

## ■ ARTHROPLASTY

# The use of patient-reported outcome measures to guide referral for hip and knee arthroplasty

## PART 2: A COST-EFFECTIVENESS ANALYSIS

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### Aims

To assess how the cost-effectiveness of total hip arthroplasty (THA) and total knee arthroplasty (TKA) varies with age, sex, and preoperative Oxford Hip or Knee Score (OHS/OKS); and to identify the patient groups for whom THA/TKA is cost-effective.

### Methods

We conducted a cost-effectiveness analysis using a Markov model from a United Kingdom NHS perspective, informed by published analyses of patient-level data. We assessed the cost-effectiveness of THA and TKA in adults with hip or knee osteoarthritis compared with having no arthroplasty surgery during the ten-year time horizon.

### Results

THA and TKA cost < £7,000 per quality-adjusted life-year (QALY) gained at all preoperative scores below the absolute referral thresholds calculated previously (40 for OHS and 41 for OKS). Furthermore, THA cost < £20,000/QALY for patients with OHS of  $\leq 45$ , while TKA was cost-effective for patients with OKS of  $\leq 43$ , since the small improvements in quality of life outweighed the cost of surgery and any subsequent revisions. Probabilistic and one-way sensitivity analyses demonstrated that there is little uncertainty around the conclusions.

### Conclusion

If society is willing to pay £20,000 per QALY gained, THA and TKA are cost-effective for nearly all patients who currently undergo surgery, including all patients at and above our calculated absolute referral thresholds.

Cite this article: *Bone Joint J* 2020;102-B(7):950–958.

### Introduction

Hip and knee arthroplasty substantially improves quality of life<sup>1</sup> and has previously been shown to be highly cost-effective.<sup>2</sup> However, within the United Kingdom, commissioners often cut access to arthroplasty or introduce arbitrary referral criteria under budgetary pressure.<sup>3</sup> Many clinical commissioning groups in the United Kingdom set thresholds for access to arthroplasty based on the patient-reported Oxford Hip/Knee Score (OHS/OKS) questionnaires,<sup>4</sup> which measure joint function as values between 0 (severe problems) and 48 (no problems).<sup>3</sup> There are currently little data to support these thresholds, which led the National Institute of Health and Care Excellence (NICE) to recommend against basing referral decisions on scoring tools.<sup>5</sup> The accompanying paper demonstrates that OHS and OKS can be used to identify

which patients are most likely to benefit from hip/knee arthroplasty, and finds that patients with scores well above the thresholds currently used by many commissioning groups still have a high chance of a good outcome.<sup>6</sup>

There are currently few data showing how the costs and cost-effectiveness of arthroplasty vary with OHS/OKS. Dakin et al<sup>7</sup> assessed how the cost-effectiveness of total knee arthroplasty (TKA) varied with OKS, while Fordham et al<sup>8</sup> assessed the cost-effectiveness of total hip arthroplasty (THA) in OHS quintiles. However, these studies took a five-year time horizon and assumed that patients would accrue no costs and have no changes in quality of life without TKA. Ferket et al<sup>9</sup> recently assessed how the cost-effectiveness of TKA varied with 12-Item Short-Form Health Survey questionnaire<sup>10</sup> (SF-12) physical scores in

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© 2020 Author(s) et al.  
doi:10.1302/0301-620X.102B7.  
BJJ-2019-0105.R2 \$2.00

*Bone Joint J*  
2020;102-B(7):950–958.

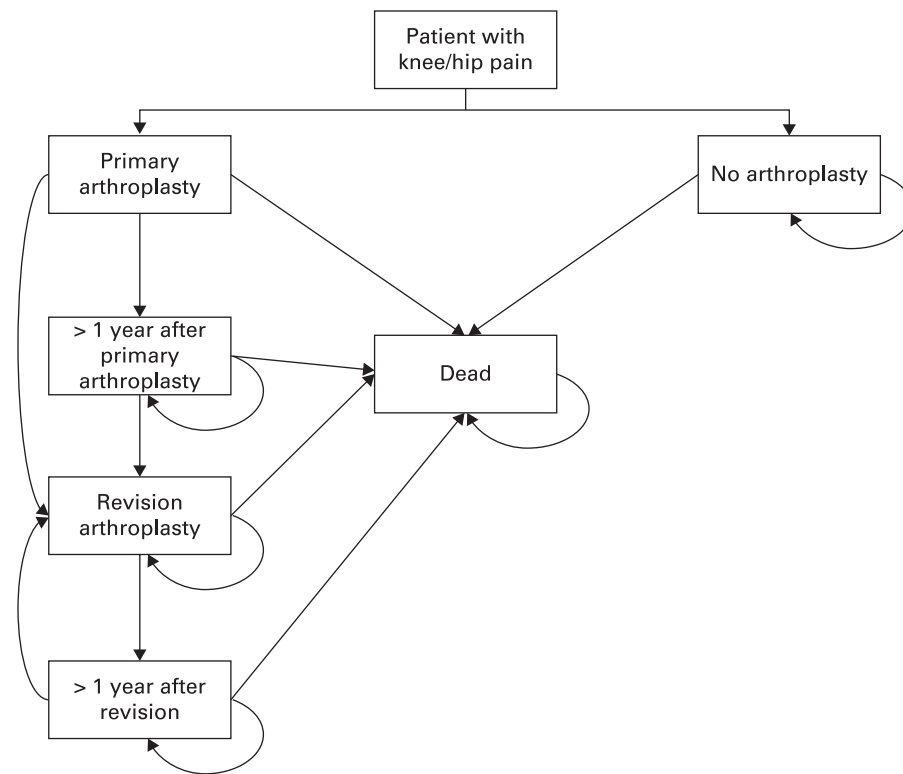


Fig. 1

State transition diagram for the Markov model. Each year, patients are assumed to follow one of the arrows with black arrowheads, but cannot make more than one move between states per year. The costs, quality of life, revision rates, and mortality rates for each health state vary with patient characteristics and time since primary arthroplasty based on the data sources described in Supplementary Table i. In the arthroplasty arm of the model, patients with pain from hip/knee osteoarthritis undergo primary arthroplasty at the start of the ten-year time horizon.

a sample from the United States, while Schilling et al<sup>11</sup> explored how the cost-effectiveness of TKA varied with SF-6D<sup>12</sup> in Australian data. Furthermore, while all four studies relied upon small cohorts of trial/observational data, routinely collected datasets now provide sample sizes several magnitudes larger and include many more observations with very low or very high scores.

We used routinely-collected data and trial/observational cohorts to: 1) assess how the cost-effectiveness of THA and TKA vary with age, sex, and preoperative OHS/OKS, and 2) identify the patient groups for whom THA and TKA are cost-effective, with reference to the potential thresholds for referral calculated in the accompanying paper describing part 1 of the Arthroplasty Candidacy Help Engine (ACHE) project.<sup>6</sup>

## Methods

We assessed the cost-effectiveness of THA and TKA compared with having no arthroplasty surgery for at least ten years. We analyzed a United Kingdom setting from a NHS perspective.<sup>13</sup> We focused on the cost of hospital admissions and outpatient/general practitioner (GP)/physiotherapy/nurse consultations related to arthroplasty or osteoarthritis since no data were available on wider costs (e.g. medication or social care).<sup>14</sup> The analysis primarily concerned patients aged 50 to 90 years who were undergoing unilateral THA or TKA for osteoarthritis. However, patients not meeting these criteria were not excluded

from the datasets used to estimate model inputs, since data on operation type and indication were not consistently recorded.<sup>14</sup> Health benefits were measured in quality-adjusted life-years (QALYs),<sup>13</sup> which capture the effect of surgery on both length of life (e.g. surgical mortality) and quality of life (on a utility scale ranging from -0.594 to 1, measured using the EuroQol five-dimension questionnaire (EQ-5D-3L) questionnaire and the United Kingdom time trade-off tariff<sup>15</sup>). Costs and QALYs beyond year 1 were discounted at 3.5%/year,<sup>13</sup> following NICE guidelines.<sup>16</sup>

We constructed Markov models<sup>13</sup> of THA and TKA in Excel 2010 (Microsoft, Redmond, Washington, USA) to combine data from different datasets and extrapolate beyond the end of the available data. The model used annual cycles and mirrored the structure (Figure 1) used in previous model-based economic evaluations on arthroplasty identified in a comprehensive literature review (see Supplementary Material). Hypothetical patients of different age, sex, and OHS/OKS were run through the models separately and the costs and QALYs with and without arthroplasty were calculated for each hypothetical patient. A ten-year time horizon was chosen to reflect the longest duration of available data.

Patients in the 'no arthroplasty' arm were assumed to not undergo hip/knee arthroplasty within ten years. In practice, patients with mild symptoms may delay surgery until their symptoms have worsened as allowing for such variations in the

**Table I.** Results of sensitivity analysis.

Variable	Weighted mean economic Oxford Score threshold across all age/sex subgroups (points out of 48)	
	Knee arthroplasty	Hip arthroplasty
Base case analysis	43	45
5 year time horizon	42	44
20 year time horizon	43	45
60 year (lifetime) time horizon	43	45
EQ-5D utility without arthroplasty worsens by 0.025 per year	46	48
EQ-5D utility without arthroplasty increases by 0.115 in the first year (the average change in the control arm of the study by Skou et al <sup>13</sup> ) and follows age-related decline thereafter	39	41
Assuming that patients accrued no costs in the absence of arthroplasty	43	44
Halving the cost in the absence of arthroplasty	43	45
Doubling the cost in the absence of arthroplasty	43	45
Discounting QALYs at 1.5% and costs 3.5%	43	45
No discounting	43	45

EQ-5D, EuroQol five-dimension questionnaire; QALYs, quality-adjusted life-years.

timing of surgery would have greatly complicated the model structure. We compared arthroplasty against no arthroplasty to assess how the cost-effectiveness of arthroplasty varies between patient groups. Only one small randomized trial has compared arthroplasty against no arthroplasty,<sup>17</sup> and in observational studies it is not necessarily clear which patients with arthritis would be eligible for arthroplasty. Our 2015 literature review identified little evidence on how hip/knee function changes over time in the absence of arthroplasty, with some patients worsening and some improving (see Supplementary Material). We therefore assumed that OHS/OKS would remain constant without arthroplasty; however (unlike previous United Kingdom analyses that assumed no change in quality of life<sup>7,8</sup>) we assumed that EQ-5D utility would decline with age based on a published model.<sup>18</sup> These assumptions were varied in sensitivity analyses. We based costs in the no arthroplasty arm on costs accrued in the year before arthroplasty, assuming that in the absence of surgery, patients' annual healthcare resource use would remain constant. Our literature review identified no data to support or refute this assumption.

We used published regression models predicting costs and utilities as a function of age, sex, and OHS/OKS,<sup>14</sup> which were estimated using patient-level data from the linked Hospital Episode Statistics (HES) and Patient-Reported Outcome Measures (PROMs) datasets,<sup>1</sup> the Knee Arthroplasty Trial (KAT),<sup>19</sup> and the Clinical Outcomes in Arthroplasty Study (COAST)<sup>20</sup> (Supplementary Table ii). Other regression models identified in literature reviews were used to predict how mortality and revision rates vary with age and sex (Supplementary Table ii).<sup>21,22</sup> The cost of community/outpatient consultations one year

after THA was based on a previous analysis conducted as part of COAST (inflated from 2010 to 2011 using the hospital and community health services index<sup>23</sup>).<sup>20,24</sup> The reference year for costs was 2014.

Based on our 2015 literature reviews, we made the following assumptions (see Supplementary Material for less influential assumptions):

1. As the cost of primary arthroplasty is incurred at the start of the model, we did not apply a half-cycle correction to all health states. Instead, we assumed that patients who die in the same year as primary implantation or revision surgery incur the entire cost of the hospital stay in which the arthroplasty/revision was conducted. The cost of hospital admissions was assumed to be independent of whether patients died before hospital discharge. We assumed that in the last year of life, patients would accrue half of the cost and half of the number of QALYs that they would have accrued if they had lived for the whole year.
2. All-cause mortality rates were adjusted to allow for a healthy patient effect,<sup>21,22</sup> which reflects the observation that patients selected to undergo arthroplasty have lower mortality than people who are not considered candidates for arthroplasty. Since the patients in the no arthroplasty arm were assumed to be identical to those in the arthroplasty arm, the healthy patient effect was applied for the first eight years in both model arms, following Pennington et al.<sup>21,22</sup>
3. We also allowed for surgical mortality associated with primary and revision arthroplasty.<sup>21,22</sup>
4. We followed Pennington et al<sup>21,22</sup> by capping mortality in the year of revision at 10% above all-cause mortality to avoid extrapolating very high mortality rates to very old patients.
5. Due to lack of data, we assumed that mortality and revision rates do not vary with OHS/OKS and used published models<sup>21,22</sup> predicting revision rates conditional on age, sex, time since primary TJR, and other variables.
6. For simplicity, postoperative utilities and the cost of readmissions and ambulatory consultations in the first postoperative year were estimated across all patients, regardless of whether they underwent revision in this year.

Hypothetical individuals with different combinations of age, sex, and OHS/OKS were run through the model sequentially to calculate the costs and QALYs with and without arthroplasty for each group. All 49 OHS/OKS values were evaluated for men and women aged exactly 50, 60, 70, 80, and 90 years. NHS treatments are generally considered cost-effective if their incremental cost-effectiveness ratio (i.e. difference in cost ÷ difference in QALYs) is less than £20,000 per QALY gained (the ceiling ratio).<sup>25</sup> We therefore calculated the OHS/OKS threshold as the highest score at which the cost-effectiveness ratio for arthroplasty versus no arthroplasty is less than £20,000/QALY gained.

The models took account of uncertainty around all uncertain parameters, including regression coefficients, using probabilistic sensitivity analysis (see Supplementary Material). Ten sensitivity analyses assessed the sensitivity of the results to changes in discount rates, time horizon, and the assumptions made around the costs and EQ-5D utilities without THA/TKA (Table I).

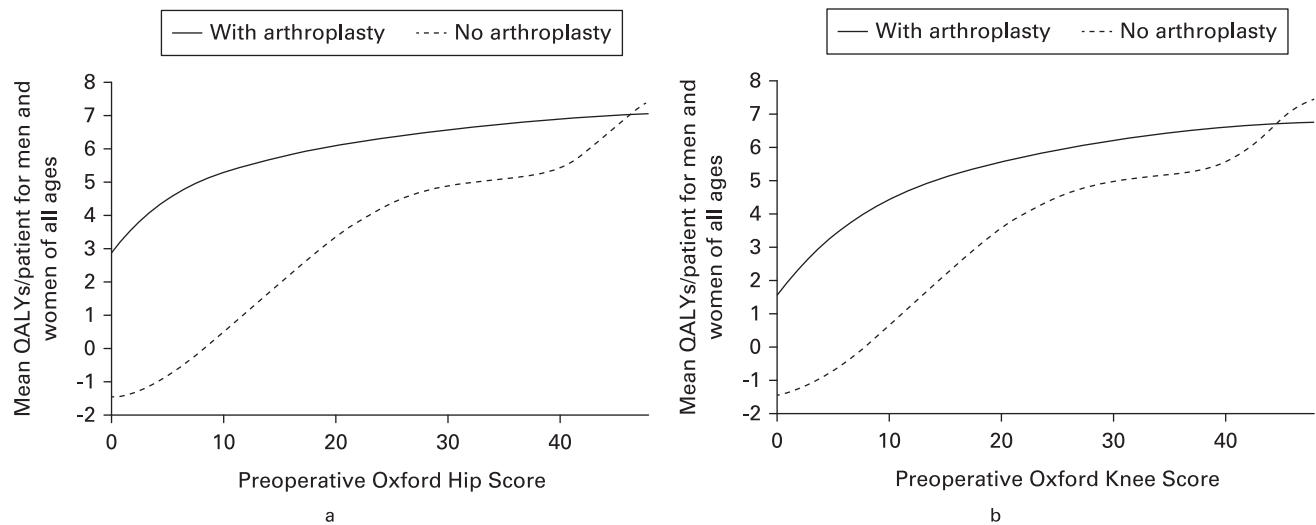


Fig. 2

Charts showing weighted mean total discounted quality-adjusted life-years (QALYs) per patient over men and women of all ages with and without a) hip or b) knee arthroplasty over the ten-year time horizon.

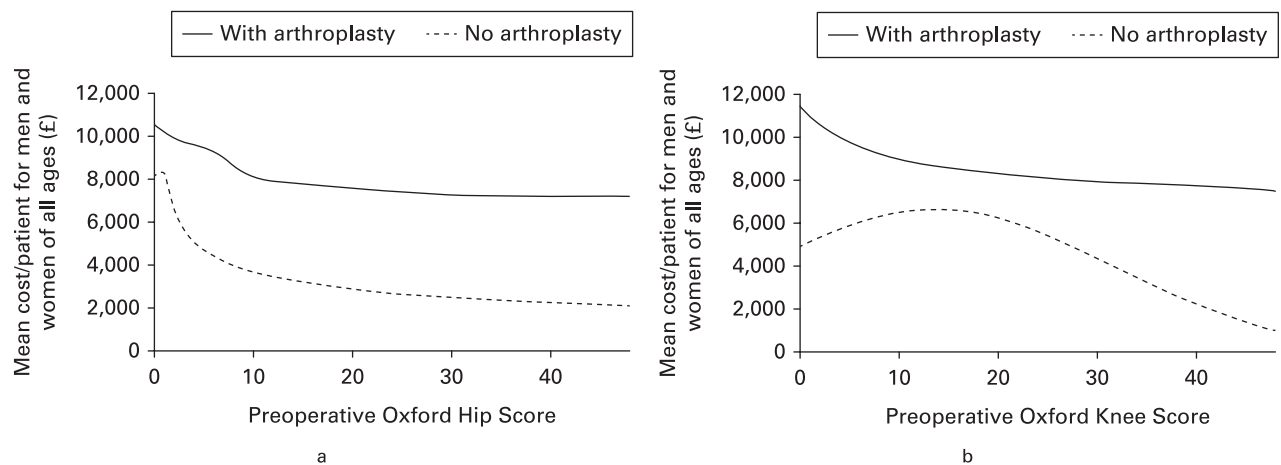


Fig. 3

Charts showing weighted mean total discounted cost per patient over men and women of all ages with and without a) hip or b) knee arthroplasty over the ten-year time horizon.

## Results

**Hip arthroplasty.** Both QALYs and costs varied markedly between patients with preoperative OHS of zero points (indicating severe problems on all 12 items) and those with scores of 48 points (indicating no problems). Without arthroplasty, patients with preoperative OHS  $\leq 8$  points were predicted to have negative EQ-5D utility, while those with OHS of 48 points accrued 7.42 QALYs over the ten-year time horizon (Figure 2a). The QALYs accrued by patients undergoing surgery increased from 2.91 for OHS of zero points to 7.08 for OHS of 48 points. QALY gains from THA were greatest for patients with OHS of five points (mean ten-year QALY gain: 5.28) or six points and declined steadily as OHS increased. For patients with OHS of 47 or 48 points, and for 80- or 90-year-olds with an OHS of 46

points, the model predicted that THA would worsen health by a mean of 0.44 QALYs.

The mean cost per patient with and without arthroplasty fell sharply as preoperative OHS increased from 0 to 10 and then reached a plateau (Figure 3a). For patients with preoperative OHS of 20, the total ten-year cost was £7,600 with arthroplasty (of which £7,014 was accrued in secondary care) and £2,892 without arthroplasty (of which £1,099 was in secondary care). The difference in cost between patients with and without THA was smallest for patients with an OHS of one (mean £1,975/patient across all ages) and rose gradually as OHS increased, to £5,113/patient with an OHS of 48. THA was predicted to be less costly than no arthroplasty for 50-year-old women with an OHS of one, but was more costly for all other groups.

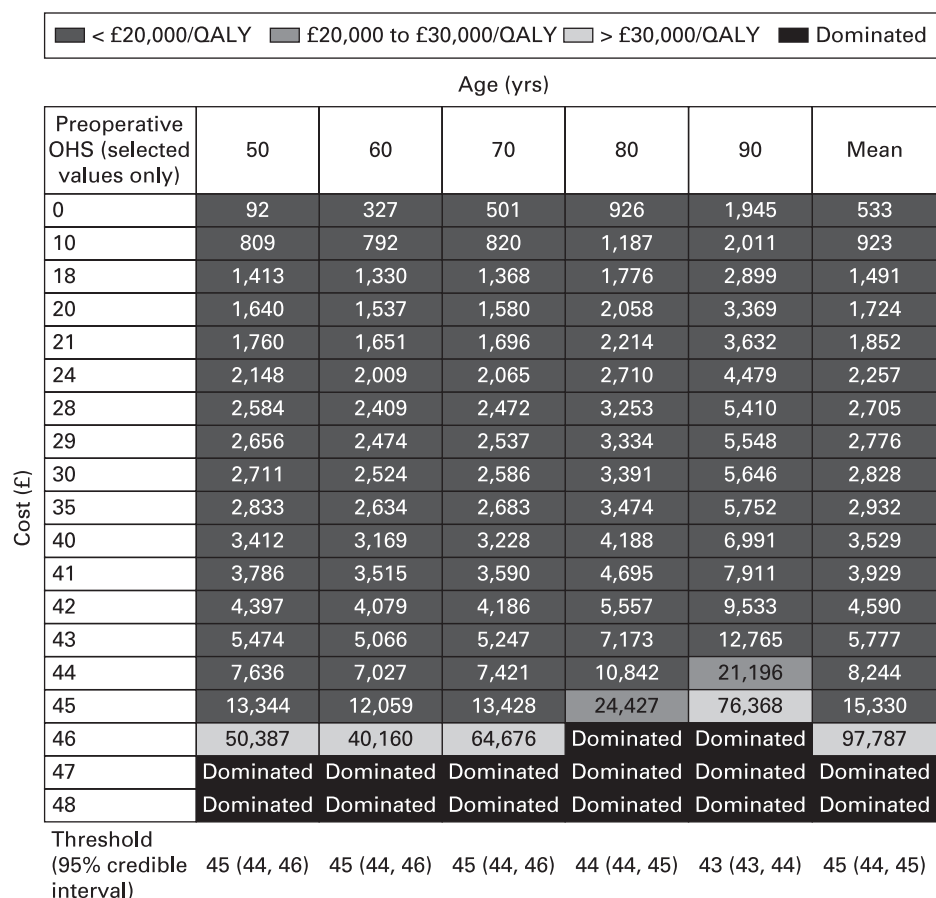


Fig. 4

Cost-effectiveness of total hip arthroplasty (THA) in patients of different ages and baseline Oxford Hip Score (OHS). Results are the weighted mean over men and women. Values indicate the cost per quality-adjusted life-year (QALY) gained for THA versus no arthroplasty (£). The decision grid focuses on OHS values in the region of the threshold; THA costs less than £20,000 per QALY gained for all age groups at the OHS values omitted from the grid. 95% credible intervals are analogous to 95% confidence intervals and show the range of values in which we can be 95% certain that the true threshold lies.

The cost/QALY gained rose with preoperative OHS (Figure 4). Based on the weighted mean across all ages, THA was dominated by no arthroplasty (i.e. produced fewer QALYs at greater cost) only for patients with OHS of 47 or 48 points and there was only one OHS value (46) at which THA improved patients' health but was not cost-effective (shown in red/orange in Figure 2 of the online version). For patients aged 70 years and less, THA cost less than £20,000 per QALY gained when OHS was 45 points or lower. The economic threshold (i.e. the highest OHS at which THA costs < £20,000/QALY gained, shown in green on Figure 2 of the online version) reduced to 43 points (95% credible interval (CrI) 43 to 44 points) for 90-year-olds. If a single threshold were to be set across all ages, 45 points (95% CrI: 44 to 45 points) would be the most cost-effective value to choose. Thresholds did not differ between men and women.

Based on the HES/PROMs data, only 0.03% (79/286,812) of patients currently undergoing arthroplasty have OHS greater than 45 points. Based on the distribution of age and OHS in the HES/PROMs dataset, 99.96% of THA operations currently conducted are cost-effective (i.e. cost < £20,000/QALY gained

compared with no arthroplasty); indeed 99.16% of operations cost < £5000 per QALY gained.

However, there was some uncertainty around the results. The 95% CrIs demonstrated that we can be 95% confident that the economic threshold for all ages combined lies between 44 and 45 points. The probability that THA is cost-effective varied with age and OHS (Figure 5a) and with the ceiling ratio (which indicates how much the NHS is willing or able to pay per QALY gained). For a population of 70-year-olds, the probability that THA is cost-effective at a £20,000/QALY ceiling ratio was greater than 95% at OHS of 44 points and below, 90% at an OHS of 45 points, and 5% at an OHS of 46 points. There was markedly greater uncertainty for patients aged 80 and 90 years. **Knee arthroplasty.** The absolute numbers of QALYs accrued over the ten-year time horizon followed similar trends to hip arthroplasty (Figure 2b). The QALY gain from TKA was highest for patients with preoperative OKS of 6 to 7 points and declined steadily with increasing OKS. Taking the weighted mean across all ages, TKA generated 2.99 additional QALYs/patient at an OKS of zero points, 4.05 QALYs/patient at an OKS of 6 points,



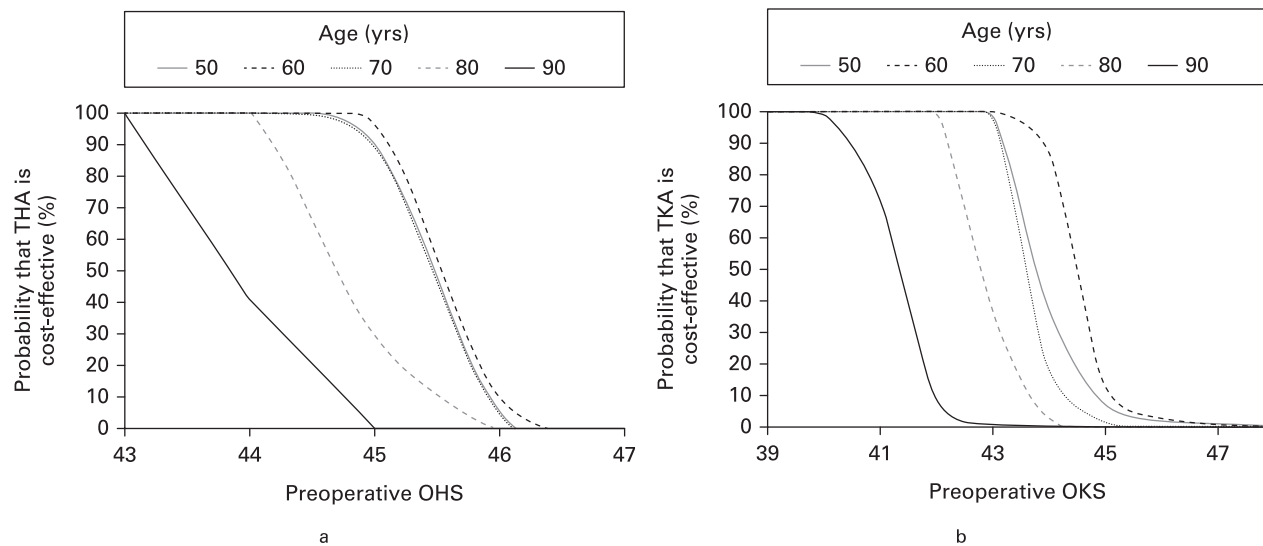


Fig. 5

Charts showing the effect of Oxford Hip/Knee Score (OHS/OKS) on the probability that a) total hip arthroplasty (THA) and (b) total knee arthroplasty (TKA) are cost-effective at a £20,000/QALY ceiling ratio.

and 0.19 QALYs/patient at an OKS of 44 points. The model predicted that TKA would increase QALYs for all patients with OKS below 44 to 46 points (depending on age).

For patients undergoing TKA, ten-year costs fell with OKS from £11,447/patient with OKS of 0 points to £7,516/patient with OKS of 48 points (Figure 3b). By contrast, without TKA, mean costs rose from £4,990 to £6,690 with OKS between zero and 14 points and then fell to £1,035 at OKS of 48 points. At all OKS, secondary care accounted for around 90% of costs for patients undergoing TKA and 43% of costs without TKA. The incremental cost of TKA was lowest for patients with OKS of 16 to 19 points but was markedly higher for patients with lower or higher scores. TKA was predicted to be less costly than no surgery for 50-year-old men with OKS between 15 and 18 points and for 50-year-old women with OKS between 10 and 21 points. Taking the weighted mean across all ages and sexes, the incremental cost was £6,457/patient with an OKS of zero, £1,898/patient with an OKS of 16, and £6,481/patient with an OKS of 48.

The cost per QALY gained was lowest for patients with OKS between 9 and 15 points and rose as OKS increased beyond this range (Figure 6). TKA was dominated by no arthroplasty for patients with OKS of 44 to 46 or greater. The threshold OKS was 44 points (95% CrI 43 to 48) for 60-year-olds and 41 points (95% CrI 40 to 42) for 90-year-olds. Taking a weighted mean across all age groups, the threshold was 43 points (95% CrI 43 to 44). Thresholds did not differ between men and women.

Based on PROMs/HES, around 0.06% (198/309,001) patients currently undergoing knee arthroplasty have OKS over 43 points; 99.93% of TKA procedures are therefore cost-effective (< £20,000/QALY gained compared with no arthroplasty) and 96.64% cost less than £5,000/QALY gained.

Probabilistic sensitivity analysis demonstrated that there is a 95% probability that the threshold, ignoring age and sex, is between 43 and 44 points. For a population of 70-year-olds,

we can be more than 99% confident that TKA is cost-effective at a £20,000/QALY ceiling ratio at OKS of 42 points or less, although this falls to 98% for patients with OKS of 43 points, 18% for patients with OKS of 44, and 2% for patients with OKS of 45 points (Figure 5b). Substantially greater uncertainty was observed for patients aged 50 or 90 years.

**Sensitivity analyses.** The ten sensitivity analyses demonstrated that the results are reasonably robust to changes in all the key assumptions, including model time horizon (Table I). Changing the assumptions about EQ-5D utilities in the absence of THA/TKA had the greatest impact: assuming that EQ-5D utility would increase by 0.115 in the first year (the mean change in the control arm of the study by Skou et al<sup>17</sup>) reduced the threshold to 41 points for THA and 39 points for TKA. Assuming a decrease in EQ-5D utility without surgery increased thresholds to 48 points for THA and 46 points for TKA. In other sensitivity analyses, the threshold varied between 42 and 45 points.

## Discussion

The results demonstrate that if society is willing to pay £20,000 per QALY gained, THA is cost-effective for patients with preoperative OHS 45 points or less, while TKA is cost-effective for patients with OKS of 43 points or less. We found little evidence that economic thresholds vary with age or sex. Sensitivity analyses demonstrated that there is little uncertainty around the conclusions. Arthroplasty is therefore cost-effective for all patients shown to have capacity to benefit in the accompanying paper.<sup>6</sup> The calculated economic thresholds are slightly higher than the calculated absolute thresholds (indicating the OHS/OKS above which patients cannot achieve a 7 to 8 point improvement<sup>6</sup>) since clinical improvements of less than seven points can still produce QALY gains on a population level that justify the cost of surgery, even after allowing for the risk of revisions and perioperative mortality. Whereas the accompanying paper estimated the probability of achieving a minimally important

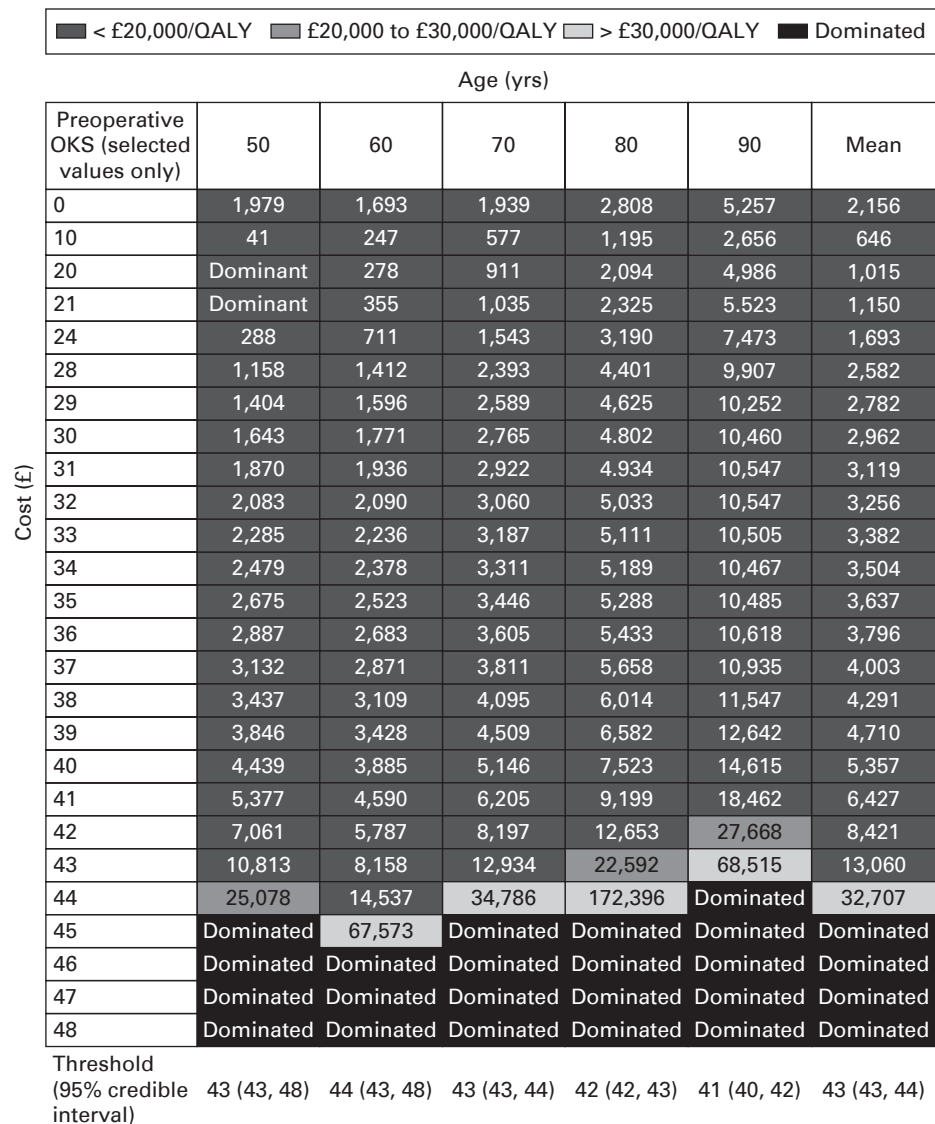


Fig. 6

Chart showing cost-effectiveness of total knee arthroplasty (TKA) in patients of different ages and baseline Oxford Knee Score (OKS). Results are weighted mean of men and women. Values indicate the cost per quality-adjusted life-year (QALY) gained for TKA versus no arthroplasty (£). The decision grid focuses on OKS values in the region of the threshold; TKA costs < £20,000 per QALY gained for all age groups at the OKS values omitted from the grid. 95% credible intervals are analogous to 95% confidence intervals and show the range of values in which we can be 95% certain that the true threshold lies.

change, the economic evaluation estimated the QALY gains from treatment based on absolute changes in quality of life (EQ-5D utility), regardless of how small (or large) such changes were.

Our model was based on the best available data for the United Kingdom, including data on 608,170 operations. We also used patient-level data on use of resources before arthroplasty and for up to 12 years after surgery. However, only 0.5% of the HES/PROMs sample had OHS/OKS over 40 points, 95% were aged between 50 and 90 years and the mortality and revision rates used in the model<sup>21,22</sup> excluded patients aged < 55 or > 84 years of age. Results for 50- and 90-year-olds should therefore be interpreted with caution. There are currently no United Kingdom-based longitudinal studies on patients who are eligible for arthroplasty but have not undergone surgery.

The analysis is therefore based on before and after studies and relies upon assumptions about long-term changes in costs and utilities without arthroplasty. We focused on the cost of hospital admissions and ambulatory consultations for hip/knee osteoarthritis; broadening the perspective could have improved the cost-effectiveness of arthroplasty by including reductions in nursing home admissions.

The results confirm the findings of previous studies in a United Kingdom setting;<sup>7,8</sup> Dakin et al<sup>7</sup> estimated the OKS threshold to be 34 to 39 points using a shorter time horizon and conservative assumptions,<sup>7</sup> compared with 43 points in our analysis. However, Ferket et al<sup>9</sup> found TKA to increase SF-6D utility by just 0.008 and cost over \$100,000/QALY gained for patients with SF-12 physical scores of 20 points or more; the

difference between studies may reflect differences between SF-6D and EQ-5D and/or the small sample of patients in United States with mild osteoarthritis used by Ferket et al.

Our results demonstrate that the model proposed in the accompanying paper,<sup>6</sup> which identified patients for referral based on OHS/OKS thresholds of 40/41 points, would identify a population of patients for whom arthroplasty is highly cost-effective. It is therefore not appropriate to use cost-effectiveness as grounds for restricting access to arthroplasty for any patients who have capacity to achieve a good clinical outcome. Even the relatively small improvements experienced by patients with preoperative OHS of 41 to 45 points and OKS of 42 to 43 points represent good value for money on a population level. However, on an individual level, these patients cannot achieve our definition of a minimally important improvement (OHS change of eight points or OKS change of seven points), which may mean that arthroplasty will not meet the expectations of these individual patients. Currently very few patients at this preoperative level undergo arthroplasty in the United Kingdom, and any such individuals considering arthroplasty should be made aware of their risk of not improving.

Differences between our study and others<sup>9</sup> demonstrate the need for more data on how OHS/OKS, costs and utilities change over time without arthroplasty. Future work should also assess whether thresholds vary with body mass index and whether revision rates vary with OHS/OKS since the available datasets did not provide these data.

In summary, at the £20,000/QALY ceiling ratio typically used in NHS decision-making, it is cost-effective to refer patients with OHS/OKS below the absolute thresholds calculated in the accompanying paper<sup>6</sup> (OHS  $\leq$  40 points, OKS  $\leq$  41 points) for possible arthroplasty. However, referrals must be based on a multifaceted assessment by experienced health professionals, not just OHS/OKS. Once referred, patients and surgeons will continue to make a shared decision about whether arthroplasty is appropriate and likely to meet the patients' expectations. Performing arthroplasty on patients with preoperative OHS of 41 to 45 points or OKS 42 to 43 points can still be cost-effective, although individuals cannot reach our definition of minimally important change. Further research is needed to assess the impact of introducing OHS/OKS thresholds on the number of referrals/operations and on health outcomes and costs for patients above and below the threshold.



### Take home message

- We found hip and knee arthroplasty to be cost-effective for more than 99% of patients who currently undergo surgery.
- Hip and knee arthroplasty are highly cost-effective for the population of patients with preoperative scores below the calculated absolute threshold for referral (Oxford Hip Score (OHS) 40 and Oxford Knee Score (OKS) 41).
- Arthroplasty remains cost-effective for patients with preoperative OHS of 45 or less, or OKS of 43 or less, although patients may only achieve a small improvement in quality of life.

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### Supplementary material



Additional information on methods and results are given in the Supplementary Material, including: a table of data sources; methods and results of literature searches used to inform assumptions and data inputs; and additional information on model parameters and assumptions.

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#### Funding statement:

The ACHE study and economic evaluation was funded by the NIHR Health Technology Assessment Programme (project number 11/63/01) and is published in full in Health Technology Assessment. Visit the HTA programme website ([www.hta.ac.uk](http://www.hta.ac.uk)) for further project information. The views and opinions expressed therein are those of the authors and do not necessarily reflect those of the HTA programme, NIHR, NHS or the

Department of Health. AP and AG are part-funded through the Oxford NIHR Biomedical Research Centre. The funder had no involvement in: the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. The authors had full access to the data (including statistical reports and tables), can take responsibility for the integrity of the data and the accuracy of the data analysis, and are responsible for submitting this paper.

The author or one or more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article.

#### ICMJE COI statement:

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#### Data sharing:

The Markov models used in this paper are available from the corresponding author on request.

#### Acknowledgements:

We would like to thank the ACHE patient and public representatives, user group and steering group for their role in the project: Anne Clarkson Webb, Anthony Johnson, Chad Lion Cachet, Fiona Watt, Fraser Old, Gill Dean, Gillian Kempster, Jannie Kramer, Jennifer Bostock, Jiyang Li, Jo Hewanicka, John Nolan, Kate Jackson, Laura Ingle, Mary Snow, Matthew Cheetham, Patricia Mary Rubery, Sharon Barrington, Sujin Kang, Tim Wilton, Vida Field, Sunny Deo, Malvin Drakely, Jon Campion, George Peat, Peter Kay, Jon Waite and Sue Woollacott. We would also like to thank Mark Pennington for providing the model inputs and variance-covariance matrices for his papers on knee and hip arthroplasty, as well as for helpful responses to questions on his modelling approach. Similarly, we would like to thank Rafael Pinedo Villanueva for useful discussions about his modelling approach, and for providing variance-covariance matrices and additional information on the model inputs used in his thesis. We thank Nicola Beddows for proofreading the manuscript. Data on NHS PROMs linked to HES APC data were reused with the permission of NHS Digital, copyright 2015, with all rights reserved. The views and opinions expressed in this paper are those of the authors and do not necessarily reflect those of the HTA programme, NIHR, NHS, NHS Digital or the Department of Health. We would also like to thank the contributors: Sujin Kang, Jonathan Cook, Ray Fitzpatrick, David Murray, Nigel Arden, Andy Carr, Karen Barker, James Smith, Stephanie Smith, Kristina Harris, Rob Middleton, Elizabeth Gibbons, Elena Benedetto, Jill Dawson, Adrian Sayers, Laura Miller, Elsa Marques, Rachael Goberman-Hill, Ashley Blom, Andrew Judge, and Siôn Glyn-Jones.

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This article was primary edited by K. Logishetty and first proof edited by G. Scott.