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ORIGINAL RESEARCH

Patient appropriateness for total knee arthroplasty and predicted probability of a good outcome

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ABSTRACT

Objectives One-fifth of total knee arthroplasty (TKA) recipients experience a suboptimal outcome. Incorporation of patients' preferences in TKA assessment may improve outcomes. We determined the discriminant ability of preoperative measures of TKA need, readiness/willingness and expectations for a good TKA outcome.

Methods In patients with knee osteoarthritis (OA) undergoing primary TKA, we preoperatively assessed TKA need (Western Ontario-McMaster Universities OA Index (WOMAC) Pain Score and Knee injury and Osteoarthritis Outcome Score (KOOS) function, arthritis coping), health status, readiness (Patient Acceptable Symptom State, depressive symptoms), willingness (definitely yes—yes/no) and expectations (outcomes deemed 'very important'). A good outcome was defined as symptom improvement (met Outcome Measures in Rheumatology and Osteoarthritis Research Society International (OMERACT–OARSI) responder criteria) and satisfaction with results 1 year post TKA. Using logistic regression, we assessed independent outcome predictors, model discrimination (area under the receiver operating characteristic curve, AUC) and the predicted probability of a good outcome for different need, readiness/willingness and expectations scenarios.

Results Of 1,053 TKA recipients (mean age 66.9 years (SD 8.8); 58.6% women), 78.1% achieved a good outcome. With TKA need alone (WOMAC pain subscale, KOOS physical function short-form), model discrimination was good (AUC 0.67, 95% CI 0.63 to 0.71). Inclusion of readiness/willingness, depressive symptoms and expectations regarding kneeling, stair climbing, well-being and performing recreational activities improved discrimination (p=0.01; optimism corrected AUC 0.70, 0.66–0.74). The predicted probability of a good outcome ranged from 44.4% (33.9–55.5) to 92.4% (88.4–95.1) depending on level of TKA need, readiness/willingness, depressive symptoms and surgical expectations.

Conclusions Although external validation is required, our findings suggest that incorporation of patients' TKA readiness, willingness and expectations in TKA decision-making may improve the proportion of recipients that experience a good outcome.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Total knee arthroplasty (TKA) is an effective treatment for knee osteoarthritis (OA), but a substantial proportion of recipients report little symptom improvement or dissatisfaction with results, questioning their surgical appropriateness.

⇒ TKA is a preference-sensitive procedure, performed to improve patients' quality of life. Yet, to date, there has been little consideration of preferences or values of patients with knee OA in determining patient appropriateness for TKA. Incorporation of patients' perspectives in TKA decision-making may improve outcomes.

WHAT THIS STUDY ADDS

⇒ In a large prospective cohort study, we found that preoperatively patient-reported measures of TKA readiness, willingness and expectations significantly enhanced ability to discriminate those who did versus did not go on to experience a good TKA outcome compared with measures of TKA need alone. Given documented wide variability among participants with respect to preoperative measures of TKA need, readiness/willingness and surgical expectations, these findings have the potential to improve shared patient–physician TKA decision-making.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ More explicit incorporation of patients' perspectives in assessment of TKA appropriateness has the potential to improve TKA outcomes and the use of valuable healthcare resources.

INTRODUCTION

Total knee arthroplasty (TKA) is used widely to treat advanced symptomatic knee osteoarthritis (OA).[1 2] Over 75,000 TKAs are

Table 1 Variables considered as measures of TKA appropriateness criteria

Patient appropriateness construct	Measure of assessment
TKA need	
Evidence of knee OA on clinical and radiographic examination of the joint being considered for surgery	Confirmed by surgeon post consultation in all participants.
Patient reports that knee OA symptoms are negatively impacting their overall quality of life	**Knee pain:** 5-item WOMAC pain subscale Likert V.3.0 (0–20, higher scores indicate greater pain). **Knee (lower extremity) function:** 7-item Knee injury and Osteoarthritis Outcome Score physical function short-form (0–100, higher scores indicate worse function). **Perceived arthritis coping:** 4-item Arthritis Coping Efficacy Scale (4–20, higher scores indicate better perceived arthritis coping).
An adequate trial of non-surgical OA treatment has been provided	**Prior OA treatment:** Participants were asked to indicate if they had 'ever' tried (yes/no): exercise—formal or informal; physiotherapy; weight loss; acetaminophen; anti-inflammatories; codeine; joint injection; and walking aids. Individuals were considered to have received recommended OA therapies if they had 'ever tried' formal exercise *or* physiotherapy and weight loss if overweight/obese and any analgesic.
TKA readiness/willingness	
The patient is ready and willing to have surgery	**Patient Health Questionnaire Depression Scale (PHQ-8)**: This 8-item scale assesses depressive symptoms; total score from 0 to 24, with higher scores indicating more depressive symptoms. **Patient Acceptable Symptom State**: "Think about all the ways your knee OA has affected you during the last 48 hours. If you were to remain in the next few months as you were the last 48 hours would this be acceptable or unacceptable to you?" **TKA willingness:** "Based on your current understanding of the risks and benefits of knee replacement surgery and the severity of your knee arthritis, what is your current preference regarding having TKA?" Response options: 1, 'would definitely not consider surgery now', to 5, 'would definitely consider surgery now'.
TKA expectations	
The patients' expectations for knee replacement surgery are reasonable and thus achievable	**Hospital for Special Surgery Knee Expectations Questionnaire**: For each of 17 TKA outcomes, participants asked "How important are these expectations in the treatment of your knee arthritis?" Response options were: 4, very important, 3, somewhat important, 2, a little important, 1, I do not expect this, or 0, this does not apply to me. Summary score 0–100, with higher scores indicating a greater number of 'very important' TKA expectations. Expectations were: relieve knee pain, enjoy psychological well-being, and improve ability to perform daily activities, go upstairs, walk, squat, kneel, change position, for example, get up from a chair, straighten knee/leg, exercise or participate in sports, engage in sexual activity, participate in recreational activities, work for pay, interact with others, for example, care giving, walk without aids, take public transit or drive.
Health status	
Patient and surgeon agree that the potential risks associated with surgery do not outweigh potential benefits	**Body mass index**, kg/m^2: calculated from reported height and weight. **Comorbidity:** for a list of ten common conditions, subjects indicated if they had the condition and, if so, if they were receiving treatment. **Other troublesome lower extremity joints**: participants indicated on a joint homunculus which joints were painful, swollen, tender or stiff. **Smoking status:** self-reported smoking status (never, past, current).

OA, osteoarthritis; TKA, total knee arthroplasty; WOMAC, Western Ontario-McMaster Universities OA Index.

performed annually in Canada for knee OA, with inpatient costs of approximately $1 billion.[3] TKA rates are rising due to obesity and ageing, both risk factors for knee OA.[1 4 5] While, on average, TKA is highly effective, 15%–30% of recipients report little or no symptom improvement and/or dissatisfaction with results.[6 7] Among primary TKA recipients in an Ontario OA cohort, we found that changes in pain, function and health resource use after TKA varied substantially; while mean changes were positive, 23.6% experienced no meaningful change in symptoms and 17.1% were worse after surgery.[8] More appropriate selection of TKA candidates offers the opportunity to improve both patient outcomes and the use of valuable healthcare resources.[9]

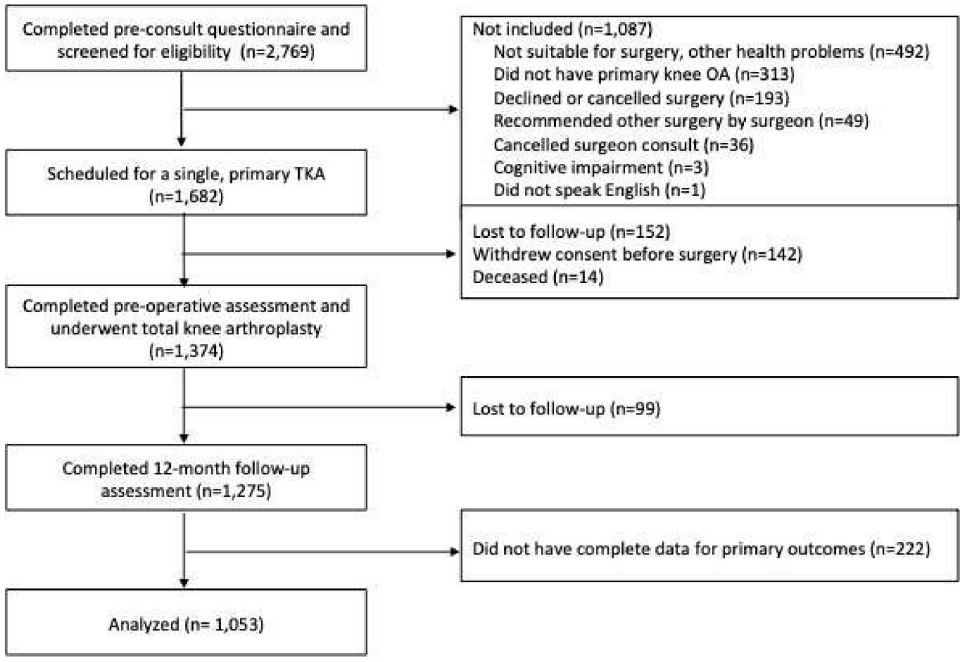

Figure 1 Participant recruitment flow chart.

TKA is a preference-sensitive procedure, performed to improve patients' quality of life. Patients must weigh the benefits and risks of surgery in the context of their personal preferences and values.[10 11] Thus, TKA appropriateness criteria should be used to determine if it is reasonable to consider operating given a patient's particular circumstances.[12 13] Yet, to date, there has been little or no involvement of patients with knee OA in the development or validation of TKA appropriateness criteria or decision-support tools.[14–18] Most have been developed based on expert clinician consensus informed by the best available scientific evidence.[9 15 16 18–20] Existing tools generally consider patients' symptoms, comorbidity, radiographic severity and clinical examination (knee mobility and stability).[17 21] While shared patient–physician decision-making is encouraged,[16 22–24] no criteria explicitly incorporate patients' expectations or preferences for care. While studies have shown that patients who meet existing criteria for appropriateness experience greater improvements in pain and function than those that do not, no significant differences have been found with respect to patient satisfaction with surgical results.[15 25–28] Incorporation of patients' perspectives in TKA appropriateness assessment may improve ability to identify at surgeon consultation those patients most likely to benefit from surgery.

In a prior population-based cohort study, we showed that patient willingness to undergo TKA was the strongest predictor of subsequent receipt of surgery and that TKA willingness reflected patients' perceptions of their candidacy for surgery, including perceived OA severity, coping efficacy and risks and benefits of surgery.[29–31] In subsequent qualitative research to elucidate key stakeholders' opinions about patient appropriateness for TKA, people with OA and orthopaedic surgeons agreed that it was important to consider four appropriateness domains: patient's need for TKA (symptom severity, prior therapies tried and evidence of knee OA on clinical and radiographic examination), health status (surgical risk), psychological readiness and willingness for TKA and expectations of TKA.[32–34] Participants with a prior knee replacement recalled the challenges of getting through the early postoperative period. They emphasised the importance of having a positive attitude and feeling mentally prepared to undergo surgery to experiencing a good surgical outcome.

Informed by this work, the current study sought to establish the predictive validity, and relative weights, of valid and reliable measures of the four appropriateness domains (TKA need, health status, readiness and willingness and surgical expectations) for TKA 'benefit', defined as a composite dichotomous outcome incorporating symptom improvement and satisfaction with surgical results. In particular, we were interested in the contribution, if any, made by measures of readiness, willingness and expectations to our ability to discriminate, preoperatively, those who would versus would not experience a good TKA outcome.

METHODS

Setting and design

This prospective cohort study recruited people with knee OA referred for elective TKA to two orthopaedic clinics responsible for approximately 60% of joint replacements in Alberta, Canada, between 2014 and 2016. Those aged 30 years or older, able to read and comprehend English, and confirmed to have knee OA on physical examination and imaging were eligible. Individuals with inflammatory

Table 2 Preoperative characteristics of knee OA participants

Participant characteristic	n=1053
Key contextual factors	
Age (years), mean (SD)	66.9 (8.8)
Sex=female, n (%)	617 (58.6)
Employed for pay, n (%)	344/1040 (33.1)
Education=post-secondary, n (%)	584/1036 (56.4)
Lubben Social Network Score, mean (SD)	18.0 (5.5)
Previous hip/knee replacement, n (%)	164 (15.9)
Measures of TKA appropriateness	
TKA need	
WOMAC Pain Score (0–100), mean (SD) (higher scores worse)	57.2 (17.3)
KOOS-PS (0–100), mean (SD) (higher scores worse)	52.8 (17.1)
Arthritis coping efficacy (4–20), mean (SD) (higher scores better)	13.4 (3.8)
Received OA treatment previously, n (%)	731/1029 (71.0)
Readiness and willingness to undergo TKA	
PHQ-8 (0–24), median (IQR)	5.0 (2–10)
PHQ-8 Score≥10/24, n (%) (moderate–severe depressive symptoms)	271 (25.8)
Definitely willing, n (%)	905/1031 (87.8)
PASS=unacceptable, n (%)	836/1049 (79.7)
Health status	
BMI, mean (SD)	32.5 (6.3)
Number of comorbid conditions, n (%)	
0	272/1034 (26.3)
1	363 (35.1)
2	244 (23.6)
3+	155 (15.0)
Current smoker, n (%)	74/1041 (7.1)
Troublesome hip(s), n (%)	239/1034 (23.1)
Troublesome contralateral knee, n (%)	523/1034 (50.6)
Low back pain, n (%)	267/1053 (25.4)
TKA expectations, n (%) indicating a 'very important' TKA outcome	
Perform daily activities	867/1052 (82.4)
Go upstairs	899/1051 (85.5)
Walk	1011/1046 (96.7)
Relieve pain	983/1051 (93.5)
Squat	604/1051 (57.5)
Kneel	651/1050 (62.0)
Change position, for example, get up from chair	831/1047 (79.4)
Straighten knee/leg	622/1048 (59.5)
Exercise or participate in sports	687/1048 (65.6)
Engage in sexual activity	391/1040 (37.6)
Participate in recreational activities	793/1050 (75.5)
Work for pay	317/1042 (30.4)
Interact with others, for example, care giving	704/1051 (67.0)
Walk without aids	699/1045 (66.9)
Take public transit or drive	657/1051 (62.5)
Enjoy well-being	697/1046 (66.6)

Continued

Table 2 Continued

Participant characteristic	n=1053

Denominator is shown when response is <100%.
BMI, body mass index; KOOS-PS, Knee injury and Osteoarthritis Outcome Score physical function short-form; OA, osteoarthritis; PASS, Patient Acceptable Symptom State; PHQ-8, Patient Health Questionnaire; TKA, total knee arthroplasty; WOMAC, Western Ontario-McMaster Universities OA Index.

arthritis were excluded. All 45 clinic surgeons agreed to participate.

Assessments

Pre consultation, consenting patients completed a standardised questionnaire to assess appropriateness domains and contextual factors. In the absence of consensus on how best to measure the domains, we conducted a comprehensive search for reliable and valid self-complete questionnaires and selected for use those that were brief and validated for use in knee OA, ideally in the TKA setting (Table 1). To assess TKA need, participants reported their knee pain and disability (Western Ontario-McMaster Universities OA Index (WOMAC) pain subscale[35] and Knee injury and Osteoarthritis Outcome Score physical function short-form, KOOS-PS[36]), perceived ability to cope with knee symptoms (four-item Arthritis Coping Efficacy Scale)[37] and prior OA therapies (formal or informal exercise, physiotherapy, weight loss, acetaminophen, anti-inflammatories, codeine, joint injection and walking aids).[38] To assess psychological readiness for TKA, participants completed the Patient Health Questionnaire (PHQ-8) to assess for symptoms of depression[39] and the Patient Acceptable Symptom State (PASS) to assess the acceptability of their knee symptoms (acceptable or unacceptable)[40] and reported their willingness to consider TKA if recommended (5-point Likert scale from 'definitely willing' to 'definitely not willing'). To assess health status, we ascertained height/weight to calculate body mass index (BMI), physician-diagnosed comorbidities[41] and pain or stiffness in the hips, contralateral knee or low back. To assess TKA expectations, participants completed the Hospital for Special Surgery Knee Replacement Expectations Questionnaire[42]; they rated the importance of 17 TKA outcomes as 'very important', 'somewhat important', 'a little important', 'I do not expect this' or 'this does not apply to me' and those deemed 'very important' were considered expectations. We also assessed level of social support (Lubben Social Support Scale)[43] and prior joint replacement (hip or contralateral knee). Patient age and sex were obtained from clinic records. Evidence of knee OA on clinical and radiographic examination of the joint being considered for surgery were confirmed by the surgeon (yes/no) post consultation.

One year post surgery, we reassessed knee symptoms in addition to patient global assessment (PGA) of change in knee pain and function (5-point Likert scale: 'much better' to 'much worse'),[44] overall satisfaction (Patient Satisfaction Scale for Primary Hip and Knee Arthroplasty,

Table 3 Proportion (95% CI) that achieved net benefit from TKA at 1 year post TKA

Definition of net benefit from TKA	Proportion achieved (95% CI)
OMERACT–OARSI responder criteria (modified)	
a) PGA knee pain much or somewhat improved	93.5 (91.95 to 94.9)
b) ≥20% improvement in WOMAC Pain Score	94.1 (92.7 to 95.5)
c) ≥20% improvement in KOOS-PS	85.3 (83.1 to 87.4)
d) Absolute change in WOMAC Pain Score≥2/20	95.8 (94.6 to 97.0)
e) Absolute change in KOOS-PS≥10/100	83.3 (81.0 to 85.5)
Met all the above criteria (a–e), indicating treatment response*	79.5 (76.9 to 81.9)
Overall satisfaction with TKA results	
Very satisfied	74.7 (72.1 to 77.4)
Somewhat satisfied	16.7 (14.5 to 19.0)
Somewhat or very satisfied	91.45 (89.8 to 93.1)
Somewhat or very dissatisfied	8.55 (6.9 to 10.4)
OMERACT–OARSI and somewhat/very satisfied	78.1 (75.4 to 80.5)

*Each of the five Outcome Measures in Rheumatology and Osteoarthritis Research Society International (OMERACT–OARSI) criteria (a–e) were assessed individually; those who met all the criteria were considered to have responded to the treatment (TKA).
KOOS-PS, Knee injury and Osteoarthritis Outcome Score physical function short-form; PGA, patient global assessment; TKA, total knee arthroplasty; WOMAC, Western Ontario-McMaster Universities Osteoarthritis Index.

4-point Likert scale: 'very dissatisfied' to 'very satisfied')[45] and occurrence of TKA complications (verified in patients' medical record).

Primary outcome

In our prior qualitative research,[32–34] patients with OA and surgeons told us that both meaningful symptom improvement and satisfaction with surgical results should be considered if assessing post hoc whether a TKA had been appropriate. Thus, we defined a *good TKA outcome* (yes/no) as both *meaningful improvement in OA symptoms and patient-reported satisfaction* (very or somewhat) with TKA results overall. Symptom improvement was defined as fulfilment of the Outcome Measures in Rheumatology and Osteoarthritis Research Society International (OMERACT–OARSI) OA responder criteria[46]: PGA pain and function 'much' or 'somewhat improved' and a relative change in both WOMAC Pain Score and KOOS-PS function of ≥20% and an absolute change in these scores of ≥10 points/100.

Exposures were our measures of the appropriateness domains. Individuals were considered to have 'received recommended OA therapies' (yes/no) if they had 'ever tried' formal exercise or physiotherapy and weight loss if overweight/obese and any analgesic. TKA willingness was categorised as definitely willing (yes/no). *Covariates* were age, gender, social support and prior joint replacement.

Statistical analyses

Variables were summarised as proportions, means and medians, as appropriate. KOOS-PS and WOMAC Pain Score were transformed to a 0–100 scale with higher scores indicating greater severity. Collinearity was assessed using a variance inflation factor of >4[47]; as perceived importance of kneeling and going upstairs was collinear with perceived importance of squatting and going downstairs, respectively, the latter was excluded from analyses.

Given the large number of potential predictors, we used logistic regression and best possible subsets variable selection to identify the fewest predictors with the best discriminative ability for our outcome, defined as the smallest Akaike's information criterion.[48] All-possible-subset regression then determined the best model of that variable number. All potential predictors, irrespective of appropriateness domain, were considered. Diagnostics, including a check of the residuals and tests for influential observations, were run.[49] To control for potential clustering by surgeon, we used multivariable log Poisson regression[50] to assess the unadjusted and adjusted risk ratios (RRs) for a good TKA outcome associated with the identified predictors. Receiver operating characteristic (ROC) curves were generated to examine and compare the discriminant ability of significant predictors of TKA outcome by appropriateness domain and overall based on the area under the ROC curve (AUC). Effron's enhanced bootstrap was used to generate an optimism corrected AUC for the multivariable model.[51 52]

To assess the potential usefulness of the findings in appropriateness assessment, we categorised each participant's level of appropriateness (low to high) for each of the appropriateness domains (TKA need, health status, readiness/willingness, expectations) based on the variables in the final model. Multivariable logistic regression was then used to calculate the predicted probability of a good TKA outcome for various TKA appropriateness scenarios. Statistical significance was based on a two-sided p value<0.05.

Patient and public involvement

Public involvement was first initiated during the design stage of the study through interviews with patients and stakeholders. Patients and members of the public served as consultants for initial questionnaire design, methods of administration and time required for administration of the questionnaire. No patients were involved in setting the research question or the outcome measures, nor were they asked to advise on interpretation or writing up of results.

RESULTS

Study sample

Of 1374 consenting, eligible patients who completed preoperative assessments and underwent TKA for knee

OA, 1275 patients completed the 1-year assessment. In total, 1053 (82.6%) patients with data to assess our TKA outcome were included (figure 1). Responses were missing for less than 10% of variables except for KOOS-PS, where scores could not be calculated for 12.6%.

Cohort characteristics pre TKA

Participant characteristics pre TKA are shown in table 2. Mean age was 66.9 years (SD, 8.8) and 58.6% of participants were women. Mean WOMAC Pain Score was 57.2/100 (SD 17.3), mean KOOS-PS was 52.8/100 (SD 17.1) and 71.0% had received recommended OA treatments, as defined. The median PHQ-8 Score was 5/24 (IQR, 2–10); 25.8% had scores≥10 indicating moderate-to-severe depressive symptoms. Overall, 79.7% indicated their knee symptoms were unacceptable and 87.8% indicated definite willingness to undergo TKA at consultation. Mean BMI was 32.5 kg/m^2 (SD 6.3), 38.6% had two or more non-musculoskeletal (MSK) comorbid conditions and 70.3% had MSK comorbidities. Most participants indicated that improved ability to walk and reduced knee pain were very important TKA outcomes (96.7% and 93.5%, respectively), while 75%–85% considered improved ability to perform daily activities, climb stairs, participate in recreational activities and change position very important. More variability was observed with respect to the importance of other outcomes.

TKA outcome at 1 year

In 23 participants (2.2%) experienced a TKA complication: 18 revisions (13 unspecified, 2 for infection and 3 for patellar resurfacing) and 10 manipulations under anaesthesia. Including these individuals, 79.5% (76.9–81.9) met OMERACT–OARSI criteria for response and 74.7% (72.1–77.4) and 16.7% (14.5–19.0) were very or somewhat satisfied with their surgical results, respectively. Overall, 78.1% (95% CI 75.4% to 80.5%) met our composite criteria for a good TKA outcome (table 3).

Results of stepwise variable selection

Optimal outcome discrimination was achieved with 13 variables. The best 13-variable model included WOMAC Pain Score and KOOS-PS (measures of TKA need), PHQ-8 depressed mood, PASS knee symptom acceptability and definite TKA willingness (measures of readiness/willingness), troublesome contralateral knee or low back (measures of health status), five TKA expectations (improved psychological well-being and improved ability to go upstairs, kneel, perform recreational activities and perform activities of daily living) and patient age. All other factors, including prior OA treatment, BMI, non-MSK comorbidities, sex and level of social support, were not selected for inclusion.

Predictors of a good TKA outcome: result of log Poisson regression modelling

The unadjusted and adjusted RRs for a good TKA outcome associated with identified predictors are shown in table 4. In the multivariable model, the probability of a good TKA outcome was significantly higher for those with greater TKA need (adjusted RR per 10-unit increase WOMAC Pain Score 1.03, 95% CI 1.01 to 1.05; adjusted RR per 10-unit increase KOOS-PS 1.06, 95% CI 1.03 to 1.08), greater TKA readiness and willingness (unacceptable knee symptoms adjusted RR 1.14, 95% CI 1.03 to 1.27; definitely willing adjusted RR 1.20, 95% CI 1.05 to 1.37), fewer symptoms of depressed mood (adjusted RR per 10-unit increase in PHQ-8 0.94, 95% CI 0.89 to 0.99) and who considered it 'very important' that TKA improve their ability to go upstairs or perform recreational activities (adjusted RR and 95% CI 1.15, 1.02 to 1.30 and 1.10, 1.01 to 1.20, respectively). Those who considered it 'very important' that TKA improve ability to kneel or psychological well-being had a significantly lower probability of achieving a good outcome (adjusted RR and 95% CI 0.93, 0.87 to 0.99 and 0.92, 0.86 to 0.99, respectively).

Discriminant ability of appropriateness domains for achievement of a good TKA outcome

Model discrimination for TKA need (WOMAC Pain Score and KOOS-PS) was good (AUC 0.67, 95% CI 0.63 to 0.71). Inclusion of readiness/willingness (PASS and TKA willingness), symptoms of depression and TKA expectations (importance of improved kneeling, stair climbing, psychological well-being and ability to perform recreational activities) significantly improved model discrimination (p=0.01), giving an optimism corrected AUC of 0.70 (0.66–0.74) (figure 2).

Cohort distribution by level of appropriateness

TKA need was considered low if WOMAC Pain Score and KOOS-PS were in the lowest tertiles of preoperative scores (WOMAC Pain Score≤45 and KOOS-PS≤44), high if both scores were in the uppermost tertiles (WOMAC Pain Score≥60 and KOOS-PS≥62) and moderate otherwise. Readiness/willingness was considered high if knee symptoms were unacceptable and the individual indicated definite willingness for TKA and moderate otherwise. Symptoms of depression were categorised as per PHQ-8 recommendations[39]: no depressed mood (high appropriateness) if ≤4, mild depressed mood (moderate appropriateness) if 5–9 and moderate/severe depressed mood (low appropriateness) if ≥10. TKA expectations that were positively associated with our TKA outcome in our multivariable regression model (improved ability to go upstairs and perform recreational activities) were considered 'realistic', while those that were negatively associated with our outcome (improved ability to kneel or improved psychological well-being) were considered 'unrealistic'. For each participant, we assigned an expectation score of 1 for each realistic expectation deemed 'very important' and a score of −1 for each unrealistic expectation indicated as 'very important'. Participant expectation scores were then summed (−2 to +2) and appropriateness was considered to be low if the summary score was <0 (preponderance of unrealistic expectations), moderate if 0 and high if >0, indicating a preponderance of realistic

Table 4 Preoperative predictors of a good TKA outcome*: results of multivariable robust Poisson regression

Preoperative predictors	Dependent variable: good TKA outcome* (yes vs no)		
	Unadjusted risk ratio (RR) (95% CI)	Adjusted RR † (95% CI)	P value
TKA need			
WOMAC Pain Score, per 10-unit increase	**1.06 (1.04 to 1.08)**	**1.03 (1.01 to 1.05)**	**0.01**
KOOS-PS, per 10-unit increase	**1.07 (1.05 to 1.09)**	**1.06 (1.03 to 1.08)**	**<0.0001**
Health status			
Troublesome contralateral knee	**1.09 (1.02 to 1.16)**	1.05 (0.99 to 1.12)	0.13
Low back pain	0.97 (0.90 to 1.05)	0.93 (0.87 to 1.00)	0.06
Readiness/willingness			
PHQ-8 depression, per 10-unit increase	**1.05 (1.00 to 1.11)**	**0.94 (0.89 to 0.99)**	**0.04**
PASS knee symptoms, unacceptable	**1.26 (1.13 to 1.39)**	**1.14 (1.03 to 1.27)**	**0.02**
'Definitely willing' to undergo TKA	**1.26 (1.10 to 1.44)**	**1.20 (1.05 to 1.37)**	**0.007**
TKA expectations			
Go upstairs	**1.19 (1.05 to 1.33)**	**1.15 (1.02 to 1.30)**	**0.02**
Perform daily activities	1.03 (0.94 to 1.12)	0.92 (0.84 to 1.02)	0.10
Kneel	1.00 (0.94 to 1.17)	**0.93 (0.87 to 0.99)**	**0.03**
Perform recreational activities	1.08 (0.99 to 1.17)	**1.10 (1.01 to 1.20)**	**0.04**
Improve psychological well-being	0.99 (0.22 to 1.06)	**0.92 (0.86 to 0.99)**	**0.04**
Patient age, per 10-year increase	1.00 (0.99 to 1.00)	1.03 (1.00 to 1.07)	0.10

*Met Outcome Measures in Rheumatology and Osteoarthritis Research Society International (OMERACT–OARSI) response criteria+reported being somewhat or very satisfied overall with TKA results.
†RRs adjusted for all other variables in the model.
KOOS-PS, Knee injury and Osteoarthritis Outcome Score physical function short-form; PASS, Patient Acceptable Symptom State; PHQ-8, Patient Health Questionnaire; TKA, total knee arthroplasty; WOMAC, Western Ontario-McMaster Universities Osteoarthritis Index.

expectations (table 5). Using this approach, 211 participants (20.0%) had low need, 630 (59.8%) had moderate need and 212 (20.1%) had high need. Readiness/willingness was moderate in 299 (29.1%) and high in 728 (70.9%). Almost half (n=496, 47.2%) had no depressive symptoms (high appropriateness), 285 (27.1%) had mild symptoms (moderate appropriateness) and 271 (25.8%) had moderate or severe symptoms (low appropriateness). Over half of the participants (n=547, 52.0%) had both realistic and unrealistic expectations (moderate appropriateness), while 130 (12.4%) and 376 (35.7%) had a preponderance of unrealistic and realistic expectations (low and high expectations), respectively.

Predicted probability of a good TKA outcome by level of TKA appropriateness

The predicted probability of a good TKA outcome ranged from 44.4% (33.9–55.5) for those with low TKA need, moderate readiness/willingness, moderate/severe symptoms of depression and a preponderance of unrealistic expectations to 92.4% (88.4–95.1) for those with high TKA need, moderate readiness and willingness, mild depressive symptoms and predominantly realistic expectations (table 5).

DISCUSSION

In prior qualitative research, patients and surgeons agreed that evidence of demonstrable TKA need and fitness for surgery were important to consider in assessing patient appropriateness for TKA.[32–34] In addition, people with OA stressed that patients should be ready and willing to undergo TKA and have a positive attitude and realistic expectations for surgery.[32] In a large cohort of knee OA TKA recipients, we asked if patients who met these criteria would be more likely than those who did not to experience a good outcome. One year post surgery, 78% achieved a good TKA outcome, defined as patient-reported symptom improvement and satisfaction with results. The model that included preoperative measures of TKA need, readiness/willingness and surgical expectations had good discrimination for our outcome, with a model AUC of 0.70 and discrimination was significantly better than for measures of TKA need alone. Although external validation is required, our findings support the need for more explicit consideration of patients' preferences and values in TKA decision-making.

There is strong consensus that TKA should be offered to individuals with knee symptoms that are negatively affecting quality of life despite a trial of non-surgical therapies.[15 16 25–27] However, only 71% of our TKA recipients had received recommended OA therapies. Although we did not find that receipt of prior recommended OA therapies was associated with TKA outcome, it is reasonable to expect that non-surgical therapies have been exhausted before a costly and potentially risky procedure is performed. Furthermore, preoperative WOMAC Pain

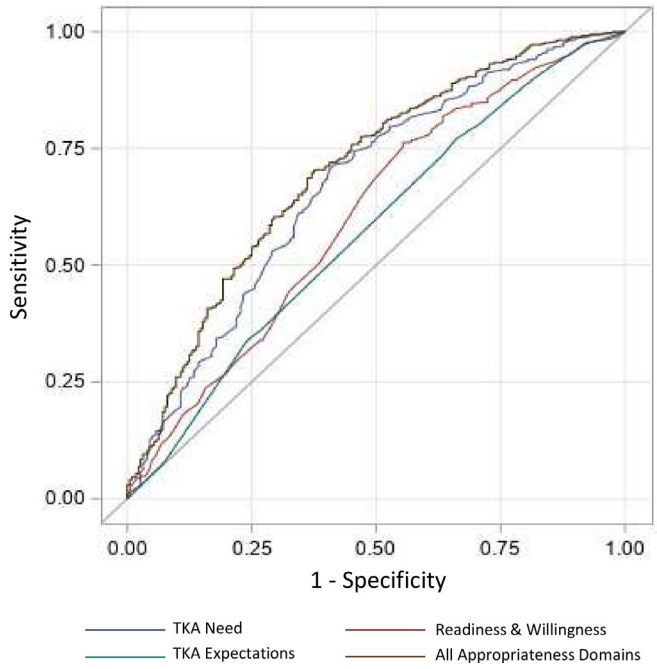

Figure 2 Area under the receiver operating characteristic (AUROC) curves by TKA appropriateness domain. The corresponding AUROC curves and 95% CIs are as follows: TKA need (WOMAC Pain Score and KOOS-PS) 0.67 (0.63–0.71); TKA readiness and willingness (PASS knee symptoms and definite willingness and PHQ-8 depressive symptoms) 0.61 (0.57–0.64); TKA expectations (importance of four TKA outcomes: improvements in going upstairs, performing recreational activities, kneeling and psychological well-being) 0.57 (0.53–0.62); and for all appropriateness domains combined 0.70 (0.66–0.74). KOOS-PS, Knee injury and Osteoarthritis Outcome Score physical function short-form; PASS, Patient Acceptable Symptom State; PHQ-8, Patient Health Questionnaire; TKA, total knee arthroplasty; WOMAC, Western Ontario-McMaster Universities Osteoarthritis Index.

Score and KOOS-PS spanned the full range and one-fifth of participants reporting their symptoms as 'acceptable'. Low symptom scores at surgery may reflect patient avoidance of activities that exacerbate knee symptoms, use of analgesic therapies or simply less TKA need. Participants with low symptom scores were *less likely* than those with higher scores to report unacceptable knee symptoms, suggesting the latter may be the case.

Our findings raise concerns regarding the prior use of the RAND appropriateness methodology to develop TKA appropriateness criteria.[9 20] The RAND approach is based on expert consensus and best-available evidence from literature review. There is no incorporation of patients' perspectives and validation of preliminary criteria is not based a priori on demonstration that patients deemed appropriate versus uncertain or inappropriate prior to surgery are more likely to achieve 'net benefit' from TKA. The revised Spanish criteria and those from the American Academy of Orthopaedic Surgery (AAOS) were developed in this manner.[15 16 18] Using the Spanish criteria, Escobar *et al* found that appropriate candidates were more likely than those deemed inappropriate to experience minimally important improvements in pain and function at follow-up, but outcomes were similar for those deemed appropriate versus uncertain and level of satisfaction was similar across groups.[15] Furthermore, both the Spanish and AAOS criteria ask surgeons to make assumptions regarding the patients whose TKA appropriateness they are assessing. In development of the Spanish criteria, experts were instructed to assume that the patient had unilateral knee symptoms, a BMI<40 kg/m^2, adequate social support and received appropriate knee OA management and their expectations had been addressed appropriately.[18] The AAOS TKA Criteria similarly asked clinical experts to assume that the patient had failed other relevant appropriate treatments.[16] Our findings question the validity of these assumptions.

Others have made recommendations on appropriate use of TKA based on statistical modelling of the predictors of TKA outcomes.[17 28] These studies have variably found that younger patient age, greater BMI and the presence of comorbidities were associated with worse TKA outcomes. Despite wide variability in age, BMI and comorbidities, none of these variables independently predicted our TKA outcome. A possible explanation for this finding is that these factors influence TKA outcome through their effects on TKA need, readiness and willingness and expectations for surgery.[31 53]

Appropriateness criteria should inform shared decision-making with the patient, not replace it.[54] The extent to which our identified criteria are considered and weighed in the TKA decision is unclear and, to our knowledge, no existing TKA decision-support tools incorporate the criteria we have identified in this study as important. In our prior work,[33] orthopaedic surgeons were generally supportive of the use of a TKA decision support tool, but not if it produced a score or threshold to determine appropriateness as clinical judgement should ultimately guide decision-making. Thus, in the current study, we did not categorise participants as appropriate or inappropriate for surgery, but rather considered TKA appropriateness on a spectrum, from low to high, for each appropriateness domain. Although there were small numbers of participants in many cells resulting in wide CIs around our probability estimates, categorising participants post hoc using this approach demonstrated more than twofold variability in the predicted probability of a good TKA outcome. Incorporation of these findings into a TKA decision-support tool has the potential to improve identification of those patients most likely to benefit from surgery and is the focus of ongoing work.

Patients' expectations for TKA, as assessed in this study, were associated with both increased and decreased probability of a good TKA outcome. This finding is consistent with the premise that dissatisfaction with results may result, in part, from failure to achieve preoperative expectations. Many factors may influence both individuals' expectations for TKA, as well as the likelihood that the expectations are achievable, including age, social support, OA severity and comorbidities. In other words,

Table 5 Estimated probability of a good TKA outcome by level of TKA appropriateness

TKA need*	TKA readiness willingness†	Symptoms of depression‡	TKA expectations§	Estimate (95% CI)
Low (n=207)	Moderate (n=106)	Moderate/severe (low appropriateness) (n=6)	Low (n=0) Moderate (n=4) High (n=2)	44.4 (33.9 to 55.5) 53.9 (45.4 to 62.1) 63.0 (53.9 to 71.3)
		Mild (moderate appropriateness) (n=18)	Low (n=4) Moderate (n=6) High (n=8)	65.7 (55.2 to 74.8) 73.6 (66.6 to 79.6) 80.3 (73.6 to 85.6)
		None (high appropriateness) (n=82)	Low (n=8) Moderate (n=33) High (n=41)	46.9 (36.4 to 57.6) 56.3 (48.6 to 63.7) 65.2 (57.2 to 72.5)
	High (n=101)	Moderate/severe (n=8)	Low (n=3) Moderate (n=4) High (n=1)	61.2 (48.4 to 72.7) 69.7 (59.2 to 78.4) 77.0 (66.9 to 84.8)
		Mild (n=17)	Low (n=4) Moderate (n=5) High (n=8)	42.1 (29.7 to 55.5) 51.4 (39.9 to 62.8) 60.7 (48.3 to 72.7)
		None (n=6)	Low (n=8) Moderate (n=35) High (n=33)	63.5 (52.8 to 72.9) 71.7 (64.2 to 78.2) 78.7 (71.3 to 84.6)
Moderate (n=611)	Moderate (n=173)	Moderate/severe (n=28)	Low (n=3) Moderate (n=15) High (n=10)	58.1 (48.5 to 67.0) 66.9 (60.7 to 72.5) 74.7 (68.0 to 72.5)
		Mild (n=57)	Low (n=8) Moderate (n=33) High (n=16)	76.8 (69.3 to 82.9) 82.8 (78.7 to 86.3) 87.6 (83.5 to 90.7)
		None (n=88)	Low (n=8) Moderate (n=47) High (n=33)	60.4 (50.1 to 69.8) 69.0 (62.2 to 75.1) 76.5 (69.7 to 82.1)
	High (n=438)	Moderate/severe (n=114)	Low (n=15) Moderate (n=72) High (n=27)	73.2 (65.0 to 80.0) 79.9 (74.7 to 84.3) 85.3 (79.9 to 89.4)
		Mild (n=137)	Low (n=17) Moderate (n=68) High (n=52)	55.7 (44.5 to 66.3) 61.2 (48.3 to 72.7) 69.7 (59.2 to 78.4)
		None (n=187)	Low (n=22) Moderate (n=89) High (n=76)	75.0 (68.5 to 80.6) 81.4 (78.2 to 84.2) 86.5 (82.7 to 89.5)
High (n=209)	Moderate (n=20)	Moderate/severe (n=10)	Low (n=0) Moderate (n=7) High (n=3)	70.5 (59.3 to 79.7) 77.7 (69.6 to 84.2) 83.6 (76.2 to 89.0)
		Mild (n=4)	Low (n=0) Moderate (n=3) High (n=1)	85.2 (77.7 to 90.4) 89.3 (84.5 to 92.7) 92.4 (88.4 to 95.1)
		None (n=6)	Low (n=0) Moderate (n=4) High (n=2)	72.5 (60.1 to 82.2) 79.4 (70.3 to 86.2) 84.9 (77.0 to 90.4)
	High (n=189)	Moderate/severe (n=99)	Low (n=16) Moderate (n=63) High (n=20)	82.5 (75.7 to 87.7) 87.3 (83.0 to 90.7) 90.9 (86.8 to 93.9)
		Mild (n=50)	Low (n=6) Moderate (n=24) High (n=20)	68.5 (56.5 to 78.4) 76.0 (66.9 to 83.2) 82.2 (73.7 to 88.4)

Continued

Table 5 Continued

TKA need*	TKA readiness willingness†	Symptoms of depression‡	TKA expectations§	Estimate (95% CI)
		None (n=39)	Low (n=6)	83.9 (77.5 to 88.7)
			Moderate (n=22)	88.3 (84.5 to 91.3)
			High (n=11)	91.7 (88.1 to 94.3)

*TKA need was considered low if WOMAC Pain Score and KOOS-PS were in the lowest tertiles of preoperative scores (WOMAC Pain Score≤45 and KOOS-PS≤44), high if both scores were in the uppermost tertiles (WOMAC Pain Score≥60 and KOOS-PS≥62) and moderate otherwise.
†Readiness/willingness was considered high if knee symptoms were unacceptable and the individual indicated definite willingness for TKA and moderate otherwise.
‡Symptoms of depression were categorised as per PHQ-8 recommendations: no depressed mood (high appropriateness) if ≤4, mild depressed mood (moderate appropriateness) if 5–9 and moderate/severe depressed mood (low appropriateness) if ≥10.
§TKA expectations that were positively associated with our TKA outcome in our multivariable regression model (improved ability to go upstairs and perform recreational activities) were considered 'realistic', while those that were negatively associated with our outcome (improved ability to kneel or improved psychological well-being) were considered 'unrealistic'. For each participant, we assigned an expectation score of 1 for each realistic expectation deemed 'very important' and a score of −1 for each unrealistic expectation indicated as 'very important'. Participant expectation scores were then summed (−2 to +2) and appropriateness was considered to be low if the summary score was <0 (preponderance of unrealistic expectations), moderate if 0 and high if >0, indicating a preponderance of realistic expectations.
KOOS-PS, Knee injury and Osteoarthritis Outcome Score physical function short-form; PHQ-8, Patient Health Questionnaire; TKA, total knee arthroplasty; WOMAC, Western Ontario-McMaster Universities OA Index.

what might be unrealistic in one patient may be totally realistic in another. Given this, assessment of whether patients' expectations are realistic must take these contextual factors into consideration. This is likely best done by the surgeon or another skilled clinician with deep understanding of TKA at the time of consultation regarding TKA.

Study strengths include our focus on people with knee OA undergoing primary TKA, which represents the majority of TKA recipients, and inclusion of TKA recipients across 45 arthroplasty surgeons, who perform approximately 60% of all TKAs in the province of Alberta, Canada. Appropriateness domains were assessed preoperatively using simple, brief, validated measures. Our sample size, with broad representation of patients by age and gender, enabled consideration of multiple predictor variables. As patients with severe preoperatively symptoms may report comparable, or even greater, improvements as compared with patients with lesser severity and be very satisfied with their TKA results, despite higher postoperative pain and disability scores, we chose a dichotomous outcome that incorporated symptom improvement (the journey), final status (the destination) and satisfaction with results. Follow-up at 1 year and data completeness were high, and analyses controlled for clustering among surgeons. There are also study limitations. Our final model had only good discriminant ability for our outcome. Inclusion of additional factors, such as findings on knee examination or imaging, may further enhance discrimination and should be considered in future work. Participating surgeons were unaware of patients' study responses; whether they elicited and discussed patients' readiness, willingness or TKA expectations is unknown. Finally, our study was performed in Alberta, thus results may not be generalisable to other provincial healthcare systems.

In conclusion, this prospective cohort study confirmed that incorporation of patients' readiness, willingness and expectations for TKA with TKA need improved ability to discriminate, preoperatively, those TKA recipients who did versus did not experience a good TKA outcome at 1-year follow-up. These findings highlight the need for explicit incorporation of patients' preferences and values in assessment of TKA appropriateness and suggest that doing so has the potential to improve the proportion of TKA recipients who experience a good surgical outcome.

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