The Journal of Arthroplasty xxx (2016) 1–7

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Original Article

Predicting the Long-Term Gains in Health-Related Quality of Life After Total Knee Arthroplasty

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ARTICLE INFO

Article history:
Received 5 April 2016
Received in revised form
27 June 2016
Accepted 19 July 2016
Available online xxx

Keywords:
health-related quality of life
total knee arthroplasty
prediction
cost-effectiveness
QALYs

ABSTRACT

Background: We investigated the predictors of long-term gains in quality-adjusted life years (QALYs) from total knee arthroplasty (TKA) and the patient attributes that predicted cost-effective TKA.
Methods: Data on TKA patients (n = 570) from 2006 to 2007 were extracted from a single-institution registry. QALY gains over 7 years post surgery were calculated from health-related quality of life (HrQoL) scores measured preoperatively and annually postoperatively using the short-form health survey (SF-12) instrument. Multivariate linear regression analysis investigated the predictors of QALY gain from TKA from a broad range of preoperative patient characteristics and was used to predict QALY gains for each individual. Patients were grouped into deciles according to their predicted QALY gain, and the cost-effectiveness of each decile was plotted on the cost-effectiveness plane. Patient attribute differences between deciles were decomposed.
Results: After exclusions and dropout, data were available for 488 patients. The average estimated QALY gain over 7 years was 0.77 (95% confidence interval [CI] 0.70-0.83). Predictors significantly associated with smaller QALY gains were comorbidities (Charlson comorbidity index 3+ coefficient −0.54 CI −0.15 to −0.92), the absence of severe osteoarthritis in the ipsilateral knee (−0.51 CI −0.16 to −0.85), preoperative HrQoL (standardized coefficient −0.34 CI −0.26 to −0.43), the requirement for an interpreter (−0.24 CI −0.05 to −0.44), and age (−0.01 CI −0.01 to −0.02). The largest difference between cost-effective and non−cost-effective deciles was relatively high preoperative HrQoL in the non−cost-effective decile.
Conclusion: TKA is likely to be cost-effective for most patients except those with unusually high preoperative HrQoL or a lack of severe osteoarthritis. The poorer outcomes for those requiring an interpreter requires further research.

Total knee arthroplasty (TKA) is presently considered an effective and cost-effective procedure for treating patients with end-stage arthritis [1]. Yet, up to 30% of patients remain dissatisfied with their outcomes [2], indicating that while TKA might be cost-effective on average, outcomes can vary dramatically across individuals. Given the volumes of TKA, it is important to understand the drivers of positive outcomes. Similarly, with the volumes of TKA expected to increase substantially over the next 15 years [3], it is important that we can identify those for whom the procedure will be most cost-effective as population characteristics change. In Australia, as in many Western countries, obesity rates are climbing while smoking prevalence is declining [4]. These and other time-varying factors may affect the future cost-effectiveness of surgery.

The authors are supported by the Australian Research Council's Discovery Early Career Awards funding scheme (Project DE150100309), a National Health and Medical Research Council postgraduate award (AP1093229), and a National Health and Medical Research Council Early Career Australian Clinical Fellowship (APP1035810).

The views expressed herein are those of the authors and are not necessarily those of the Australian Research Council or the National Health and Medical Research Council.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2016.07.036.

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http://dx.doi.org/10.1016/j.arth.2016.07.036
0883-5403/

A range of literature has investigated the predictors of pain, function, and health-related quality of life (HrQoL) outcomes after TKA or total joint arthroplasty [5-8]. Dowsey and Choong [6] summarize both nonmodifiable (eg, age, gender, ethnicity, and socioeconomic status) and some modifiable (eg, comorbidities, obesity, baseline health, and patient expectation) risk factors associated with short- and long-term pain and function outcomes. Smoking has also been shown to be systematically associated with poorer complication and mortality outcomes after TKA [8]. Older age, comorbidities, and poorer mental health negatively impacted on longer term function and HrQoL outcomes [7]. Desmeules et al [5] identified lower preoperative HrQoL, contralateral knee pain, and comorbidities were significantly associated with poorer outcomes at 6 months post surgery.

However, few in the literature have investigated the predictors of HrQoL utility scores or quality-adjusted life year (QALY) outcomes used in economic evaluations. Using multivariate linear regression, Jenkins et al [9] found that younger age and poorer preoperative HrQoL were associated with greater QALY gains. The limitation to this analysis was the use of one single patient-reported outcome at 12 months and the assumption that the 12-month HrQoL utility score was maintained until death. While the largest improvement in HrQoL typically occurs in the first 6 months post surgery [10], recent literature suggests that the long-term pain and function trajectory can vary significantly between patients [11]. Longer term follow-up would allow the explicit analysis of the predictors of long-term QALY gains. Using generalized linear models, Dakin et al [12] assessed the importance of 6 patient attributes (age, gender, body mass index [BMI], baseline Oxford Knee Score, American Society of Anesthesiologists (ASA) illness grade, and the presence of osteoarthritis in both rather than 1 knee) over 5 years. They found that all but BMI significantly influenced cost-effectiveness, with higher age, Oxford Knee Score, and ASA score reducing cost-effectiveness and cost-effectiveness lower for men than women (although TKA as a treatment was cost-effective across the vast majority of cases).

In this research, we investigate the preoperative predictors of QALY gains from TKA after 7 years. We use a rich patient level data set with 7-year follow-up that incorporates a broad range of patient attributes: age, gender, comorbidities, osteoarthritis severity, BMI and obesity, socioeconomic indicators, and risk factors such as smoking. This extends the previous literature in both predictor breadth and length of follow-up. By using patient-reported data for 7 years, we aim to capture the long-term impact of patient attributes on QALY gain from TKA and to identify attributes that predict cost-effective TKA vs attributes that suggest TKA is unlikely to be cost-effective.

Methods

Data

Data on all patients who had a TKA between January 1, 2006 and December 31, 2007 were extracted from a single-institution clinical registry that houses clinical and patient-reported outcome data in patients who undergo elective lower limb arthroplasty by 1 of 15 surgeons. Baseline data are prospectively collected and includes patient sociodemographics and self-reported comorbidities. Follow-up captures an extensive range of outcomes, including surgery and prosthesis-related variables. Patients complete a general health questionnaire (Short Form Health Survey [SF]-12) within 12 weeks before surgery and annually postoperatively to 5 years, then at 7 years. Study exclusions were due to loss to follow-up or revisions, with a sensitivity analysis completed with revisions included.

Estimation of QALY Gain

HrQoL utility scores are calculated from the SF-12 using the standard Brazier algorithm [13]. The QALY gain from TKA was calculated as the area between the utility curve after TKA, and the hypothetical utility curve had the patient not had a TKA. The utility curve after TKA was calculated by linearly interpolating between measurement points. For the hypothetical "without TKA" curve, we assumed the preoperative HrQoL utility score remained constant for 7 years, as is standard in the literature [9,12]. QALY gains for patients that died or were revised (when included in the sensitivity analysis) within the 7-year follow-up were calculated in same way up until the year of death or revision, with zero QALY gains accrued thereafter.

Potential Preoperative Predictors

Baseline patient socioeconomic and demographic characteristics included age, gender, and BMI which was categorized into nonobese (BMI < 30 kg/m^2), mildly obese ($30 \leq$ BMI < 35 kg/m^2), moderately obese ($35 \leq$ BMI < 40 kg/m^2), and morbidly obese (BMI ≥ 40 kg/m^2), HrQoL utility score, mental component summary (MCS) score (the physical component summary score is excluded due to collinearity with the HrQoL and MCS scores), smoking status (current smoker, previous smoker, or nonsmoker), and comorbidities assessed via the Charlson comorbidity index. Socioeconomic status was assessed via the Socio-Economic Index For Areas deciles, developed by the Australian Bureau of Statistics for ranking geographic regions within Australia according to relative socioeconomic disadvantage [14]. Clinical variables included contralateral TKA, severity of osteoarthritis as categorized by a score of 3 or higher on the Kellgren-Lawrence scale for both ipsilateral and contralateral sides, and the ASA physical functioning score.

Statistical Analysis

We applied multivariate linear regression analysis to investigate the predictors of QALY gain from TKA after 7 years. Alternative model specifications were tested in supplementary analysis provided in the Appendices. The Ramsey Regression Equation Specification Error Test (RESET) test was conducted to test for model misspecification such as incorrect functional form and/or omitted variables [15]. Preoperative HrQoL and MCS utility scores were standardized to a mean of zero and a standard deviation of 1, and age centralized to the mean, to improve interpretation of results.

We then used the estimated regression model to predict the QALY gains for each individual based on their characteristics and evaluated the implications for the expected cost-effectiveness of their TKA. Patients were grouped into deciles according to their predicted long-term QALY gains. To provide an insight into the characteristics of the patients in each decile, a representative patient for each decile was generated based on the median attributes. The cost-effectiveness of TKA for each representative patient was plotted on the cost-effectiveness plane, using a standardized cost per TKA of $21,530 (estimated from our data set) and confidence intervals (CIs) generated from the standard error of QALY gain prediction. We did not explicitly estimate the incremental cost-effectiveness ratio for each patient due to a smaller set of available cost data; however, we show in the Appendix that the cost of TKA was relatively invariant to the predictors evaluated (Appendix 3). Finally, we compared the attributes between predicted cost-effective and non–cost-effective patients and highlighted the attribute differences that on average made the largest contribution to the lower QALY gains for the non–cost-effective