National Institute for Health and Care Excellence

Final

Hip fracture: management (update)

Economic model report for total hip replacement versus hemiarthroplasty

NICE guideline CG124

Economic model underpinning recommendation 1.6.3 and a research recommendation in the NICE guideline

January 2023

Final

Commissioned by the National Institute for Health and Care Excellence

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Healthcare professionals are expected to take NICE clinical guidelines fully into account when exercising their clinical judgement. However, the guidance does not override the responsibility of healthcare professionals to make decisions appropriate to the circumstances of each patient, in consultation with the patient and/or their guardian or carer.

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HE1 Methods

HE1.1 Model overview

The objective of the model was to investigate the cost effectiveness of total hip replacement (THR) and hemiarthroplasty (HA) undergoing surgery for the management of displaced intracapsular hip fracture.

This model is based on a model developed for the same review question for the previous update of the guideline that was published in 2017. We retained the structure of the original model, however, we have updated the majority of model inputs as a result of the clinical review undertaken for this question and to provide recent estimates of costs.

HE1.1.1 Population(s)

The population of interest was adults presenting to the health service with a firm or provisional clinical diagnosis of fragility fracture of the hip and a displaced intracapsular hip fracture. Patients are previously healthy and medical fit for anaesthesia, were previously able to walk independently, and are not severely cognitively impaired.

HE1.1.2 Interventions

The model assessed two different treatments for hip fracture:

- Total hip replacement,
- Hemiarthroplasty.

The original model also considered Internal Fixation as a comparator; however, this was excluded from the current review question therefore, it was excluded from this analysis.

HE1.1.3 Type of evaluation, time horizon, perspective, discount rate

The analysis measures outcomes as the expected number of quality-adjusted life years (QALYs), and the results are presented using incremental cost-effectiveness ratios (ICERs) that express the cost per QALY gain of using a specific surgery for hip fracture compared to the next best alternative.

The model has a lifetime horizon, to reflect all important differences in costs and outcomes between the interventions being compared.

The analysis was conducted from the perspective of the NHS and Personal Services in England.

The analysis discounts all costs and QALYs at a rate of 3.5% per year, as required by Developing NICE guidelines: the manual (2018).

HE1.2 Model structure

In line with the original model, a Markov model with a cycle length of one year was used to simulate the progression of patients over a lifetime time horizon. The structure of the model is displayed in Figure HE001.

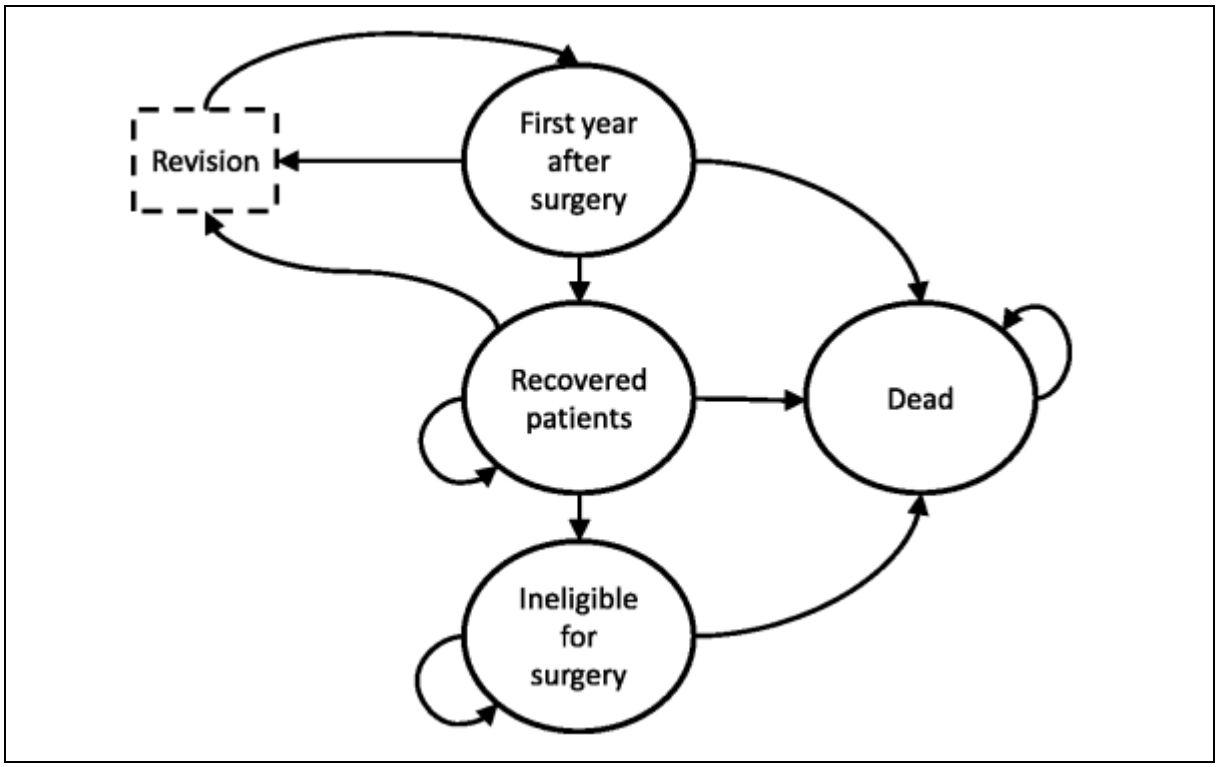

Figure HE001: Structure of original cost–utility model

At the start of the model, all patients undergo a surgical procedure (THR or HA) and enter the 'first year after surgery' state. During this year, patients may die or require a revision procedure, which results in those patients returning to the 'first year after surgery' state for the next cycle of the model. The remainder of patients progress to the 'recovered patients' state. Patients in this state also have an annual probability of death and revision. However, in the last model it is also assumed that 50% of patients in this state who require revision are deemed too risky for additional surgery, and progress to 'ineligible for surgery' state, where they remain for the rest of the model. In the updated version of the model the revision rate was calculated to only contain those patients that are eligible for surgery. Therefore, those patients that are ineligible for surgery will now remain in the recovered patient health state until they die.

Based on expert opinion, it is assumed that, in the HA arm of the model, 80% of patients requiring a revision procedure receive THR, while the remaining 20% receive HA. For patients in the THR arm, it is assumed that all patients requiring a revision procedure receive THR.

HE1.3 Model parameterisation

Identifying sources of parameters

Alongside the update of this economic analysis, a clinical review was undertaken [see Evidence Review B]. During development of the review question, a Cochrane systematic review, Lewis et al. (2022) was identified that included RCT comparisons relevant to this review question. The event rates used are those in the Cochrane review.

We obtained the following parameters from the clinical review:

- Unplanned return to theatre (also referred to as revision rate for brevity)

- Quality of life at 4 months
- Quality of life at 12 months
- Mortality for the first year after surgery
- Length of stay in hospital after surgery

An additional RCT search was performed by NICE to identify any RCTs published after the Cochrane review's final search date (6th July 2020). The clinical review used analysis from the Cochrane review and is presented directly where possible. New data from the NICE sift beyond July 2020 was pooled with the Cochrane analysis, and since it did not alter the interpretation of effect it was presented as a separate analysis in the clinical review. The outcomes in the economic model that had additional analyses included mortality and length of stay. These analyses were incorporated into the economic analysis as scenario analyses.

When searching for resource use and cost parameters, we assessed the cost-effectiveness studies that were identified as part of the review of cost-effectiveness evidence for suitable sources of data [see Evidence Review B]. As part of the review of cost-effectiveness evidence, we conducted searches in specific databases designed for this purpose, including the CEA (Cost-Effectiveness Analysis) Registry and the NHS Economic Evaluation Database (NHS EED).

The national hip fracture database (NHFD) currently collects data for patients who receive THR, and it does not collect data for hemiarthroplasties. Long term data available in registries is also only available for patients receiving elective procedures, rather than non-elective procedures for trauma, which is the population in this guideline. The committee expected that elective patients in the registry would have poorer outcomes compared to trauma (non-elective) patients, and so any attempt to extrapolate outcomes from one population to the other will be associated with a high degree of uncertainty. For this reason, we used data from the randomised controlled trials in the Cochrane review. This did however mean that the model does not necessarily reflect the full range of patients available.

Selecting parameters

Our overriding selection criteria for identifying cost and resource use studies were as follows:

- The selected studies should report outcomes that correspond as closely as possible to the health states and events simulated in the model.
- The selected studies should report a population that closely matches the UK population (ideally, they should come from the UK population).
- All other things being equal, we preferred more powerful studies (based on sample size and/or number of events).
- Where there was no reason to discriminate between multiple possible sources for a given parameter, we gave consideration to quantitative synthesis (meta-analysis), to provide a single summary estimate.

HE1.4 Parameters

HE1.4.1 Cohort parameters

HE1.4.1.1 Starting demographics and characteristics

The model was based on a cohort of patients with a starting age of 79 which was based on the HEALTH 2019 study. We selected this study to inform patient age, due to it being the largest study in the clinical review and it has been recently published. Patient age was

included in the model to allow us to capture age-related mortality from one year after the original procedure.

We did not formally include any other patient characteristics in the model as there were no inputs in the model that were a function of a patient characteristic other than age, and we were unable to conduct subgroup analyses due to a lack of subgroup-specific data. However, it could be thought that the population of the economic model reflected those in the trials in the clinical review due to the underlying clinical data underpinning the economic analysis.

HE1.4.2 Event rates

HE1.4.2.1 Mortality

For patients in the first year after surgery, we applied the mortality rates identified in the clinical review. This is because having surgery is associated with an increased mortality rate. The relative risk for the mortality for THR relative to HA was calculated in the clinical review and was 1.03 (CI 0.82, 1.28) with the baseline mortality for HA at 8.2% (SE 0.01). The relative risk was not statistically significant and showed that there is higher mortality with THR. Each trial reported mortality at different time points so to calculate the baseline mortality for HA, outcomes in each of the trials were converted to one-year probabilities and then pooled according to the study size.

From one year after surgery, patients in every health state die of causes other than surgery for hip fracture and therefore overall background mortality is modelled. Overall age-related background mortality was sourced from the ONS lifetables for the general population between 2018-20, the latest available data when the model was updated. The use of general population mortality from one year after the procedure was an assumption in the previous version of the model and the committee did not prioritise this for an update. However, there is uncertainty around this parameter and therefore we completed a scenario analysis where we applied a relative risk of 1.5 to estimate a higher mortality than the general population. Further information around the scenario analyses can be found in HE1.5.1. We also assumed that mortality was the same between the two arms from 12 months post-surgery which was supported by the clinical review which had a relative risk of 0.79 (CI 0.72, 1.32) which was not statistically significant.

HE1.4.2.2 Unplanned return to theatre

After a patient has received a THR or a HA, a proportion of them will need to return to surgery. This can occur for a number of reasons, for example dislocation, implant exchange and adjustment.

The annual baseline rate of unplanned return to surgery for patients who had originally received HA was 0.03 (SE 0.01). A similar process to mortality was taken to calculate this value: first an annual probability was calculated from data in each of the trials in the review of this outcome, then a weighted average was taken with the weight based on the study size. The relative risk for unplanned return to surgery was 0.86 (CI 0.59, 1.25), which was estimated in the Cochrane review. This value was not significant but showed that fewer people returned to surgery if they received a THR than a HA.

The event rate estimated from the trials in the Cochrane review was applied in the model for one year following the original procedure. Thereafter, data from the Swedish Hip Arthroplasty Register (Annual Report, 2014) was used. This data was not prioritised for update from the previous version of the guideline. It was previously selected due to a lack of long term revision rate data with a specific endpoint for the English population and was agreed by the

guideline committee to be the most appropriate source. The revision rate from 2005 to 2014 was 4.5% (SE 0.0009) with a rate of 2.8% in the first six months of surgery after arthroplasty for hip fracture. The difference between these provided a long term revision rate of 1.7% over 9.5 years, which we converted to an annual revision rate. The relative difference in revision rates between THR and HA from one year after the original procedure (RR of 0.86) was then used to estimate long term revision rates for each procedure.

HE1.4.2.3 Operating time

We searched for and extracted the mean operating time for each type of procedure from each study in the clinical review. We were unable to source information from patient registries that provided operating times for HA procedure and a THR separately. We created a pooled average and standard error using the sample sizes of the trials; where a range was provided, we assumed that the difference between the minimum and maximum value was equivalent to four standard deviations of the mean, and if no variation was reported then we assumed that the standard deviation in that trial was equal to the mean standard deviation in the trials that did report it.

The pooled average operating time for a HA procedure was estimated to be 76.62 minutes (SE 18.61 minutes). The mean additional operating time for THR compared with a HA procedure was 19.35 minutes (SE 4.51 minutes. The forest plot is presented in Figure HE002.

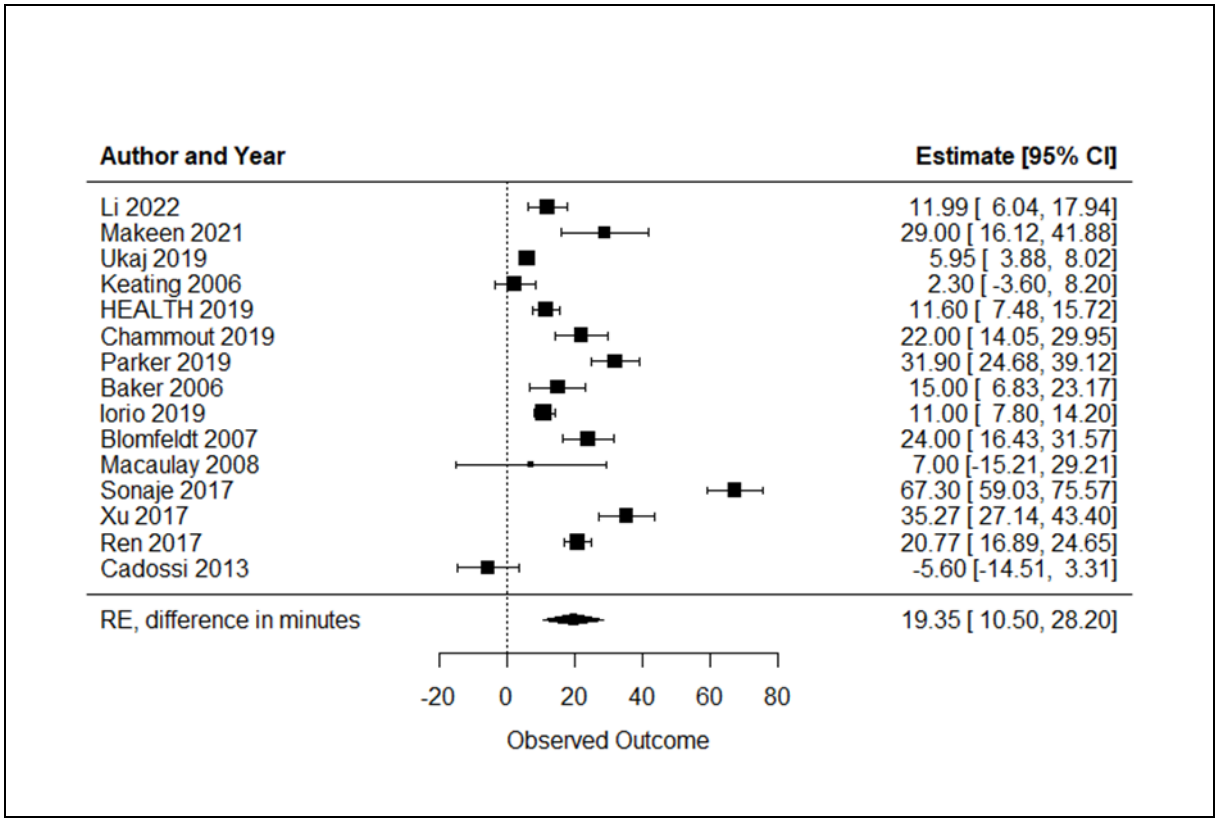

Figure HE002: Impact of THR versus HA on operating time

HE1.4.3 Quality of life

Quality of life in the model was represented by utility values, which is measured on a 0 to 1 scale where 0 is equal to death and 1 is equivalent to a year in perfect health. NICE's preferred method for obtained utility is the EQ-5D, Developing NICE guidelines: the manual (2018).

The quality-of-life data were obtained from the trials in the clinical review, which reported outcomes at 4 and 12 months. Data that were included in the economic model were from those trials that measured the quality of life using the EQ-5D, and a pooled average was estimated and weighted by study size. The values that we estimated for the economic model are shown in Table HE001.

The original 2017 hip fracture model incorporated the difference in quality of life data at 4 months after the procedure; however, as the data was available in the Cochrane review for quality of life at 12 months in our model, we updated the model structure to incorporate these data. The Cochrane review also provided an analysis for quality of life after 24 months, but this was based on one small study that did not use the EQ-5D, so we did not include this in the economic analysis.

Table HE001: Quality of life data

Parameter	Total hip replacement	Hemiarthroplasty
Quality of life at four months	0.67 (SE 0.04)	0.63 (SE 0.04)
Quality of life at 12 months	0.78 (SE 0.02)	0.74 (SE 0.02)

The utility immediately after surgery was calculated in the original model using the utility score of internal fixation which was calculated to be 0.578. Then for the first 6 weeks after the procedure a decrement was sourced from Parsons et al. 2014 which gave a utility of 0.575. The original model calculated the utility for the first year of surgery by using the utility scores 4 months after each procedure, which were sourced from the clinical review and was assumed to apply between 4 months and one year following surgery. For the initial four months after surgery, it was assumed that patients' utility progressed linearly from the utility score immediately following surgery to the utility score at four months. This gave the QALYs for the first year for THR as 0.65 and for HA as 0.62. The 12-month utility values are then assumed to apply from 12 months after the procedure.

It was assumed that the quality-of-life benefit of THR over HA at 12 months extended for the rest of the patient's life. No evidence could be found to show if the long term benefit of THR compared with HA does last for the lifetime of the patient. The committee felt that the difference between the two procedures in the long term was highly uncertain and was driven by many factors such as unplanned return to theatre, an outcome that is also uncertain. Therefore, we undertook various scenario analyses to estimate the impact on the cost effectiveness results if the quality of life benefit of THR was restricted to a shorter period of time after the initial procedure. Due to the uncertainty in this parameter we decided not to have a single base case but to have multiple scenarios that are investigated based on this parameter.

HE1.4.4 Cost and healthcare resource use identification, measurement and valuation

Where possible, we drew resource-use information from the primary evidence-base identified in our systematic review of clinical evidence (see Evidence review B). In the absence of such data, we attempted to locate published economic evaluations or costing studies providing relevant information. We filled any remaining gaps with estimates from the experts on the guideline committee.

We obtained unit costs for each of the resource use elements from a number of standard sources.

- We use NHS National Cost Collection data 19/20 (previously known as NHS Reference Costs) as the source of unit costs for inpatient and outpatient procedures as well as hospital stay information.
- We use the annual report on Unit Costs for Health and Social Care by the Personal Social Services Research Unit (PSSRU; 2021 Curtis et al.) to specify costs for both community and hospital-based healthcare staff.
- Where we cannot source an appropriate unit cost from these sources, we may use values from a relevant published study, in which case we inflate them to current prices using HCIS inflation indices from Unit Costs for Health and Social Care (PSSRU; 2021 Curtis et al).

There were some costs that we did not include in the analysis. For example, we excluded the costs of some of the adverse events. This is due to these events not being included in the original model and we didn't prioritise these because the Cochrane review did not find evidence to differentiate between the two procedures and the studies were assessed as being of low quality. Discharge location (for example a nursing home or an independent home), may have an effect on the outcomes for a patient and the utility the patient received. This may be higher for one procedure over another. There was some evidence for the proportion of patients discharged into older persons ward but it was assessed as being of very low quality and therefore not felt appropriate to include in the model. None the less, the committee considered this an important outcome and this is associated with high costs and may mean the model underestimates total cost.

HE1.4.4.1 Direct costs of interventions

When the economic model was originally developed for the 2017 update of the guideline, the cost of providing the procedures were estimated from Keating et al. (2005). Keating et al. (2005) used costs from 2000/01 which the 2017 update of the guideline uprated to 2015 prices. It was felt that it would be inappropriate to uprate costs over 20 years it was felt that both the standard of care and the prices of treatments will have changed during that period, and we cannot be sure that the costs are comparable to current procedure. Therefore, a different approach was taken.

The costs in the model were calculated using a bottom-up approach, this included:

- The cost of the operative time,
- The cost of the inpatient recovery time,
- The cost of the prosthesis.

Operative time costs

The operative time for each procedure was estimated from studies identified in the clinical review, and this was combined with the cost of each member of staff that would be in the surgery, as shown in Table HE002. The cost per minute of all the members of staff in the surgery was £7.90. The additional cost of running the operating room was found from a published study and was £298 per hour. Other costs, for example the cost of medications or equipment, was not included in the analysis as it was assumed that these were the same for each procedure and therefore, would not affect the results. The cost of operative time for THR was £1,300.40 and for HA was £1038.17.

The committee were aware that a proportion of patients received a blood transfusion as part of their treatment. The clinical review demonstrated a significant difference between the two types of procedure, with fewer patients with HA requiring a transfusion (RR 2.14, 95%CI 1.27 to 3.61). The committee considered that the difference in need for a blood transfusion was directly related to the nature of the procedure; generally, this is because a HA requires operating on one bone only while THR requires operating on two bones. We estimated the total proportion requiring transfusion from the studies in the clinical review. Therefore, the cost of this was added into the treatment costs, the values are shown in Table HE002.

Inpatient recovery time

The cost of the recovery time for each procedure was calculated using the length of stay in Table HE002 which was obtained from the clinical review, and the cost per day of recovery time. We used a cost for the rehabilitation of a hip fracture: previous models have used a nonelective inpatient cost, however the NHS Cost Collection no longer provides length of stay data and simply provides the cost per episode, and we were unable to estimate the cost per day which is required to differentiate the costs after THR and after HA. This value was uncertain and therefore, scenario analysis was completed (further information can be found in HE1.5.1). The total cost of the recovery time for THR was £4,991.01 and for HA was £4,610.21.

We did not include length of stay before the procedure. The committee noted that patients may be required to wait a number of days in hospital before a THR compared with a HA. Surgeons with the experience to conduct a THR may not be available every day of the week, while there is expected to be a surgical team available daily for HA. However, since patients in the trials are randomised at the point of the procedure, the pre-procedure length of stay was not captured in the evidence. We conducted a scenario analysis assuming that patients receiving THR had an additional three days in hospital.

Prosthesis cost

The cost of the prostheses was obtained from GIRFT 2020, who obtained these costs from the NHS Spend Comparison Service in 2018. We uprated these costs to present values using the NHS Cost Inflation Index.

For a THR, there are four components required: a cup, a stem, a liner and a head. There are many prostheses available for THR from a number of different suppliers. We received advice from our committee that it is possible to “mix and match” each type of component from different suppliers, but generally a trauma centre will negotiate a contract with a particular supplier and will use components from a single supplier. For simplicity, we used the most common type of prosthesis system to estimate costs in our analysis, and our committee advised that these were the Exeter components from Stryker. For HA, we assumed that the Exeter Trauma System (ETS) was the most commonly used.

There was some uncertainty associated with these costs: they were obtained from NHS Spend Comparison Service in 2018, so prices of components may have changed since then as centres continue to renegotiate contracts with suppliers. To address the uncertainty in prices, we varied the prosthesis cost for each type of procedure in a series of scenario analyses where the prosthesis cost was varied by plus or minus 50%.

Table HE002: Cost data

Parameter	Value	Source
Operating costs		

Parameter	Value	Source
Surgeon (per hour)	£123	Curtis et al. (2021)
Assistant (per hour)	£52	Curtis et al. (2021)
Scrub nurse (per hour)	£41	Curtis et al. (2021)
Nurse runner (per hour)	£32	Curtis et al. (2021)
Anaesthetist (per hour)	£123	Curtis et al. (2021)
Anaesthetic assistant (per hour)	£62	Curtis et al. (2021)
Recovery nurse (per hour)	£41	Curtis et al. (2021)
Operating room (per minute)	£4.98	Griffin et al. 2022
Operative time (hemiarthroplasty, minutes)	76.62	Clinical review
Mean difference of operative time (minutes)	19.35	Clinical review
Transfusions with total hip replacement	22.31%	Clinical review
Transfusions with Hemiarthroplasty	11.59%	Clinical review
Cost of transfusion	£700.91	NHS cost collection 19/20 (SA44A)
Recovery costs		
Cost of a recovery day	£476	NHS cost collection 19/20 (VC16Z)
Length of stay (hemiarthroplasty, days)	9.69	Clinical review
Mean difference of length of stay (days)	0.80	Clinical review
Prosthesis costs		
Hemiarthroplasty stem	£283	GIRFT 2020
Total hip replacement, Trident cup	£398	GIRFT 2020
Total hip replacement, Exeter V40 Orthinox head	£126	GIRFT 2020
Total hip replacement, Trident liner	£245	GIRFT 2020
Total hip replacement, Exeter V40 stem	£438	GIRFT 2020

HE1.4.4.2 Costs associated with revision surgery

Patients may be readmitted to hospital required after the primary surgery for a number of different reasons. Open and closed reduction of dislocation, implant exchange and soft tissue procedures (e.g. to treat infection) are the most common reasons for an unplanned return to theatre. We found very little evidence for unplanned return to theatre that distinguished between the two types of procedure, and so we made a number of assumptions supported by the committee.

Firstly, these can be divided into two types for costing purposes: those that require a replacement prosthesis and those that do not. The HEALTH study reported the number and

types of revision surgeries, and we used this to calculate the percentage of patients that had a replacement prosthesis in both types of surgeries as shown in Table HE003.

The HEALTH trial did not report operative time or recovery time for the revision procedure. Therefore, we assumed that these were equal to that of the original procedure.

Lastly, we assumed that a proportion of patients that originally had HA who required a prosthesis exchange would receive THR as their revision procedure. We assumed that 80% of patients returning to theatre for implant exchange would receive a THR. All patients who originally received THR and required an implant exchange would also receive THR, as it is not possible to give an HA on the same hip for a patient who previously received THR. This assumption was made in the original model, and the committee agreed to retain it for the model update. Since it was not made on the basis of any evidence, we conducted a scenario analysis where fewer patients with an initial HA would require a THR revision procedure.

Table HE003: Type of revision surgery

Parameter	Value	Source
Total hip replacement with prosthesis	41.9%	HEALTH 2019
Hemiarthroplasty with prosthesis	49.5%	HEALTH 2019
Total hip replacement without prosthesis	58.1%	HEALTH 2019
Hemiarthroplasty without prosthesis	50.5%	HEALTH 2019

HE1.4.5 Summary

All parameters used in the model are summarised in Table HE004, including details of the distributions and parameters used in probabilistic analysis.

Table HE004: All parameters in original cost–utility model

Parameter	Point estimate	Probabilistic analysis		Source
		Distribution	Parameters	
Baseline utility for patients 75 and above	0.79	Beta	α=3092.78 β=847.07	Janssen 2021
Utility decrement 6 weeks after procedure	0.21	Beta	α=23.06 β=86.74	Parsons 2014
4 months after total hip replacement	0.67	Beta	α=81.26 β=40.74	Clinical review
4 months after hemiarthroplasty	0.63	Beta	α=97.77 β=57.23	Clinical review
12 months after total hip replacement	0.78	Beta	α=434.23 β=119.77	Clinical review
12 months after hemiarthroplasty	0.74	Beta	α=414.01 β=147.99	Clinical review
Baseline mortality, annual probability (hemiarthroplasty)	8.2%	Beta	α=108.32 β=1218.68	Clinical review

Parameter	Point estimate	Probabilistic analysis		Source
		Distribution	Parameters	
Relative Risk - Total hip replacement versus hemiarthroplasty	1.03	Lognormal	SE=0.11	Clinical review
Baseline revision rate (hemiarthroplasty, annual probability)	0.03	Beta	α=43.18 β=1203.82	Clinical review
Relative Risk - Total hip replacement versus hemiarthroplasty	0.86	Lognormal	SE=0.19	Clinical review
Baseline length of stay (hemiarthroplasty, days)	9.69	Gamma	α=35.02 β=0.28	Clinical review
Mean difference of length of stay - Total hip replacement versus hemiarthroplasty	0.8	Normal	SE=0.98	Clinical review
Baseline operative time (hemiarthroplasty, minutes)	76.62	Gamma	α=16.96 β=4.52	Clinical review
Mean difference for the operative time - Total hip replacement versus hemiarthroplasty	19.35	Normal	SE=4.52	Clinical review
Revision rate from 2005 to 2014	4.5%	Beta	α=2295.96 β=55091.93	Garellick 2014
Revision rate within 6 months of surgery	2.8%	Beta	α=7730.01 β=268341.87	Garellick 2014
Proportion of people receiving Total hip replacement in Swedish Hip Arthroplasty Register	29%	Beta	α=1695.71 β=4138.29	Garellick 2014
Proportion of people receiving hemiarthroplasty in Swedish Hip Arthroplasty Register	71%	Beta	α=6.56 β=2.69	Garellick 2014
Total hip replacement as revision procedure	80%	Beta	α=4.2 β=1.05	Expert opinion
Hemiarthroplasty as revision procedure	20%	Beta	α=19.8 β=79.2	Expert opinion
Trident Cup (Total hip replacement)	£398	Gamma	α=818425 β=0.00049	GRIFT 2020
Exeter V40 Orthinox Head (Total hip replacement)	£126	Gamma	α=261017 β=0.00048	GRIFT 2020
Trident liner (Total hip replacement)	£245	Gamma	α=376474 β=0.00065	GRIFT 2020
Exeter V40 Stem (Total hip replacement)	£438	Gamma	α=1762697 β=0.00025	GRIFT 2020
Hemiarthroplasty stem	£283	Gamma	α=507822 β=0.00056	GRIFT 2020
Cost per minute of operative time (staff)	£8.58	N/A	N/A	Curtis et al. (2021)
Cost per minute of operating room	£4.97	N/A	N/A	Griffin et al. 2022

Parameter	Point estimate	Probabilistic analysis		Source
		Distribution	Parameters	
Transfusion	£700.91	N/A	N/A	NHS cost collection
Cost per day of recovery time	£476	N/A	N/A	NHS cost collection
Revision of total hip replacement with prosthesis	41.9%	Beta	α=41.86 β=58.14	HEALTH 2019
Revision of hemiarthroplasty with prosthesis	49.5%	Beta	α=49.50 β=50.50	HEALTH 2019
Revision of total hip replacement without prosthesis	58.1%	N/A	N/A	HEALTH 2019
Revision of hemiarthroplasty without prosthesis	50.5%	N/A	N/A	HEALTH 2019
Discount rate	3.5%	N/A	N/A	
Starting age	79	Normal	SE=0.31	HEALTH 2019

HE1.5 Sensitivity analyses

HE1.5.1 Deterministic sensitivity analyses

We conducted a number of scenario analyses to discover the parameters which had the biggest impact on the results, in areas where we identified uncertainty in our sources of data or modelling assumptions. In particular, we wanted to discover if changing any of the parameters would change the result of the preferred type of surgery for a hip fracture. A brief description of each scenario is provided in Table HE005.

Table HE005: Description of scenarios

Scenario	Description of Scenario
Utility values after 1 year set to those of THR	Utility value HA set to those of THR after 1 year. In this scenario, the quality of life benefits associated with THR would only last for one year, after which there would be no difference between procedures.
Utility values after 2 years set to those of THR	Utility value for HA set to those of THR after 2 years. In this scenario, the quality of life benefits associated with THR would only last for two years, after which there would be no difference between procedures.
Utility values after 3 years set to those of THR	Utility value after HA set to those of THR after 3 years. In this scenario, the quality of life benefits associated with THR would only last for three years, after which there would be no difference between procedures.
Utility values after 4 years set to those of THR	Utility value after HA set to those of THR after 4 years. In this scenario, the quality of life benefits associated with THR would only last for four years, after which there would be no difference between procedures.
Utility values after 5 years set to those of THR	Utility value for HA set to those of THR after 5 years. In this scenario, the quality of life benefits associated with THR would only last for five years, after which there would be no difference between procedures.

Scenario	Description of Scenario
Lower starting age	The mean age at which patients entered the model was 74 years (minus 5 years). Mean patient age was taken from HEALTH trial, who may not be representative of the general hip fracture population. Age- and sex-related population life tables were used to model mortality from one year after the procedure, and so this scenario resulted in lower mortality rates being applied. It was not possible to differentiate other input values by age, and so this scenario does not capture all age-related effects.
Higher starting age	The mean age at which patients entered the model was 84 years (plus 5 years). Age- and sex-related population life tables were used to model mortality from one year after the procedure, and so this scenario resulted in higher mortality rates.
Lower discount rate	A discount rate of 1.5% was explored. This value is not in alignment with the NICE reference case but allowed us to compare results of the model with other published analyses.
Increased cost of THR prosthesis	The costs of THR prosthesis were increased by 50%. The costs of the prostheses were identified from a 2018 report on elective hip arthroplasty procedures, leading to some uncertainty in the accuracy of their values. Additionally, there has been variation in prosthesis costs nationally, and the cost of prosthesis may be higher or lower than estimated.
Decreased cost of THR prosthesis	The costs of THR prosthesis were decreased by 50%.
Increased cost of HA prosthesis	The costs of HA prosthesis were increased by 50%.
Increased cost of HA prosthesis	The costs of HA prosthesis were decreased by 50%.
Increased cost of inpatient stay	The unit cost of a day spent in hospital after the procedure was increased by 50%.
Decreased cost of inpatient stay	The unit cost of a day spent in hospital after the procedure was decreased by 50%.
THR has additional days of hospital stay	Three additional days are included in the length of stay for THR. This is to account that these patients may have a longer time between admittance and receiving the procedure, but is not captured in the data.
Fewer patients have THR as secondary procedure	80% of patients in HA arm receive hemiarthroplasty as their revision procedure. 20% of revision procedures after a primary HA were assumed to be another HA, based on expert opinion. The expected impact of this scenario is that there will be lower costs in the HA arm since more patients will be having a less expensive revision procedure, but that outcomes will be lower.
Event rates from HEALTH trial	Event rates were estimated from the HEALTH study (see sections on operative time, revision rate at 12 months, mortality at 12 months, quality of life at 12 months). Outcomes in the HEALTH study were reported at two years; these were converted to one year rates to align with the model structure, assuming that events in HEALTH occurred at a constant rate throughout Year 1 and Year 2.
Revision rate from HEALTH trial	Revision rates were estimated from the HEALTH study. In this scenario, time-specific revision rates were applied in the model, to account for difference in risks between the two procedures at

Scenario	Description of Scenario
	different time points. The risk ratio in Year 2 was applied for the remainder of the model time horizon.
Revision rate based on HEALTH trial and two-year time horizon	Revision rate based on HEALTH and two-year time horizon. This scenario mirrors the key assumptions in the Axelrod (2020) cost-effectiveness analysis and allows us to make a direct comparison.
Effectiveness data from updated Cochrane review	The event rates in the model were based on the Cochrane review (Lewis 2022) that was updated by the NICE review team. The two events in the model for which there were additional studies identified were specifically mortality and length of stay after the procedure (see Section X for details of rates).
Additional post-procedure mortality	A relative risk adjustment (RR=1.5) was applied to general population mortality, which is applied in the model from one year after the procedures. This is to reflect that mortality rates after the procedure are likely to be higher than that of the general population.
Shorter time horizon (2 years)	The model ends after 2 years. This assumes that after this point, there are no differences in costs or outcomes between the two types of procedures.
Shorter time horizon (3 years)	The model ends after 3 years.
Shorter time horizon (4 years)	The model ends after 4 years.
Shorter time horizon (5 years)	The model ends after 5 years.

HE1.5.2 Probabilistic sensitivity analyses

We configured the model to perform probabilistic sensitivity analysis to quantify uncertainty in the true values of input parameters. We specified probability distributions for all input variables. We decided the type of distribution with reference to the properties of data of that type (for example, we use beta distributions for probabilities that are bounded between 0 and 1 and we use gamma distributions for cost parameters that cannot be negative). Where possible, we parameterised each distribution using dispersion data from the source from which the value was obtained; where no such data were available, we gave consideration to applying plausible ranges based on committee advice and the usual properties of similar data. We generated cost effectiveness results from 10,000 iterations of the decision model to ensure convergence of mean values.

HE2 Results

HE2.1 Sensitivity analysis

HE2.1.1 Scenario analyses

A number of scenarios had a large impact on the cost effectiveness results. These were all concerning the long term extrapolation of benefits for THR relative to HA (Table HE006). The main parameter that had the biggest impact on cost effectiveness was the length of time that the benefit of THR lasts. This was one of the parameters that there was very little evidence around. If the benefit of THR lasts for longer than two years then it is likely that THR is cost effective. However, if the benefit of THR lasts for less than two years then it is more likely that HA is cost effective. Two other scenarios that changed the results of the analysis when we assumed the benefit of THR lasted the rest of the patient's lifetime were revision rate based on HEALTH with a two-year time horizon, and model ends after two years. These analyses put the ICER slightly above the £20,000 per QALY gained threshold. This demonstrates that THR may only be cost effective if we assume that it is associated with long term benefits compared with HA (Table HE007).

We looked at the different scenarios that assumed that the benefit of THR only lasted two years after which it was the same as HA. In these scenarios the costs of THR prosthesis decrease by 50%, time horizon is four or five years and THR has additional three days length of stay all showed that THR was cost effective..

The remaining scenarios conducted had less of an impact on the cost effectiveness results (Table HE009), and the ICER in these scenarios remained below NICE's £20,000 per QALY gained threshold.

We found that the length of time that the benefit of THR lasts needed to be between two and three years for THR to be cost effective.

Table HE006: Scenario analyses

Scenario	Total hip replacement		Hemiarthroplasty		ICER
	Costs	QALYs	Costs	QALYs	
Utility values after 1 year set to those of THR (lifetime horizon)	£7,867	6.11	£6,273	6.09	£82,510
Utility values after two years set to those of THR (lifetime horizon)	£7,867	6.11	£6,273	6.05	£26,765
Utility values after three years set to those of THR (lifetime horizon)	£7,867	6.11	£6,273	6.01	£16,513
Utility values after four years set to those of THR (lifetime horizon)	£7,867	6.11	£6,273	5.98	£12,233
Utility values after five years set to those of THR (lifetime horizon)	£7,867	6.11	£6,273	5.95	£9,903
Utility values for lifetime (lifetime horizon)	£7,867	6.11	£6,273	5.78	£4,781
Model ends after two years (utility maintained for two years)	£7,786	1.341	£6,181	1.273	£23,379
Model ends after three years (utility maintained for two years)	£7,800	1.979	£6,198	1.911	£23,783

Scenario	Total hip replacement		Hemiarthroplasty		ICER
	Costs	QALYs	Costs	QALYs	
Model ends after four years (utility maintained for two years)	£7,809	2.562	£6,208	2.425	£11,690
Model ends after five years (utility maintained for two years)	£7,818	3.093	£6,217	2.926	£9,605
Model ends after two years (utility maintains for lifetime)	£7,756	1.34	£6,181	1.27	£23,379
Model ends after three years (utility maintains for lifetime)	£7,800	1.98	£6,189	1.87	£15,356
Model ends after four years (utility maintains for lifetime)	£7,809	2.56	£6,208	2.43	£11,690
Model ends after five years (utility maintains for lifetime)	£7,818	3.09	£6,217	2.93	£9,605

Table HE007: Sensitivity analyses

Scenario	Total hip replacement		Hemiarthroplasty		ICER
	Costs	QALYs	Costs	QALYs	
Age (-5yrs) (utility maintained for two years)	£7,887	7.569	£6,296	7.511	£27,502
Age (+5yrs) (utility maintained for two years)	£7,848	4.766	£6,252	4.705	£26,088
Discount rate (1.5%) (utility maintained for 2 years)	£7,883	6.820	£6,291	6.761	£26,976
Costs of THR prosthesis increase by 50% (utility maintained for two years)	£8,481	6.111	£6,283	6.052	£36,916
Costs of THR prosthesis decrease by 50% (utility maintained for two years)	£7,253	6.111	£6,264	6.052	£16,613
Costs of HA prosthesis increase by 50% (utility maintained for two years)	£7,867	6.111	£6,415	6.052	£24,377
Costs of HA prosthesis decrease by 50% (utility maintained for two years)	£7,867	6.111	£6,131	6.052	£29,152
Cost per inpatient stay increase by 50% (utility maintained for two years)	£10,464	6.111	£8,695	6.052	£29,713
Cost per inpatient stay decrease by 50% (utility maintained for two years)	£5,270	6.111	£3,852	6.052	£23,817
80% of patients in HA arm receive hemiarthroplasty as revision procedure (utility maintained for two years)	£7,867	6.111	£6,245	6.043	£23,880
Effectiveness data from HEALTH (utility maintained for two years)	£7,905	6.352	£6,382	6.324	£53,575
Revision rate based on HEALTH (utility maintained for two years)	£8,178	6.094	£6,512	6.040	£30,641
Revision rate based on HEALTH and two year time horizon (utility maintained for two years)	£8,105	1.335	£6,374	1.270	£26,597
Clinical data including non-Cochrane study (utility maintained for two years)	£9,594	6.023	£7,858	6.012	£156,599
Mortality one year after surgery has RR=1.5 relative to GPmort (utility maintained for two years)	£7,854	5.133	£6,258	5.072	£26,260

Scenario	Total hip replacement		Hemiarthroplasty		ICER
	Costs	QALYs	Costs	QALYs	
THR has additional three days LOS (utility maintained for two years)	£9,383	6.111	£6,329	5.778	£9,160
Lower starting age (utility maintained for lifetime)	£7,867	7.57	£6,296	7.15	£3,835
Higher starting age (utility maintained for lifetime)	£7,848	4.77	£6,252	4.51	£6,190
Lower discount rate (utility maintained for lifetime)	£7,883	6.82	£6,291	6.45	£4,273
Increased cost of THR prosthesis (utility maintained for lifetime)	£8,481	6.11	£6,283	5.78	£6,594
Decreased cost of THR prosthesis (utility maintained for lifetime)	£7,253	6.11	£6,264	5.78	£2,967
Increased cost of HA prosthesis (utility maintained for lifetime)	£7,867	6.11	£6,415	5.78	£4,354
Decreased cost of HA prosthesis (utility maintained for lifetime)	£7,867	6.11	£6,131	5.78	£5,207
Increased cost of inpatient stay (utility maintained for lifetime)	£10,464	6.11	£8,695	5.78	£6,307
Decreased cost of inpatient stay (utility maintained for lifetime)	£5,270	6.11	£3,852	5.78	£4,254
THR has additional days of hospital stay (utility maintained for lifetime)	£9,383	6.11	£6,329	5.78	£9,160
Fewer patients have THR as secondary procedure (utility maintained for lifetime)	£7,867	6.11	£6,245	5.77	£4,745
Event rates from HEALTH trial (utility maintained for lifetime)	£7,905	6.35	£6,382	6.09	£5,802
Revision rate from HEALTH trial (utility maintained for lifetime)	£8,178	6.09	£6,512	5.78	£5,237
Revision rate based on HEALTH trial and two-year time horizon (utility maintained for lifetime)	£8,105	1.34	£6,374	1.27	£26,597
Effectiveness data from updated Cochrane review (utility maintained for lifetime)	£9,594	6.02	£7,858	5.74	£6,133
Additional post-procedure mortality (utility maintained for lifetime)	£7,854	5.13	£6,258	4.85	£5,728
THR has additional three days LOS(utility maintained for lifetime)	£9,383	6.111	£6,329	5.778	£9,160

HE2.1.2 Probabilistic sensitivity analysis

The probabilistic sensitivity results are shown in Table HE008 and are congruent to the deterministic results for the scenario when the benefit of THR was assumed to last for two years and three years over a lifetime horizon.

Table HE008: Probabilistic cost–utility results (utility maintains for two and three years)

Strategy	Absolute		Incremental		
	Costs	QALYs	Costs	QALYs	ICER
Hemiarthroplasty	£6,270	6.19		-	-
Total hip replacement	£7,874	6.25	£1,604	0.06	£28,092
Hemiarthroplasty	£6,272	6.16	-	-	-
Total hip replacement	£7,866	6.25	£1,593	0.09	£17,307

Under the scenario where the utility benefit of THR lasts for two years, the cost-effectiveness acceptability curve (Figure HE003) shows is 71.5% likely to be cost effective at NICE's £20,000 per QALY. Under the scenario where the utility benefit of THR lasts for three years. the cost effectiveness acceptability curve (Figure HE004) shows that is 81.3% likely to be cost effective at NICE's £20,000 per QALY.

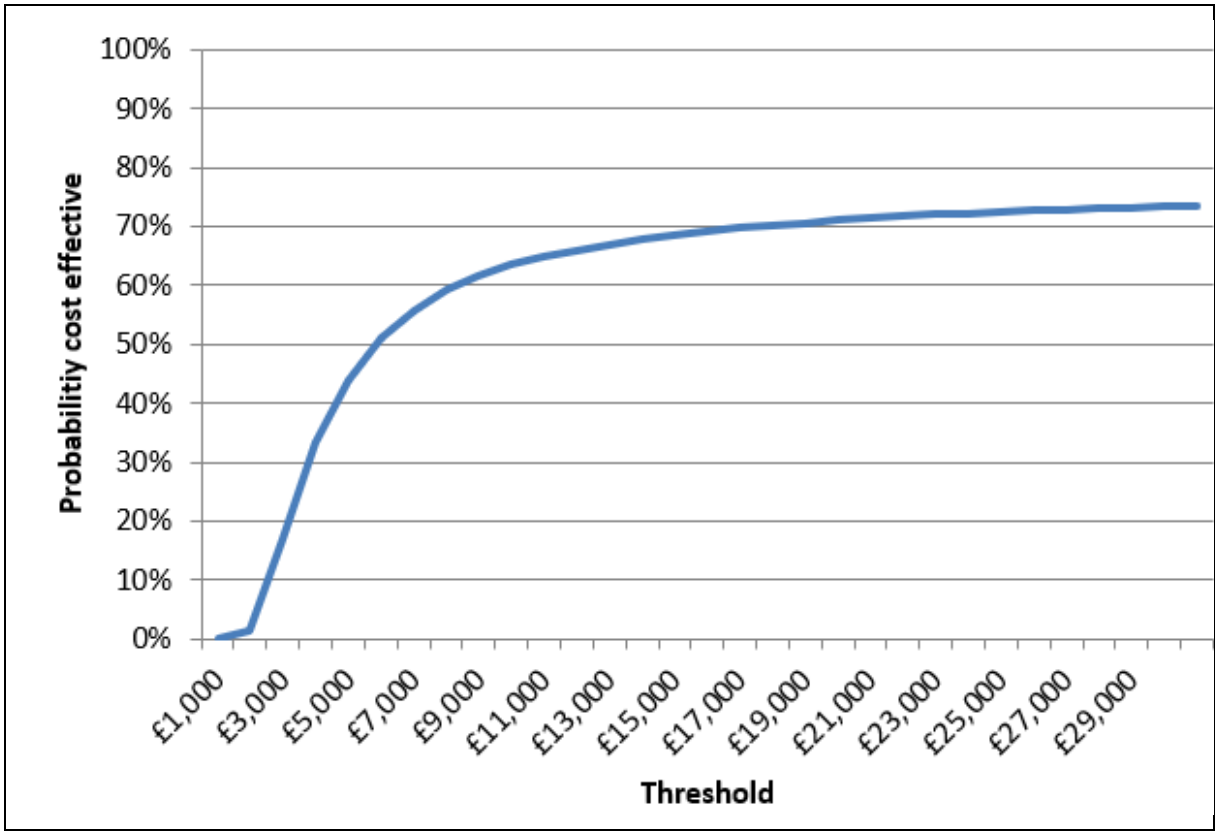

Figure HE003: Probabilistic results – cost–effectiveness acceptability curve (Two years)

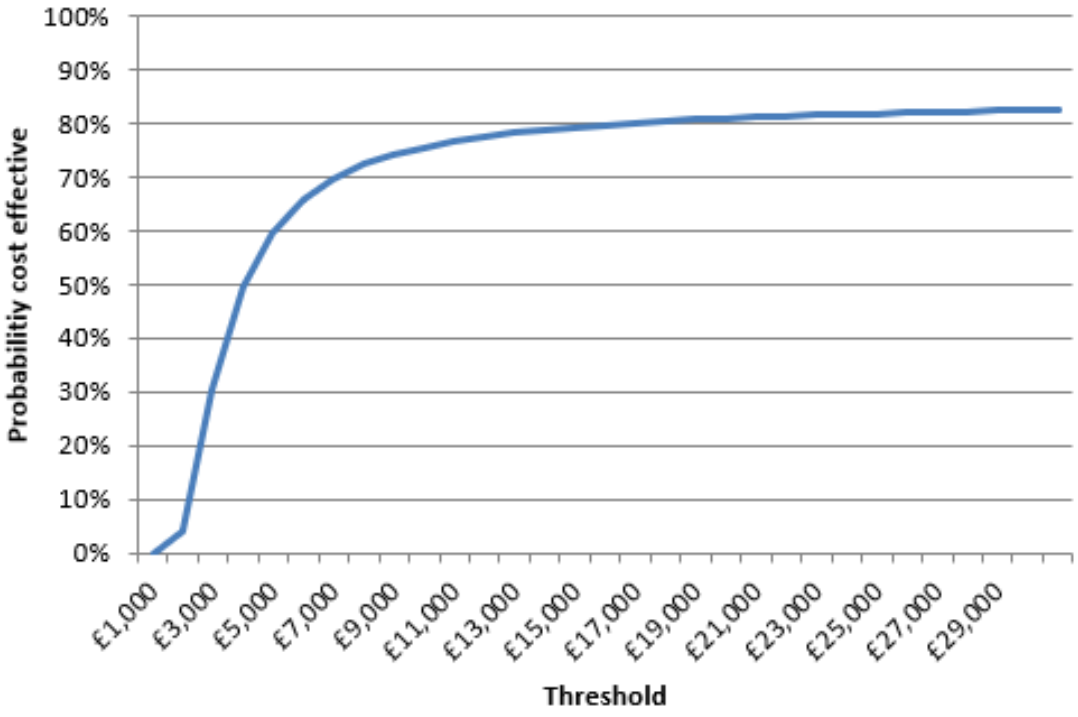

Figure HE004: Probabilistic results – cost–effectiveness acceptability curve (Three years)

The probabilistic sensitivity results are shown in Table HE009 and are congruent to the deterministic results for the scenario when the benefit of THR was assumed to last for the patient's lifetime.

Table HE009: Probabilistic cost–utility results (utility maintains for lifetime)

	Absolute		Incremental		
Strategy	**Costs**	**QALYs**	**Costs**	**QALYs**	**ICER**
Hemiarthroplasty	£6,293	5.91	-	-	-
Total hip replacement	£7,892	6.25	£1,600	0.34	£4,703

The cost-effectiveness acceptability curve (Figure HE005) shows that the THR is over 90% likely to be cost effective if the threshold is £4,000 per QALY. At NICE's £20,000 per QALY gained threshold THR is 95.6% likely to be cost effective.

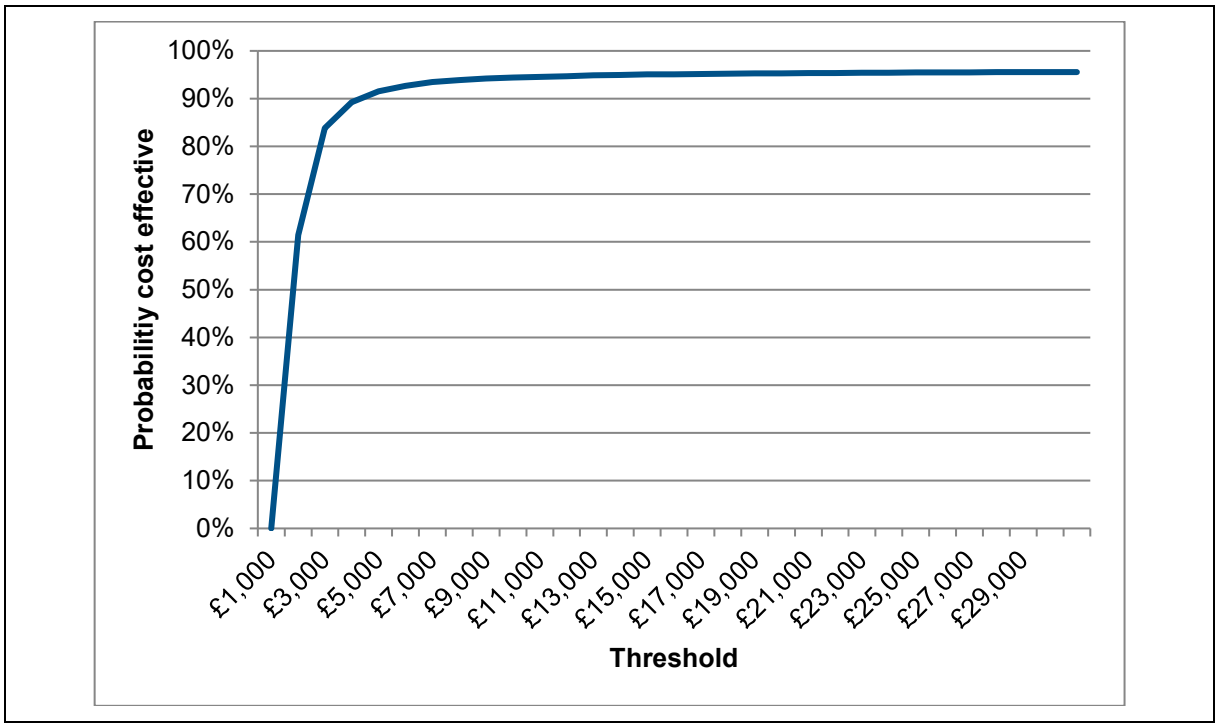

Figure HE005: Probabilistic results – cost–effectiveness acceptability curve

HE2.2 Discussion

HE2.2.1 Principal findings

If we accept the assumption that the quality of life benefit of THR lasts for the patient's lifetime, then THR may be a cost-effective option for patients with a firm or provisional clinical diagnosis of fragility fracture of the hip and a displaced intracapsular hip fracture. If there are unlikely to be differences between HA and THR in the long term, HA is likely to be a cost-effective option.

While the model was generally robust to a number of scenario analyses, the results were particularly sensitive to assumptions regarding the long term extrapolation of outcomes for THR relative to HA. THR will always be more expensive regardless of the time horizon of the analysis, given its higher prosthesis and associated hospital costs. Therefore, the duration over which benefits are accrued is the key driver of the analysis and determines which is the most cost effective procedure. Although the difference in quality of life at one year is small, the Cochrane review found that it was statistically significant when pooling evidence from all available studies. If the benefit in quality of life will endure over the patients remaining lifetime, then this small benefit accumulates and may be sufficient that THR could be considered cost effective.

A number of scenario analyses were performed to investigate the benefit of THR lasting two, three, four and five years over a lifetime horizon. This found that THR would be cost effective if the benefit lasted somewhere between two and three years.

HE2.2.2 Strengths of the analysis

One of the strengths of the model is that it is robust to the majority of the parameters explored. The only parameters that effect the result are the time horizon or the length of time the QALY increase of THR remains.

Another benefit of this analysis is that it includes the HEALTH trial which is one of the largest trials looking at THR vs HA. The HEALTH trial assigned 1,495 patients to either THR or HA and followed them for 24 months.

This analysis also incorporates the data from a recent Cochrane review, which we updated to include more recent studies. The cost effectiveness analysis builds upon a previous model that was developed for the previous update of the guideline. It has been developed using the expert guidance of two NICE committees. Therefore, this current model uses the most up to date clinical data available and includes more relevant and recent costs of the procedure, which included prosthesis costs.

HE2.2.3 Weaknesses of the analysis

Assumptions around long term outcomes

One of the main weaknesses of this analysis is regarding the long term assumptions regarding the benefits of THR relative to HA. There is currently little contemporary, prospective randomised evidence comparing the two types of procedure beyond a relatively short time frame, and observational data has mostly been collected for elective rather than trauma hip fracture patients and is highly subjective to confounding. Therefore, we had to make certain assumptions about what would happen to patients beyond the time frames of the trials. Sensitivity analyses showed that the model was highly sensitive to these assumptions: if the difference in quality of life between THR and HA was limited to 12 months, then HA is the most cost-effective option whereas, if it were to last after 5 years then THR would appear to be the most cost-effective option. This shows that the length of time the QALY increase for THR has a large effect on the cost effectiveness. No available evidence could be found to indicate how long the benefit would last. The committee felt it was unlikely that the benefit would last for the entire patient's life, but advised that many surgeons expect patients with a HA to not fare as well in the long term due to erosion and the eventual need to "upgrade" to a THR. However, they were unable to give an estimate for how long this may be. Therefore, this shows that there is significant uncertainty around this value.

Model update

For this guideline update, we updated the existing model that was developed for the previous guideline update in 2017. We therefore had to prioritise which areas to update. This also meant that assumptions from the previous model had to be carried forward into our model, and there are some sources of data or assumptions which may not reflect the most up to date reality. We prioritised the areas to update based on the impact they would have on the cost effectiveness results, and so this limitation is not likely to have large ramifications. As part of this update, we used data for event rates from a published Cochrane review, which extracted and presented outcomes in a slightly different format to the review that was conducted for the previous guideline update and upon which the previous model was designed to incorporate. As such, the available data had to be fitted to the model rather than the model being fitted to the data, and we had to make some assumptions regarding the nature of the event rates in order to include them in the existing model structure.

Subgroup analyses

Another limitation of this analysis was that we were not able to conduct subgroup analyses due to a lack of available data. This meant that we were unable to fully investigate which groups may benefit the most from a THR rather than a HA. Also, a lot of data was only available for elective patients rather than trauma patients, elective patients are likely to be fitter and more able to cope with the surgery that trauma patients. If more trauma data was available, then we would be better able to model the patients who have suffered a fragility fracture of the hip and a displaced intracapsular hip fracture.

Dislocation rates

Due to a lack of suitable data, it was necessary to make assumptions regarding the resources associated with a revision procedure. The cost may be underestimated for procedures involving implant exchange, as this may involve removal of the original implant and additional preparation prior to insertion of the new component. Conversely, the committee advised that a revision of a HA would be an elective or semi-elective procedure and so would be carried out on a patient who had the opportunity for preoperative preparation and hence in all likelihood would have a shorter hospital stay than one recently injured. It is likely to be skewed towards those patients who are more fit and active and hence the period of hospitalisation may be less.

Since the Cochrane review and results from the HEALTH trial indicate that there is little difference between the overall unplanned return to theatre, the cost effectiveness results are not sensitive to the cost of revision surgery, as demonstrated by a number of sensitivity analyses. A time-to-event analysis of HEALTH data showed that there were significantly fewer unplanned procedures in the THR group than the HA between 12 and 24 months. THR and with HA are each associated with different complications, with each presenting at different times after the procedure; for example, acetabular erosion is specific to HA, and THR has historically had higher dislocation rates than HA, although the risk of these has reduced in recent years. Judge (2022) noted how unplanned return to theatre was analysed as a binary outcome, yet there were important differences in the types of unplanned procedures after THR and after HA. There are differences in magnitudes of risk between the types of reoperation, e.g. closed reduction of fracture which may require sedation in an emergency department, compared with revision surgery.

A study with a longer follow up time could clarify how time-dependent complications specific to each procedure will affect this outcome at later timepoints. When the long term differences between treatments are better understood, including the nature of the unplanned procedure and the time after the initial procedure, there may be value in exploring these costs further.

Length of stay

We considered obtaining length of stay data from national databases, such as the NHFD or HES. However, we the committee advised that these data are challenging to interpret, and are subject to a large degree of confounding. The length of stay after a hip procedure for trauma is primarily dependent upon the medical comorbidities and social circumstances of the patient. As these admissions are all unplanned then resolving social circumstances is a significant contributor to length of stay. Patients who have a greater number of comorbidities are more likely to be a resident in a care home, and are also more likely to have a HA as they may not be fit enough to receive THR. Because they have an environment ready for when they are discharged, they may stay in hospital for a shorter period of time than a patient who would be discharged to the home. In practice, a range of patients undergoing a primary HA following trauma, from those who are pre-terminal and the procedure is done for pain relief even if that is only going to be for a short period of time, to the fit and active with the aim is restoration of good function. Without access to patient level data for each type of

procedure in the necessary population, it was necessary to estimate length of stay from randomised evidence, that was identified in the Cochrane review.

HE2.2.4 Comparison with other CUAs

Four published cost effectiveness studies were identified and there was a previous economic evaluation that was developed to support the previous update of this guideline that was published in 2017. Two of the five analyses were from the UK perspective. All studies had serious to very serious limitations. The model that was developed for the review question for this guideline in 2017 incorporated intervention costs from the 2000/2001 cost year, collected from trauma units in Scotland. The existing evidence for the cost effectiveness of THR compared with HA was contradictory, and largely depended on two factors: the time horizon that was taken for the analysis and extrapolation of benefits, and the age group in which the procedure was given. Some studies demonstrated that THR was not cost effective in the general hip fracture population but was more likely to be a cost-effective treatment for younger patients. Studies that presented results for shorter time horizons, such as Axelrod et al. (2020) and Carroll et al. (2011) show that HA is the most cost-effective treatment for a 2-year time horizon. In contrast, Blythe et al. (2020), Larranaga et al. (2022), and the model from the previous version of the guideline all showed that THR is the cost effective compared with HA. Therefore, this analysis fits in with some of the previous analyses but contradicts others.

Axelrod et al. (2020) was a model which was based on the HEALTH trial but was based in Canada. This is similar to our model in which the HEALTH model made up a significant percentage of the trial data. However, the main difference was the costs involved in the model. Even though Canada is a similar health care system the costs were significantly higher in the model and therefore Axelrod et al. (2020) found that HA was the most cost effective option whereas we found that THR was the more cost effective option.

HE2.3 Conclusions

Total hip replacement may be a cost-effective option for patients with a firm or provisional clinical diagnosis of fragility fracture of the hip and a displaced intracapsular hip fracture, if the small quality of life benefit of the THR compared with HA lasts for the patient's lifetime. If there are unlikely to be differences between HA and THR in the long term, the most cost-effective option would be HA. Scenario analyses showed that if the benefit of THR lasts longer than two years then THR is the most cost effective option. Generation of suitable, good quality long term data for this group of patients would allow us to model this with more certainty, and to determine which group of patients would benefit most from each type of procedure.

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