Published in final edited form as:
J Arthroplasty. 2014 July ; 29(7): 1383–1387. doi:10.1016/j.arth.2014.01.034.

Preoperative Predictors of Pain Following Total Knee Arthroplasty

Nicolas O. Noiseux, MD, MS, FRCSC[1], **John J. Callaghan, MD**[1], **Charles R. Clark, MD**[1], **M. Bridget Zimmerman, PhD, MS**[2], **Kathleen A. Sluka, PhD, PT**[3], and **Barbara A. Rakel, PhD, RN**[4]

[1]Department of Orthopedics and Rehabilitation, University of Iowa, Iowa City, IA

[2]College of Public Health, Department of Biostatistics, University of Iowa, Iowa City, IA

[3]College of Medicine, Department of Physical Therapy and Rehabilitation, University of Iowa, Iowa City, IA

[4]College of Nursing, University of Iowa, Iowa City, IA

Abstract

Total knee arthroplasty has provided dramatic improvements in function and pain for the majority of patients with knee arthritis, yet a significant proportion of patients remain dissatisfied with their results. We performed a prospective analysis of 215 patients undergoing TKA who underwent a comprehensive array of evaluations to discover whether any preoperative assessment could predict high pain scores and functional limitations postoperatively. Patients with severe pain with a simple knee range-of-motion test prior to TKA had a 10x higher likelihood of moderate to severe pain at 6 months. A simple test of pain intensity with active flexion and extension preoperatively was a significant predictor of postoperative pain at 6 months after surgery. Strategies to address this particular patient group may improve satisfaction rates of TKA.

Introduction

Condylar-type total knee replacement has been performed in the United States for four decades. Implants, surgical techniques and instrumentation have been continuously developed to provide durable results at 20-year follow-up and more [9, 40, 45, 48, 53]. Improvements in the development of kinematically functioning designs, user-friendly instruments, peri-operative pain management and accelerated post-operative rehabilitation regimens have been implemented since the beginnings of the operation [22, 31, 32, 42, 55].

Corresponding Author: Nicolas O. Noiseux, MD, MS, FRCSC, nicolas-noiseux@uiowa.edu, University of Iowa Hospitals and Clinics, Department of Orthopedics and Rehabilitation, 200 Hawkins Drive, 01073 JPP, Iowa City, IA, 52242, Phone: 319-384-5737, Fax: 319-384-9066.
john-callaghan@uiowa.edu; charles-clark@uiowa.edu; bridget-zimmerman@uiowa.edu; kathleen-sluka@uiowa.edu; barbara-rakel@uiowa.edu

Although significant improvements in pain and function related to end-stage arthritis of the knee has occurred in millions of patients who have undergone total knee arthroplasty procedures, many studies suggest that an important proportion of total knee replacement recipients are dissatisfied with the procedure and have not had their expectations met [5, 12, 37, 38]. Recent reports have demonstrated only 70-88% satisfaction rates following TKA in regards to improvement in function and decrease in pain [1, 5, 14, 21, 23], and persistent moderate to severe pain in ten to thirty percent of patients at 1 to 7 year follow-up [5, 10, 29, 46]. These studies have led certain agencies and payors to question whether this commonly performed yet expensive operation should be reimbursed in patients with such reported levels of dissatisfaction as their outcome [34].

Several investigators have begun to prospectively evaluate patients who are considering or undergoing total knee replacement using validated outcome and performance assessments to determine factors that contribute to better or worse outcomes and to affirm the effectiveness of the procedure [2, 3, 8, 33, 43]. Our multidisciplinary research group became interested in this area of investigation five years ago with the intent of a critical evaluation of pain and function pre- and postoperatively in total knee arthroplasty. The group hoped to develop a systematic assessment that could then be utilized to determine whether specific pain management interventions could be effective in reducing short and long term (6-12 months) pain and improve short and long term function following TKA. The purpose of the present investigation was to analyze patient characteristics including pain and function preoperatively with a combination of validated sensory tests, psychological questionnaires and pain rating assessments and to determine whether these evaluations could predict pain relief and return to function after knee replacement surgery.

The authors attempted to answer the following questions:

What is the distribution of pain intensity ratings before and six months following TKA?

Does pain intensity rating during functional assessment of the knee preoperatively predict pain intensity six months post-total knee arthroplasty?

Do high patient scores on scales of psychological state prior to TKA, such as depression, anxiety and pain catastrophizing, predict pain intensity ratings after total knee?

We have previously reported factors predicting high pain on postoperative day two (in-hospital) and analgesic medication intake following TKA in this study group [41].

Patients and Methods

Patients

This was a prospective cohort study involving patients recruited to a larger randomized controlled trial studying the effectiveness of TENS on pain and function after total knee arthroplasty.

215 patients underwent a comprehensive multi-faceted evaluation during their TKA preoperative visit. Postoperative assessments were performed at the 6-month clinic visit

(n=193). All patients provided informed consent and the study was approved by the University of Iowa and VA Institutional Review Boards.

Inclusion criteria were:

1. patients ≥30 years
2. diagnosis of knee osteoarthritis
3. spoke English
4. indicated for a primary, unilateral TKA at the University of Iowa Hospitals and Clinics or at the Iowa City VA Medical Center.

Patients were excluded if they had used the investigational device (TENS unit) in the past, could not use the device, had significant chronic pain at a secondary site such as opposite knee, ipsilateral hip or back, had a central or peripheral neurological disorder, were non-ambulatory or could not provide informed consent.

343 eligible patients were approached, 100 declined to participate and 15 did not complete the required preoperative testing. Postoperatively, 13 subjects were excluded due to surgical complications leaving 215 patients in the final cohort.

Twenty-two patients did not complete a 6-month visit despite attempts at contact from the study team. Analysis of preoperative variables revealed that missing patients at the postoperative evaluation were not different than tested patients, except more were male. Thus, uni- and multivariate analysis would not have been any different with their inclusion, except that these results may generalize more to female patients.

All patients received a cemented modern condylar-type total knee arthroplasty with patellar resurfacing. Operative anesthesia included spinal anesthesia with bupivacaine or general anesthesia with propofol followed by isoflurane or sevoflurane if a spinal was contraindicated or refused by the patient. Intraoperative and early postoperative analgesia included single-shot spinal analgesia using preservative free morphine or single-shot femoral block analgesia using ropivacaine.

Preoperative evaluations

Pain Intensity rating—Patients were asked to rate the pain in their operative knee on a vertical, 21-point (0-20) numerical rating scale (NRS) where 0 was no pain and 20 was the most intense pain.

Pain intensity at rest was measured prior to any range-of-motion, limb manipulation or other study procedure.

The range-of-motion pain test (pain intensity with range-of-motion) was scored during active extension, then flexion of the operative knee. For active extension: a rolled towel was placed under the ankle of the surgical leg and subjects actively extended their leg as much as possible by pressing their knee toward the examination table. Pain intensity was rated by the patient when maximum extension was reached. For active flexion, patients were supine and

flexed the study knee as far as possible while keeping their foot flat on the examination table. Again, patients were asked to rate the intensity of pain in the surgical knee at maximum flexion.

A 0-20 numerical rating scale (NRS) has established validity and reliability for assessing acute and postoperative pain [18, 28, 39]. It correlates highly with the Visual Analogue Scale (VAS) [13, 19, 26] and has been shown to be easier to use across all age groups [11, 24, 25, 52].

Quantitative Sensory Testing—Three quantitative sensory tests were used to measure pain sensitivity to mechanical and thermal stimuli: Cutaneous mechanical pain sensitivity was measured with von Frey Pain intensities (VFPI). A standardized monofilament is pressed at a right angle to the skin's surface with a standard force sufficient to bend the filament. Patients were asked to rate the pain intensity caused by this force on the 0-20 NRS [30].

Cutaneous thermal pain sensitivity was measured by heat pain threshold (HPT). A Neurosensory Analyzer with a 16x16 mm thermode placed at an initial temperature of 34°C is increased at a rate of 1°C/s to a maximum 52°C. Patients were instructed to press a button when the heat sensation is first perceived as painful. If the temperature reached 52°C, this was recorded as the threshold [16, 20, 47, 51].

Deep mechanical pain sensitivity was measured with pressure pain thresholds (PPT). A hand-held pressure algometer with a $1cm^2$ digital probe was applied perpendicularly to the skin at 40kPa/s and the patient was asked to press a button when the applied pressure was first perceived as pain. Measurements were performed in three locations medial to the center of the patella approximating the area of the incision. The average of the three scores was used as the final value [16, 20, 47].

Psychological Variables—Anxiety, depression, and pain catastrophizing were measured during the preoperative clinic visit using the Trait Anxiety Form of the State Trait Anxiety Inventory (STAI) [49], the Geriatric Depression Scale (GDS) [27], and the Pain Catastrophizing Scale (PCS) [50], respectively.

The Trait Anxiety scale (STAI Form Y-2) consists of twenty statements that assess how respondents generally respond to perceived threats in the environment rated on a 4-point scale.

This instrument has been used in prior TKA and THA outcome studies [15]. The GDS is a five item-screening tool for depression in the older population. Subjects are considered to screen positive for depression if they answer positive to two or more questions [35, 36, 44].

The PCS is a 13–item survey designed to measure the tendency for catastrophizing in response to pain by measuring: rumination, magnification, and helplessness. Subjects rate their thoughts regarding pain using a 5-point scale. The PCS has been demonstrated to be a significant predictor of pain after TKA [17, 43, 54].

Data Collection Protocol—At the preoperative TKA work-up clinic visit, all consented patients completed demographics forms and the psychological questionnaires (STAI, GDS, PCS). Pain intensity at rest was measured and then the three quantitative sensory tests were performed on the surgical knee. The range-of-motion pain test was then performed.

At the standard 6-month clinic visit, patients were reassessed for pain in their total knee arthroplasty, prior to the encounter with their surgeon. Patients' pain intensity was measured at rest and with the extension and flexion range-of-motion test on an examination table and scored on the 0-20 NRS.

Statistical Analysis—Descriptive statistics were used to describe preoperative and postoperative pain variables using percentages for categorical variables, and mean ± SD for continuous variables. Pain with the range-of-motion pain test was determined by averaging the pain intensity ratings during active extension and active flexion. These scores were then coded as low, moderate, or severe pain using cutoff points established in previous literature [8]. Low pain = 0-7 out of 20, moderate pain = 8-14 out of 20, and severe pain = 15-20. For each candidate explanatory variable, a generalized logit model for pain at rest and pain with range-of-motion was fitted which included the candidate variable as the independent variable. Results were adjusted for the treatment received (TENS vs. placebo) from the main RCT study. Odds ratios for moderate pain and severe pain, using low pain as reference, were calculated for each of the variables. Those variables with $p < 0.10$ were then included in a stepwise logistic regression analysis with criteria of $p<0.10$ for entry and $p>0.10$ for removal from the model. The final model used a $p<0.05$ for included variables.

Results

There were 215 patients in the study. Mean age 61.68 ± 9.82 years. Mean BMI of 38.18 ± 11.43. Most were women (n=125, 58%), white (n=200, 98%), had college education (n=130, 61%), and married (n=119, 55.3%). The affected knee in most subjects had an OA K/L grade > or = 3 (n=172, 80%) and had been painful for > 5 years.

The distribution of patient-scored pain intensity ratings in the surgical knee *preoperatively* and at *six months postoperatively* is presented in Table 1.

Univariate Analysis (single factor model)

At 6 months, variables with $p<0.10$ for association with moderate or severe TKA pain with range-of-motion were: severe preoperative knee pain with the range-of-motion test, severe preoperative knee pain at rest, marital status, depression, anxiety, and pain catastrophizing.

Gender, educational level, BMI, pain duration prior to surgery, von Frey pain intensity, heat pain threshold, pressure pain threshold, age, and OA grade were not significantly associated with postoperative TKA pain with range-of-motion ($p > 0.10$).

Multivariate Logistic Regression Analysis (multi-factor model)

The 6-month post-operative fitted model is presented in Table 2. Significant predictors included preoperative knee pain with range-of-motion and anxiety. The odds ratio indicated

that people with severe preoperative knee pain with range-of-motion were 10 times more likely to have moderate or severe TKA pain with knee motion after 6 months. Anxiety was the other variable found to be significant in the postoperative multi-factor analysis, with an odds ratio of 1.40.

Discussion

Many investigators have documented the improvement in function and long term durability of total knee replacement procedures [9, 40, 45, 48, 53]. Surgeons performing the operation have increasingly been aware that a non-trivial percentage of patients are unhappy following the procedure even though there are no recognized complications such as infection, instability, loosening, malalignment or implant failure [4, 6, 8, 12, 23, 29, 37]. Recent investigations have documented 15-20% rates of patient dissatisfaction with pain or function following total knee replacement [1, 5, 23, 37, 46]. These studies prompted our group to prospectively evaluate a group of patients undergoing total knee arthroplasty with comprehensive, multi-modal, validated pain and functional assessment tools preoperatively and postoperatively (up to 6 months) to determine patterns of pain intensity in the knee and whether any of the preoperative assessments performed could highly predict postoperative knee pain and function.

Studying this large cohort of patients undergoing total knee arthroplasty who were thoroughly evaluated and followed pre- and postoperatively regarding demographic data, psychological state questionnaires, quantitative sensory tests and functional pain intensity ratings; the authors answered several questions and discovered a simple preoperative test of pain intensity with active knee range-of-motion which strongly predicted the amount and intensity of knee pain two days post-op (previously reported) [41] as well as 6 months following the procedure.

Concerning the intensity of pain in the operative knee before and after TKA, preoperatively 17% of patients had moderate to severe pain at rest, and 52% had moderate to severe pain with the range-of-motion pain test. At the 6-month postoperative evaluation, the proportion of patients with moderate to severe pain at rest was 5%, and it was 16% for moderate to severe pain with range-of-motion. This amount of pain, particularly the pain with knee motion at six months after TKA, is consistent with rates of ongoing pain in total knees reported in prior studies [5, 8, 10, 23, 37].

With regards to which, if any, of the pain and functional assessments performed preoperatively could predict the group of patients with marked residual pain after TKA, the variable that was most highly correlated with moderate to severe pain at six months after TKA was the preoperative pain intensity rating with knee range-of-motion or ‘range-of-motion pain test’. This finding was highly significant in both univariate and multivariate analyses, with a final multivariate model Odds ratio of 10.15 (p=0.001) at 6 months. Thus, patients with severe pain with ROM pre-op were ten times more likely to have ongoing moderate to severe pain with movement of the knee at 6 months. Regarding patients’ preoperative psychological state affecting continued postoperative pain at 6 months, those patients with high anxiety scores were 40% more likely to have severe pain with range-of-

motion. Thus, anxiety was the other factor predictive of severe pain in the multivariate logistic regression model at 6 months.

In the univariate analysis: severe preoperative pain at rest, depression, and pain catastrophizing were also significantly correlated with high levels of ongoing pain at 6 months post-TKA ($p<0.10$). The impact of high scores on psychological tests assessing for such traits as anxiety, depression and pain catastrophizing is in keeping with prior reports of pain predictors after total knee [7, 8, 17]. It is also consistent with a systematic review of 43 studies with 23,057 patients undergoing a variety of surgical procedures that found higher anxiety pre-operatively to consistently predict higher pain after surgery.

As has been previously reported by others, we have demonstrated that an important proportion of patients, 16% in this study, have significant residual pain even 6 months following TKA [8, 17, 37]; and that this significant pain can be, to some extent, associated with elevated preoperative anxiety, depression or pain catastrophizing scores [3, 7, 8, 15, 33]. However, the novel finding in our study is the very high correlation between preoperative pain intensity with active knee range-of-motion and six-month pain levels.

The generalizability of our discovered relationship needs to be confirmed in larger TKA populations. If these findings are corroborated, this subset of patients considering TKA may need more thorough consulting and tailoring of expectations, as well as consideration of better preoperative interventions such as psychological counseling, medications or physical therapy to attempt to manage high pain levels with mild tasks such as simple un-weighted range-of-motion. Increased efforts to help this subgroup physically and mentally manage the decision-making process as to whether or not to undergo knee replacement surgery, as well as a focus on the possible residual symptoms after the TKA intervention, could be very beneficial [38]. This may ultimately increase the patient-reported satisfaction rates that both surgeons and patients would eagerly like to see improve as the cost-effectiveness of total knee surgery is further reassessed. Continued follow-up of this and similar cohorts will be important to evaluate longer term residual pain after TKA and its risk factors. In addition, determining whether short-term post operative pain is a major determinant of longer term residual pain and dysfunction will be an invaluable next step in understanding patients who are dissatisfied with their TKA.

The strengths of the present study were the extensive, prospectively collected pre- and postoperative pain and functional evaluations performed by a team of doctoral-level physical therapy and nursing researchers trained specifically for this study group.

The limitations include the varying modalities of anesthesia and perioperative analgesia utilized, and as with all prospective patient-consented studies, the dropout rate and issues of generalizability to an entire total knee arthroplasty patient population. Not all potentially important variables relating to TKA outcome were investigated, such as the actual numerical value of pre- or postoperative range-of-motion, or the influence of weight-bearing on pain ratings. In addition, although one therapeutic intervention was also investigated in the main randomized trial (TENS unit), there was no demonstrable effect of this intervention on

postoperative pain at six months, and more importantly all other data were adjusted for treatment group.

In summary, a simple test of pain intensity with active flexion and extension preoperatively was found to be highly predictive of ongoing moderate to severe pain after total knee arthroplasty. Patients with severe, greater than 15 out of 20 pain with this gentle ‘range-of-motion pain test’ were ten times more likely to have moderate to severe pain with knee motion at six months after TKA. Strategies to reduce these patients pain levels and psychological distress pre-operatively may improve outcomes in total knee replacement.

Acknowledgments

We would like to thank the following for contributions to study design, data collection and data analysis: Nicole Petsas-Blodgett, PhD, MSN, RN; Nyla Logsdon-Sackett, MS; Timothy Brennan, PhD; Keela Herr, PhD, RN, FAAN; Katharine Geasland, BS, RN; Xiaoyan Yang, MS.

Funding Source: National Institute of Nursing Research (NINR) R01 NR009844

References

1. Anderson JG, Wixson RL, Tsai D, Stulberg SD, Chang RW. Functional outcome and patient satisfaction in total knee patients over the age of 75. The Journal of arthroplasty. 1996; 11:831–840. [PubMed: 8934323]
2. Blackburn J, Qureshi A, Amirfeyz R, Bannister G. Does preoperative anxiety and depression predict satisfaction after total knee replacement? The Knee. 2012; 19:522–524. [PubMed: 21846588]
3. Bonnin MP, Basiglini L, Archbold HA. What are the factors of residual pain after uncomplicated TKA? Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA. 2011; 19:1411–1417.
4. Bourne RB. Measuring tools for functional outcomes in total knee arthroplasty. Clinical orthopaedics and related research. 2008; 466:2634–2638. [PubMed: 18780136]
5. Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KD. Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? Clinical orthopaedics and related research. 2010; 468:57–63. [PubMed: 19844772]
6. Bourne RB, McCalden RW, MacDonald SJ, Mokete L, Guerin J. Influence of patient factors on TKA outcomes at 5 to 11 years followup. Clinical orthopaedics and related research. 2007; 464:27–31. [PubMed: 17891041]
7. Brander V, Gondek S, Martin E, Stulberg SD. Pain and depression influence outcome 5 years after knee replacement surgery. Clinical orthopaedics and related research. 2007; 464:21–26. [PubMed: 17603386]
8. Brander VA, Stulberg SD, Adams AD, Harden RN, Bruehl S, Stanos SP, Houle T. Predicting total knee replacement pain: a prospective, observational study. Clinical orthopaedics and related research. 2003:27–36. [PubMed: 14646737]
9. Callaghan JJ, Wells CW, Liu SS, Goetz DD, Johnston RC. Cemented rotating-platform total knee replacement: a concise follow-up, at a minimum of twenty years, of a previous report. The Journal of bone and joint surgery. American volume. 2010; 92:1635–1639. [PubMed: 20595570]
10. Chesworth BM, Mahomed NN, Bourne RB, Davis AM, Group OS. Willingness to go through surgery again validated the WOMAC clinically important difference from THR/TKR surgery. Journal of clinical epidemiology. 2008; 61:907–918. [PubMed: 18687289]
11. Chibnall JT, Tait RC. Pain assessment in cognitively impaired and unimpaired older adults: a comparison of four scales. Pain. 2001; 92:173–186. [PubMed: 11323138]
12. Culliton SE, Bryant DM, Overend TJ, MacDonald SJ, Chesworth BM. The relationship between expectations and satisfaction in patients undergoing primary total knee arthroplasty. The Journal of arthroplasty. 2012; 27:490–492. [PubMed: 22115761]

13. DeLoach LJ, Higgins MS, Caplan AB, Stiff JL. The visual analog scale in the immediate postoperative period: intrasubject variability and correlation with a numeric scale. Anesthesia and analgesia. 1998; 86:102–106. [PubMed: 9428860]

14. Dunbar MJ, Robertsson O, Ryd L, Lidgren L. Appropriate questionnaires for knee arthroplasty. Results of a survey of 3600 patients from The Swedish Knee Arthroplasty Registry. The Journal of bone and joint surgery. British volume. 2001; 83:339–344. [PubMed: 11341416]

15. Feeney SL. The relationship between pain and negative affect in older adults: anxiety as a predictor of pain. J Anxiety Disord. 2004; 18:733–744. [PubMed: 15474849]

16. Fillingim RB, Ness TJ, Glover TL, Campbell CM, Price DD, Staud R. Experimental pain models reveal no sex differences in pentazocine analgesia in humans. Anesthesiology. 2004; 100:1263–1270. [PubMed: 15114226]

17. Forsythe ME, Dunbar MJ, Hennigar AW, Sullivan MJ, Gross M. Prospective relation between catastrophizing and residual pain following knee arthroplasty: two-year follow-up. Pain research & management: the journal of the Canadian Pain Society = journal de la societe canadienne pour le traitement de la douleur. 2008; 13:335–341.

18. Gagliese L, Gauthier LR, Macpherson AK, Jovellanos M, Chan VW. Correlates of postoperative pain and intravenous patient-controlled analgesia use in younger and older surgical patients. Pain medicine. 2008; 9:299–314. [PubMed: 18366510]

19. Gagliese L, Weizblit N, Ellis W, Chan VW. The measurement of postoperative pain: a comparison of intensity scales in younger and older surgical patients. Pain. 2005; 117:412–420. [PubMed: 16153776]

20. Hastie BA, Riley JL 3rd, Robinson ME, Glover T, Campbell CM, Staud R, Fillingim RB. Cluster analysis of multiple experimental pain modalities. Pain. 2005; 116:227–237. [PubMed: 15964682]

21. Hawker G, Wright J, Coyte P, Paul J, Dittus R, Croxford R, Katz B, Bombardier C, Heck D, Freund D. Health-related quality of life after knee replacement. The Journal of bone and joint surgery. American volume. 1998; 80:163–173. [PubMed: 9486722]

22. Hebl JR, Dilger JA, Byer DE, Kopp SL, Stevens SR, Pagnano MW, Hanssen AD, Horlocker TT. A pre-emptive multimodal pathway featuring peripheral nerve block improves perioperative outcomes after major orthopedic surgery. Regional anesthesia and pain medicine. 2008; 33:510–517. [PubMed: 19258965]

23. Heck DA, Robinson RL, Partridge CM, Lubitz RM, Freund DA. Patient outcomes after knee replacement. Clinical orthopaedics and related research. 1998:93–110. [PubMed: 9917673]

24. Herr KA, Mobily PR, Kohout FJ, Wagenaar D. Evaluation of the Faces Pain Scale for use with the elderly. The Clinical journal of pain. 1998; 14:29–38. [PubMed: 9535311]

25. Herr KA, Spratt K, Mobily PR, Richardson G. Pain intensity assessment in older adults: use of experimental pain to compare psychometric properties and usability of selected pain scales with younger adults. The Clinical journal of pain. 2004; 20:207–219. [PubMed: 15218405]

26. Hjermstad MJ, Fayers PM, Haugen DF, Caraceni A, Hanks GW, Loge JH, Fainsinger R, Aass N, Kaasa S. European Palliative Care Research C. Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual Analogue Scales for assessment of pain intensity in adults: a systematic literature review. Journal of pain and symptom management. 2011; 41:1073–1093. [PubMed: 21621130]

27. Hoyl MT, Alessi CA, Harker JO, Josephson KR, Pietruszka FM, Koelfgen M, Mervis JR, Fitten LJ, Rubenstein LZ. Development and testing of a five-item version of the Geriatric Depression Scale. Journal of the American Geriatrics Society. 1999; 47:873–878. [PubMed: 10404935]

28. Jensen MP. The validity and reliability of pain measures in adults with cancer. The journal of pain: official journal of the American Pain Society. 2003; 4:2–21. [PubMed: 14622723]

29. Jorn LP, Johnsson R, Toksvig-Larsen S. Patient satisfaction, function and return to work after knee arthroplasty. Acta orthopaedica Scandinavica. 1999; 70:343–347. [PubMed: 10569263]

30. Keizer D, Fael D, Wierda JM, van Wijhe M. Quantitative sensory testing with Von Frey monofilaments in patients with allodynia: what are we quantifying? The Clinical journal of pain. 2008; 24:463–466. [PubMed: 18496312]

31. Kuzyk PR, Higgins GA, Tunggal JA, Sellan ME, Waddell JP, Schemitsch EH. Computer navigation vs extramedullary guide for sagittal alignment of tibial components: radiographic study and meta-analysis. The Journal of arthroplasty. 2012; 27:630–637. [PubMed: 21917415]
32. Larsen K, Hansen TB, Thomsen PB, Christiansen T, Soballe K. Cost-effectiveness of accelerated perioperative care and rehabilitation after total hip and knee arthroplasty. The Journal of bone and joint surgery. American volume. 2009; 91:761–772. [PubMed: 19339559]
33. Lingard EA, Katz JN, Wright EA, Sledge CB. Kinemax Outcomes G. Predicting the outcome of total knee arthroplasty. The Journal of bone and joint surgery. American volume. 2004; 86-A: 2179–2186. [PubMed: 15466726]
34. Losina E, Walensky RP, Kessler CL, Emrani PS, Reichmann WM, Wright EA, Holt HL, Solomon DH, Yelin E, Paltiel AD, Katz JN. Cost-effectiveness of total knee arthroplasty in the United States: patient risk and hospital volume. Archives of internal medicine. 2009; 169:1113–1121. discussion 1121-1112. [PubMed: 19546411]
35. Mitchell AJ, Bird V, Rizzo M, Meader N. Diagnostic validity and added value of the Geriatric Depression Scale for depression in primary care: a meta-analysis of GDS30 and GDS15. Journal of affective disorders. 2010; 125:10–17. [PubMed: 19800132]
36. Mitchell AJ, Bird V, Rizzo M, Meader N. Which version of the geriatric depression scale is most useful in medical settings and nursing homes? Diagnostic validity meta-analysis. The American journal of geriatric psychiatry: official journal of the American Association for Geriatric Psychiatry. 2010; 18:1066–1077. [PubMed: 21155144]
37. Nilsdotter AK, Toksvig-Larsen S, Roos EM. Knee arthroplasty: are patients' expectations fulfilled? A prospective study of pain and function in 102 patients with 5-year follow-up. Acta orthopaedica. 2009; 80:55–61. [PubMed: 19234886]
38. Noble PC, Conditt MA, Cook KF, Mathis KB. The John Insall Award: Patient expectations affect satisfaction with total knee arthroplasty. Clinical orthopaedics and related research. 2006; 452:35–43. [PubMed: 16967035]
39. Paice JA, Cohen FL. Validity of a verbally administered numeric rating scale to measure cancer pain intensity. Cancer nursing. 1997; 20:88–93. [PubMed: 9145556]
40. Pavone V, Boettner F, Fickert S, Sculco TP. Total condylar knee arthroplasty: a long-term followup. Clinical orthopaedics and related research. 2001:18–25. [PubMed: 11451118]
41. Rakel BA, Blodgett NP, Bridget Zimmerman M, Logsden-Sackett N, Clark C, Noiseux N, Callaghan J, Herr K, Geasland K, Yang X, Sluka KA. Predictors of postoperative movement and resting pain following total knee replacement. Pain. 2012
42. Ranawat AS, Ranawat CS. Pain management and accelerated rehabilitation for total hip and total knee arthroplasty. The Journal of arthroplasty. 2007; 22:12–15. [PubMed: 17919586]
43. Riddle DL, Wade JB, Jiranek WA, Kong X. Preoperative pain catastrophizing predicts pain outcome after knee arthroplasty. Clinical orthopaedics and related research. 2010; 468:798–806. [PubMed: 19585177]
44. Rinaldi P, Mecocci P, Benedetti C, Ercolani S, Bregnocchi M, Menculini G, Catani M, Senin U, Cherubini A. Validation of the five-item geriatric depression scale in elderly subjects in three different settings. Journal of the American Geriatrics Society. 2003; 51:694–698. [PubMed: 12752847]
45. Ritter MA. The Anatomical Graduated Component total knee replacement: a long-term evaluation with 20-year survival analysis. The Journal of bone and joint surgery. British volume. 2009; 91:745–749. [PubMed: 19483226]
46. Robertsson O, Dunbar M, Pehrsson T, Knutson K, Lidgren L. Patient satisfaction after knee arthroplasty: a report on 27,372 knees operated on between 1981 and 1995 in Sweden. Acta orthopaedica Scandinavica. 2000; 71:262–267. [PubMed: 10919297]
47. Robinson ME, Wise EA, Gagnon C, Fillingim RB, Price DD. Influences of gender role and anxiety on sex differences in temporal summation of pain. The journal of pain: official journal of the American Pain Society. 2004; 5:77–82. [PubMed: 15042515]
48. Rodriguez JA, Bhende H, Ranawat CS. Total condylar knee replacement: a 20-year followup study. Clinical orthopaedics and related research. 2001:10–17. [PubMed: 11451106]

49. Spielberger, CD. State-trait anxiety inventory: a comprehensive bibliography. Consulting Psychologists Press; Palo Alto, CA: 1984.
50. Sullivan MJ, Weinshenker B, Mikail S, Bishop SR. Screening for major depression in the early stages of multiple sclerosis. The Canadian journal of neurological sciences. Le journal canadien des sciences neurologiques. 1995; 22:228–231. [PubMed: 8529176]
51. Valencia C, Fillingim RB, George SZ. Suprathreshold heat pain response is associated with clinical pain intensity for patients with shoulder pain. The journal of pain: official journal of the American Pain Society. 2011; 12:133–140. [PubMed: 20692209]
52. Ware LJ, Epps CD, Herr K, Packard A. Evaluation of the Revised Faces Pain Scale, Verbal Descriptor Scale, Numeric Rating Scale, and Iowa Pain Thermometer in older minority adults. Pain management nursing: official journal of the American Society of Pain Management Nurses. 2006; 7:117–125. [PubMed: 16931417]
53. Whiteside LA. Long-term followup of the bone-ingrowth Ortholoc knee system without a metal-backed patella. Clinical orthopaedics and related research. 2001:77–84. [PubMed: 11451136]
54. Witvrouw E, Pattyn E, Almqvist KF, Crombez G, Accoe C, Cambier D, Verdonk R. Catastrophic thinking about pain as a predictor of length of hospital stay after total knee arthroplasty: a prospective study. Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA. 2009; 17:1189–1194.
55. Wong JM, Khan WS, Chimutengwende-Gordon M, Dowd GS. Recent advances in designs, approaches and materials in total knee replacement: literature review and evidence today. Journal of perioperative practice. 2011; 21:165–171. [PubMed: 21834287]

Table 1

The Percentage Distributions of Knee Pain Intensity Ratings at the Preoperative and Postoperative Time Points Evaluated

	Pain at rest		Pain with Range-of-Motion	
Time / **Pain**	**Preoperative (n=215)**	**6 months (n=193)**	**Preoperative (n=215)**	**6 months (n=193)**
Low	83%	95%	48%	84%
Moderate	15%	5%	35%	**14%**
Severe	2%	0%	17%	**2%**

Table 2

Final 6-month Postoperative Multivariate Logistic Regression Analysis Model

	Moderate/Severe Pain with ROM (vs. Mild/No pain)		
Variable	**Odds Ratio**	**95% CI**	**p-value**
Preoperative Pain with ROM test (Severe)	**10.15**	[2.50-41.28]	0.001
Anxiety	1.40*	[1.09-1.79]	0.009

* per 5 point increase in anxiety score.