictors of outcome were the baseline OKS, area deprivation, diagnosis of RA and anxiety/depression, with other predictors having smaller but significant effects.

Repeating analyses to identify clinically important predictors (as opposed to statistically important) (Table 3), confirmed the predictors identified above have clinical relevance, with one important exception: we did not find evidence of an association of BMI on outcome. Worse pre-operative pain/function and living in a deprived area were associated with being less likely to achieve a PASS at 6 months. Differences were observed between predictors of pain and functional outcomes. Specifically for pain, patients with a diagnosis of RA had better outcomes compared with those with primary OA, and people with anxiety/depression had worse outcomes. Looking at functional outcomes, older people and women had worse outcomes. Assessing discrimination, the area under the ROC curve of the total PASS score model was 0.71

TABLE 1 Descriptive statistics and comparison of those who did and did not complete the 6-month questionnaire

Predictor variable	Baseline ($n = 3608$)	6-month follow-up		*P*-value
		Non-completers ($n = 1617$)	Completers ($n = 1991$)	
Age, mean (S.D.), years	71.3 (9.4)	70.8 (9.7)	71.7 (9.1)	0.005
Missing ($n = 3$)				
Sex, *n* (%)				
Male	1365 (37.9)	590 (36.6)	775 (39.0)	0.15
Female	2236 (62.1)	1022 (63.4)	1214 (61.0)	
Missing ($n = 7$)				
BMI, mean (S.D.)	29.4 (5.3)	30.3 (5.5)	28.9 (5.1)	<0.001
Missing ($n = 952$)				
IMD 2004 deprivation, medium (IQR)	11.0 (6.8–18.8)	11.5 (6.8–19.0)	10.5 (6.8–18.3)	0.14
Missing ($n = 63$)				
Knee joint being replaced, *n* (%)				
Left	1687 (46.8)	752 (46.5)	935 (47.0)	0.79
Right	1921 (53.2)	865 (53.5)	1056 (53.0)	
Missing ($n = 0$)				
Main diagnosis, *n* (%)				
OA	2412 (94.4)	975 (95.5)	1437 (93.7)	0.097
RA	71 (2.8)	26 (2.6)	45 (2.9)	
Other	71 (2.8)	20 (2.0)	51 (3.3)	
Missing ($n = 1054$)				
Operation type, *n* (%)				
TKR	3320 (92.0)	1493 (92.3)	1827 (91.8)	0.53
Unicompartmental knee	288 (8.0)	124 (7.7)	164 (8.2)	
Missing ($n = 0$)				
ASA grade, *n* (%)				
1	247 (10.4)	79 (9.2)	168 (11.2)	0.27
2	1725 (72.9)	646 (74.9)	1079 (71.8)	
3	388 (16.4)	137 (15.9)	251 (16.7)	
4	6 (0.3)	1 (0.1)	5 (0.3)	
Missing ($n = 1242$)				
Baseline OKS, mean (S.D.)	40.1 (8.1)	40.4 (8.1)	39.9 (8.1)	0.077
Missing ($n = 55$)				
EQ5D anxiety, *n* (%)				
Not anxious/depressed	1802 (52.7)	758 (50.7)	1044 (54.2)	0.006
Moderately anxious/depressed	1428 (41.8)	634 (42.4)	794 (41.3)	
Extremely anxious/depressed	189 (5.5)	102 (6.8)	87 (4.5)	
Missing ($n = 189$)				

The *t*-tests are used for continuous variables and χ^2 tests for categorical variables. Where continuous variables were not normally distributed, a non-parametric *t*-test (Kruskal–Wallis) was used. Fisher's exact test is used where expected counts are <5. IQR: interquartile range.

(95% CI 0.68, 0.74), for the pain PASS model 0.66 (95% CI 0.63, 0.69) and function PASS 0.73 (95% CI 0.70, 0.75).

Discussion

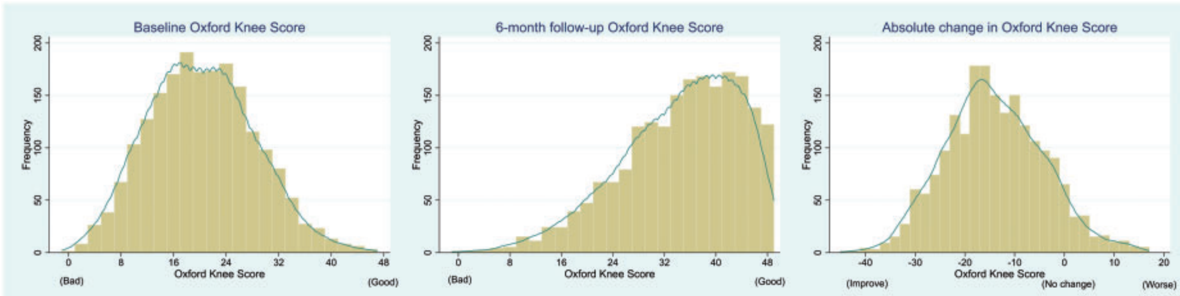
Main findings

Using a large prospective cohort of patients receiving primary TKR in the UK NHS, we identified a number of clinically important predictions of attained pain and function by deriving a PASS to define outcome (a threshold for the 6-month OKS associated with satisfaction with surgery). The strongest determinants of outcomes include pre-operative pain and function—the better a patient is before surgery the better they will be after it; diagnosis in relation to pain outcome—those with RA did better than those with OA; area deprivation—those living in poorer areas had worse outcomes than people living in affluent areas; and anxiety/depression—worse pre-operative anxiety/depression led to worse pain outcomes. Other statistically significant predictors with small effects included age and sex—BMI was not a clinically important predictor of outcome. Differences were observed between predictors of pain and functional outcomes. Diagnosis of RA and anxiety/depression were only associated with pain outcomes, whereas age and gender were specifically associated with function.

What is already known

In our study, an important new finding was that area deprivation was a significant predictor of outcome,

FIG. 1 Distributions of OKS at baseline, 6 months and difference in scores.



where people living in poor areas have worse outcomes. Within the literature it has been suggested that people from more deprived areas tend to accept a greater degree of ill health as normal and are less likely to consult a general practitioner (GP) [28]. Those who seek help from a GP consult at a later stage of disease [29], hence such groups may make poorer candidates for surgery and have worse outcomes than if they had sought help at an earlier stage. The literature regarding the effect of education and income suggests there is no evidence of an association with outcomes of TKR [8, 30–32], although effects have been observed for hip replacement, where more educated people have better outcomes [30, 31]. This suggests that ecological fallacy may be present, where an association observed at an area level is not the same as at the individual level, hence area deprivation may be a proxy for other unobserved effects in poorer areas.

Worse pre-operative mental health was a predictor of poor outcome, consistent with others in the literature using more detailed measures of mental health such as the SF-36 mental health component [6, 8, 32–34] and disease-specific tools like the Beck Depression Inventory [35]. Patients with RA had better pain outcomes compared with those with OA as observed by others [9, 12, 36, 37]. This may be related to patients with RA having worse pain and function at the time of surgery due to the polyarticular nature of disease and hence the potential for more improvement [9, 37].

Within our study we found that older patients and women had worse outcomes, but although statistically significant, the effect size was small. In addition, we found no evidence that BMI was a clinically important predictor of outcome. This is in line with the conclusions of large literature reviews stating such factors are not strong predictors of functional outcomes [36, 37]. The findings are important to decision-making, as physicians often advise patients they are too old or obese to receive TKR [13, 14]. We can conclude that in relation to patient-reported outcomes of TKR, age and BMI should not be a barrier to surgery. Even if some groups fare less well after TKR, it does not mean these patients do not benefit from surgery [14]. However, this is within the context of patient-reported outcomes, and consideration must also be given to the risks of prosthesis failure and post-operative complications. Expectations of the patients may also play a role, where for example, what a young person wants to achieve in functional rehabilitation is different from an older person, for whom a lower attained functional score may be perfectly acceptable.

It is already well known within the literature that patients with better pre-operative pain and functional status achieve better post-operative pain/function [6, 30, 32, 33, 38]. It is also well known that when using change (difference in pre- and post-operative score) as the outcome, those with worse pain and function scores get the greatest improvement, but never return to the same level of function as those with the least pre-operative pain/functional limitation [5, 39, 40]. Floor and ceiling effects in the PROM scoring tools [4, 6] may be important where patients with a poor pre-operative score can derive the most gain in health-related quality of life, but it could be the result of the fact that they have more room for improvement on fixed-end scales (the ceiling effect) [1]. The pre-operative OKS of patients in this study was normally distributed, where some patients had good scores (little pre-operative pain and functional limitation), whereas others had bad scores and hence greater room for improvement. Within this study, 24 (1.2%) patients had a very good pre-operative OKS of 40 or more, indicating potential ceiling effects, as these patients have little room to improve on the 0 (bad) to 48 (good) scale. Of these patients, 10 improved, 3 stayed the same and 11 got worse.

Within this study, we were able to explain <20% of the variability in patient-reported outcomes of TKR. Although the predictive power of the model is relatively low, it is consistent with other studies attempting to explain the variability in outcome of TKR [6, 32]. In comparison, cardiovascular risk prediction tools such as QRISK and Framingham explain ~30% of the variability in outcome [26]. This must therefore be due to other factors that may explain a greater proportion of the variability in outcome of TKR, such as co-morbidities and surgical technique. The literature highlights that having a greater number of pre-operative co-morbidities is associated with worse outcomes [6, 32, 33, 40], but this is not seen in all studies [8, 30, 38]. Patients with better social support/not living alone have better outcomes [33, 38, 40], and worse outcomes are seen in those with low back pain [33] and pain in other joint sites [39, 40].

TABLE 2 ANCOVA models to identify predictors of the 6-month follow-up OKS

Predictor variable	Total OKS: Univariable coefficient (95% CI)	Total OKS: Multivariable[a] coefficient (95% CI)	OKS pain score: Univariable coefficient (95% CI)	OKS pain score: Multivariable[a] coefficient (95% CI)	OKS function score: Univariable coefficient (95% CI)	OKS function score: Multivariable[a] coefficient (95% CI)
Baseline OKS[b]	2.01 (1.79, 2.24)	1.70 (1.43, 1.96)	1.54 (1.30, 1.78)	1.30 (1.03, 1.57)	2.16 (1.95, 2.37)	1.82 (1.58, 2.06)
Age[b]	−0.18 (−0.39, 0.03)	−0.20 (−0.43, 0.03)	0.02 (−0.09, 0.12)	0.01 (−0.10, 0.12)	−0.18 (−0.30, −0.06)	−0.21 (−0.34, −0.08)
Sex						
Male	0.000	0.000	0.000	0.000	0.000	0.000
Female	−0.99 (−1.78, −0.20)	−0.88 (−1.68, −0.08)	−0.17 (−0.55, 0.21)	−0.13 (−0.52, 0.25)	−0.89 (−1.35, −0.44)	−0.79 (−1.25, −0.33)
BMI[b]	−0.51 (−0.92, −0.09)	−0.44 (−0.86, −0.01)	−0.19 (−0.40, 0.02)	−0.13 (−0.36, 0.09)	−0.35 (−0.59, −0.12)	−0.33 (−0.57, −0.09)
Log IMD 2004	−1.43 (−1.98, −0.88)	−1.40 (−1.96, −0.85)	−0.69 (−0.95, −0.43)	−0.64 (−0.91, −0.37)	−0.77 (−1.09, −0.45)	−0.79 (−1.11, −0.46)
Side						
Left	0.000	0.000	0.000	0.000	0.000	0.000
Right	−0.30 (−1.06, 0.46)	−0.22 (−0.97, 0.54)	−0.15 (−0.51, 0.22)	−0.13 (−0.50, 0.23)	−0.14 (−0.57, 0.30)	−0.07 (−0.50, 0.36)
Diagnosis						
Primary OA	0.000	0.000	0.000	0.000	0.000	0.000
RA	3.17 (0.75, 5.59)	2.90 (0.42, 5.37)	1.68 (0.55, 2.82)	1.75 (0.61, 2.89)	1.23 (−0.29, 2.75)	1.01 (−0.48, 2.51)
Other	0.99 (−1.41, 3.38)	1.17 (−1.27, 3.60)	0.62 (−0.36, 1.61)	0.76 (−0.27, 1.78)	0.34 (−0.90, 1.58)	0.39 (−0.89, 1.66)
Operation type						
TKR	0.000	0.000	0.000	0.000	0.000	0.000
Unicompartmental knee	1.12 (−0.36, 2.60)	0.47 (−1.04, 1.99)	0.31 (−0.36, 0.97)	0.13 (−0.55, 0.81)	0.81 (−0.06, 1.68)	0.34 (−0.55, 1.23)
ASA grade						
1	1.41 (0.15, 2.67)	1.00 (−0.29, 2.29)	0.56 (−0.05, 1.18)	0.51 (−0.12, 1.14)	0.80 (0.01, 1.60)	0.39 (−0.43, 1.20)
2	0.000	0.000	0.000	0.000	0.000	0.000
3	−0.03 (−1.23, 1.18)	0.02 (−1.20, 1.24)	0.19 (−0.39, 0.76)	0.18 (−0.40, 0.75)	−0.25 (−0.99, 0.49)	−0.18 (−0.91, 0.56)
EQ5D anxiety						
Not anxious/depressed	0.000	0.000	0.000	0.000	0.000	0.000
Moderately anxious/depressed	−0.96 (−1.78, −0.13)	−0.85 (−1.68, −0.03)	−0.48 (−0.87, −0.08)	−0.43 (−0.82, −0.03)	−0.52 (−0.99, −0.04)	−0.45 (−0.92, 0.02)
Extremely anxious/depressed	−2.01 (−4.16, 0.13)	−2.21 (−4.34, −0.09)	−1.09 (-2.10, −0.08)	−1.19 (−2.19, −0.18)	−1.11 (−2.34, 0.12)	−1.20 (−2.43, 0.02)
Year						
2005–06	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.53 (−0.37, 1.43)	0.66 (−0.24, 1.55)	0.37 (−0.06, 0.80)	0.39 (−0.03, 0.82)	0.14 (−0.38, 0.66)	0.23 (−0.29, 0.75)
2008	0.22 (−0.79, 1.23)	0.23 (−0.77, 1.24)	0.20 (−0.28, 0.69)	0.20 (−0.28, 0.69)	0.00 (−0.58, 0.58)	0.01 (−0.57, 0.59)

[a]Multivariable: mutually adjusted for all predictor variables. [b]5-unit increase. Models are fitted on multiple imputation datasets ($n = 1991$). Univariable: each predictor in the model is adjusted for baseline OKS only. Coefficient: the regression coefficient. Represents the difference in 6-month OKS compared with the reference group. A positive value indicates that the group has better post-operative pain/function.

TABLE 3 Logistic regression model to identify predictors of 6-month PASS score

Predictor variable	Total OKS		OKS pain score		OKS function score	
	Univariable OR (95% CI)	Multivariable[a] OR (95% CI)	Univariable OR (95% CI)	Multivariable[a] OR (95% CI)	Univariable OR (95% CI)	Multivariable[a] OR (95% CI)
Baseline OKS[b]	1.59 (1.48, 1.72)	1.52 (1.40, 1.66)	2.04 (1.73, 2.39)	1.81 (1.52, 2.17)	2.31 (2.05, 2.61)	2.08 (1.82, 2.39)
Age[b]	0.95 (0.90, 1.01)	0.94 (0.88, 1.00)	0.99 (0.93, 1.04)	0.98 (0.92, 1.05)	0.93 (0.88, 0.99)	0.93 (0.87, 0.99)
Sex						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	0.88 (0.70, 1.11)	0.92 (0.72, 1.17)	0.98 (0.79, 1.22)	1.02 (0.81, 1.28)	0.76 (0.60, 0.96)	0.79 (0.62, 1.00)
BMI[b]	0.90 (0.81, 1.00)	0.90 (0.80, 1.01)	0.93 (0.84, 1.04)	0.94 (0.84, 1.06)	0.92 (0.82, 1.02)	0.92 (0.82, 1.04)
Log IMD 2004	0.74 (0.63, 0.87)	0.73 (0.62, 0.87)	0.78 (0.67, 0.91)	0.80 (0.68, 0.94)	0.76 (0.65, 0.90)	0.76 (0.64, 0.89)
Side						
Left	1.00	1.00	1.00	1.00	1.00	1.00
Right	0.96 (0.78, 1.20)	0.97 (0.78, 1.21)	1.02 (0.83, 1.25)	1.03 (0.83, 1.27)	1.04 (0.84, 1.29)	1.06 (0.85, 1.31)
Diagnosis						
Primary OA	1.00	1.00	1.00	1.00	1.00	1.00
RA	2.40 (1.15, 4.99)	2.17 (1.02, 4.60)	2.22 (1.02, 4.85)	2.33 (1.03, 5.29)	1.76 (0.86, 3.61)	1.56 (0.73, 3.31)
Other	1.07 (0.53, 2.16)	1.09 (0.53, 2.23)	1.01 (0.52, 1.95)	1.05 (0.54, 2.03)	1.22 (0.60, 2.48)	1.27 (0.61, 2.67)
Operation type						
TKR	1.00	1.00	1.00	1.00	1.00	1.00
Unicompartmental knee	1.04 (0.69, 1.56)	0.91 (0.59, 1.39)	0.99 (0.68, 1.44)	0.92 (0.62, 1.36)	1.13 (0.74, 1.72)	0.97 (0.63, 1.49)
ASA grade						
1	1.43 (0.91, 2.25)	1.30 (0.81, 2.08)	1.32 (0.87, 1.98)	1.26 (0.83, 1.93)	1.63 (1.03, 2.57)	1.45 (0.90, 2.33)
2	1.00	1.00	1.00	1.00	1.00	1.00
3	1.00 (0.71, 1.39)	1.03 (0.72, 1.46)	0.95 (0.70, 1.30)	0.97 (0.70, 1.33)	0.88 (0.65, 1.20)	0.89 (0.65, 1.23)
EQ5D anxiety						
Not anxious/depressed	1.00	1.00	1.00	1.00	1.00	1.00
Moderately anxious/depressed	0.79 (0.63, 1.00)	0.80 (0.63, 1.01)	0.67 (0.54, 0.83)	0.67 (0.54, 0.84)	0.76 (0.60, 0.96)	0.77 (0.61, 0.97)
Extremely anxious/depressed	0.76 (0.46, 1.25)	0.70 (0.42, 1.18)	0.54 (0.33, 0.88)	0.51 (0.31, 0.84)	0.80 (0.48, 1.33)	0.77 (0.45, 1.29)
Year						
2005–06	1.00	1.00	1.00	1.00	1.00	1.00
2007	1.16 (0.89, 1.50)	1.21 (0.91, 1.59)	1.13 (0.87, 1.47)	1.15 (0.88, 1.49)	1.17 (0.89, 1.54)	1.22 (0.93, 1.61)
2008	1.07 (0.80, 1.43)	1.07 (0.79, 1.46)	1.11 (0.83, 1.49)	1.12 (0.84, 1.51)	0.99 (0.73, 1.33)	1.00 (0.74, 1.36)

[a]Multivariable: mutually adjusted for all predictor variables. OR >1 implies a group has a better post-operative outcome compared with the reference group. [b]5-unit increase. Univariable: each predictor in the model is adjusted for baseline OKS only. OR: odds ratio.

Greater severity of arthritis on X-ray is also associated with better outcomes [39]. It is possible that the way information on pre-operative pain/function, mental health and co-morbidities is measured is not detailed enough to capture variability in its relation to outcome. For example, in relation to pain, a possible biological factor in the maintenance of chronic pain after TKR is a dysfunction of pain modulation in the CNS, known as central sensitization, and evidence that some OA patients have manifestations of central sensitization has been obtained using Quantitative Sensory Testing [2, 41].

Strengths and limitations

The strengths of this study include the relatively large cohort, the use of a reliable, valid and responsive instrument for assessing outcomes of TKR [17, 42] and data collected prospectively with a good rate of follow-up within a standard NHS setting with multiple surgeons. The findings are therefore representative of general orthopaedic practice in the UK. Limitations are that other potential predictive variables were not collected for this study, such as co-morbidities, type and extent of joint damage and operative factors. Response bias may play a role, as responders were older, had a lower average BMI and were less likely to be anxious/depressed, hence the true effects of these predictors may be underestimated in this study. The strength of our study is the use of the 6-month post-operative OKS as the outcome, adjusting for baseline score. This is the only unbiased method of analysis and it is also the most precise [43]. Within this study, differences were observed between predictors of pain and functional outcomes, hence the OKS may not be the best outcome measure to assess individual domains of pain and function, as it was designed to be used as a total score. Although it is relatively easy to separate out questions measuring pain and function, a more suitable scoring tool may be required that has been designed to measure outcomes for individual domains of pain and function, such as the WOMAC OA index [44], which is a reliable, valid and responsive instrument for examining outcomes in patients with OA undergoing joint replacement.

What this study adds

Within this study, we identified predictors of clinically important attained pain and function 6 months post-TKR surgery by deriving a PASS to define outcome. Predictors of pain were not necessarily the same as for functional outcomes, which may be important in the context of patient's expectations of their surgery. An important new finding was that area deprivation was a significant predictor of outcome, where those living in affluent areas had the best outcomes, although it is more likely this reflects an ecological effect of the area rather than individual level measures of education and income. The strongest predictors of outcome were pre-operative pain/function, baseline anxiety/depression, diagnosis of RA *vs* OA and area deprivation. Small effects were observed for age and gender, whereas BMI was not clinically important in predicting outcome. Further research is required using more detailed measures of existing predictive variables, and other factors need to be identified beyond those observed in this study and within the literature, to improve our predictive ability to identify patients at risk of poor outcomes of TKR surgery.

Rheumatology key messages

- The PASS score can be used to identify clinically important predictors of TKR outcome.
- Predictors of pain outcome are not necessarily the same as functional outcomes of TKR.
- Other factors must be identified to improve detection of patients getting poor TKR outcome.

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Supplementary data

Supplementary data are available at *Rheumatology* Online.

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Clinical vignette

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[18F]fluorodeoxyglucose positron emission tomography imaging in a case of relapsing polychondritis

A 77-year-old man presented with headache, monolateral conjunctivitis, swelling and redness of the nasal bridge and external ear cartilage. After 2 months, he developed bilateral episcleritis, left hearing loss, laryngitis and dysphonia. A CT scan showed inflammatory tissue filling the tympanic cavity and left mastoid. Laboratory examination showed the following: CRP 9.77 mg/dl (normal value <0.5 mg/dl), ESR 120 mm/1st h (normal value <15). Relapsing polychondritis (RPC) was suspected and [^{18}F]fluorodeoxyglucose (FDG) PET/CT was performed, to exclude a co-existing large-vessel vasculitis or neoplastic conditions. Fig. 1 shows unexpected marked FDG uptake at the right auricle. Lower uptake was evident on the ipsilateral cervical lymph node and on the cartilage of the contralateral auditory canal. We started prednisone at a dose of 50 mg daily.

Symptoms and laboratory tests normalized in a few months. Thirteen months later a second FDG PET/CT was negative. Nishiyama *et al.*, De Geeter and Vandecasteele, and Sato *et al.* [1–3] used FDG PET in RPC to evaluate the residual activity of the disease or to localize useful sites for diagnostic biopsy. Fig. 1 shows that in inflamed cartilage, there is recruitment of cells with increased metabolic activity, and that PET/CT is useful in the diagnosis and follow-up of RPC.

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Fig. 1 FDG PET/CT showing tracer uptake at the cartilage of the right ear auricle and of the contralateral auditory canal.