### **Lifetime cost-effectiveness of alternative prosthesis brands for total hip replacement: A study using the NJR dataset**

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**ABSTRACT**

There is little evidence on the cost-effectiveness of hip prosthesis brands. We compared lifetime cost-effectiveness of frequently used brands within prosthesis type: cemented (Exeter V40 Contemporary, Exeter V40 Duration and Exeter V40 Elite Plus Ogee), cementless (Corail Pinnacle, Accolade Trident, and Taperloc Exceed), and hybrid prostheses (Exeter V40 Trilogy, Exeter V40 Trident, and CPT Trilogy). We used data from three linked English national databases to estimate lifetime revision risk, quality-adjusted life years (QALYs) and cost.

For women with osteoarthritis aged 70, the Exeter V40 Elite Plus Ogee had the lowest revision risk (5.9% revision risk, 9.0 QALYs) and the CPT Trilogy had the highest QALYs (10.9% revision risk, 9.3 QALYs). Compared with the Corail Pinnacle (9.3% revision risk, 9.22 QALYs), the most commonly used brand, and assuming willingness-to-pay of £20,000 per QALY gain, the CPT Trilogy is most cost-effective with an incremental net monetary benefit of £876. Differences in cost-effectiveness between the hybrid CPT Trilogy and Exeter V40 Trident and the cementless Corail Pinnacle and Taperloc Exceed were small, and a cautious interpretation is required, given the limitations of the available information.

However, it is unlikely that cemented brands are among the most cost-effective. Similar patterns of results were observed for men and other ages. The gain in quality of life after THR, rather than revision risk, was the main driver of cost-effectiveness.

**INTRODUCTION**

Total hip replacement (THR) is a highly effective surgical intervention improving quality of life (QoL) for patients with osteoarthritis.1 Many alternative prosthesis brands have been developed. There is considerable variation in the price of the different brands,2 but there is relatively little evidence on their effectiveness in terms of their durability and impact on patients’ symptoms, functional status and QoL.3,4

The currently available studies on the cost-effectiveness of prosthesis brands are outdated,5,6 which may account or the lack of recommendation of brands in the 2014 National Institute for Health and Care Excellence (NICE) guidance documents.7 Our previous economic evaluation comparing types of hip prostheses based on large national databases of patients who had a hip replacements in England or Wales found that fully cementless prostheses were less cost-effective than hybrid prostheses (with a cemented stem and cementless acetabular component) for most subgroups.8 Our comparison of outcomes of the THR with three frequently used brands within each type of reconstruction (cemented, uncemented, hybrid), based on the same national databases demonstrated that the largest improvements of symptoms and functional status (Oxford Hip Score, OHS) were seen with the hybrid cemented Exeter V40 stem and an uncemented Trident acetabular component (both Stryker, Newbury, United Kingdom) whereas 5-year revision rates were lowest with the fully cemented Exeter V40 stem and the Elite Plus Ogee acetabular component (DePuy, Leeds, United Kingdom).9 However, this study did not consider either revision rates beyond five years or costs.

The aim of this paper is to compare the lifetime cost-effectiveness of frequently used prosthesis brands, building on an earlier analysis reporting functional outcome at six months, risk of revision and mortality at five years after the THR.9 We used data on case-mix and post-operative QoL from the national programme that collects patient reported outcomes (PROMs) immediately before and six months after elective THR in the English National Health Service (NHS).10 These data were linked to records from the National Joint Registry for England, Wales and Northern Ireland (NJR), the largest joint registry in the world, and the Hospital Episode Statistics (HES),11 an administrative database of all admissions to NHS hospitals in England.

# Methods

## Model overview

The lifetime cost-effectiveness of each brand was assessed using a Markov model previously developed to compare the cost-effectiveness of different types of prosthesis. The model’s main assumptions have been described in detail elsewhere.8 In brief, the model simulates transitions between health states over a patient’s lifetime. For each prosthesis brand, costs and outcomes are estimated for a hypothetical cohort of patients who enter the model at the time of their primary THR (Figure 1). There is a probability of death immediately after surgery and an annual probability of all-cause mortality and revision of the THR, either in one stage or in two stages if the revision is due to infection. The time in each health state is summed over annual cycles weighted for QoL to estimate life expectancy in terms of quality-adjusted life years (QALYs). Lifetime costs are calculated by adding costs of the primary THR to the costs of one-stage or two-stage revisions.8

**Sources of clinical data**

Data to estimate model parameters were taken from three English national databases containing data on individual patients undergoing primary and revision THR.

*Comorbidity, symptoms and disability, QoL, length of stay (linked PROMs-NJR-HES data)*

Since 2008, the PROMs programme has collected data on symptom severity, functional status and quality of life (QoL) immediately before and six months after surgery reported by patients undergoing elective THR funded by the NHS in England.12,13 We obtained the PROMs records of 178,723 patients who had an NHS-funded elective THR between April 2008 and June 2011 and who had completed a PROMs questionnaire. This questionnaire provided information on pre-operative comorbidities, symptoms and disability (OHS, 0 to 48, worst to best)14 and pre and post-operative QoL assessed using the EuroQol (EQ-5D-3L) proforma.15 The EQ-5D-3L has five dimensions (mobility, self-care, usual activities, pain and discomfort, anxiety and depression) and three levels (no problems, some problems, severe problems) for each dimension. The EQ-5D-3L responses were combined with health state preference values from the UK general population16 to report an index score anchored at 1 (perfect health) and 0 (death).

Of the patients who had completed a pre-operative PROMs questionnaire, 108,474 (60.7%) could be linked to the NJR and HES. The NJR record provided data on prosthesis brand, reason for the THA (osteoarthritis or other), body mass index (BMI), American Society of Anesthesiologists (ASA) grade,17 hospital type (NHS hospital or independent sector treatment centre), and surgeon grade (senior or junior ). The HES databases contain records that are submitted by English NHS hospitals to a national data warehouse to allow them to be paid for the care they deliver.18,19 HES records include data item on diagnoses (coded according to the International Classification of Diseases fourth edition),20 procedures (coded according to the OPCS Classification of Surgical Operations and Procedures, fourth revision),21 administrative data including dates of admission and discharge, and patient details. The latter are used to determine the Index of Multiple Deprivation (IMD) for each patient, a measure of socioeconomic deprivation, based on the area in which the patient lived.22

We excluded 17,161 patients who were aged < 55 or > 84 years, 9867 who did not receive a cemented, cementless or hybrid THR, 4288 with diagnoses additional to osteoarthritis, 4024 whose THR was privately funded or who had a non-standard surgical procedure, and 587 who died or underwent revision in the first year after surgery. We also excluded 27,322 patients for whom the prosthesis brand was unknown and 1701 patients who had a prosthesis with a metal-on-metal or metal-on-ceramic bearing surface leaving 43,524 patients. This represented 24.4% of all PROMs data and 40.1% of data with linked HES and NJR records.

For the health state representing the year in which a patient’s THR is revised, QoL was estimated from the pre-operative data available for 5,058 patients who were found to have had revision surgery in the linked PROMs-NJR-HES data. QoL after revision surgery was estimated from post-operative data available for 3,561 patents.

*Revision rates and mortality (NJR-HES data)*

We used the NJR records for 239,012 patients aged 55 to 84 with a diagnosis of osteoarthritis who had a unilateral primary THR funded by the NHS between April 2003 and March 2012, and the HES records of 599,543 patients aged 55 to 84 who had a unilateral primary THR between April 1997 and March 2012. Of these patients, 178,289 (74.6%) of NJR records could be linked to HES. After applying the same exclusion criteria as for the linked PROMs-NJR-HES data, the data contained 147,337 patients with linked records, 45,309 unlinked NJR records and 311,653 unlinked HES records. The prosthesis brand was derived from NJR data and revisions were identified in both NJR and HES data.

Mortality within 30 days of the primary THR was estimated from HES data. Mortality after the first 30 days was estimated from age and sex-matched general population data for England with adjustment for the “healthy patient” effect (see below).23

*Re-revision rates and mortality after revision (HES data)*

We identified 123,897 revisions in the HES dataset. We lacked data on the reason for the primary THR for most of these patients, and therefore we excluded 38,557 patients under 65, because younger patients are likely to have a THR for other diagnoses than osteoarthritis. After linking first revisions to subsequent revisions on the same hip we had 67,291 patients of whom 6,242 had undergone re-revision. These patients were used to estimate re-revision rates and mortality in the year following revision.

**Costs**

The unit costs of the nine prosthesis brands were taken from data supplied by an employee of NHS Supply Chain , and included all components and instrumentation.24 Theatre cost and cost per bed day were taken from national studies; theatre cost varied according to prostheses type.25,26 In order to reflect the fact that the cost of a revision is higher than that of a primary THR,27 we used a cost study of revision THRs. The cost of a one-stage revision was estimated to be 1.4 times higher than the cost of a primary THR (resulting in a cost of £7,828) and the cost of a two-stage procedures 3.6 times higher (resulting in £20,421).28 All unit costs were reported in British pounds (1 British pound ≈ 1.70 US dollars ≈ 1.20 Euros; prices valid at 2010 to 2011).

**Statistical analysis to provide parameters for the cost-effectiveness model**

*QoL after primary THR and revision*

The effect of the prosthesis brand on post-operative QoL was predicted using a linear regression model that included age, sex, comorbidites, BMI, ASA grade, IMD, pre-operative symptoms and disability, pre-operative QoL, surgeon grade, and hospital type. The percentage of missing values was less than 5% for all predictors with the exception of self-reported disability status and BMI. Post-operative QoL was missing in 19.1%. Linear and quadratic terms were included for age and fractional polynomials for the other predictors to specify the relationship with post-operative QoL.29 To allow for any modification of the effect of prosthesis type on QoL, we included age and sex as interaction terms.

We assumed that all differences in QoL were maintained beyond six months unless the prosthesis was revised but we allowed QoL to decline with increasing age over time by applying the age gradient estimated from a large UK observational study.30 In order to reduce the risk of bias from missing data in the estimation of QOL after primary THR, we imputed missing items using multiple imputation with 50 imputations.31,32

QoL in the year during which revision surgery occurs was predicted using a linear regression model that included age, sex and type of revision (one-stage or two-stage). QoL in the years following revision was also predicted as a function of age and sex. Complete cases were analysed to estimate QOL after revision THR.

*Rate of revision and re-revision*

The risk of a revision according to prosthesis *type* was predicted over a patient’s lifetime using parametric survival models fitted to the NJR-HES data after excluding unlinked NJR records. We fitted restricted cubic spline survival models separately for each prosthesis *type* as a function of age and sex.33 We applied Cox regression to the NJR-HES data after excluding unlinked HES records to estimate the relative risks for prosthesis *brands* within each *type*. The Cox models adjusted for age, sex, ASA grade, BMI (categorised as < 30, 30 to 35, > 35), hospital type, and surgeon grade. The resulting relative risks were applied to the appropriate baseline revision risk by *type* to estimate the risk of revision by *brand*. Logistic regression was used to predict whether revisions were one-stage or two-stage procedures.

Re-revision rates were estimated with a Piece-wise Constant survival regression model that allowed for different revision rates in the first and latter years after a THR.34 All re-revisions were assumed to be one-stage.

*Mortality*

Mortality within the first 30 days after a primary THR and mortality in the year during which revision occurs, was predicted using a logistic regression model which included age and sex. Mortality after the first 30 days was adjusted for the ‘healthy patient’ effect using linear regression to estimate the ratio of mortality in patients who had a THR and in the general population as a function of age, sex and years after primary THR.

## Cost-effectiveness analysis

For each of the nine brands, we report QALYs, lifetime revision rates and THR related costs for men and women aged 60, 70 and 80 years old. We undertook a probabilistic analysis in which each model parameter was specified as a random variable reflecting sampling uncertainty around the mean estimates.6 Model results are reported after averaging across 1000 simulations in which each parameter value was sampled from the specified probability distribution. In order to reflect societal time preferences, future costs and outcomes were discounted at an annual discount rate of 3.5%.35

In each simulation, we calculated the net monetary benefit (NMB) for each prosthesis brand by multiplying the lifetime QALYs by a range of values that a society may be willing to pay for a QALY and then subtracting the total lifetime cost (see also footnote of Table 3).36,37 The willingness-to-pay values varied from £0 to £50,000. We calculated the proportion of the 1000 simulations for which each brand had the highest NMB across this range of willingness-to-pay values, and present these proportions as cost-effectiveness acceptability frontiers.38,39 These frontiers indicate which prosthesis brand is the most cost-effective as a function of the society’s willingness-to-pay values, and reflect the associated uncertainty.

We also report incremental net monetary benefits (INB) for each brand by calculating the difference between their NMB and the corresponding NMB of the pairing of the Corail stem and the Pinnacle acetabular component (both DePuy), the most commonly used prosthesis brand. A positive INB indicates that the brand is likely to be more cost-effective than the Corail Pinnacle. We report a non-parametric 95% confidence interval (CI) for INB derived from the model simulations. Confidence intervals for the INBs were defined as the 2.5 and 97.5 percentiles of the 1000 simulations.nterval of the INBs were defined as the 2.5 and 97.5 percentiles of the 1000 simulation results.

**Sensitivity Analysis**

We tested whether the cost-effectiveness results were robust to four alternative scenarios, by modifying parameters in the Markov model. Firstly, we ignored differences in brand costs and applied the same average cost to all brands. Secondly, we re-estimated the survival model that predicted revision rates for each brand using Piece-wise Constant model that allowed for differences by *brand* in the first five years and a Weibull model that allowed for differences by *type* in subsequent years. Thirdly, we allowed the differences in post-operative QoL between prosthesis brands to decrease with time after surgery so that any differences fall to zero after ten years. Fourthly, we re-estimated the effect of prosthesis brand on QoL by including interaction terms for age and sex with prosthesis *brand* rather than *type*.

**RESULTS**

**Pre-operative characteristics**

Patients who received a cemented brand were older than patients who received a cementless or hybrid brand (Table 1). Pre-operative symptom severity and disability, and QoL were similar across prosthesis types and brands. Patients who received a cementless Corail-Pinnacle brand were more often treated at an independent sector treatment centre and those who had received a hybrid CPT stem and uncemented Trilogy acetabular component (both Zimmer, Warsaw, Indiana) were less often treatment by a senior surgeon.

**Post-operative outcomes**

For men and women aged 70, the hybrid Exeter V40-Trident and CPT-Trilogy prostheses and the cementless Corail-Pinnacle were predicted to produce the highest QoL six months after the THR (Table 2). The cemented Exeter V40-Elite Plus Ogee had the lowest revision rates. The initial costs of the primary THR were highest in patients who received a Corail-Pinnacle and lowest in those who received any of the three cemented brands. Findings were similar for patients aged 60 and 80 (see web appendix).

**Cost-effectiveness analysis**

For men and women aged 70 years, the predicted lifetime costs were lowest with the three cemented brands and highest with the hybrid CPT-Trilogy and Exeter V40-Trilogy and for the cementless Corail-Pinnacle (Table 3). The CPT-Trilogy, Exeter V40-Trident, Corail-Pinnacle and the cementless Taperloc stem with Exceed cementless acetabular component (both Biomet, Bridgend, United Kingdom) had the highest lifetime QALYs.

Table 3 also shows that with a society’s willingness-to-pay of £20,000 per QALY gain the two hybrid brands (CPT-Trilogy and Exeter V40-Trident) had the highest NMB. Compared with the Corail-Pinnacle in men aged 70 years, the INB was £954 for the CPT-Trilogy and £344 for the Exeter V40-Trident. For women aged 70 years, the corresponding INB was £876 for the CPT-Trilogy and £71 for the Exeter V40-Trident. All other brands had lower NMBs than the Corail-Pinnacle, which corresponds to negative INBs, and they were therefore less cost effective, albeit that the differences between the Corail-Pinnacle and the Taperloc-Exeed were very small.

Table 3 also shows the 95% CI around the INB estimates. These are wide compared with many of the INBs themselves. Only the CI for the Exeter V40-Contemporary, the Exeter V40-Duration and the cementless Accolade stem with a cementless Trident acetabular component (both Stryker, Newbury, UK) did not include 0, which indicates that only for these brands can we be reasonably confident, based on the traditional 95% level, that they had lower NMBs than the Corail-Pinnacle. The results for 60 and 80 year old patients were similar (see web appendix).

Figure 2 shows the cost-effectiveness acceptability frontiers for men and women aged 70. Below a willingness-to-pay threshold of £3,000-4,000 per QALY gain, the cemented Exeter V40 Elite Plus Ogee was most likely to be cost-effective. Above a threshold of £12,000 for women and £18,000 for men the hybrid CPT Trilogy was most likely to be cost-effective. These results show again the considerable uncertainty in the cost-effectiveness results. For example, the CPT Trilogy was more likely to be cost-effective than any other brand for men and women at the £20,000 to £30,000 per QALY threshold used by NICE. However, the probability that it was the most cost-effective brand, plotted on the y-axis as a function of threshold willingness-to-pay values, did not exceed 50%.

**Sensitivity analysis**

Table 4 presents the results of the sensitivity analyses of the cost-effectiveness results for each brand in terms of their INB for men and women aged 70 years. The hybrid CPT-Trilogy remained the most cost-effective brand after assuming the same prosthesis cost for each brand. After applying an alternative survival model to estimate revision rates the Exeter V40-Trident (hybrid) was the most cost-effective brand in men aged 70 years. In the sensitivity analyses where differences in post-operative QoL were allowed to taper to zero over ten years and where the statistical model estimating the effect of prosthesis brand on QoL was changed to include interactions of prosthesis brand with age and sex, the cost-effectiveness estimates became more uncertain and in each case the most cost-effective brand was either the Exeter V40-Trident or CPT-Trilogy. In each sensitivity analysis for men and women aged 70 the Corail-Pinnacle was the second or third most cost-effective brand.

**DISCUSSSION**

This cost-effectiveness analysis suggests that the hybrid CPT-Trilogy prosthesis is the most cost-effective prosthesis brand. However, differences with the hybrid Exeter V40-Trident and the cementless Corail-Pinnacle and Taperloc-Exceed were very small. These four brands did not have the lowest revision rates and neither were they the cheapest, but they produced the greatest gain in QoL after a THR.

The uncertainty in the cost-effectiveness estimates is large compared to the small differences between the prosthesis brands. Based on the CI of the INB estimates, only the cemented Exeter V40-Contemporary and Exeter V40-Duration and the cementless Accolade-Trident (Stryker) could be identified with some confidence as being less cost-effective than the Corail-Pinnacle, which is currently the most commonly used combination in England, Wales and Northern Ireland.

The higher lifetime costs of the cementless and hybrid brands partly reflect the relatively high prices charged for these prostheses. The prosthesis prices used in this analysis represented averages charged across NHS providers. The prices of prosthesis brands may vary according to price negotiations, but the results were robust to a sensitivity analysis in which the same price was used for all brands.

This study has a number of strengths. Firstly, the parameters of our cost-effectiveness model were derived from the world’s largest joint registry linked to records of a national PROMs database and an administrative database of hospital admissions. This allowed precise predictions of the effect of brand on post-operative QoL and revision rates. Secondly, we could include information on symptoms, functional status and QoL reported by the patients themselves immediately before the THR in regression models to adjust for differences in case mix across prosthesis brands. Thirdly, the study could build on previously developed approaches to model lifetime costs and outcomes after joint replacement.6,8 Fourthly, the analysis fully considered the uncertainties in the model parameters, including revision risk, in our probabilistic analysis. We also carried out a sensitivity analysis exploring the impact of key modelling assumptions on the results.

The first limitation of our study is that all our model parameters were derived from observational studies and, despite our extensive risk adjustment approach, residual confounding cannot be ruled out, especially given the small differences in the results of some of the prosthesis brands. Whilst linkage across datasets increased data on the characteristics of both patients and providers, we could only link 60% of patients. Secondly, our QoL estimates could only be based on PROMs collected six months after THR. Therefore, we had to make assumptions about how long differences between prosthesis brands in QoL gains after THR would continue to exist. Our sensitivity analysis demonstrates that these assumptions are important but the hybrid CPT-Trilogy and Exeter V40-Trident and the cementless Corail-Pinnacle and Taperloc-Exceed always remained among the most cost effective brands. Thirdly, we had to extrapolate the revision rates of the prosthesis brands beyond the maximum follow-up period of the NJR. This extrapolation was based on parametric survival models and the appropriateness of these models cannot be tested directly. However, our sensitivity analysis showed that hybrid prosthesis brands remained the most cost-effective with different specifications of the survival model. There is also evidence that the NJR under reports revisions, although this is unlikely to favour a particular brand.40 Finally, in the absence of evidence to the contrary, we assumed that prosthesis brand had no impact on post-discharge rehabilitation or on rates of adverse events.

**Comparison with other studies**

This study extends previous studies which have compared brands6,9 and types of prosthesis types.8,41 It confirms that hybrid prosthesis brands are likely to be among the most cost-effective.8 The differences between some of the hybrid and cementless prosthesis brands were small, but the finding that the cemented brands are unlikely to be cost-effective was robust to alternative assumptions in sensitivity analyses. The brand is not the only factor determining rates of revision. A recent analysis of predictors of revision for 35,386 patients receiving the Corail-Pinnacle prosthesis found increased risk with hard bearing surfaces, especially metal-on-metal bearings, and short length of stem.42

A recent review of randomised controlled trials comparing hip prostheses with a different design, fixation method, or bearing surface concluded that the available evidence was inconclusive due to poor reporting, missing data, or uncertainty in the assessment of treatment.43 The authors concluded that in the absence of evidence from experimental studies, “judicious consideration” of observational data from joint registry “provide a better guide than inconclusive results from small randomised controlled trials of short duration,” which is what our cost-effectiveness analysis has attempted to undertake.

Another systematic review demonstrated that most of the improvement in QoL after a THR occurs in the first six months, but also found evidence of a further subsequent improvement.44 If a greater improvement seen in first six month in patients who received a hybrid or cementless prosthesis is also linked to greater improvement after six months, our cost effectiveness results may be an underestimate of the true differences.

In conclusion, we found that the hybrid CPT-Trilogy is the most cost-effective brand but differences with the hybrid Exeter V40-Trident and the cementless Corail-Pinnacle and Taperloc-Exceed were small. Our study demonstrates the importance of linking PROMs with data on revision rates after THR, but given the extended period of recovery after a THR, collecting further patient-reported data on symptoms, disability and QoL beyond the first six months after THR is an important next step which would strengthen future economic evaluations of brands of hip prosthesis.

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**Table 1: Pre-operative characteristics of patients undergoing a primary THR according to prosthesis brands**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Cemented prostheses | | | | Cementless prostheses | | | | Hybrid prostheses | | |
| Stem brand  Cup brand | Exeter V40 Contemp. | Exeter V40 Duration | Exeter V40  Elite Plus Ogee | Corail Pinnacle | | Accolade Trident | Taperloc Exceed | Exeter V40 Trident | | Exeter V40 Trilogy | CPT Trilogy |
| No. of patients | 6798 | 1129 | 1479 | 9550 | | 1889 | 1171 | 2812 | | 904 | 880 |
| Mean (SD) age (years) | 72.9 (6.5) | 72.0 (6.9) | 73.0 (6.6) | 67.7 (7.2) | | 67.8 (7.2) | 66.9 (7.0) | 69.0 (7.5) | | 69.9 (6.7) | 71.2 (7.3) |
| Most deprived fifth | 1270 (18.7) | 208 (24.1) | 272 (24.1) | 2046 (21.4) | | 430 (22.8) | 251 (21.4) | 647 (23.0) | | 202 (22.3) | 217 (24.7) |
| Two or more Comorbidities | 1808 (26.6) | 300 (26.6) | 393 (26.6) | 2058 (21.5) | | 431 (22.8) | 252 (21.5) | 648 (23.0) | | 203 (22.5) | 220 (25.0) |
| ASA grade 3 or higher | 1364 (20.1) | 220 (19.5) | 254 (17.2) | 1124 (11.8) | | 280 (14.8) | 134 (11.4) | 451 (16.0) | | 154 (17.0) | 119 (13.5) |
| Mean (SD) BMI (kg/m2) | 28.9 (5.35) | 28.6 (5.57) | 28.8 (5.17) | 29.3 (5.48) | | 29.5 (5.48) | 29.3 (5.17) | 29.1 (5.51) | | 28.5 (6.17) | 28.7 (5.47) |
| Operation at independent sector treatment centre | 439 (6.5) | 8 (0.7) | 38 (2.6) | 1595 (16.7) | | 166 (8.8) | 50 (4.3) | 170 (6.0) | | 2 (0.2) | 25 (2.8) |
| Operation by senior surgeon | 5437 (80.0) | 911 (80.7) | 1181 (79.9) | 8438 (88.4) | | 1654 (87.6) | 1043 (89.1) | 2378 (84.6) | | 786 (86.9) | 519 (59.0) |
| Pre-operative Mean (SD) Oxford hip score | 17.5 (7.96) | 17.8 (8.11) | 17.5 (7.97) | 18.3 (8.19) | | 18.6 (8.18) | 18.1 (7.97) | 18.3 (8.23) | | 18.3 (7.70) | 18.7 (8.52) |
| Pre-operative Mean (SD) EQ-5D-3L index | 0.33 (0.32) | 0.33 (0.32) | 0.34 (0.32) | 0.36 (0.32) | | 0.37 (0.32) | 0.36 (0.31) | 0.35 (0.32) | | 0.35 (0.31) | 0.35 (0.32) |

**Table 2: Predicted quality of life (EQ-5D-3L index) six months after primary THR, initial cost of primary THR, revision rates by brand after adjusting for pre-operative differences for men and women aged 70 years old**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Cemented prostheses | | | Cementless prostheses | | | Hybrid prostheses | | |
| Stem brand  Cup brand | Exeter V40 Contemp. | Exeter V40 Duration | Exeter V40 Elite Plus Ogee | Corail Pinnacle | Accolade Trident | Taperloc Exceed | Exeter V40 Trident | Exeter V40 Trilogy | CPT  Trilogy |
|  | Men aged 70 | | | | | | | | |
| 6-month EQ-5D-3L index | 0.804 | 0.801 | 0.805 | 0.822 | 0.808 | 0.818 | 0.823 | 0.815 | 0.832 |
| Initial cost (£) | 6,821 | 6,791 | 6,832 | 7,767 | 7,421 | 7,271 | 7,365 | 7,545 | 7,713 |
| 5-year revision rate | 2.2% | 2.7% | 1.8% | 2.8% | 3.5% | 2.9% | 2.0% | 2.1% | 2.6% |
| 10-year revision rate | 4.3% | 4.9% | 3.4% | 4.6% | 5.8% | 4.7% | 4.5% | 5.0% | 5.8% |
|  | Women aged 70 | | | | | | | | |
| 6-month EQ-5D-3L index | 0.781 | 0.778 | 0.782 | 0.805 | 0.791 | 0.801 | 0.803 | 0.796 | 0.812 |
| Initial cost (£) | 6,845 | 6,815 | 6,857 | 7,789 | 7,443 | 7,293 | 7,404 | 7,585 | 7,753 |
| 5-year revision rate | 1.7% | 2.1% | 1.4% | 2.6% | 3.2% | 2.7% | 1.6% | 1.7% | 2.1% |
| 10-year revision rate | 3.3% | 3.8% | 2.7% | 4.3% | 5.4% | 4.4% | 3.7% | 4.1% | 4.7% |

**Table 3: Predicted lifetime risk of revision, quality-adjusted life years (QALYs), cost, net monetary benefit (NMB)\* and the incremental net monetary benefit (INB)\*\* compared to the Corail Pinnacle for men and women aged 70 (mean results of 1000 simulations).**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Cemented prostheses | | | Cementless prostheses | | | Hybrid prostheses | | |
| Stem brand  Cup brand | Exeter V40 Contemp. | Exeter V40 Duration | Exeter V40  Elite Plus Ogee | Corail Pinnacle | Accolade Trident | Taperloc Exceed | Exeter V40 Trident | Exeter V40 Trilogy | CPT  Trilogy |
|  | Men aged 70 | | | | | | | | |
| Risk of revision | 8.1% | 9.1% | 6.6% | 7.3% | 9.0% | 7.4% | 9.1% | 10.2% | 11.5% |
| QALYs | 8.28 | 8.22 | 8.31 | 8.45 | 8.28 | 8.42 | 8.46 | 8.38 | 8.51 |
| Cost (£) | 7,413 | 7,471 | 7,310 | 8,306 | 8,088 | 7,829 | 7,977 | 8,219 | 8,480 |
| NMB (£)\* | 158,107 | 156,951 | 158,901 | 160,792 | 157,525 | 160,472 | 161,136 | 159,125 | 161,746 |
| INB (£)\*\* | -2,685 | -3,841 | -1,891 | 0 | -3,267 | -320 | 344 | -1,667 | 954 |
| 95% uncertainty interval for INB | -4,922 to  -273 | -7,239 to  -408 | -5,403 to  1,643 | - | -6,129 to  -835 | -3,904 to  3,230 | -2,951 to 3,654 | -5,884 to 2,360 | -3,801 to 5,620 |
|  | Women aged 70 | | | | | | | | |
| Risk of revision | 7.3% | 8.1% | 5.9% | 7.5% | 9.3% | 7.6% | 8.7% | 9.8% | 10.9% |
| QALYs | 8.96 | 8.89 | 8.99 | 9.21 | 9.01 | 9.16 | 9.20 | 9.10 | 9.26 |
| Cost (£) | 7,308 | 7,354 | 7,235 | 8,284 | 8,054 | 7,799 | 7,930 | 8,169 | 8,417 |
| NMB (£)\* | 171,922 | 170,541 | 172,611 | 175,962 | 172229 | 175,491 | 176,033 | 173,774 | 176,838 |
| INB (£)\*\* | -4,040 | -5,421 | -3,351 | 0 | -3,733 | -471 | 71 | -2,188 | 876 |
| 95% uncertainty interval for INB | -6,593 to  -1,630 | -9,548 to  -1,689 | -6,873 to  141 | - | -6,642 to  -659 | -4,157 to  3,443 | -3,476 to 3,452 | -6,927 to 2,559 | -4,291 to 5,840 |

\*NMB and \*\*INB calculated after assuming \* Incremental net monetary benefit (IMB) was calculated with a society’s willingness-to-pay for a QALY gain of £20,000.

NMBCorail Pinnacle.

\*\*\* Interval between the 2.5 and 97.5 percentiles of the simulation results.

**Table 4: Sensitivity analysis: incremental net benefit (INB)\* compared to the Corail Pinnacle for men and women aged 70**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Cemented prostheses | | | Cementless prostheses | | | Hybrid prostheses | | |
| Stem brand  Cup brand | Exeter V40 Contemp. | Exeter V40 Duration | Exeter V40 Elite Plus Ogee | Corail Pinnacle | Accolade Trident | Taperloc Exceed | Exeter V40 Trident | Exeter V40 Trilogy | CPT  Trilogy |
| Scenario | Men aged 70 | | | | | | | | |
| Same cost for all prosthesis brands | -2,322 | -3,277 | -1,921 | 0 | -2,985 | -99 | -967 | -2,813 | 225 |
| Piecewise Constant/Weibull survival model for revision rates | -667 | -1,462 | -5 | 0 | -1,645 | 0 | 298 | -855 | -162 |
| Tapering differences in QoL between prosthesis brands to 0 after 10 years | -1,871 | -3,540 | -198 | 0 | -3,611 | 1,201 | 1,350 | -160 | -383 |
| Prediction of QoL with interaction between prosthesis brand and age and sex | -2,322 | -3,277 | -1,921 | 0 | -2,985 | -99 | -967 | -2,813 | 225 |
|  | Women aged 70 | | | | | | | | |
| Same cost for all prosthesis brands | -5,065 | -6,354 | -4,319 | 0 | -4,075 | -1,033 | -368 | -2,435 | 876 |
| Piecewise Constant/Weibull survival model for revision rates | -4,074 | -5,175 | -3,671 | 0 | -3,361 | -180 | -925 | -2,849 | 583 |
| Tapering differences in QoL between prosthesis brands to 0 after 10 years | -746 | -1,502 | -120 | 0 | -1,737 | 144 | 311 | -848 | -89 |
| Prediction of QoL with interaction between prosthesis brand and age and sex | -3,522 | -3,369 | -2,651 | 0 | -1,523 | 863 | 895 | -441 | -2,420 |

\*INB calculated after assuming \* Incremental net monetary benefit (IMB) was calculated with a society’s willingness-to-pay for a QALY gain of £20,000.

**Figures**

Figure 1 Markov model simulating the lifetime of a patient following primary hip replacement

Figure 2 Cost-effectiveness acceptability frontier for men and women aged 70

**Web Appendix**

**Cost-effectiveness of alternative prosthesis brands for total hip replacement: A study using the NJR dataset.**

**Contents**

Section 1: Predicted survival curves for each prosthesis brand by subgroup

Section 2: Model parameters

Section 5: Base case results for subgroups aged 60 and 80 aged 70

Section 6: Further details and results of sensitivity analyses

**Section 1: Predicted survival curves for each prosthesis brand by subgroup**



**Section 2: Model parameters**

|  |  |
| --- | --- |
| **Parameter** | **Value\*** |
| QOL in Primary THR state | Values tabulated in Table 2 (main text) |
| QOL in one stage revision state | 0.350 + 0.062\**Male* – 0.0035\**Age* |
| QOL in two stage revision state | 0.259 + 0.062\**Male* – 0.0035\**Age* |
| QOL in revised THR state | 0.655 + 0.031\**Male* – 0.0019\**Age* |
| Revision of primary THR | illustrated in section 1; 5 and 10 year values in table 2 (main text) |
| Probability of two stage revision | Exp**/(1+exp**) where ** = -0.938 + 0.538\**Male* +0.0052\**Age* – 0.0017\**Time-2* – 0.0298\**Time*2 – 0.786\**Cemless* – 0.296\**Hybrid* |
| Failure in year of revision | 1-exp(-exp**)) where ** = -2.932 + 0.139\**Male* – 0.0281\**Age* |
| Revision of revised THR after first year | 1-exp(-exp**)) where ** = -4.520 + 0.139\**Male* – 0.0580\**Age* – 0.0017\**Age*2 |
| 30d mortality after primary THR | 1/(1+exp**) where ** = –7.523 + 0.727\**Male* + 0.1007\**Age* + 0.0012\**Age*2 |
| Death in year of revision surgery | 1/(1+exp**) where ** = -2.932 + 0.258\**Male* + 0.1140\**Age* + 0.0011\**Age*2 |
| Death in other years | ONS value multiplied by (0.803 + 0.004\**Male* + 0.0259\**Age* – 0.0159\**Age*2 + 0.702\**Time* – 0.0711\**Time\*Age* -0.0305\**Time\*Age*2) |
| Cost of Primary THR | Values tabulated in Table 2 (main text) |

\**Age* is patient age, *Male* is 1 for male, 0 for female, *Time* is time in years after surgery, LoS is length of stay in days, *Cemless* indicates a cementless prosthesis, *Hybrid* indicates a hybrid prosthesis.

**Table 1A** **Markov model parameters**

**Section 3: Base case results for subgroups aged 60 and 80 aged 70**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Cemented prostheses | | | Cementless prostheses | | | Hybrid prostheses | | |
| Stem brand  Cup brand | Exeter V40 Contemp. | Exeter V40 Duration | Exeter V40 Elite + Og. | Corail Pinnacle | Accolade Trident | Taperloc Exceed | Exeter V40 Trident | Exeter V40 Trilogy | CPT  Trilogy |
|  | Men aged 60 | | | | | | | | |
| EQ-5D-3L index | 0.811 | 0.808 | 0.812 | 0.805 | 0.791 | 0.801 | 0.825 | 0.818 | 0.834 |
| Initial Cost (£) | 6,614 | 6,584 | 6,626 | 7,560 | 7,214 | 7,064 | 7,180 | 7,361 | 7,528 |
| 5-year revision rate | 2.7% | 3.2% | 2.2% | 3.2% | 4.0% | 3.3% | 2.1% | 2.2% | 2.7% |
| 10-year revision rate | 6.0% | 6.7% | 4.8% | 5.7% | 7.1% | 5.8% | 5.2% | 5.8% | 6.5% |
|  | Women aged 60 | | | | | | | | |
| EQ-5D-3L index | 0.789 | 0.785 | 0.789 | 0.788 | 0.774 | 0.784 | 0.805 | 0.798 | 0.815 |
| Initial Cost (£) | 6,627 | 6,597 | 6,639 | 7,570 | 7,225 | 7,074 | 7,208 | 7,389 | 7,556 |
| 5-year revision rate | 2.1% | 2.5% | 1.7% | 3.0% | 3.7% | 3.0% | 1.7% | 1.8% | 2.2% |
| 10-year revision rate | 4.6% | 5.2% | 3.7% | 5.4% | 6.6% | 5.4% | 4.2% | 4.7% | 5.3% |

**Table 2A Initial THR cost, QOL after primary THR and survival at five and ten years, by brand after adjusting for casemix differences for men and women aged 60**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Cemented prostheses | | | Cementless prostheses | | | Hybrid prostheses | | |
| Stem brand  Cup brand | Exeter V40 Contemp. | Exeter V40 Duration | Exeter V40 Elite + Og. | Corail Pinnacle | Accolade Trident | Taperloc Exceed | Exeter V40 Trident | Exeter V40 Trilogy | CPT  Trilogy |
|  | Men aged 80 | | | | | | | | |
| EQ-5D-3L index | 0.788 | 0.784 | 0.788 | 0.798 | 0.784 | 0.794 | 0.795 | 0.787 | 0.804 |
| Initial Cost (£) | 7,265 | 7,235 | 7,276 | 8,213 | 7,868 | 7,718 | 7,733 | 7,914 | 8,081 |
| 5-year revision rate | 1.8% | 2.3% | 1.4% | 2.6% | 3.2% | 2.7% | 1.9% | 1.9% | 2.6% |
| 10-year revision rate | 3.1% | 3.7% | 2.5% | 3.9% | 4.8% | 4.0% | 4.0% | 4.4% | 5.2% |
|  | Women aged 80 | | | | | | | | |
| EQ-5D-3L index | 0.767 | 0.763 | 0.767 | 0.782 | 0.769 | 0.779 | 0.777 | 0.770 | 0.786 |
| Initial Cost (£) | 7,315 | 7,285 | 7,326 | 8,261 | 7,915 | 7,765 | 7,798 | 7,979 | 8,147 |
| 5-year revision rate | 1.4% | 1.8% | 1.1% | 2.4% | 2.9% | 2.5% | 1.6% | 1.6% | 2.1% |
| 10-year revision rate | 2.4% | 2.9% | 1.9% | 3.6% | 4.4% | 3.7% | 3.3% | 3.6% | 4.2% |

**Table 3A Initial THR cost, QOL after primary THR and survival at five and ten years, by brand after adjusting for casemix differences for men and women aged 80**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Cemented prostheses | | | Cementless prostheses | | | Hybrid prostheses | | |
| Stem brand  Cup brand | Exeter V40 Contemp. | Exeter V40 Duration | Exeter V40 Elite + Og. | Corail Pinnacle | Accolade Trident | Taperloc Exceed | Exeter V40 Trident | Exeter V40 Trilogy | CPT  Trilogy |
|  | Men aged 60 | | | | | | | | |
| Proportion revised | 21.1% | 23.0% | 17.4% | 14.4% | 17.7% | 14.5% | 19.0% | 21.5% | 23.4% |
| Mean Cost (£) | 7,819 | 7,916 | 7,604 | 8,432 | 8,294 | 7,955 | 8,227 | 8,524 | 8,828 |
| Mean QALYs | 10.96 | 10.88 | 11.03 | 10.94 | 10.70 | 10.89 | 11.18 | 11.06 | 11.24 |
| INB (£) | 1,056 | -655 | 2,564 | 0 | -4,741 | -515 | 4,998 | 2,344 | 5,464 |
| Uncertainty Interval | -3,184 to 5,354 | -6,418 to 5,209 | -3,007 to 8,097 | - | -8,395 to -1,076 | -4,993 to 4,192 | -305 to 10,499 | -4,521 to 8,863 | -1,900 to 12,933 |
|  | Women aged 60 | | | | | | | | |
| Proportion revised | 19.1% | 20.8% | 15.7% | 14.8% | 18.2% | 14.9% | 18.1% | 20.4% | 22.2% |
| Mean Cost (£) | 7,591 | 7,671 | 7,425 | 8,392 | 8,235 | 7,908 | 8,114 | 8,413 | 8,673 |
| Mean QALYs | 11.65 | 11.57 | 11.71 | 11.66 | 11.39 | 11.59 | 11.91 | 11.76 | 11.99 |
| INB (£) | 698 | -1,001 | 2,149 | 0 | -5,109 | -830 | 5,408 | 2,148 | 6,333 |
| Uncertainty Interval | -3,706 to 4,920 | -7,074 to 4,886 | -3,568 to 7,827 | - | -8,834 to -1,040 | -5,755 to 4,376 | -194 to 10,764 | -4,953 to 9,027 | -1,561 to 13,966 |

**Table 4A Lifetime costs, lifetime QALYs, proportion of patients undergoing revision and incremental net benefits (INB) relative to the Corail Pinnacle for men and women aged 60**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Cemented prostheses | | | Cementless prostheses | | | Hybrid prostheses | | |
| Stem brand  Cup brand | Exeter V40 Contemp. | Exeter V40 Duration | Exeter V40 Elite + Og. | Corail Pinnacle | Accolade Trident | Taperloc Exceed | Exeter V40 Trident | Exeter V40 Trilogy | CPT  Trilogy |
|  | Men aged 80 | | | | | | | | |
| Proportion revised | 3.3% | 3.9% | 2.7% | 4.0% | 5.0% | 4.2% | 4.4% | 4.8% | 5.6% |
| Mean Cost (£) | 7,574 | 7,615 | 7,524 | 8,563 | 8,306 | 8,089 | 8,100 | 8,304 | 8,561 |
| Mean QALYs | 5.52 | 5.48 | 5.54 | 5.58 | 5.46 | 5.55 | 5.56 | 5.50 | 5.60 |
| INB (£) | -139 | -906 | 286 | 0 | -2,079 | -147 | 115 | -1,243 | 528 |
| Uncertainty Interval | -2,008 to 1,806 | -3,595 to 1,754 | -2,087 to 2,673 | - | -3,761 to -363 | -2,263 to 2,316 | -2,604 to 2,781 | -4,437 to 1,885 | -2,866 to 3,744 |
|  | Women aged 80 | | | | | | | | |
| Proportion revised | 2.9% | 3.4% | 2.3% | 4.0% | 5.0% | 4.1% | 4.1% | 4.4% | 5.2% |
| Mean Cost (£) | 7,556 | 7,576 | 7,519 | 8,578 | 8,311 | 8,097 | 8,108 | 8,309 | 8,547 |
| Mean QALYs | 6.02 | 5.98 | 6.03 | 6.12 | 5.99 | 6.08 | 6.09 | 6.02 | 6.14 |
| INB (£) | -992 | -1,902 | -692 | 0 | -2,431 | -307 | -244 | -1,666 | 451 |
| Uncertainty Interval | -2,953 to 1,012 | -4,694 to 913 | -3,184 to 2,046 | - | -4,495 to -507 | -2,821 to 2,139 | -3,221 to 2,573 | -5,219 to 1,808 | -2,735 to 3,859 |

**Table 5A Lifetime costs, lifetime QALYs, proportion of patients undergoing revision and incremental net benefits (INB) relative to the Corail Pinnacle for men and women aged 80**



**Figure 1: CEAFs for 60 year olds**



**Figure 2: CEAFs for 80 year olds**

**Section 4: Results of sensitivity analyses**

 

**Figure 3A: CEAFs by subgroup after assuming the same cost for all prostheses**



**Figure 4A: CEAFs by subgroup after applying an alternative survival model to estimate revision rates**



**Figure 5A: CEAFs by subgroup after tapering differences in QOL across brands to zero over ten years**



**Figure 6A: CEAFs by subgroup after including brand-subgroup interactions in the analysis of post-operative QOL**