Cost-effectiveness of total hip arthroplasty versus resurfacing arthroplasty: economic evaluation alongside a clinical trial

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Complete List of Authors:	Edlin, Richard; University of Auckland, Health Systems, School of Population Health Tubeuf, Sandy; University of Leeds, Academic Unit of Health Economics Achten, Juul; University of Warwick, Division of Health Sciences Parsons, Nicholas; University of Warwick, Division of Health Sciences Costa, Matthew; University of Warwick, Warwick Clinical Trials Unit

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Objectives: To report on the relative cost-effectiveness of total hip arthroplasty and resurfacing arthroplasty (replacement of articular surface of femoral head only) in patients with severe arthritis suitable for hip joint resurfacing arthroplasty.

Design: Cost-effectiveness analysis (cost per QALY) on an intention to treat basis of a single-centre, single-blind randomised controlled trial of 126 adult patients within 12 months of treatment. Missing data was assessed using multiple imputations with differences in baseline quality of life and gender adjusted using regression techniques.

Setting: A large teaching hospital trust in the UK

Participants: 126 adult patients with severe arthritis of the hip joint suitable for a resurfacing arthroplasty of the hip.

Results: Data was received for 126 patients, 4 of whom did not provide any resource use data. For the remainder, data was imputed for costs or quality of life in at least one time point (baseline, 3 months, 6 months, 1 year) for 18 patients. Patients in the resurfacing arm had higher quality of life at 12 months (0.795 vs. 0.727) and received 0.033 more QALYs within the first 12 months post operation. At an additional cost of £410, resurfacing arthroplasty offers benefits at £12,374 per QALY within the first 12 months of treatment. When covariates are considered, the health economic case is stronger in men than women.

Conclusions: Resurfacing arthroplasty appears to offer very short term efficiency benefits over total hip arthroplasty within a selected patient group. This conclusion should be tested over a longer period through longer series following up resurfacing arthroplasty and through decision analytic modelling.

Trial registration: Current controlled Trials ISRCTN33354155. UKCRN 4093.

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Introduction

Hip arthroplasty is acknowledged to be a highly effective and cost-effective procedure for treating patients with severe arthritis of the hip joint, with 87% of patients reporting an improvement in their general health following surgery.[1] The total health gain is expected to be substantial given the effectiveness of treatment; EQ-5D based quality of life improvements following surgery are estimated to be 0.409, within the 45,000 cases measured in the UK Patient Reported Outcomes programme[2]. 97% of UK hip replacements are still working (unrevised) at 5 years[3] and 83% of all primary hip arthroplasty (all age, all implant types) are unrevised at 17 years post surgery in Sweden[4]. If the initial quality of life gains are maintained, each unrevised surgery represents over five discounted QALYs gained and a benefit of over one hundred thousand pounds at the £20,000 per QALY threshold used by NICE. Compared to these gains, the costs of hip arthroplasty surgery appear modest. As a result, most analyses considering health economics have concentrated on questions of which type of prosthesis to use, and many cost-effectiveness analyses have involved analysis of newer, more expensive operations against older, established comparators.[5-7] Resurfacing arthroplasty of the hip is a newer alternative form of arthroplasty designed for younger, active patients with severe arthritis of the hip.

Hip resurfacing arthroplasty involves the insertion of an acetabular component and the 'capping' of the femoral neck, rather than its removal and replacement with a femoral component in a standard total hip arthroplasty. Of the 70,000 hip arthroplasty operations conducted in England and Wales every year[3], approximately 6% are hip resurfacings. The equivalent figure amongst men aged under 55 is 33%. As resurfacing preserves the bone of the proximal femur, it may be expected to provide better clinical outcomes on revision of this component than available with a standard hip arthroplasty. Despite advances in their construction, there are still questions about the durability of modern resurfacing implants and there have been few explicit economic evaluations comparing resurfacing arthroplasties against total hip arthroplasties.[8 9] Few RCTs have been conducted to assess the outcomes of hip resurfacing, and those that exist provide little detail about the economic costs and benefits within the initial year following surgery. This paper reports the first within-trial economic evaluation of resurfacing arthroplasty versus total hip arthroplasty.

Methods

Interventions and sample

This evaluation reports on the efficiency of resurfacing arthroplasty versus total hip arthroplasty. Patients were deemed eligible for the trial if they were aged over 18 years of age, were medically fit for an operation, and were deemed suitable to receive a resurfacing arthroplasty. Patients were only excluded from the study if there was evidence that the patient would be unable to adhere to trial procedures or complete questionnaires. Patients were randomised on a 1:1 basis between THA and RSA, with each patient operated on according to the preferred technique of the operating surgeon. Other perioperative interventions, such as prophylactic antibiotics and thrombo-prophylaxis were the same for all patients and the same standardised rehabilitation plan was employed for both trial arms. Further details on recruitment and randomisation procedures are reported elsewhere.[10]

Perspective

The aim of the economic study is to determine the intervention that would maximise health outcomes within the limited NHS budget in this period, and so a cost-effectiveness (cost-utility) analysis with an NHS and Personal Social Services (PSS) perspective is adopted. This paper considers the within-trial period (as intention to treat) of the first 12 months follow up. It considers only resources used within the NHS setting including any aids and adaptations required. The base year for all costs figures was 2009/10, with figures from other years converted using the HCHS Pay and Prices Index (for adults, excluding capital).[11] For current costs, figures are deflated assuming an estimated inflation rate of 1.9% to 2010 from this index for both 2009/10 and 2010/11. As the analysis uses a one year time horizon, discounting for the future cost and health outcome is not necessary in this analysis. The currency used was the pound sterling (£).

Quality of life

Responses from the EQ-5D were obtained from patients at baseline, 3 months, 6 months and 12 months as secondary outcomes of the trial[10]; results from other outcomes are reported in greater depth elsewhere.[12] The standard tariff values[13] were applied to these responses at each time point to provide EQ-5D quality of life values. Quality-adjusted life-years (QALYs) were calculated as an "area under the curve" and form the main outcome measure of the study.

Resource use and valuation

The costs of THA and RSA treatments were considered across six broad categories – the costs of the initial operation, of inpatient care post-discharge, of outpatient care, of primary/community care, and of medications, and aids/adaptations required whilst in the community.

The current Healthcare Resource Group v.4 (HRG4) reference costs do not include a single category for primary replacements (as appeared in previous versions). Identified HRG4 frequencies for primary hip replacements are available[14] and these are used to calculate average costs, average length of stay, and average cost per excess bed day. Using these figures, the average cost of the initial hospitalisation is calculated for each patient by using the mean cost and LOS figures and adjusting for each patient's length of stay (as a number of bed days from the mean). In this way, a person admitted for the average length of stay would be assigned the average cost of treatment, with those staying shorter and longer periods assigned lower and higher costs, respectively.

These initial cost figures were calculated for both THA and RSA groups, and used as costs for the initial operation in the THA group. For the RSA group, the operative costs for THA are adjusted for differences in the expected implant/operative costs. All RSA patients received a Cormet resurfacing (Corin Group, Cirencester, UK), whilst THA patients received their surgeon's preference of prosthesis. For THA, prosthesis type was identified from patient records with three types of bearing surface (ceramic femoral head on ceramic socket, metal-on-metal and metal-on-polyethylene) accounting for 95% of cases. The University Hospitals Coventry and Warwickshire NHS Trust Finance Department provided implant costs for both the resurfacing implant and representative cost figures for the three types of prosthesis used. The expected difference in implant costs between RSA and THA patients was added to the operative costs for RSA patients and adjusted for inflation.

Patient-reported data on resource usage were collected alongside other outcomes at 3 months, 6 months and 12 months. For the 3 month data, the recall period was since discharge from hospital. For the other cases, it was since the last questionnaire was due to be completed. The questionnaires included sections on further inpatient care following the initial operation (speciality and length of stay/day case), outpatient care, primary and community care, aids and adaptations provided by the NHS/social services, and medication (pain relief and other NHS medication). Medicines usage was estimated based on mean dosage when used and average usage within the three budgetary periods (discharge to 3 months, 3-6 months, 6-12 months). In order to convert resource usage figures into costs, unit cost figures were assigned from NHS Reference costs[15], PSSRU unit costs[11], NHS Electronic

Drug Tariff[16], and relevant RCTs in the relevant year. Individual resource items and unit prices, including for aids and adaptations, are available in Tables provided as a Web Extra. Where resource usage data is analysed between trials, t-tests are used to calculate for significance in expected usage.

Data on personal costs (private treatments, out of pocket expenditures and time off work) were also collected but are not reported in the present analysis. Productivity data may be of some relevance given the age of participants but is outside the scope of the perspective used here.

Cost-effectiveness

Using the methods identified above, total costs and QALY figures were calculated for all patients where response data was available. For those cases in which either resource usage or quality of life data was unavailable, these figures cannot be calculated. In these cases, we used multiple imputation via chained equations[17] to complete missing data using STATA 11 (StataCorp 2009, TX, USA). [18 19] Missing cost data was predicted in terms of QALYs, treatment received, length of stay (LOS), age, gender, height, weight, and baseline clinical scores (Oxford Hip, Harris Hip); missing QALY data was predicted in terms of this same list (excluding QALYs), plus each of the cost items; missing LOS was predicted using the same list as for QALYs, with QALYs included. In order to remove implausible data, missing cost data was constrained to be positive and length of stay was constrained to be at least 3 days post-imputation. A total of 500 imputations were used to inform each item of missing data.

For the cost-effectiveness analysis, we identified the differences between costs and QALYs between the two arms, dividing the former by the latter to compute an incremental cost-effectiveness ratio (ICER). When compared against the marginal trade-off for the NHS as a whole – the cost-effectiveness threshold – the ICER gives an indication of whether spending additional money on hip arthroplasty appears efficient. This analysis is used as our base case.

Scenarios/univariate sensitivity analyses

Key uncertainties in the scenarios considered were explored using univariate sensitivity analyses. The results for complete cost and quality of life data (i.e. those with no missing data) were provided to identify the impact of missing data on the analysis, as is a strict per-protocol analysis of the data to reflect any sensitivity to protocol violations. As patients might also recover function within the first three months (rather than continuously to three months), a quicker initial recovery was explored in QALY calculations, where each patient's quality of life was assumed to reach its observed 3 month level at 6 weeks post-operatively. (When imputing for missing data, this was performed alongside the main imputation, using the same predictors as when imputing for the base case QALY measure.) The cost assumptions in the analysis were modified by assessing the impact of assuming the least expensive THA implant was used throughout with no effect on observed outcomes, to reflect the potential concern that the THA arm might not reflect cost-effective practice.

Adjustment for baseline differences

As the baseline randomisation did not stratify by quality of life, the impact of potential baseline differences are corrected for using regression analysis. The number of QALYs received (average quality of life over 12 months) is assumed to be a normal distribution, conditional on whether a resurfacing was intended, gender and baseline EQ-5D value. Likewise, total cost over 12 months is assumed to be lognormal, so that the natural logarithm of costs is a normal distribution, conditional on resurfacing, gender and baseline EQ-5D.

As any relationship between uncertainty in the extra costs and benefits associated with RSA is important when assessing the likelihood of cost-effectiveness, equations for cost and QALYs must be estimated together. As the statistical methods to do this are not established with multiply-imputed data, the data were first averaged across imputations before the equations were estimated as seemingly-unrelated regression[20]. Estimates of both cost and QALY outcomes were generated by considering the impact of clinical option (RSA vs. THA), the impact of covariates on outcomes (baseline EQ-5D and gender) for the population enrolled in the trial, and the relationships between each of these parameters. An overall ICER and cost-effectiveness acceptability curve (CEACs) [21] was obtained by sampling for all parameters within the variance-covariance matrix. As gender so heavily affects the clinical use of RSA, this analysis was also repeated allowing the effects of RSA to be assessed separately for men and women.

Results

Trial recruitment

The trial recruited a total of 126 patients (RSA=60; THA=66) between May 2007 to February 2010. Two patients from each arm of the study did not have surgery and provided only baseline quality of life/demographic data, leaving a total of 58 and 64 patients in each arm. As the analysis estimates data on costs and outcomes conditional on baseline quality of life, these patients cannot contribute any data to our analysis and are excluded from the analyses here.

Quality of life

Table 1 summarises quality of life estimates at the four time points and calculates QALY estimates both with and without data imputation in the two arms. Overall, those in the RSA group started in worse health (as measured by the EQ-5D) and received 0.033 more QALYs within the 12 months of the trial. Within the trial, the difference in quality of life between the RSA and THA arms of the trial appears to increase at each post-operative time point.

Costs and resource usage

Overall, NHS and social care costs were significantly higher amongst the RSA group with an average of £410 more spent within the first 12 months from the operation (Table 2), of which the majority is due to further inpatient care after initial discharge (£279) and outpatient care (£83). Relatively little of the cost difference between RSA and THA was due to the initial operation, as the deflated cost of the RSA implants including operative consumables used in this study was £1,850 vs. an average of £1,738 for THA operations. The trial used surgeon's preference of THA implant and as expected this implant as well as consumables cost varied by the type of implant, with the most expensive being ceramic on ceramic implants (£2,042) and those using metal on metal implants costing slightly less than RSA implants (£1,625). Implants and consumables in metal on polyethylene operations (£843) were associated with only 40% of the cost of ceramic on ceramic implant. Whilst the resurfacing implants were more expensive, they were also associated with a slightly shorter length of stay (5.7 vs. 5.5 days), although this difference was not statistically significant (P = 0.528). In total, costs in the initial operative period were only £31 more expensive in the resurfacing group, although it is acknowledged that this might differ if less expensive types of implant were used.

Those in the RSA arm had significantly more outpatient visits than those in the THA arm (5.155 vs. 3.063, P = 0.0054). Here, both the number of physiotherapy sessions and the use of DVT assessments were significantly higher amongst this group (P = 0.002, P = 0.011). For inpatient care, only subsequent inpatient attendances (0.155 vs. 0.047, P = 0.066) approached significance, with the only significant difference (P = 0.009) in aids and adaptations favouring RSA. For full details on individual resource use items and their unit costs, please see the tables available as a Web Extra.

Cost-effectiveness and sensitivity analyses

Whilst RSA is expected to cost more over the first 12 months following an operation, it appears to provide a difference in quality of life. Here, the incremental cost-effectiveness ratio (ICER) for RSA is £12,374 per QALY (£410/0.033 QALY). Within most of the sensitivity tests explored here, the figure appears to remain below the £20k-£30k per QALY range used by the National Institute for Health and Clinical Excellence as its estimate of the cost-effectiveness threshold, except where cheaper THA implants are used in place of surgeon's preference (Table 3). If cheaper (metal-on-polyethylene) implants are used, the increased cost of RSA vs. THA implants is enough to raise the average cost difference above £1,000 which, given the small quality of life difference observed here, is enough to prevent RSA being cost effective.

Adjustment for baseline differences

Once baseline differences in EQ-5D and the numbers of men and women in each arm are considered, the QALY estimates for the first 12 months appear to change. Within the regression analysis, those treated in the RSA arm receive 0.059 more QALYs than those treated with THA (P=0.064), as do women (P=0.126) and people with better baseline EQ-5D scores (P<0.001). In contrast, incremental costs appears to be relatively unaffected by either EQ-5D or gender, with no significant relationships found on either regressions (P=0.769; P=0.211). When considering the revised base case, costs are 4.9% higher (95%CI: 1.1%-8.9%) for those who received RSA when other factors are removed.

Whilst correcting for baseline differences leaves the incremental costs largely unchanged (£354; 95%CI: 85-623), the estimated QALY benefit almost doubles (0.059, 95%CI: -0.004-0.122). Consequently, the ICER is around half as large (£5,980 per QALY) as the non-adjusted case. In 89% of cases investigated, RSA is recommended when valuing health at £20,000 per QALY – suggesting that there is very little parameter uncertainty that RSA is the most cost-effective option within the first 12 months of treatment (Figure 1).

Whilst the incremental cost and QALY figures are not significantly related to gender (cost interaction 0.034, P=0.373; QALY interaction -0.385, P=0.551), their potential impact is relatively large. For women, RSA had higher costs and lower benefits, with the latter exacerbated by a much lower baseline quality of life (female 0.257, male 0.389). This led to an ICER of £13,800 per QALY for RSA, with a 58% chance of being cost-effective at £20,000 per QALY. Correspondingly, the ICER for men decreased to £3,445 per QALY, with a 92% chance of cost-effectiveness at £20,000 per QALY.

Discussion

In comparison to standard total hip arthroplasty, hip resurfacing arthroplasty appears to provide a modest QALY gain for a modest sum within the first 12 months from surgery; whilst the additional costs of RSA are statistically significant, the additional benefits are not. The analysis presented here analyses the data by considering potential confounding due to both gender and baseline quality of life, and this nearly doubles the estimate of RSA effect size. Whilst the main analysis of the trial data[12] found no statistically significant difference between the RSA and THA groups at 12 months, it seems likely that some short term difference in quality of life exists favouring RSA and that – again within 12 months – there is enough evidence to suggest that it may be cost-effective.

Within the first 12 months of treatment, the main caveat to our results deals with the comparator THA arm. The pragmatic nature of the trial data used here [12] is one of its key strengths, since it reflects current practice. Any changes to this practice may affect cost-effectiveness though, so that RSA may become more/less cost-effective as less/more cost-effective THA implants are used. A recent (US) analysis of registry data suggests that more expensive implants do not provide a substantive age-adjusted advantage over less expensive prostheses.[22] Where the sensitivity analysis assumed the use of the cheapest metal-on-polyethylene implants (without incorporating a possible impact on quality of life), RSA was no longer cost-effective within-trial.

Clearly, the cost-effectiveness of resurfacing is likely to require assessment over a longer period of time – as is typically the case for any health economic analysis of trial data.[23] Importantly, the higher revision rates reported for resurfacing arthroplasty suggest that the additional costs of RSA may be higher if a longer period is considered. On the benefit side of the equation, the impact of extending the time period is unclear as RSA may improve quality of life in the short term but lead to a quicker deterioration once revisions are necessary. One method to explore these questions may be decision analytic modelling.[23] The trial provides an estimate of short term clinical benefits from hip function and quality of life (conditional on EQ-5D), with longer follow up series (from trials or registry data) needed to model implant survival for both RSA and THA.

As THA revision surgery may be surgically more complex, financially more costly, and less effective than a primary THA, a key question when interpreting this study is the prognosis for patients after their RSA is revised. An Australian registry analysis suggests poor implant survival amongst patients receiving a revision of only the acetabular RSA component, and some evidence of higher revision risks among other types of RSA revisions such as where both components are revised.[24] It is unclear, however, whether a revised RSA is more similar, in terms of quality of life, to a primary THA or a revision THA. Further research is necessary to assess the likely impact of this and other questions to guide future research, and the findings of this paper are by no means a complete answer to the decision problem.

Registry data reveals that women represent 61% of primary THA patients in the UK but make up only 25% of RSA patients.3 These figures reflect relevant gender differences from both a clinical and a health economic perspective as women appear to obtain higher quality of life gains from THA, and face an increased revision rate from RSA.[4 25] This trial may also suggest a lower benefit from RSA relative to THA amongst women, although the finding was not statistically significant (or powered to be so). Despite the conclusions of the within-trial analysis, it seems clear that until such work is done and further data is available, the cost-effectiveness of resurfacing arthroplasty in a UK context remains potentially promising but as yet unproven.

Table 1. EQ-5D quality of life at each measurement and converted into QALYs (missing data imputed)

Quality of life	RSA (SD) n =58	THA (SD) n =64	Difference (95% CI)
Baseline	0.308 (0.338)	0.356 (0.335)	-0.048 (-0.168, 0.073)
3 months	0.722 (0.229)	0.698 (0.284)	0.023 (-0.711, 0.118)
6 months	0.796 (0.244)	0.747 (0.287)	0.050 (-0.046, 0.146)
12 months	0.795 (0.282)	0.727 (0.319)	0.067 (-0.042, 0.177)
QALYs	0.716 (0.216)	0.683 (0.252)	0.033 (-0.053, 0.120)
QALYs*	0.713 (0.216)	0.680 (0.251)	0.033 (-0.053, 0.120)

* With imputed data

Table 2. Costs by type, summed across trial period (missing data imputed)

Costs	RSA (SD) n =58	THA (SD) n =64	Difference (95% CI)
Initial operation/care	6740 (528)	6710 (482)	31 (-155, 217)
Subsequent inpatient	464 (953)	184 (556)	279 (-11, 569)
Outpatient	359 (292)	276 (211)	83 (-13, 179)
Primary/community	63 (98)	49 (70)	14 (-18, 45)
Aids and adaptations	21 (34)	21 (40)	0 (-13, 14)
Medication	26 (41)	23 (39)	3 (-12, 18)
Total Costs	7675 (1078)	7265 (647)	410 (79, 740)

Table 3. Incremental cost effectiveness

Scenario	Incremental costs	Incremental QALYs	ICER (Cost per QALY)
Base case (BC)	410 (79, 740)	0.033 (-0.053, 0.120)	12,374
Per protocol	472 (117, 826)	0.025 (-0.64, 0.114)	19,187
Complete case data (no imputation)	420 (70, 770)	0.032 (-0.062, 0.127)	12,961
BC + cheaper THA implants	1130 (777, 1484)	0.033 (-0.053, 0.120)	31,134
BC + quicker initial recovery	410 (79, 740)	0.039 (-0.048, 0.125)	10,518
Adjustments for EQ-5D, gender (all)	356 (84, 630)	0.059 (-0.003, 0.122)	6,054
Adjustments for EQ-5D, gender (male)	258 (-96, 612)	0.075 (-0.006, 0.156)	3,445
Adjustments for EQ-5D, gender (female)	499 (81, 916)	0.036 (-0.061, 0.134)	13,799

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- Please ensure that all references are in the following format:
1 (list 3 authors et al if there are more than 3, or all author names if there are fewer) Surname AB, Surname CD. Article title. Journal abbreviation Year;Vol:Start page-End page. (see punctuation and no month after year of publication)

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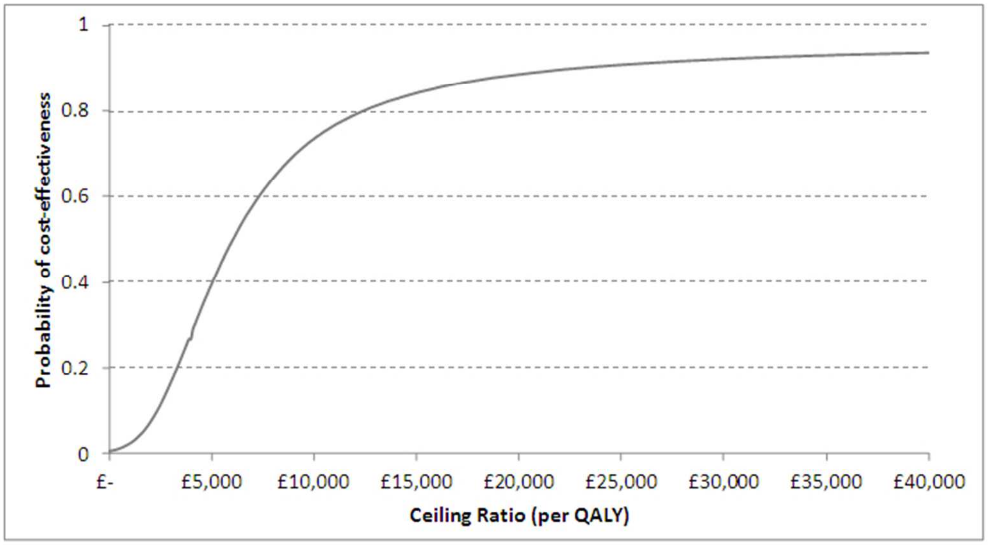

Figure 1: Cost-Effectiveness Acceptability Curve for Resurfacing Arthroplasty (vs. THA)
189x109mm (96 x 96 DPI)

Web Extra: Table 1 – Unit cost of resources

Item	Cost	Source
Initial Operation		
Cost for average THA	£6381	Uses weighted average of outcomes from HB11B, HB11C, HB12A, HB12B, HB12C.*
Average LOS for THA	6.57 days	
Adjustment per day ± av. LOS	£296	
THA: implant + consumables	£2,042	Ceramic femoral head, ceramic socket
	£1,625	Metal femoral head, metal socket
	£843	Metal femoral head, polyurethane socket
	£1,738	Weighted average of THA implants + consumables
RSA: implant + consumables	£1,850	Cormet resurfacing
Subsequent Inpatient Care		
Inpatient (orthopaedics)		
Day case	£874	TPCTDC. Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Cost for average LOS	£1,888	TPCTEI: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Average LOS	1.98 days	TPCTEI: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Adjustment per day ± av. LOS	£340	TPCTEIXS: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Inpatient (other)		
Elective, non-investigational	£668	Average across all day cases (TPCTDC)*
Elective, investigational	£243	Average cost radiotherapy inpatient, PSSRU 2010
Acute surgical/medical	£535	Average across all non-elective (short stay) cases (TPCTNEI_S)
Outpatient care		
Orthopaedics	£96	OPATT: Trauma & Orthopaedics: Non-Trauma (110N)*
Haematology	£128	OPATT: Clinical Haematology (303) *
Pathology or radiology	£114	Average cost per outpatient radiotherapy contact, PSSRU 2010
Ophthalmology	£80	OPATT: Ophthalmology (130) *
Orthotics	£96	OPATT: Trauma & Orthopaedics: Non-Trauma (110N)*
Physiotherapy	£39	OPATT: Physiotherapy Total Attendances - Adult (19 and Over (650A)*
Chiropractor	£17	Ongoing treatment session from UK BEAM trial http://www.bmj.com/content/329/7479/1381.full costed at £12.17 in 2000 base year. Reflated using NHS Pay and Prices Index.
Dermatology	£92	OPATT: Dermatology (330)*
Acupuncture	£30	Ongoing treatment session from RCT http://www.bmj.com/content/333/7569/626.full costed at £24 in 2002-3 base year. Reflated using NHS Pay and Prices Index.
Accident and Emergency	£113	OPATT: Accident and Emergency (180)*
DVT assessment service	£129	TPCTDC. Deep Vein Thrombosis (QZ20Z)*
Heart specialist/cardiologist	£124	OPATT: Cardiology (320)*
Urology	£99	OPATT: Urology (101)*
Neurophysiologist/neurologist	£166	OPATT: Neurology (400)*
Eye clinic	£80	OPATT: Ophthalmology (130) *
Oncologist	£107	OPATT: Clinical Oncology (800) *
Dietician	£32	PSSRU 2009-10: Cost per hour in clinic, incl. qualifications

Item	Cost	Source
Dentist	£100	OPATT: Dental Medicine Specialties (450) *
Thoracic	£216	OPATT: Thoracic Surgery (173) *
Primary and community care		
In surgery/clinic		
GPs	£28	Cost per surgery consultation, PSSRU Unit Costs 2010
Practice Nurse	£9	Cost per surgery consultation, PSSRU Unit Costs 2010
District nurse	£22	Cost per 15.5 minutes community nurse, PSSRU Unit Costs 2010
Physiotherapist	£15	Cost per clinic visit, PSSRU Unit Costs 2010
Occupational therapist	£15	Cost per surgery visit, PSSRU Unit Costs 2010
At home		
GPs	£94	Cost per home visit, PSSRU Unit Costs 2010
Practice Nurse	£13	Cost per home visit, PSSRU Unit Costs 2010
District Nurse	£37	Cost per home visit, community nurse, PSSRU Unit Costs 2010
Physiotherapist	£41	Cost per home visit, PSSRU Unit Costs 2010
Chiropodist	£20	Cost per home visit, PSSRU Unit Costs 2010
Dermatologist	£92	As for outpatient. OPATT: Dermatology (330)*
Aids and adaptation		
Walking stick	£8.02†	http://www.mobilitysmart.cc/sticks-crutches-canes/walking-sticks-canes/metal-sticks-canes/economy-ergonomic-walking-stick-p-16711.html
Crutches	£25.03†	http://www.mobilitysmart.cc/sticks-crutches-canes/crutches/closed-cuff-crutches/coopers-elbow-crutches-plastic-handles-p-13037.html
Wheelchair	£146.54†	http://www.mobilitysmart.cc/wheelchairs/self-propelled-wheelchairs/lightweight-self-propelling-wheelchair-p-14090.html
Insoles	£22.15†	http://www.mobilitysmart.cc/footcare/insoles-heel-pads/cosyfeet-orthaheel-workforce-p-17086.html
Zimmer	£44.29†	http://www.mobilitysmart.cc/walkers-shoppers/walkers-zimmer-frames/folding-walking-zimmer-frame-with-wheels-p-10599.html
Toilet seat	£12.84†	http://www.mobilitysmart.cc/toileting/toilet-seat-cushions/padded-toilet-seat-with-rim-vinyl-cover-p-671.html
Sock aid	£4.01†	http://www.mobilitysmart.cc/by-activity/getting-dressed/sock-stocking-aid-p-14742.html
Grabber	£5.89†	http://www.mobilitysmart.cc/home-garden-aids/reachers-grabbers/reacher-grabber-pick-up-tool-p-13495.html
Shoe horn	£3.85†	http://www.mobilitysmart.cc/plastic-shoe-horn-p-9955.html
Trolley	£28.53†	http://www.mobilitysmart.cc/trolleys-steps-stools/trolleys/tri-wheeled-shopping-trolley-p-10107.html
Perching stool	£43.33†	http://www.mobilitysmart.cc/trolleys-steps-stools/perching-

Item	Cost	Source
		stools/standard-perching-stool-p-765.html
Frame	£44.29[†]	http://www.mobilitysmart.cc/walkers-shoppers/walkers-zimmer-frames/folding-walking-zimmer-frame-with-wheels-p-10599.html
Clothes aid	£11.08[†]	http://www.mobilitysmart.cc/comfort-dressing/dressing-aids/dressing-stick-p-300.html
Medications (price per tablet /tube)		
Co-codamol	£0.05[†]	30mg/500mg capsules (from pack of 100)
Codeine	£0.04[†]	30mg tablets (from pack of 28)
Paracetamol	£0.03[†]	500mg capsules (from pack of 32)
Tramadol	£0.04[†]	50mg capsules (from pack of 30)
Amitriptyline	£0.03[†]	25mg tablets (from pack of 28)
Dihydrocodeine	£0.03[†]	30mg tablets (from pack of 100)
Diclofenac	£0.28[†]	50mg tablets (from pack of 21)
Ibuprofen	£0.02[†]	400mg tablets (from pack of 84)
Naproxen	£0.06[†]	500mg tablets (from pack of 28)
Aspirin	£0.01[†]	300mg tablets (from pack of 32)
Warfarin	£0.03[†]	5mg tablets (from pack of 28)
Zopiclone	£0.05[†]	7.5mg tablets (from pack of 28)
Flucloxacillin	£0.10[†]	500mg capsules (from pack of 28)
Morphine	£0.09[†]	10mg tablets (from pack of 56)
Hydrocortisone	£3.44[†]	Cream 1% tube (from single tube)
Furosemide	£0.03[†]	40mg tablets (from pack of 28)
Buprenorphine	£0.24[†]	400µg tablets (from pack of 7)
Omeprazole	£0.20[†]	10mg tables (from pack of 28)

* 2009-10 Reference Costs

[†] Figure shown is inflation adjusted.

Web Extra: Table 2 - Resource use by patients according to the arm intervention

	Mean Costs (SD)		Difference: p-value of t test
	RSA (n =58)	THA (n =64)	
Subsequent Inpatient Care			
Orthopaedics	0.155 (0.410)	0.047 (0.213)	0.066
Elective, non-investigational	0.034 (0.184)	0 (0)	0.136
Elective, investigational	0 (0)	0.016 (0.125)	0.343
Acute surgical/medical	0.086 (0.283)	0.063 (0.302)	0.656
Outpatient care			
Orthopaedics	1.569 (1.464)	1.672 (1.196)	0.670
Haematology	0.121 (0.378)	0.109 (0.475)	0.885
Pathology or radiology	0.397 (1.388)	0.234 (0.660)	0.405
Ophthalmology	0 (0)	0.016 (0.125)	0.343
Orthotics	0.017 (0.131)	0 (0)	0.295
Physiotherapy	2.534 (4.096)	0.656 (2.169)	0.002
Chiropractor	0.103 (0.552)	0 (0)	0.136
Dermatology	0.172 (0.131)	0 (0)	0.295
Acupuncture	0.052 (0.394)	0 (0)	0.295
A and E	0.052 (0.223)	0.047 (0.213)	0.903
DVT assessment service	0.155 (0.410)	0.016 (0.125)	0.011
Heart specialist/ cardiologist	0.034 (0.263)	0.094 (0.635)	0.510
Urology	0 (0)	0.047 (0.278)	0.201
Neurophysiologist/neurologist	0.017 (0.131)	0.016 (0.125)	0.945
Eye clinic	0.0344 (0.263)	0.063 (0.393)	0.648
Oncologist	0.017 (0.131)	0 (0)	0.295
Dietician	0.172 (0.131)	0 (0)	0.295
Dentist	0.172 (0.131)	0.031 (0.25)	0.703
Thoracic	0 (0)	0.016 (0.125)	0.343
Primary and community care			
In surgery/clinic			
GPs	1.224 (2.193)	0.938 (1.833)	0.434
Practice Nurse	0.345 (1.101)	0.516 (1.553)	0.489
District nurse	0.034 (0.263)	0 (0)	0.295
Physiotherapist	0.103 (0.788)	0.125 (1)	0.896
Occupational therapist	0 (0)	0.016 (0.125)	0.343
At home			
GPs	0 (0)	0.047 (0.278)	0.201
Practice Nurse	0.103 (0.447)	0.047 (0.035)	0.067

		Mean Costs (SD)		Difference:
		RSA (n =58)	THA (n =64)	p-value of t test
Chiropodist		0.034 (0.263)	0 (0)	0.295
District Nurse		0.155 (0.951)	0.031 (0.175)	0.308
Physiotherapist		0.121 (0.796)	0 (0)	0.228
Dermatologist		0.052 (0.292)	0.016 (0.125)	0.368
Aids and adaptation				
Walking stick		0.269 (0.597)	0.259 (0.902)	0.946
Crutches		0.431 (0.901)	0.421 (0.826)	0.950
Wheelchair		0.017 (0.131)	0 (0)	0.295
Insoles		0.034 (0.184)	0 (0)	0.136
Zimmer		0.017 (0.131)	0 (0)	0.295
Toilet seat		0.103 (0.307)	0.125 (0.333)	0.712
Sock aid		0.017 (0.131)	0.031 (0.175)	0.621
Grabber		0 (0)	0.109 (0.315)	0.009
Shoe horn		0 (0)	0.031 (0.175)	0.178
Trolley		0 (0)	0.031 (0.25)	0.343
Perching stool		0 (0)	0.047 (0.278)	0.201
Frame		0.017 (0.131)	0.016 (0.125)	0.945
Clothes aid		0.017 (0.131)	0 (0)	0.295
Medications				
Co-codamol	30mg/500mg	77.51 (141.29)	84.02 (172.51)	0.821
Codeine	30mg tablets	6.62 (33.08)	0 (0)	0.130
Paracetamol	500mg capsules	53.07 (148.95)	46.54 (136.14)	0.811
Tramadol	50mg capsules	54.98 (169.59)	17.88 (63.05)	0.124
Amitriptyline	25mg tablets	2.30 (16.45)	8.04 (33.61)	0.270
Dihydrocodeine	30mg tablets	7.42 (53.00)	1.51 (11.46)	0.409
Diclofenac	50mg tablets	44.67 (121.91)	38.15 (103.72)	0.764
Ibuprofen	400mg tablets	54.63 (146.76)	25.44 (100.35)	0.224
Naproxen	500mg tablets	21.34 (106.88)	13.59 (77.87)	0.662
Aspirin	300mg tablets	6.94 (34.69)	0 (0)	0.130
Warfarin	5mg tablets	13.76 (98.25)	0 (0)	0.288
Zopiclone	7.5mg tablets	2.30 (11.53)	0.97 (7.37)	0.467
Flucloxacillin	500mg capsules	6.94 (34.69)	3.05 (23.23)	0.489
Morphine	10mg tablets	0 (0)	5.06 (27.06)	0.184
Hydrocortisone	cream 1%	0 (0)	0.02 (0.13)	0.351
Furosemide	40mg tablets	0 (0)	3.05 (23.24)	0.351
Buprenorphine	400µg tablets	0 (0)	4.73 (35.99)	0.351
Omeprazole	10 mg tablets	3.21 (24.48)	2.91 (23.30)	0.945

Cost-effectiveness of total hip arthroplasty versus resurfacing arthroplasty: economic evaluation alongside a clinical trial

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Objectives: To report on the relative cost-effectiveness of total hip arthroplasty and resurfacing arthroplasty (replacement of articular surface of femoral head only) in patients with severe arthritis suitable for hip joint resurfacing arthroplasty.

Design: Cost-effectiveness analysis ~~(cost per QALY)~~ on an intention to treat basis of a single-centre, single-blind randomised controlled trial of 126 adult patients within 12 months of treatment. Missing data ~~was assessed~~ were imputed using multiple imputations with differences in baseline quality of life and gender adjusted using regression techniques.

Setting: A large teaching hospital trust in the UK

Participants: 126 adult patients with severe arthritis of the hip joint suitable for a resurfacing arthroplasty of the hip.

Results: Data was received for 126 patients, 4 of whom did not provide any resource use data. For the remainder, data was imputed for costs or quality of life in at least one time point (baseline, 3 months, 6 months, 1 year) for 18 patients. Patients in the resurfacing arm had higher quality of life at 12 months (0.795 vs. 0.727) and received 0.~~033~~ 032 more QALYs within the first 12 months post operation. At an additional cost of £564~~410~~, resurfacing arthroplasty offers benefits at £~~12~~17,451~~,374~~ per QALY within the first 12 months of treatment. When covariates are considered, the health economic case is stronger in men than women.

Conclusions: Resurfacing arthroplasty appears to offer very short term efficiency benefits over total hip arthroplasty within a selected patient group. This conclusion should be tested over a longer period through longer series following up resurfacing arthroplasty and through decision analytic modelling.

Trial registration: Current controlled Trials ISRCTN33354155. UKCRN 4093.

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Introduction

Hip arthroplasty is acknowledged to be a highly effective and cost-effective procedure for treating patients with severe arthritis of the hip joint, with 87% of patients reporting an improvement in their general health following surgery.[1] The total health gain is expected to be substantial given the effectiveness of treatment; EuroQol (EQ-5D-3L) based quality of life improvements following surgery are estimated to be 0.409, within the 45,000 cases measured in the UK Patient Reported Outcomes programme[2]. 97% of UK hip replacements are still working (unrevised) at 5 years[3] and 83% of all primary hip arthroplasty (all age, all implant types) are unrevised at 17 years post surgery in Sweden[4]. If the initial quality of life gains are maintained, each unrevised surgery represents over five discounted quality-adjusted life-years (QALYs) gained and a benefit of over one hundred thousand pounds at the £20,000 per QALY threshold used by the National Institute of Health and Clinical Excellence (NICE). Compared to these gains, the costs of hip arthroplasty surgery appear modest. As a result, most analyses considering health economics have concentrated on questions of which type of prosthesis to use, and many cost-effectiveness analyses have involved analysis of newer, more expensive operations against older, established comparators.[5-7] Resurfacing arthroplasty of the hip is a newer alternative form of arthroplasty designed for younger, active patients with severe arthritis of the hip.

Hip resurfacing arthroplasty involves the insertion of an acetabular component and the 'capping' of the femoral neck, rather than its removal and replacement with a femoral component in a standard total hip arthroplasty. Of the 70,000 hip arthroplasty operations conducted in England and Wales every year[3], approximately 6% are hip resurfacings. The equivalent figure amongst men aged under 55 is 33%. As resurfacing preserves the bone of the proximal femur, it may be expected to provide better clinical outcomes on revision of this component than available with a standard hip arthroplasty. Despite advances in their construction, there are still questions about the durability of modern resurfacing implants and there have been few explicit economic evaluations comparing resurfacing arthroplasties against total hip arthroplasties.[8 9] Few randomised controlled trials ~~RCTs~~ have been conducted to assess the outcomes of hip resurfacing, and those that exist provide little detail about the economic costs and benefits within the initial year following surgery. This paper reports the first within-trial economic evaluation of resurfacing arthroplasty versus total hip arthroplasty.

Methods

Interventions and sample

This evaluation reports on the efficiency of resurfacing arthroplasty (RSA) versus total hip arthroplasty (THA). Patients were deemed eligible for the trial if they were aged over 18 years of age, were medically fit for an operation, and were deemed suitable to receive a resurfacing arthroplasty. Patients were only excluded from the study if there was evidence that the patient would be unable to adhere to trial procedures or complete questionnaires. Patients were randomised on a 1:1 basis between THA and RSA, with each patient operated on according to the preferred technique of the operating surgeon. Other perioperative interventions, such as prophylactic antibiotics and thrombo-prophylaxis were the same for all patients and the same standardised rehabilitation plan was employed for both trial arms. Further details on recruitment, and ethics, and randomisation procedures are reported elsewhere.[10] The main outcome measure of the trial was hip function (Oxford Hip Score; Harris Hip Score) at 12 months, and the trial found no evidence of a difference between RSA and THA.

Perspective

The aim of the economic study is to determine the intervention that would maximise health outcomes within the limited National Health Service (NHS) budget in this period, and so a cost-effectiveness (cost-utility) analysis with an NHS and Personal Social Services (PSS) perspective is adopted in the base case. This paper considers the within-trial period (as intention to treat) of the first 12 months follow up. It considers only resources used within the NHS setting including any aids and adaptations required. The base year for all costs figures was 2009/10, with figures from other years converted using the hospital and community health services HCHS Pay and Prices Index (for adults, excluding capital).[11] For current costs, figures are deflated assuming an estimated inflation rate of 1.9% to 2010 from this index for both 2009/10 and 2010/11. As the analysis uses a one year time horizon, discounting for the future cost and health outcome is not necessary in this analysis. The currency used was the pound sterling (£).

Quality of life

Responses from the EQ-5D-3L were obtained from patients at baseline, 3 months, 6 months and 12 months as secondary outcomes of the trial[10]; results from other outcomes are reported in greater depth elsewhere.[12] The standard tariff values[13] were applied to these responses at each time point to provide EQ-5D-3L quality of life values~~.~~. Quality-adjusted life-years (QALYs) were calculated as an "area under the curve" and form the main outcome measure of the study~~.~~. Where comparisons between the RSA and THA arms are based on non-imputed data, a two-sample t-test assuming equal variances is used.

Resource use and valuation

The costs of THA and RSA treatments were considered across six broad categories – the costs of the initial operation, of inpatient care post-discharge, of outpatient care, of primary/community care, and of medications, and aids/adaptations required whilst in the community.

~~These initial cost figures were calculated for both THA and RSA groups, and used as costs for the initial operation in the THA group. For the RSA group, the operative costs for THA are adjusted for differences in the expected implant/operative costs.~~ All RSA patients received a Cormet resurfacing (Corin Group, Cirencester, UK), whilst THA patients received their surgeon's preference of prosthesis~~.~~. For the patients having RSA this was a Cormet resurfacing implant (Corin Group, Cirencester, UK). For the patients having THA~~For THA,~~ the prosthesis type was identified from patient records, with three types of bearing surface (ceramic femoral head on ceramic socket, metal-on-metal and metal-on-polyethylene) accounting for 95% of cases. The University Hospitals Coventry and Warwickshire NHS Trust Finance Department provided implant costs for both the resurfacing implant and representative cost figures for these three types of prosthesis~~ used.~~. In the remaining 5% of cases, implant type was treated as missing and were imputed to fall in one of these groups.

The current Healthcare Resource Group v.4 (HRG4) reference costs include the cost of prosthesis across all ages, and in most cases this will be a THR as HRG4 does ~~do~~ not include a single category for primary replacements (as appeared in previous versions)~~.~~. Identified national-level HRG4 frequencies for primary hip replacements are available[14] and these are used to calculate an average cost~~costs~~, average length of stay, and average cost per excess bed day~~.~~. By deducting the expected THA cost from the average cost, we obtain a non-prosthesis average cost, to which it is possible to add the appropriate prosthesis cost relevant to each individual. From here, ~~Using these figures, the~~ an average ~~average~~ cost of the initial hospitalisation is calculated for each patient by ~~using the mean cost and LOS figures and~~ adjusting for each patient's length of stay (as a number of bed days from the mean)~~.~~. In this way, a person admitted for the average length of stay would be assigned the average cost of treatment, with those staying shorter and longer periods assigned lower and higher costs, respectively.

Data regarding length of stay and implant received were obtained from hospital records, with the remainder of the costing information obtained from patient-reported data. Resource usage ~~These initial cost figures were calculated for both THA and RSA groups, and used as costs for the initial operation in the THA group. For the RSA group, the operative costs for THA are adjusted for differences in the expected implant/operative costs. All RSA patients received a Cormet resurfacing (Corin Group, Cirencester, UK), whilst THA patients received their surgeon's preference of prosthesis. For THA, prosthesis type was identified from patient records with three types of bearing surface (ceramic femoral head on ceramic socket, metal-on-metal and metal-on-polyethylene) accounting for 95% of cases. The University Hospitals Coventry and Warwickshire NHS Trust Finance Department provided implant costs for both the resurfacing implant and representative cost figures for the three types of prosthesis used. The expected difference in implant costs between RSA and THA patients was added to the operative costs for RSA patients and adjusted for inflation.~~

~~Patient-reported data on resource usage were collected~~ was assessed alongside other outcomes at 3 months, 6 months and 12 months. For the 3 month data, the recall period was since discharge from hospital~~–~~. For the other cases, it was since the last questionnaire was due to be completed~~–~~. The questionnaires included sections on further inpatient care following the initial operation (speciality and length of stay/day case), outpatient care, primary and community care, aids and adaptations provided by the NHS/social services, and medication (pain relief and other NHS medication)~~–~~. Medicines usage was estimated based on mean dosage when used and average usage within the three budgetary periods (discharge to 3 months, 3-6 months, 6-12 months)~~–~~. In order to convert resource usage figures into costs, unit cost figures were assigned from NHS Reference costs[15], PSSRU unit costs[11], NHS Electronic Drug Tariff[16], and reported unit costs of acupuncture and chiropractic from previous studies.~~, and relevant RCTs in the relevant year.~~ Individual resource items and unit prices, including for aids and adaptations, are available in Tables provided as a Web Extra~~–~~. Where statistical tests analyse resource usage data, t-tests are used to test for differences in expected usage (assuming equal variance and non-imputed data)~~Where resource usage data is analysed between trials, t-tests are used to calculate for significance in expected usage~~.~~.~~

Data on personal costs (private treatments, out of pocket medicine usage expenditures and time off work for either the patient or a carer) were also collected. but are not reported in the present analysis. NHS unit costs were used to provide an indicative figure for private medicines costs, whilst 2009 median gross weekly earnings from full time jobs (£488.70) was used to identify a daily productivity cost of £97.74. These are used in the sensitivity analysis considering societal costs. Productivity data may be of some relevance given the age of participants but is outside the scope of the perspective used here.

Missing data

Where data was incomplete we used multiple imputation via chained equations (ice)[17] to complete missing data using STATA 11 (StataCorp 2009, TX, USA). [18 19] Missing cost data was predicted in terms of QALYs, treatment received, length of stay (LOS), age, gender, height, weight, and baseline clinical scores (Oxford Hip Score, Harris Hip Score); missing QALY data was predicted in terms of this same list (excluding QALYs), plus each of the cost items; missing LOS was predicted using the same list as for QALYs, with QALYs included. In order to remove implausible data, missing cost data was constrained to be positive and length of stay was constrained to be at least three days post-imputation. A total of 50 imputations were used to inform each item of missing data. Where tests are conducted to detect significant differences in mean values between the RSA and THA groups based on imputed data (i.e. incremental costs and QALYs), the analysis uses an OLS regression within the STATA's mim command.

Cost-effectiveness

Using the methods identified above, total costs and QALY figures were calculated for all patients including imputated data. where response data was available. For those cases in which either resource usage or quality of life data was unavailable, these figures cannot be calculated. In these cases, we used multiple imputation via chained equations[17] to complete missing data using STATA 11 (StataCorp 2009, TX, USA). [18 19] Missing cost data was predicted in terms of QALYs, treatment received, length of stay (LOS), age, gender, height, weight, and baseline clinical scores (Oxford Hip, Harris Hip); missing QALY data was predicted in terms of this same list (excluding QALYs), plus each of the cost items; missing LOS was predicted using the same list as for QALYs, with QALYs included. In order to remove implausible data, missing cost data was constrained to be positive and length of

~~stay was constrained to be at least 3 days post-imputation. A total of 500 imputations were used to inform each item of missing data.~~

For the cost-effectiveness analysis, we identified the differences between costs and QALYs between the two arms, dividing the former by the latter to compute an incremental cost-effectiveness ratio (ICER). ~~–~~When compared against the marginal trade-off for the NHS as a whole – the cost-effectiveness threshold – the ICER gives a broad ~~n~~ indication of whether spending additional money on hip arthroplasty appears efficient~~.~~. The ICER figure is not ~~This analysis is used as our base case.~~presented with a confidence interval due to difficulties in interpreting a ratio of two random variables. Instead, we assume that each QALY is valued at £20,000 and subtract costs from this 'monetised' QALY in order to obtain a net monetary benefit (NMB). Any treatment with an ICER below £20,000 will have a positive NMB, with higher NMB figures unambiguously better and lower NMB figures unambiguously worse. As before, a 95% confidence interval is formed for NMB using linear regression using STATA's mim command.

Scenarios/univariate sensitivity analyses

Key uncertainties in the scenarios considered were explored using univariate sensitivity analyses. The results for complete cost and quality of life data (i.e. those with no missing data) were provided to identify the impact of missing data on the analysis. A ~~, as is a~~ strict per-protocol analysis of the data is also used to reflect any sensitivity to protocol violations. A societal perspective was also explored by adding the patient medicines and productivity costs outlined above to the NHS + PSS costs. As patients might also recover function within the first three months (rather than continuously to three months), a quicker initial recovery was explored in QALY calculations, where each patient's quality of life was assumed to reach its observed 3-~~-~~month level at 6 weeks post-operatively~~.~~. ~~(When imputing for missing data, this was performed alongside the main imputation, using the same predictors as when imputing for the base case QALY measure.)~~ The cost assumptions in the analysis were modified by assessing the impact of assuming the least expensive (metal on polyethylene) THA implant was used throughout with no effect on observed outcomes, to reflect the potential concern that the THA arm might not reflect cost-effective practice~~.~~. The recent (after the trial)current recommendations against the use of metal on metal THA prostheses are briefly considered by setting all 'metal on metal' implants to missing, estimating which THA prosthesis (i.e. metal on polyethylene or ceramic on ceramic) each patient will receive using multiple imputation, and considering the cost implications within these alternative estimates.

Adjustment for potential baseline differences

As the baseline randomisation did not stratify by quality of life, the impact of potential baseline differences are corrected for using regression analysis. The number of QALYs received (average quality of life over 12 months) is assumed to be a normal distribution, conditional on ~~whether a resurfacing was intended, gender and baseline EQ-5D value. Likewise, total~~trial arm (RSA or THA))and baseline EQ-5D-3L value. Total cost over 12 months is assumed to be lognormal, so that the natural logarithm of costs is a normal distribution, conditional on ~~resurfacing~~trial arm, ~~gender and~~ baseline EQ-5D-3L.

QALYs and (log-)costs for each person are estimated using ordinary least squares regression (using STATA's mim command to handle imputed data).

As any relationship between uncertainty in the extra costs and benefits associated with RSA is important when assessing the likelihood of cost-effectiveness, we use a seemingly unrelated regression to do this.~~, equations for cost and QALYs must be estimated together.~~ . By using a Cholesky Decomposition of the variance-covariance matrix, (log-)costs and QALYs are modelled as if they come from a multivariate normal distribution. Uncertainty in the value of other items in the regression is ignored. From here, costs are estimated as if all patients receive THA, and incremental costs are calculated as a proportion of the average THA cost. In this way, a distribution is built up for incremental costs and incremental QALYs that can be analysed using ~~As the statistical methods to do this are not established with multiply imputed data, the data were first averaged across imputations before the equations were estimated as seemingly unrelated regression[20]. Estimates of both cost and QALY outcomes were generated by considering the impact of clinical option (RSA vs. THA), the impact of covariates on outcomes (baseline EQ-5D and gender) for the population enrolled in the trial, and the relationships between each of these parameters. An overall ICER and~~ cost-effectiveness acceptability curve (CEAC~~CEACs~~) can be formed for this analysis. [21] This CEAC indicates the likelihood that RSA will be cost-effective at different 'values' for a QALY.

~~was obtained by sampling for all parameters within the variance-covariance matrix.~~ As gender so heavily affects the clinical use of RSA, this analysis was re-run for both male patients only and female patients only. This allows the ~~also repeated allowing the~~ effects of RSA to be assessed separately for men and women, with this figure presented as the likelihood of that RSA would be cost-effective~~.~~ at a threshold value of £20,000 per QALY.

Results

Trial recruitment

The trial[12] recruited a total of 126 patients (RSA=60; THA=66) between May 2007 to February 2010~~-~~. Two patients from each arm of the study did not have surgery and provided only baseline quality of life/demographic data, leaving a total of 58 and 64 patients in each arm. The sample was representative of the broader population undergoing resurfacing in the UK during the period of recruitment; no significant differences were identified between those who took part and those who were eligible but chose not to take part. Further details on both the ethical approval for the study and the demographics of the patients are provided in the clinical paper.[12] As the analysis estimates data on costs and outcomes conditional on baseline quality of life, these patients cannot contribute any data to our analysis and are excluded from the analyses here.

Quality of life

Table 1 summarises quality of life estimates at the four time points and calculates QALY estimates both with and without data imputation in the two arms~~.~~. Overall, those in the RSA group started in worse health (as measured by the EQ-5D-3L) and received 0.033 more QALYs within the 12 months of the trial (n=118 observations). When the small amount of missing data is imputed, the estimated benefit remains very similar at 0.032 (95%CI, -0.054, 0.119). Within the trial, the difference in quality of life between the RSA and THA arms of the trial appears to increase at each post-operative time point.

Costs and resource usage

Overall, NHS and social care costs were significantly higher amongst the RSA group with an average of £~~410~~ 564 more spent within the first 12 months from the operation (Table 2), of which the majority is due to the higher cost of implants and length of stay following the initial operation (£184), ~~further~~ subsequent inpatient care ~~after initial discharge~~ (£279) and outpatient care (£84). T~~83). Relatively little of the cost difference between RSA and THA was due to the initial operation, as t~~he deflated cost of the RSA implants including operative consumables used in this study was £1,~~850~~ 826 vs. an average of £1,~~738~~ 700 for THA operations, based on imputed data~~.~~. ~~The trial used surgeon's preference of THA implant and as expected this implant~~ THA implants differed in costs, with ~~as well as consumables cost varied by the type of implant, with~~ the most expensive being ceramic on ceramic implants (£2,042) and those using metal on metal implants costing slightly less than RSA implants (£1,625)~~.~~. Implants and consumables in metal on polyethylene operations (£843) were associated with only 40% of the cost of ceramic on ceramic implant~~.~~. Whilst the resurfacing implants were more expensive, they were also associated with a slightly ~~shorter~~ longer length of stay (5.7 vs. 5.5 days), although this difference was not statistically significant (P = 0.536; imputed data).~~528). In total, costs in the initial operative period were only £31 more expensive in the resurfacing group, although it is acknowledged that this might differ if less expensive types of implant were used.~~

Those in the RSA arm had significantly more outpatient visits than those in the THA arm (5.155 vs. 3.063, P = 0.0054; non-imputed data)~~.~~. Here, both the number of physiotherapy sessions and the use of ~~DVT~~ deep vein thrombosis assessments were significantly higher amongst this group (P = 0.002, P = 0.011; non-imputed data)~~.~~. For inpatient care, only subsequent inpatient attendances (0.155 vs. 0.047, P = 0.066; non-imputed data) approached significance, with the only significant difference (P = 0.009) in aids and adaptations favouring RSA. For full details on individual resource use items and their unit costs, please see the tables available as a Web Extra.

The private costs to patients following arthroplasty surgery are considerable, although relatively little of this is due to the purchase of medication. There are no significant differences in medication usage between the RSA and THA arms, and the total costs of this treatment is similar (£12 RSA vs. £9 THA, P = 0.667). RSA patients report an average of 73 days off work, as against 57 days for THA patients (P = 0.333). Whilst surgery results in a large number of days off work for the patient, carers tend to take very few days off work (2.1 days RSA vs. 1.6 days THA; P = 0.595). Overall, RSA patients report costs valued at £5,917, as against £5,853 in the THA arm (imputed data). This difference is small but highly uncertain, such that there is no significant difference in costs from a societal perspective (£629 higher costs in RSA, 95%CI: -£2,456 -£3,713).

Cost-effectiveness and sensitivity analyses

Whilst RSA is expected to cost more over the first 12 months following an operation, it appears to provide a difference in quality of life. Here, the incremental cost-effectiveness ratio (ICER) for RSA is £17,~~12,374~~ 451 per QALY (£564~~410~~/0.~~033~~ 032 QALY)~~.~~. Within most of the sensitivity tests explored here, the figure appears to remain within or below the £20k-£30k per QALY range used by the National Institute for Health and Clinical Excellence as its estimate of the cost-effectiveness threshold, except where cheaper THA implants are used in place of surgeon's preference (Table 3). If cheaper (metal-on-polyethylene) implants are used, the increased cost of RSA vs~~.~~. THA implants is enough to raise the average cost difference above £1,000 which, given the small quality of life difference observed here, is enough to prevent RSA being cost effective~~.~~. As is normally the case in economic evaluations, however, the confidence interval for net benefit in every analysis span zero (Table 4) so that the findings do not reach statistical significance. As clinical trials are very rarely designed with the power of cost-effectiveness conclusions in mind, very little can be inferred from this lack of significance.

Adjustment for baseline differences

Once baseline differences in EQ-5D-3L are considered, the QALYWAT estimates for the first 12 months appear to change. ~~and the numbers of men and women in each arm are considered, the QALY estimates for the first 12 months appear to change. Within the regression analysis, those treated in the RSA arm receive 0.059 more QALYs than those treated with THA (P=0.064), as do women (P=0.126) and people with better baseline EQ-5D scores (P<0.001). In contrast, incremental costs appears to be relatively unaffected by either EQ-5D or gender, with no significant relationships found on either regressions (P=0.769; P=0.211). When considering the revised base case, costs are 4.9% higher (95%CI: 1.1%-8.9%) for those who received RSA when other factors are removed.~~ QALYs are higher generally amongst those who are healthier at baseline (EQ-5D-3L; P=0.000), with those treated in the RSA arm receiving 0.053 more QALYs than those treated with THA (P=0.119). Likewise, log-costs appear to be affected by baseline health (P=0.034), with costs 7.1% higher (95%CI: 1.7%-12.9%) for those who received RSA after bootstrapping.

Whilst correcting for baseline differences leaves the incremental costs largely unchanged (£473~~354~~; 95%CI: 107-840~~85-623~~), the estimated QALY benefit almost doubles (0.053~~059~~, 95%CI: -0.014~~004~~-0.120~~122~~). Consequently, the ICER is around half as large (£~~5~~8,905~~,980~~ per QALY) as the non-adjusted case. In 79~~89~~% of cases investigated, RSA is recommended when valuing health at £20,000 per QALY – suggesting ~~that there is very little~~ quite high confidence that ~~parameter uncertainty that~~ RSA is the ~~most~~ more cost-effective option within the first 12 months of treatment across the £20k-£30k range used by NICE (Figure 1). Where this analysis is re-run for male patients only (n = 71), neither incremental costs nor incremental QALYs reach statistical significance and the ICER falls to £5,519 per QALY. For female patients (n=51), the ICER is about three times as large as for males (£16,272 per QALY) due to

~~Whilst the incremental cost and QALY figures are not significantly related to gender (cost interaction 0.034, P=0.373; QALY interaction -0.385, P=0.551), their potential impact is relatively large. For women, RSA had~~ higher costs and lower benefits, with the latter exacerbated by a much lower baseline quality of life (female 0.257, male 0.389; P=0.032). ~~). This led to an ICER of £13,800 per QALY for RSA, with a 58% chance of being cost-effective at £20,000 per QALY. Correspondingly, the~~

ICER for men decreased to £3,445 per QALY, with a 92% chance of cost-effectiveness at £20,000 per QALY.Within the scenarios used here, RSA is only 54% likely to be cost-effective for female patients at £20,000 per QALY, compared to an 86% likelihood for male patients.

Discussion

In comparison to standard total hip arthroplasty, hip resurfacing arthroplasty appears to provide a modest QALY gain for a modest sum within the first 12 months from surgery; whilst the additional costs of RSA are statistically significant, the additional benefits are not–. The higher costs of RSA treatments are largely due to slightly higher costs for the initial operative and recovery periods, and higher usage of outpatient services. Whilst the RSA group achieves slightly better health outcomes and requires more services, this may be due to heterogeneity in outcomes; if resurfacing works well for most but poor for some, then this could produce this type of phenomenon. If so, this emphasises the need to follow patients up in the longer term.

The analysis presented here analyses the data by considering potential confounding due to both gender and baseline quality of life, and this nearly doubles the estimate of RSA effect size–. Whilst the main analysis of the trial data[12] found no statistically significant difference in hip function between the RSA and THA groups at 12 months, it seems likely that some short term difference in quality of life exists favouring RSA and that – again within 12 months – there is enough evidence to suggest that it may be cost-effective.

Within the first 12 months of treatment, the main caveat to our results deals with the comparator THA arm–. The pragmatic nature of the trial data used here [12] is one of its key strengths, since it reflects current practice. Any changes to this practice may affect cost-effectiveness though, so that RSA may become more/less cost-effective as less/more cost-effective THA implants are used–. A recent (US) analysis of registry data suggests that more expensive implants do not provide a substantive age-adjusted advantage over less expensive prostheses.[22] Where the sensitivity analysis assumed the use of the cheapest metal-on-polyethylene implants (without incorporating a possible impact on quality of life), RSA was no longer cost-effective within-trial. However, this is somewhat unrealistic to assume, as the main alternative to metal on metal THA implants appears to be the more expensive ceramic on ceramic type. Restrictions in the use of MOM THA implants within the UK are likely to lead to more of these (likely) less cost-effective implants being used, and so an increase in the cost-effectiveness of resurfacing implants.

Beyond the issues surrounding the choice of THA, the trial is inevitably unable to consider all possible cost items. The trial did not explicitly consider any differences in operative time between the RSA and THA arms; no difference was expected and an informal analysis of the data suggests very similar operative times between the arms. This evaluation was also unable to consider the impact of variation in cost within each type of prostheses (i.e. within the three types of THA, or beyond the single RSA used in the trial) as this information is not generally available. The clinical trial upon which this analysis is based used a single type of Cormet prosthesis that has been used in the UK for around 15 years. As such, our findings are not necessarily generalisable to other types of resurfacing and we cannot identify the most cost-effective type of resurfacing as this is beyond the scope of the trial. Whilst the list price of the Cormet prosthesis is similar to other prostheses available locally, prices are hospital-specific and so some caution is warranted when seeking to generalise findings to other locations.

Clearly, the cost-effectiveness of resurfacing is likely to require assessment over a longer period of time – as is typically the case for any health economic analysis of trial data.[23] Importantly, the higher revision rates reported for resurfacing arthroplasty suggest that the additional costs of RSA may be higher if a longer period is considered–. On the benefit side of the equation, the impact of extending the time period is unclear as RSA may improve quality of life in the short term but lead to a quicker deterioration once revisions are necessary, or require additional monitoring or revisions –by virtue of its 'metal-on-metal' nature. One method to explore these questions may be decision analytic modelling.[23] The trial provides an estimate of short term clinical benefits from hip function and quality of life (conditional on EQ-5D-3L), with longer follow up series (from trials or registry data) needed to model implant survival for both RSA and THA.

As THA revision surgery may be surgically more complex, financially more costly, and less effective than a primary THA, a key question when interpreting this study is the prognosis for patients after their RSA is revised–. An Australian registry analysis suggests poor implant survival amongst patients receiving a revision of only the acetabular RSA component, and some evidence of higher revision risks among other types of RSA revisions such as where both components are revised.[24] It is unclear, however, whether a revised RSA is more similar, in terms of quality of life, to a primary THA or a revision THA–. Further research is necessary to assess the likely impact of this and other questions to guide future research, and the findings of this paper are by no means a complete answer to the decision problem.

Registry data reveals that women represent 61% of primary THA patients in the UK but make up only 25% of RSA patients.[3] These figures reflect relevant gender differences from both a clinical and a health economic perspective as women appear to obtain higher quality of life gains from THA, and face an increased revision rate from RSA.[4 25] This trial may also suggest a lower benefit from RSA relative to THA amongst women, although the finding was not statistically significant (or powered to be so)–. Despite the conclusions of the within-trial analysis, it seems clear that until such work is done and further data is available, the cost-effectiveness of resurfacing arthroplasty in a UK context remains potentially promising but as yet unproven.

Table 1. EQ-5D-3L quality of life at each measurement and converted into QALYs (missing data imputed)

Quality of life	RSA (SD) n =58	THA (SD) n =64	Difference[±] (95% CI)
Baseline	0.308 (0.338)	0.356 (0.335)	-0.048 (-0.168, 0.073)
3 months	0.722 (0.229)	0.698 (0.284)	0.023 (-0.711, 0.118)
6 months	0.796 (0.244)	0.747 (0.287)	0.050 (-0.046, 0.146)
12 months	0.795 (0.282)	0.727 (0.319)	0.067 (-0.042, 0.177)
QALYs (n = 118)	0.716 (0.216)	0.683 (0.252)	0.033 (-0.053, 0.120)
QALYs* (n = 122)	0.713 (0.216)	~~0.680 (0.251)~~0.681	~~0.033 (-0.053,~~

* With imputed data

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ing data impute

Table 2. Costs by type, summed across trial period (missing data imputed)

Costs	% imput	RSATHA (SD) n =5864	THA (SD) n	Difference (95% CI)
Initial	7%67	£6275 (557)6710 (482)	£6091	£184 (-18,
Subsequent	11%4	£470 (956)184 (556)	£191	£279 (-11,
Outpatient	11%3	£360 (294)276 (211)	£276	£84 (-13, 181)
Primary/comm	11%6	£63 (98)49 (70)	£49 (67)14 (-	£14 (-17, 45)
Aids and	11%2	£21 (33)40)	£21 (40)0 (-	£0 (-14, 14)
Medication	11%2	£27 (43)23 (39)	£24 (41)3 (-	£3 (-13, 19)
NHS + PSSTotal	--	£7217 (1320)7265 (647)	£6653	£564 (144,
Private costs	61%	£5917	£5853	£64 (-3017, 3146)
Societal cost	–	£13,134	£12,506	£629 (-2456, 3713)

Table 2. Costs by type, summed across trial period (missing data imputed)

Costs	% imput	RSA (SD) n =58	THA (SD) n =64	Difference (95% CI)
Initial	7%	£6275 (557)	£6091 (532)	£184 (-18, 386)
Subsequent	11%	£470 (956)	£191 (558)	£279 (-11, 569)
Outpatient	11%	£360 (294)	£276 (210)	£84 (-13, 181)
Primary/comm	11%	£63 (98)	£49 (67)	£14 (-17, 45)
Aids and	11%	£21 (33)	£21 (40)	£0 (-14, 14)
Medication	11%	£27 (43)	£24 (41)	£3 (-13, 19)
NHS + PSS	--	£7217	£6653 (917)	£564 (144, 985)
Private costs	61%	£5917	£5853	£64 (-3017, 3146)
Societal cost	--	£13,134	£12,506	£629 (-2456, 3713)

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Table 3. Incremental cost effectiveness

Scenario	Incremental costs (95%CI)	Incremental QALYs (95%CI)	ICER
Base case (BC)	£564 (144, 985)	0.032 (-0.054, 0.119)	£17,451 per QALY
Per protocol	£528 (85, 970)	0.024(-0.066, 0.113)	£22,227 per QALY
Complete case data (N=98)	£721 (286,	0.053 (-0.042, 0.149)	£13,443 per QALY
Societal costs	£629 (-2456,	0.032 (-0.054, 0.119)	£19,435 per QALY
Metal/polyethylene THA implants	£1271 (859,	0.032 (-0.054, 0.119)	£39,318 per QALY
No metal on metal THA implants	£522 (76, 968)	0.032 (-0.054, 0.119)	£16,137 per QALY
Quicker initial recovery	£564 (144, 985)	0.039 (-0.048, 0.127)	£14,310 per QALY
Adjustments for quality of life	£473 (113, 853)	0.053 (-0.014-0.120)	£8,905 per QALY
Adjustments for quality of life,	£402 (-82, 916)	0.073 (-0.012, 0.158)	£5,519 per QALY
Adjustments for quality of life,	£598 (64, 1172)	0.037 (-0.070, 0.144)	£16,272 per QALY

Table 4. Net Monetary Benefit

Scenario	NMB (95%CI)*
Base case (BC)	£82.46 (-1795, 1960)
Per protocol	-£53 (-2011, 1905)
Complete case data (N=98)	£353 (-1719, 2426)
Societal costs	£19 (-3641, 3680)
Metal/polyethylene THA implants	-£625 (-2515, 1265)
No metal on metal THA implants	£125 (-1750, 1999)
Quicker initial recovery	£224 (-1658, 2107)
Adjustments for quality of life	£590 (-834, 2014)
Adjustments for quality of life, males	£1055 (-843, 2954)
Adjustments for quality of life, females	£137 (-1988, 2262)

QALYs valued at £20k each

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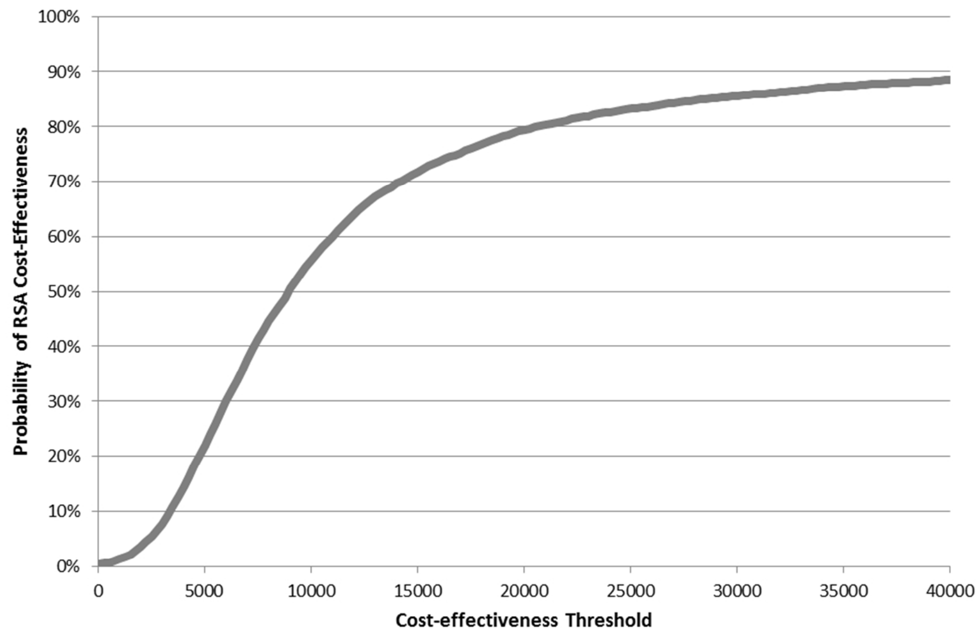

Figure 1: Cost-Effectiveness Acceptability Curve for Resurfacing Arthroplasty (vs. THA)
258x168mm (96 x 96 DPI)

Web Extra: Table 1 – Unit cost of resources

Item	Cost	Source
Initial Operation		
Cost for average THA	£6381	Uses weighted average of outcomes from HB11B, HB11C, HB12A, HB12B, HB12C.*
Average LOS for THA	6.57 days	
Adjustment per day ± av. LOS	£296	
THA: implant + consumables	£2,042	Ceramic femoral head, ceramic socket
	£1,625	Metal femoral head, metal socket
	£843	Metal femoral head, polyurethane socket
	£1,738	Weighted average of THA implants + consumables
RSA: implant + consumables	£1,850	Cormet resurfacing
Subsequent Inpatient Care		
Inpatient (orthopaedics)		
Day case	£874	TPCTDC. Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Cost for average LOS	£1,888	TPCTEI: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Average LOS	1.98 days	TPCTEI: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Adjustment per day ± av. LOS	£340	TPCTEIXS: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Inpatient (other)		
Elective, non-investigational	£668	Average across all day cases (TPCTDC)*
Elective, investigational	£243	Average cost radiotherapy inpatient, PSSRU 2010
Acute surgical/medical	£535	Average across all non-elective (short stay) cases (TPCTNEI_S)
Outpatient care		
Orthopaedics	£96	OPATT: Trauma & Orthopaedics: Non-Trauma (110N)*
Haematology	£128	OPATT: Clinical Haematology (303) *
Pathology or radiology	£114	Average cost per outpatient radiotherapy contact, PSSRU 2010
Ophthalmology	£80	OPATT: Ophthalmology (130) *
Orthotics	£96	OPATT: Trauma & Orthopaedics: Non-Trauma (110N)*
Physiotherapy	£39	OPATT: Physiotherapy Total Attendances - Adult (19 and Over (650A)*
Chiropractor	£17	Ongoing treatment session from UK BEAM trial http://www.bmj.com/content/329/7479/1381.full costed at £12.17 in 2000 base year. Reflated using NHS Pay and Prices Index.
Dermatology	£92	OPATT: Dermatology (330)*
Acupuncture	£30	Ongoing treatment session from RCT http://www.bmj.com/content/333/7569/626.full costed at £24 in 2002-3 base year. Reflated using NHS Pay and Prices Index.
Accident and Emergency	£113	OPATT: Accident and Emergency (180)*
DVT assessment service	£129	TPCTDC. Deep Vein Thrombosis (QZ20Z)*
Heart specialist/cardiologist	£124	OPATT: Cardiology (320)*
Urology	£99	OPATT: Urology (101)*
Neurophysiologist/neurologist	£166	OPATT: Neurology (400)*
Eye clinic	£80	OPATT: Ophthalmology (130) *
Oncologist	£107	OPATT: Clinical Oncology (800) *
Dietician	£32	PSSRU 2009-10: Cost per hour in clinic, incl. qualifications

Item	Cost	Source
Dentist	£100	OPATT: Dental Medicine Specialties (450) *
Thoracic	£216	OPATT: Thoracic Surgery (173) *
Primary and community care		
In surgery/clinic		
GPs	£28	Cost per surgery consultation, PSSRU Unit Costs 2010
Practice Nurse	£9	Cost per surgery consultation, PSSRU Unit Costs 2010
District nurse	£22	Cost per 15.5 minutes community nurse, PSSRU Unit Costs 2010
Physiotherapist	£15	Cost per clinic visit, PSSRU Unit Costs 2010
Occupational therapist	£15	Cost per surgery visit, PSSRU Unit Costs 2010
At home		
GPs	£94	Cost per home visit, PSSRU Unit Costs 2010
Practice Nurse	£13	Cost per home visit, PSSRU Unit Costs 2010
District Nurse	£37	Cost per home visit, community nurse, PSSRU Unit Costs 2010
Physiotherapist	£41	Cost per home visit, PSSRU Unit Costs 2010
Chiropodist	£20	Cost per home visit, PSSRU Unit Costs 2010
Dermatologist	£92	As for outpatient. OPATT: Dermatology (330)*
Aids and adaptation		
Walking stick	£8.02†	http://www.mobilitysmart.cc/sticks-crutches-canes/walking-sticks-canes/metal-sticks-canes/economy-ergonomic-walking-stick-p-16711.html
Crutches	£25.03†	http://www.mobilitysmart.cc/sticks-crutches-canes/crutches/closed-cuff-crutches/coopers-elbow-crutches-plastic-handles-p-13037.html
Wheelchair	£146.54†	http://www.mobilitysmart.cc/wheelchairs/self-propelled-wheelchairs/lightweight-self-propelling-wheelchair-p-14090.html
Insoles	£22.15†	http://www.mobilitysmart.cc/footcare/insoles-heel-pads/cosyfeet-orthaheel-workforce-p-17086.html
Zimmer	£44.29†	http://www.mobilitysmart.cc/walkers-shoppers/walkers-zimmer-frames/folding-walking-zimmer-frame-with-wheels-p-10599.html
Toilet seat	£12.84†	http://www.mobilitysmart.cc/toileting/toilet-seat-cushions/padded-toilet-seat-with-rim-vinyl-cover-p-671.html
Sock aid	£4.01†	http://www.mobilitysmart.cc/by-activity/getting-dressed/sock-stocking-aid-p-14742.html
Grabber	£5.89†	http://www.mobilitysmart.cc/home-garden-aids/reachers-grabbers/reacher-grabber-pick-up-tool-p-13495.html
Shoe horn	£3.85†	http://www.mobilitysmart.cc/plastic-shoe-horn-p-9955.html
Trolley	£28.53†	http://www.mobilitysmart.cc/trolleys-steps-stools/trolleys/tri-wheeled-shopping-trolley-p-10107.html
Perching stool	£43.33†	http://www.mobilitysmart.cc/trolleys-steps-stools/perching-

Item	Cost	Source
		stools/standard-perching-stool-p-765.html
Frame	£44.29†	http://www.mobilitysmart.cc/walkers-shoppers/walkers-zimmer-frames/folding-walking-zimmer-frame-with-wheels-p-10599.html
Clothes aid	£11.08†	http://www.mobilitysmart.cc/comfort-dressing/dressing-aids/dressing-stick-p-300.html
Medications (price per tablet /tube) related to hip/hip pain		
Co-codamol	£0.05†	30mg/500mg capsules (from pack of 100)
Codeine	£0.04†	30mg tablets (from pack of 28)
Paracetamol	£0.03†	500mg capsules (from pack of 32)
Tramadol	£0.04†	50mg capsules (from pack of 30)
Amitriptyline	£0.03†	25mg tablets (from pack of 28)
Dihydrocodeine	£0.03†	30mg tablets (from pack of 100)
Diclofenac	£0.28†	50mg tablets (from pack of 21)
Ibuprofen	£0.02†	400mg tablets (from pack of 84)
Naproxen	£0.06†	500mg tablets (from pack of 28)
Aspirin	£0.01†	300mg tablets (from pack of 32)
Warfarin	£0.03†	5mg tablets (from pack of 28)
Zopiclone	£0.05†	7.5mg tablets (from pack of 28)
Flucloxacillin	£0.10†	500mg capsules (from pack of 28)
Morphine	£0.09†	10mg tablets (from pack of 56)
Hydrocortisone	£3.44†	Cream 1% tube (from single tube)
Furosemide	£0.03†	40mg tablets (from pack of 28)
Buprenorphine	£0.24†	400µg tablets (from pack of 7)
Omeprazole	£0.20†	10mg tables (from pack of 28)
Productivity costs		
Day off work	£97.74	As 20% of £488.70; Median Gross Weekly Earnings from Full Time, Pay Unaffected by Absence, Office of National Statistics 2009 Annual Survey of Hours and Earnings. http://www.ons.gov.uk/ons/rel/ashe/annual-survey-of-hours-and-earnings/2009-results/stb-ashe-2009.pdf

* 2009-10 Reference Costs
† Figure shown is inflation adjusted.

Web Extra: Table 2 - Resource use by patients according to the arm intervention

	Mean Usage (SD)		P-value*
	RSA (n =58)	THA (n =64)	
Subsequent Inpatient Care			
Orthopaedics	0.155 (0.410)	0.047 (0.213)	0.066
Elective, non-investigational	0.034 (0.184)	0 (0)	0.136
Elective, investigational	0 (0)	0.016 (0.125)	0.343
Acute surgical/medical	0.086 (0.283)	0.063 (0.302)	0.656
Outpatient care			
Orthopaedics	1.569 (1.464)	1.672 (1.196)	0.670
Haematology	0.121 (0.378)	0.109 (0.475)	0.885
Pathology or radiology	0.397 (1.388)	0.234 (0.660)	0.405
Ophthalmology	0 (0)	0.016 (0.125)	0.343
Orthotics	0.017 (0.131)	0 (0)	0.295
Physiotherapy	2.534 (4.096)	0.656 (2.169)	0.002
Chiropractor	0.103 (0.552)	0 (0)	0.136
Dermatology	0.172 (0.131)	0 (0)	0.295
Acupuncture	0.052 (0.394)	0 (0)	0.295
A and E	0.052 (0.223)	0.047 (0.213)	0.903
DVT assessment service	0.155 (0.410)	0.016 (0.125)	0.011
Heart specialist/ cardiologist	0.034 (0.263)	0.094 (0.635)	0.510
Urology	0 (0)	0.047 (0.278)	0.201
Neurophysiologist/neurologist	0.017 (0.131)	0.016 (0.125)	0.945
Eye clinic	0.0344 (0.263)	0.063 (0.393)	0.648
Oncologist	0.017 (0.131)	0 (0)	0.295
Dietician	0.172 (0.131)	0 (0)	0.295
Dentist	0.172 (0.131)	0.031 (0.25)	0.703
Thoracic	0 (0)	0.016 (0.125)	0.343
Primary and community care			
In surgery/clinic			
GPs	1.224 (2.193)	0.938 (1.833)	0.434
Practice Nurse	0.345 (1.101)	0.516 (1.553)	0.489
District nurse	0.034 (0.263)	0 (0)	0.295
Physiotherapist	0.103 (0.788)	0.125 (1)	0.896
Occupational therapist	0 (0)	0.016 (0.125)	0.343
At home			
GPs	0 (0)	0.047 (0.278)	0.201
Practice Nurse	0.103 (0.447)	0.047 (0.035)	0.067
Chiropodist	0.034 (0.263)	0 (0)	0.295
District Nurse	0.155 (0.951)	0.031 (0.175)	0.308

		Mean Usage (SD)		P-value*
		RSA (n =58)	THA (n =64)	
Physiotherapist		0.121 (0.796)	0 (0)	0.228
Dermatologist		0.052 (0.292)	0.016 (0.125)	0.368
Aids and adaptation				
Walking stick		0.269 (0.597)	0.259 (0.902)	0.946
Crutches		0.431 (0.901)	0.421 (0.826)	0.950
Wheelchair		0.017 (0.131)	0 (0)	0.295
Insoles		0.034 (0.184)	0 (0)	0.136
Zimmer		0.017 (0.131)	0 (0)	0.295
Toilet seat		0.103 (0.307)	0.125 (0.333)	0.712
Sock aid		0.017 (0.131)	0.031 (0.175)	0.621
Grabber		0 (0)	0.109 (0.315)	0.009
Shoe horn		0 (0)	0.031 (0.175)	0.178
Trolley		0 (0)	0.031 (0.25)	0.343
Perching stool		0 (0)	0.047 (0.278)	0.201
Frame		0.017 (0.131)	0.016 (0.125)	0.945
Clothes aid		0.017 (0.131)	0 (0)	0.295
Medications				
Co-codamol	30mg/500mg	77.51 (141.29)	84.02 (172.51)	0.821
Codeine	30mg tablets	6.62 (33.08)	0 (0)	0.130
Paracetamol	500mg capsules	53.07 (148.95)	46.54 (136.14)	0.811
Tramadol	50mg capsules	54.98 (169.59)	17.88 (63.05)	0.124
Amitriptyline	25mg tablets	2.30 (16.45)	8.04 (33.61)	0.270
Dihydrocodeine	30mg tablets	7.42 (53.00)	1.51 (11.46)	0.409
Diclofenac	50mg tablets	44.67 (121.91)	38.15 (103.72)	0.764
Ibuprofen	400mg tablets	54.63 (146.76)	25.44 (100.35)	0.224
Naproxen	500mg tablets	21.34 (106.88)	13.59 (77.87)	0.662
Aspirin	300mg tablets	6.94 (34.69)	0 (0)	0.130
Warfarin	5mg tablets	13.76 (98.25)	0 (0)	0.288
Zopiclone	7.5mg tablets	2.30 (11.53)	0.97 (7.37)	0.467
Flucloxacillin	500mg capsules	6.94 (34.69)	3.05 (23.23)	0.489
Morphine	10mg tablets	0 (0)	5.06 (27.06)	0.184
Hydrocortisone	cream 1%	0 (0)	0.02 (0.13)	0.351
Furosemide	40mg tablets	0 (0)	3.05 (23.24)	0.351
Buprenorphine	400µg tablets	0 (0)	4.73 (35.99)	0.351
Omeprazole	10 mg tablets	7.12 (50.81)	6.26 (47.64)	0.927

* P-value, based on a two-sample t-test assuming equal variance

EVEREST STATEMENT / BMJ Checklist

Item	Y/N	Where?
(1) The research question is stated	Y	Page 4 "Perspective"
(2) The economic importance of the research question is justified	Y	Page 3 "Introduction"
(3) The viewpoint(s)of the analysis are clearly stated and justified	Y	Page 4 "Perspective"
(4) The rationale for choosing the alternative programmes or interventions compared is stated	Y	As a within trial analysis, this is determined by the trial design. This is varied in sensitivity analyses.
(5) The alternatives being compared are clearly described	Y	Page 3 "Introduction"
(6) The form of economic evaluation used is stated	Y	Page 4 "Perspective"
(7) The choice of form of economic evaluation is justified in relation to the questions addressed	Y	Page 4 "Perspective"
(8) The source(s) of effectiveness estimates used are stated	Y	Within trial, plus Methods section
(9) Details of the design and results of effectiveness study are given (if based on a single study)	Y	Within trial, plus Methods section. Findings of the main trial have been added.
(10) Details of the method of synthesis or meta-analysis of estimates are given (if based on an overview of a number of effectiveness studies)	NA	
(11) The primary outcome measure(s) for the economic evaluation are clearly stated	Y	Page 4-5, "Quality of life"
(12) Methods to value health states and other benefits are stated	Y	Page 4-5, "Quality of life"
(13) Details of the subjects from whom valuations were obtained are given	Y	Uses standard UK tariff to value EQ-5D outcomes, see "Quality of life"
(14) Productivity changes (if included) are reported separately	Y	These are reported in brief as a sensitivity analysis.
(15) The relevance of productivity changes to the study question is discussed	Y	Page 5-6, "Resource use and valuation". Brevity prevents this being included in depth
(16) Quantities of resources are reported separately from their unit costs	Y	Within Web Extra tables
(17) Methods for the estimation of quantities and unit costs are described	Y	Pages 5-6, "Resource use and valuation"
(18) Currency and price data are recorded	Y	Page 4 "Perspective"
(19) Details of currency of price adjustments for inflation or currency conversion are given	Y	Page 4 "Perspective"
(20) Details of any model used are given	NA	
(21) The choice of model used and the key parameters on which it is based are justified	NA	
(22) Time horizon of costs and benefits	Y	Page 4 "Perspective"
(23) The discount rate(s) is stated	NA	
(24) The choice of rate(s) is justified	NA	
(25) An explanation is given if costs or benefits are not discounted	Y	Justification is given by virtue of a 1-year timeframe.
(26) Details of statistical tests and confidence intervals are given for stochastic data	Y	Confidence intervals are inappropriate for ICERs but confidence intervals are provided for NMB. Detail on statistical tests are given throughout the methods (pp.4-8, and more detail is given

		specifically within the section on “Missing data” (p6) and “Adjustment for baseline differences” (p8)
(27) The approach to sensitivity analysis is given	Y	See Pages 7, “Cost-effectiveness”, pp7-8 “Scenarios/Univariate sensitivity analysis”, and p.8 “Adjustment for baseline differences”
(28) The choice of variables for sensitivity analysis is justified	Y	See Pages 7, “Cost-effectiveness”, pp7-8 “Scenarios/Univariate sensitivity analysis”, and p.8 “Adjustment for baseline differences”
(29) The ranges over which the variables are varied are stated	Y	We do not use one-way sensitivity analyses, and so this is not massively relevant (as are many parts of this checklist in 2012). The analyses relate more to specific changes to assumptions than arbitrary values for potentially key parameters.
(30) Relevant alternatives are compared	Y	Page 3 “Introduction”
(31) Incremental analysis is reported	Y	Page 10, “Cost-effectiveness and sensitivity analyses”, Table 3
(32) Major outcomes are presented in a disaggregated as well as aggregated form		Table 1 provides disaggregated quality of life data, Table 2 provides cost data by general area, Web Extras provide disaggregated resource data.
(33) The answer to the study question is given	Y	Pages 10-11 provide firstly results where no adjustments are made for baseline differences, and then with this adjustment.
(34) Conclusions follow from the data reported	Y	Page 11-13, “Discussion” follows on from themes introduced in results
(35) Conclusions are accompanied by the appropriate caveats	Y	Page 12-13, Particularly with respect to time and the choice of THA implant.

Cost-effectiveness of total hip arthroplasty versus resurfacing arthroplasty: economic evaluation alongside a clinical trial

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Complete List of Authors:	Edlin, Richard; University of Auckland, Health Systems, School of Population Health Tubeuf, Sandy; University of Leeds, Academic Unit of Health Economics Achten, Juul; University of Warwick, Division of Health Sciences Parsons, Nicholas; University of Warwick, Division of Health Sciences Costa, Matthew; University of Warwick, Warwick Clinical Trials Unit

Primary Subject Heading:	Health economics
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Keywords:	Hip < ORTHOPAEDIC & TRAUMA SURGERY, Adult orthopaedics < ORTHOPAEDIC & TRAUMA SURGERY, Orthopaedic & trauma surgery < SURGERY

Objectives: To report on the relative cost-effectiveness of total hip arthroplasty and resurfacing arthroplasty (replacement of articular surface of femoral head only) in patients with severe arthritis suitable for hip joint resurfacing arthroplasty.

Design: Cost-effectiveness analysis on an intention to treat basis of a single-centre, single-blind randomised controlled trial of 126 adult patients within 12 months of treatment. Missing data were imputed using multiple imputations with differences in baseline quality of life and gender adjusted using regression techniques.

Setting: A large teaching hospital trust in the UK

Participants: 126 adult patients with severe arthritis of the hip joint suitable for a resurfacing arthroplasty of the hip.

Results: Data was received for 126 patients, 4 of whom did not provide any resource use data. For the remainder, data was imputed for costs or quality of life in at least one time point (baseline, 3 months, 6 months, 1 year) for 18 patients. Patients in the resurfacing arm had higher quality of life at 12 months (0.795 vs. 0.727) and received 0.032 more QALYs within the first 12 months post operation. At an additional cost of £564, resurfacing arthroplasty offers benefits at £17,451 per QALY within the first 12 months of treatment. When covariates are considered, the health economic case is stronger in men than women.

Conclusions: Resurfacing arthroplasty appears to offer very short term efficiency benefits over total hip arthroplasty within a selected patient group. The short-term follow-up in this trial should be noted, particularly in light of the concerns raised regarding adverse reactions to metal debris from MOM bearing surfaces in the longer term. Longer term follow up of resurfacing arthroplasty patients and decision analytic modelling is also advised.

Trial registration: Current controlled Trials ISRCTN33354155. UKCRN 4093.

ARTICLE SUMMARY

Article focus:

- Hip resurfacing provides a clinical alternative to total hip arthroplasty in active patients with severe arthritis of the hip.
- This paper presents the first health economic analysis of resurfacing arthroplasty versus total hip arthroplasty in the immediate period after surgery.
- This paper analyses the impact of both baseline (EQ-5D) quality of life and gender, and presents separate findings for both men and women.

Key messages:

- Resurfacing arthroplasty appears cost-effective within the first 12 months of surgery, with modest gains in QALYs.
- The incremental cost-effectiveness ratio for resurfacing arthroplasty was below £20k per QALY in the base case and in all but two scenarios considered as sensitivity analyses.
- The effect of gender may be important, with incremental cost-effectiveness ratios for RSA vs. THA higher (worse) when treating women.

Strengths and limitations:

- The paper considers the cost and QALY consequences following THA and RSA surgery in a pragmatic RCT.
- Results within the period covered by the paper are not a definitive answer to the resource allocation decisions. Unanswered questions relate particularly to the impact of longer timeframes and the impact of implant choice.

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Contributorship Statement

RE designed the health economic analysis, with input from MC. ST managed data entry, with both RE and ST conducting elements of the health economic analysis. All authors were responsible for writing the manuscript. All authors read and approved the final manuscript.

Competing Interests Statement

All authors declare grant funding via the NIHR. In addition, MC and NP declare that manufacturers of resurfacing and total hip replacements have paid research grants to their host institutions, but not in relation to this work

Data Sharing Statement

no additional data available.

Introduction

Hip arthroplasty is acknowledged to be a highly effective and cost-effective procedure for treating patients with severe arthritis of the hip joint, with 87% of patients reporting an improvement in their general health following surgery.[1] The total health gain is expected to be substantial given the effectiveness of treatment; EuroQol (EQ-5D-3L) based quality of life improvements following surgery are estimated to be 0.409, within the 45,000 cases measured in the UK Patient Reported Outcomes programme[2]. 97% of UK hip replacements are still working (unrevised) at 5 years[3] and 83% of all primary hip arthroplasty (all age, all implant types) are unrevised at 17 years post surgery in Sweden[4]. If the initial quality of life gains are maintained, each unrevised surgery represents over five discounted quality-adjusted life-years (QALYs) gained and a benefit of over one hundred thousand pounds at the £20,000 per QALY threshold used by the National Institute of Health and Clinical Excellence (NICE). Compared to these gains, the costs of hip arthroplasty surgery appear modest. As a result, most analyses considering health economics have concentrated on questions of which type of prosthesis to use, and many cost-effectiveness analyses have involved analysis of newer, more expensive operations against older, established comparators.[5-7] Resurfacing arthroplasty of the hip is a newer alternative form of arthroplasty designed for younger, active patients with severe arthritis of the hip.

Hip resurfacing arthroplasty involves the insertion of an acetabular component and the ‘capping’ of the femoral neck, rather than its removal and replacement with a femoral component in a standard total hip arthroplasty. Of the 70,000 hip arthroplasty operations conducted in England and Wales every year[3], approximately 6% are hip resurfacings. The equivalent figure amongst men aged under 55 is 33%. As resurfacing preserves the bone of the proximal femur, it may be expected to provide better clinical outcomes on revision of this component than available with a standard hip arthroplasty. Despite advances in their construction, there are still questions about the durability of modern resurfacing implants and there have been few explicit economic evaluations comparing resurfacing arthroplasties against total hip arthroplasties.[8 9] Few randomised controlled trials have been conducted to assess the outcomes of hip resurfacing, and those that exist provide little detail about the economic costs and benefits within the initial year following surgery. This paper reports the first within-trial economic evaluation of resurfacing arthroplasty versus total hip arthroplasty.

Methods

Interventions and sample

This evaluation reports on the efficiency of resurfacing arthroplasty (RSA) versus total hip arthroplasty (THA). Patients were deemed eligible for the trial if they were aged over 18 years of age, were medically fit for an operation, and were deemed suitable to receive a resurfacing arthroplasty. Patients were only excluded from the study if there was evidence that the patient would be unable to adhere to trial procedures or complete questionnaires. Patients were randomised on a 1:1 basis between THA and RSA, with each patient operated on according to the preferred technique of the operating surgeon. Other perioperative interventions, such as prophylactic antibiotics and thrombo-prophylaxis were the same for all patients and the same standardised rehabilitation plan was employed for both trial arms. Further details on recruitment, ethics, and randomisation procedures are reported in both the RCT's protocol and reporting papers.[10, 12] The main outcome measure of the trial was hip function (Oxford Hip Score; Harris Hip Score) at 12 months, and the trial found no evidence of a difference between RSA and THA.

Perspective

The aim of the economic study is to determine the intervention that would maximise health outcomes within the limited National Health Service (NHS) budget in this period, and so a cost-effectiveness (cost-utility) analysis with an NHS and Personal Social Services (PSS) perspective is adopted in the base case. This paper considers the within-trial period (as intention to treat) of the first 12 months follow up. It considers only resources used within the NHS setting including any aids and adaptations required. The base year for all costs figures was 2009/10, with figures from other years converted using the hospital and community health services Pay and Prices Index (for adults, excluding capital).[11] For current costs, figures are deflated assuming an estimated inflation rate of 1.9% to 2010 from this index for both 2009/10 and 2010/11. As the analysis uses a one year time horizon, discounting for the future cost and health outcome is not necessary in this analysis. The currency used was the pound sterling (£).

Quality of life

Responses from the EQ-5D-3L were obtained from patients at baseline, 3 months, 6 months and 12 months as secondary outcomes of the trial[10]; results from other outcomes are reported in greater depth elsewhere.[12] The standard tariff values[13] were applied to these responses at each time point to provide EQ-5D-3L quality of life values. Quality-adjusted life-years (QALYs) were calculated as an "area under the curve" and form the main outcome measure of the study. Where comparisons between the RSA and THA arms are based on non-imputed data, a two-sample t-test assuming equal variances is used.

Resource use and valuation

The costs of THA and RSA treatments were considered across six broad categories – the costs of the initial operation, of inpatient care post-discharge, of outpatient care, of primary/community care, and of medications, and aids/adaptations required whilst in the community. The analysis considered inpatient and outpatient attendances for all reasons, and requested details of other resource usage only where it related to pain or hip surgery.

All RSA patients received a Cormet metal-on-metal resurfacing (Corin Group, Cirencester, UK), whilst THA patients received their surgeon's preference of prosthesis. For the patients having THA the prosthesis type was identified from patient records, with three types of bearing surface (ceramic femoral head on ceramic socket, metal-on-metal and metal-on-polyethylene) accounting for 95% of cases. The University Hospitals Coventry and Warwickshire NHS Trust Finance Department provided implant list prices for both the resurfacing implant and representative cost figures for these three types of prosthesis. In the remaining 5% of cases, implant type was treated as missing and were imputed to fall in one of these groups.

The current Healthcare Resource Group v.4 (HRG4) reference costs include the cost of prosthesis across all ages, and in most cases this will be a THR as HRG4 does not include a single category for primary replacements (as appeared in previous versions). Identified national-level HRG4 frequencies for primary hip replacements are available[14] and these are used to calculate an average cost, average length of stay, and average cost per excess bed day. By deducting the expected THA cost from the average cost, we obtain a non-prosthesis average cost, to which it is possible to add the appropriate prosthesis cost relevant to each individual. From here, an average cost of the initial hospitalisation is calculated for each patient by adjusting for each patient's length of stay (as a number of bed days from the mean). In this way, a person admitted for the average length of stay would be assigned the average cost of treatment, with those staying shorter and longer periods assigned lower and higher costs, respectively.

Data regarding length of stay and implant received were obtained from hospital records, with the remainder of the costing information obtained from patient-reported data. Resource usage was assessed alongside other outcomes at 3 months, 6 months and 12 months. For the 3 month data, the recall period was since discharge from hospital. For the other cases, it was since the last questionnaire was due to be completed. The questionnaires included sections on further inpatient care following the initial operation (speciality and length of stay/day case), outpatient care, primary and community care, aids and adaptations provided by the NHS/social services, and medication (pain relief and other NHS medication). Medicines usage was estimated based on mean dosage when used and average usage within the three budgetary periods (discharge to 3 months, 3-6 months, 6-12 months). In order to convert resource usage figures into costs, unit cost figures were assigned from NHS Reference costs[15], PSSRU unit costs[11], NHS Electronic Drug Tariff[16], and reported unit costs of acupuncture and chiropractic from previous studies. Individual resource items and unit prices, including for aids and adaptations, are available in Tables provided as a Web Extra. Where statistical tests analyse resource usage data, t-tests are used to test for differences in expected usage (assuming equal variance and non-imputed data).

Data on personal costs (out of pocket medicine usage and time off work for either the patient or a carer) were also collected. NHS unit costs were used to provide an indicative figure for private medicines costs, whilst 2009 median gross weekly earnings from full time jobs (£488.70) was used to identify a daily productivity cost of £97.74. These are used in the sensitivity analysis considering societal costs.

Missing data

Where data was incomplete we used multiple imputation via chained equations (ice)[17] to complete missing data using STATA 11 (StataCorp 2009, TX, USA). [18 19] Missing cost data was predicted in terms of QALYs, treatment received, length of stay (LOS), age, gender, height, weight, and baseline clinical scores (Oxford Hip Score, Harris Hip Score); missing QALY data was predicted in terms of this same list (excluding QALYs), plus each of the cost items; missing LOS was predicted using the same list as for QALYs, with QALYs included. In order to remove implausible data, missing cost data was constrained to be positive and length of stay was constrained to be at least three days post-imputation. A total of 50 imputations were used to inform each item of missing data. Where tests are conducted to detect significant differences in mean values between the RSA and THA groups based on imputed data (i.e. incremental costs and QALYs), the analysis uses an OLS regression within the STATA's mim command.

Cost-effectiveness

Using the methods identified above, total costs and QALY figures were calculated for all patients including imputed data. For the cost-effectiveness analysis, we identified the differences between costs and QALYs between the two arms, dividing the former by the latter to compute an incremental cost-effectiveness ratio (ICER). When compared against the marginal trade-off for the NHS as a whole – the cost-effectiveness threshold – the ICER gives a broad indication of whether spending additional money on hip arthroplasty appears efficient. The ICER figure is not presented with a confidence interval due to difficulties in interpreting a ratio of two random variables. Instead, we assume that each QALY is valued at £20,000 and subtract costs from this 'monetised' QALY in order to obtain a net monetary benefit (NMB). Any treatment with an ICER below £20,000 will have a positive NMB, with higher NMB figures unambiguously better and lower NMB figures unambiguously worse. As before, a 95% confidence interval is formed for NMB using linear regression using STATA's mim command.

Scenarios/univariate sensitivity analyses

Key uncertainties in the scenarios considered were explored using univariate sensitivity analyses. The results for complete cost and quality of life data (i.e. those with no missing data) were provided to identify the impact of missing data on the analysis. A strict per-protocol analysis of the data is also used to reflect any sensitivity to protocol violations. A societal perspective was also explored by adding the patient medicines and productivity costs outlined above to the NHS + PSS costs. As patients might also recover function within the first three months (rather than continuously to three months), a quicker initial recovery was explored in QALY calculations, where each patient's quality of life was assumed to reach its observed 3-month level at 6 weeks post-operatively. The cost assumptions in the analysis were modified by assessing the impact of assuming the least expensive (metal on polyethylene) THA implant was used throughout with no effect on observed outcomes, to reflect the potential concern that the THA arm might not reflect cost-effective practice. The recent (after the trial)current recommendations against the use of metal on metal THA prostheses are briefly considered by setting all 'metal on metal' implants to missing, estimating which THA prosthesis (i.e. metal on polyethylene or ceramic on ceramic) each patient will receive using multiple imputation, and considering the cost implications within these alternative estimates.

Adjustment for potential baseline differences

The base case analysis was conducted to allow for comparability between this within-trial analysis and the reporting of the main RCT[12]. These quality of life and gender-based analyses are conducted as *sensitivity* analyses to allow comparability with the main RCT, which did not find a significant difference in baseline quality of life and did not test for an interaction between efficacy and gender. Given that these issues may be important within the economic evaluation, they are considered as sensitivity analyses.

The impact of potential baseline differences in quality of life are corrected for using regression analysis within a sensitivity analysis. The number of QALYs received (average quality of life over 12 months) is assumed to be a normal distribution, conditional on trial arm (RSA or THA))and baseline EQ-5D-3L value. Total cost over 12 months is assumed to be lognormal, so that the natural logarithm of costs is a normal distribution, conditional on trial arm, baseline EQ-5D-3L.

QALYs and (log-)costs for each person are estimated using ordinary least squares regression (using STATA's mim command to handle imputed data). As any relationship between uncertainty in the extra costs and benefits associated with RSA is important when assessing the likelihood of cost-effectiveness, we use a seemingly unrelated regression to do this.. By using a Cholesky Decomposition of the variance-covariance matrix, (log-)costs and QALYs are modelled as if they come from a multivariate normal distribution. Uncertainty in the value of other items in the regression is ignored. From here, costs are estimated as if all patients receive THA, and incremental costs are calculated as a proportion of the average THA cost. In this way, a distribution is built up for incremental costs and incremental QALYs that can be analysed using cost-effectiveness acceptability curve (CEAC) can be formed for this analysis. [21] This CEAC indicates the likelihood that RSA will be cost-effective at different 'values' for a QALY.

As gender so heavily affects the clinical use of RSA, this analysis was re-run for both male patients only and female patients only. This allows the effects of RSA to be assessed separately for men and women, with this figure presented as the likelihood of that RSA would be cost-effective at a threshold value of £20,000 per QALY.

Results

Trial recruitment

The trial[12] recruited a total of 126 patients (RSA=60; THA=66) between May 2007 to February 2010. Two patients from each arm of the study did not have surgery and provided only baseline quality of life/demographic data, leaving a total of 58 and 64 patients in each arm. The sample was representative of the broader population undergoing resurfacing in the UK during the period of recruitment; no significant differences were identified between those who took part and those who were eligible but chose not to take part. Further details on both the ethical approval for the study and the demographics of the patients are provided in the clinical paper.[12] As the analysis estimates data on costs and outcomes conditional on baseline quality of life, these patients cannot contribute any data to our analysis and are excluded from the analyses here.

Quality of life

Table 1 summarises quality of life estimates at the four time points and calculates QALY estimates both with and without data imputation in the two arms. Overall, those in the RSA group started in worse health (as measured by the EQ-5D-3L) and received 0.033 more QALYs within the 12 months of the trial (n=118 observations). When the small amount of missing data is imputed, the estimated benefit remains very similar at 0.032 (95%CI, -0.054, 0.119). Within the trial, the difference in quality of life between the RSA and THA arms of the trial appears to increase at each post-operative time point.

Costs and resource usage

Overall, NHS and social care costs were significantly higher amongst the RSA group with an average of £564 more spent within the first 12 months from the operation (Table 2), of which the majority is due to the higher cost of implants and length of stay following the initial operation (£184), subsequent inpatient care (£279) and outpatient care (£84). The deflated cost of the RSA implants including operative consumables used in this study was £1,826 vs. an average of £1,700 for THA operations, based on imputed data. THA implants differed in costs, with the most expensive being ceramic on ceramic implants (£2,042) and those using metal on metal implants costing slightly less than RSA implants (£1,625). Implants and consumables in metal on polyethylene operations (£843) were associated with only 40% of the cost of ceramic on ceramic implant. Whilst the resurfacing implants were more expensive, they were also associated with a slightly longer length of stay (5.7 vs. 5.5 days), although this difference was not statistically significant (P = 0.536; imputed data).

Those in the RSA arm had significantly more outpatient visits than those in the THA arm (5.155 vs. 3.063, P = 0.0054; non-imputed data). Here, both the number of physiotherapy sessions and the use ofdeep vein thrombosis assessments were significantly higher amongst this group (P = 0.002, P = 0.011; non-imputed data). For inpatient care, only subsequent inpatient attendances (0.155 vs. 0.047, P = 0.066; non-imputed data) approached significance, with the only significant difference (P = 0.009) in aids and adaptations favouring RSA. For full details on individual resource use items and their unit costs, please see the tables available as a Web Extra.

The private costs to patients following arthroplasty surgery are considerable, although relatively little of this is due to the purchase of medication. There are no significant differences in medication usage between the RSA and THA arms, and the total costs of this treatment is similar (£12 RSA vs. £9 THA, P = 0.667). RSA patients report an average of 73 days off work, as against 57 days for THA patients (P = 0.333). Whilst surgery results in a large number of days off work for the patient, carers tend to take very few days off work (2.1 days RSA vs. 1.6 days THA; P = 0.595). Overall, RSA patients report costs valued at £5,917, as against £5,853 in the THA arm (imputed data). This difference is small but highly uncertain, such that there is no significant difference in costs from a societal perspective (£629 higher costs in RSA, 95%CI: -£2,456 -£3,713).

Cost-effectiveness and sensitivity analyses

Whilst RSA is expected to cost more over the first 12 months following an operation, it appears to provide a difference in quality of life. Here, the incremental cost-effectiveness ratio (ICER) for RSA is £17,451 per QALY (£564/0.032 QALY). Within most of the sensitivity tests explored here, the figure appears to remain within or below the £20k-£30k per QALY range used by the National Institute for Health and Clinical Excellence as its estimate of the cost-effectiveness threshold, except where cheaper THA implants are used in place of surgeon's preference, which was mostly MOM THA within the trial (Table 3). If the cheaper (metal-on-polyethylene) implants are used, the increased cost of

RSA vs. THA implants is enough to raise the average cost difference above £1,000 which, given the small quality of life difference observed here, is enough to prevent RSA being cost effective. However, if we consider *both* types of non-MOM implants (ceramic-on-ceramic and metal-on-polythene), this difference disappears entirely as the non-MOM implants were slightly more expensive on average than the MOM ones. The confidence interval for net benefit in every analysis spans zero (Table 4) so that the findings do not reach statistical significance. As clinical trials are very rarely designed with the power of cost-effectiveness conclusions in mind, very little can be inferred from this lack of significance.

Adjustment for baseline differences

Once baseline differences in EQ-5D-3L are considered, the QALYWAT estimates for the first 12 months appear to change. QALYs are higher generally amongst those who are healthier at baseline (EQ-5D-3L; P=0.000), with those treated in the RSA arm receiving 0.053 more QALYs than those treated with THA (P=0.119). Likewise, log-costs appear to be affected by baseline health (P=0.034), with costs 7.1% higher (95%CI: 1.7%-12.9%) for those who received RSA after bootstrapping.

Whilst correcting for baseline differences leaves the incremental costs largely unchanged (£473; 95%CI: 107-840), the estimated QALY benefit almost doubles (0.053, 95%CI: -0.014-0.120). Consequently, the ICER is around half as large (£8,905 per QALY) as the non-adjusted case. In 79% of cases investigated, RSA is recommended when valuing health at £20,000 per QALY – suggesting quite high confidence that RSA is the more cost-effective option within the first 12 months of treatment across the £20k-£30k range used by NICE (Figure 1). Where this analysis is re-run for male patients only (n = 71), neither incremental costs nor incremental QALYs reach statistical significance and the ICER falls to £5,519 per QALY. For female patients (n=51), the ICER is about three times as large as for males (£16,272 per QALY) due to higher costs and lower benefits, with the latter exacerbated by a much lower baseline quality of life (female 0.257, male 0.389; P=0.032). Within the scenarios used here, RSA is only 54% likely to be cost-effective for female patients at £20,000 per QALY, compared to an 86% likelihood for male patients.

Discussion

In comparison to standard total hip arthroplasty, hip resurfacing arthroplasty appears to provide a modest QALY gain for a modest sum within the first 12 months from surgery; whilst the additional costs of RSA are statistically significant, the additional benefits are not. The higher costs of RSA treatments are largely due to slightly higher costs for the initial operative and recovery periods, and higher usage of outpatient services. Whilst the RSA group achieves slightly better health outcomes and requires more services, this may be due to heterogeneity in outcomes; if resurfacing works well for most but poor for some, then this could produce this type of phenomenon. If so, this emphasises the need to follow patients up in the longer term.

The analysis presented here analyses the data by considering potential confounding due to both gender and baseline quality of life, and this nearly doubles the estimate of RSA effect size. Whilst the main analysis of the trial data[12] found no statistically significant difference in hip function between the RSA and THA groups at 12 months, it seems likely that some short term difference in quality of life exists favouring RSA and that – again within 12 months – there is enough evidence to suggest that it may be cost-effective.

Within the first 12 months of treatment, the main caveat to our results deals with the comparator THA arm. The pragmatic nature of the trial data used here [12] is one of its key strengths, since it reflects current practice. Any changes to this practice may affect cost-effectiveness though, so that RSA may become more/less cost-effective as less/more cost-effective THA implants are used. A recent (US) analysis of registry data suggests that more expensive implants do not provide a substantive age-adjusted advantage over less expensive prostheses.[22] Where the sensitivity analysis assumed the use of the cheapest metal-on-polyethylene implants (without incorporating a possible impact on quality of life), RSA was no longer cost-effective within-trial. However, these implants were used relatively rarely in practice, and the main alternative to metal on metal THA implants was the more expensive ceramic on ceramic type. Restrictions in the use of MOM THA implants within the UK are likely to lead to more costly THA implants being used, and so a net increase in the cost-effectiveness of resurfacing by comparison.

Beyond the issues surrounding the choice of THA, the trial is inevitably unable to consider all possible cost items. The trial did not explicitly consider any differences in operative time between the RSA and THA arms; no difference was expected and an informal analysis of the data suggests very similar operative times between the arms. This evaluation was also unable to consider the impact of variation in cost within each type of prostheses (i.e. within the three types of THA, or beyond the single RSA used in the trial) as this information is not generally available. The clinical trial upon which this analysis is based used a single type of Cormet prosthesis that has been used in the UK for around 15 years. Whilst the list price of the Cormet prosthesis is similar to other prostheses available locally, prices are hospital-specific and so some caution is warranted when seeking to generalise findings to other locations. We note also that our findings are not necessarily generalizable to other types of resurfacing, including emerging technologies such as ceramic on ceramic resurfacings. Whilst the cost-effectiveness of these newer treatments may differ from standard resurfacings, we cannot identify the most cost-effective type of resurfacing as this was beyond the scope of the trial and relatively little data exists on which to base even a preliminary estimate. To the degree that this may prove possible, it is an issue for subsequent decision analytic modelling.

Clearly, the cost-effectiveness of resurfacing is likely to require assessment over a longer period of time – as is typically the case for any health economic analysis of trial data.[23] Importantly, the higher revision rates reported for resurfacing arthroplasty suggest that the additional costs of RSA may be higher if a longer period is considered. On the benefit side of the equation, the impact of extending the time period is unclear as RSA may improve quality of life in the short term but lead to a quicker deterioration once revisions are necessary, or require additional monitoring or revisions by virtue of its 'metal-on-metal' nature. One method to explore these questions may be decision analytic modelling.[23] The trial provides an estimate of short term clinical benefits from hip function and quality of life (conditional on EQ-5D-3L), with longer follow up series (from trials or registry data) needed to model implant survival for both RSA and THA.

As THA revision surgery may be surgically more complex, financially more costly, and less effective than a primary THA, a key question when interpreting this study is the prognosis for patients after their RSA is revised. An Australian registry analysis suggests poor implant survival amongst patients receiving a revision of only the acetabular RSA component, and some evidence of higher revision risks among other types of RSA revisions such as where both components are revised.[24] It is unclear, however, whether a revised RSA is more similar, in terms of quality of life, to a primary THA or a revision THA. Further research is necessary to assess the likely impact of this and other questions to guide future research, and the findings of this paper are by no means a complete answer to the decision problem.

Registry data reveals that women represent 61% of primary THA patients in the UK but make up only 25% of RSA patients.[3] These figures reflect relevant gender differences from both a clinical and a health economic perspective as women appear to obtain higher quality of life gains from THA, and face an increased revision rate from RSA.[4 25] This trial may also suggest a lower benefit from RSA relative to THA amongst women, although the finding was not statistically significant (or powered to be so). Despite the conclusions of the within-trial analysis, it seems clear that until such work is done and further data is available, the cost-effectiveness of resurfacing arthroplasty in a UK context remains potentially promising but as yet unproven.

Table 1. EQ-5D-3L quality of life at each measurement and converted into QALYs (missing data imputed)

Quality of life	RSA (SD) n =58	THA (SD) n =64	Difference+ (95% CI)
Baseline	0.308 (0.338)	0.356 (0.335)	-0.048 (-0.168, 0.073)
3 months	0.722 (0.229)	0.698 (0.284)	0.023 (-0.711, 0.118)
6 months	0.796 (0.244)	0.747 (0.287)	0.050 (-0.046, 0.146)
12 months	0.795 (0.282)	0.727 (0.319)	0.067 (-0.042, 0.177)
QALYs (n = 118)	0.716 (0.216)	0.683 (0.252)	0.033 (-0.053, 0.120)
QALYs* (n = 122)	0.713 (0.216)	0.681 (0.251)	0.032 (-0.054, 0.119)

* With imputed data

Table 2. Costs by type, summed across trial period (missing data imputed)

Costs	% imputed	RSA (SD) n =58	THA (SD) n =64	Difference (95% CI)
Initial	7%	£6275 (557)	£6091 (532)	£184 (-18, 386)
Subsequent	11%	£470 (956)	£191 (558)	£279 (-11, 569)
Outpatient	11%	£360 (294)	£276 (210)	£84 (-13, 181)
Primary/community	11%	£63 (98)	£49 (67)	£14 (-17, 45)
Aids and	11%	£21 (33)	£21 (40)	£0 (-14, 14)
Medication	11%	£27 (43)	£24 (41)	£3 (-13, 19)
NHS + PSS Costs	--	£7217 (1320)	£6653 (917)	£564 (144, 985)
Private costs	61%	£5917 (5145)	£5853 (5520)	£64 (-3017, 3146)
Societal cost	--	£13,134 (5146)	£12,506 (5568)	£629 (-2456, 3713)

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Societal cost	--	£13,134 (5146)	£12,506 (5568)	£629 (-2456, 3713)

Table 3. Incremental cost effectiveness

Scenario	Incremental costs (95%CI)	Incremental QALYs (95%CI)	ICER (per QALY)
Base case (BC)	£564 (144, 985)	0.032 (-0.054, 0.119)	£17,451
Per protocol	£528 (85, 970)	0.024(-0.066, 0.113)	£22,227
Complete case data (N=98)	£721 (286, 1157)	0.053 (-0.042, 0.149)	£13,443
Societal costs	£629 (-2456, 3713)	0.032 (-0.054, 0.119)	£19,435
Metal/polyethylene THA implants	£1271 (859, 1684)	0.032 (-0.054, 0.119)	£39,318
No metal on metal THA implants	£522 (76, 968)	0.032 (-0.054, 0.119)	£16,137
Quicker initial recovery	£564 (144, 985)	0.039 (-0.048, 0.127)	£14,310
Quality of life (QoL) adjustments	£473 (113, 853)	0.053 (-0.014-0.120)	£8,905
QoL adjustments , males only	£402 (-82, 916)	0.073 (-0.012, 0.158)	£5,519
QoL adjustments, females only	£598 (64, 1172)	0.037 (-0.070, 0.144)	£16,272

Table 4. Net Monetary Benefit

Scenario	NMB (95%CI)*
Base case (BC)	£82.46 (-1795, 1960)
Per protocol	-£53 (-2011, 1905)
Complete case data (N=98)	£353 (-1719, 2426)
Societal costs	£19 (-3641, 3680)
Metal/polyethylene THA implants	-£625 (-2515, 1265)
No metal on metal THA implants	£125 (-1750, 1999)
Quicker initial recovery	£224 (-1658, 2107)
Adjustments for quality of life	£590 (-834, 2014)
Adjustments for quality of life, males	£1055 (-843, 2954)
Adjustments for quality of life, females	£137 (-1988, 2262)

QALYs valued at £20k each

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Objectives: To report on the relative cost-effectiveness of total hip arthroplasty and resurfacing arthroplasty (replacement of articular surface of femoral head only) in patients with severe arthritis suitable for hip joint resurfacing arthroplasty.

Design: Cost-effectiveness analysis on an intention to treat basis of a single-centre, single-blind randomised controlled trial of 126 adult patients within 12 months of treatment. Missing data were imputed using multiple imputations with differences in baseline quality of life and gender adjusted using regression techniques.

Setting: A large teaching hospital trust in the UK

Participants: 126 adult patients with severe arthritis of the hip joint suitable for a resurfacing arthroplasty of the hip.

Results: Data was received for 126 patients, 4 of whom did not provide any resource use data. For the remainder, data was imputed for costs or quality of life in at least one time point (baseline, 3 months, 6 months, 1 year) for 18 patients. Patients in the resurfacing arm had higher quality of life at 12 months (0.795 vs. 0.727) and received 0.032 more QALYs within the first 12 months post operation. At an additional cost of £564, resurfacing arthroplasty offers benefits at £17,451 per QALY within the first 12 months of treatment. When covariates are considered, the health economic case is stronger in men than women.

Conclusions: Resurfacing arthroplasty appears to offer very short term efficiency benefits over total hip arthroplasty within a selected patient group. The short-term follow-up in this trial should be noted, particularly in light of the concerns raised regarding adverse reactions to metal debris from MOM bearing surfaces in the longer term. Longer term follow up of resurfacing arthroplasty patients and decision analytic modelling is also advised.~~This conclusion should be tested over a longer period through longer series following up resurfacing arthroplasty and through decision analytic modelling.~~

Trial registration: Current controlled Trials ISRCTN33354155. UKCRN 4093.

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Introduction

Hip arthroplasty is acknowledged to be a highly effective and cost-effective procedure for treating patients with severe arthritis of the hip joint, with 87% of patients reporting an improvement in their general health following surgery.[1] The total health gain is expected to be substantial given the effectiveness of treatment; EuroQol (EQ-5D-3L) based quality of life improvements following surgery are estimated to be 0.409, within the 45,000 cases measured in the UK Patient Reported Outcomes programme[2]. 97% of UK hip replacements are still working (unrevised) at 5 years[3] and 83% of all primary hip arthroplasty (all age, all implant types) are unrevised at 17 years post surgery in Sweden[4]. If the initial quality of life gains are maintained, each unrevised surgery represents over five discounted quality-adjusted life-years (QALYs) gained and a benefit of over one hundred thousand pounds at the £20,000 per QALY threshold used by the National Institute of Health and Clinical Excellence (NICE). Compared to these gains, the costs of hip arthroplasty surgery appear modest. As a result, most analyses considering health economics have concentrated on questions of which type of prosthesis to use, and many cost-effectiveness analyses have involved analysis of newer, more expensive operations against older, established comparators.[5-7] Resurfacing arthroplasty of the hip is a newer alternative form of arthroplasty designed for younger, active patients with severe arthritis of the hip.

Hip resurfacing arthroplasty involves the insertion of an acetabular component and the 'capping' of the femoral neck, rather than its removal and replacement with a femoral component in a standard total hip arthroplasty. Of the 70,000 hip arthroplasty operations conducted in England and Wales every year[3], approximately 6% are hip resurfacings. The equivalent figure amongst men aged under 55 is 33%. As resurfacing preserves the bone of the proximal femur, it may be expected to provide better clinical outcomes on revision of this component than available with a standard hip arthroplasty. Despite advances in their construction, there are still questions about the durability of modern resurfacing implants and there have been few explicit economic evaluations comparing resurfacing arthroplasties against total hip arthroplasties. [8 9] Few randomised controlled trials have been conducted to assess the outcomes of hip resurfacing, and those that exist provide little detail about the economic costs and benefits within the initial year following surgery. This paper reports the first within-trial economic evaluation of resurfacing arthroplasty versus total hip arthroplasty.

Methods

Interventions and sample

This evaluation reports on the efficiency of resurfacing arthroplasty (RSA) versus total hip arthroplasty (THA). Patients were deemed eligible for the trial if they were aged over 18 years of age, were medically fit for an operation, and were deemed suitable to receive a resurfacing arthroplasty. Patients were only excluded from the study if there was evidence that the patient would be unable to adhere to trial procedures or complete questionnaires. Patients were randomised on a 1:1 basis between THA and RSA, with each patient operated on according to the preferred technique of the operating surgeon. Other perioperative interventions, such as prophylactic antibiotics and thrombo-prophylaxis were the same for all patients and the same standardised rehabilitation plan was employed for both trial arms. Further details on recruitment, ethics, and randomisation procedures are reported ~~elsewhere~~in both the RCT's protocol and reporting papers.[10, 12] The main outcome measure of the trial was hip function (Oxford Hip Score; Harris Hip Score) at 12 months, and the trial found no evidence of a difference between RSA and THA.

Perspective

The aim of the economic study is to determine the intervention that would maximise health outcomes within the limited National Health Service (NHS) budget in this period, and so a cost-effectiveness (cost-utility) analysis with an NHS and Personal Social Services (PSS) perspective is adopted in the base case. This paper considers the within-trial period (as intention to treat) of the first 12 months follow up. It considers only resources used within the NHS setting including any aids and adaptations required. The base year for all costs figures was 2009/10, with figures from other years converted using the hospital and community health services Pay and Prices Index (for adults, excluding capital).[11] For current costs, figures are deflated assuming an estimated inflation rate of 1.9% to 2010 from this index for both 2009/10 and 2010/11. As the analysis uses a one year time horizon, discounting for the future cost and health outcome is not necessary in this analysis. The currency used was the pound sterling (£).

Quality of life

Responses from the EQ-5D-3L were obtained from patients at baseline, 3 months, 6 months and 12 months as secondary outcomes of the trial[10]; results from other outcomes are reported in greater depth elsewhere.[12] The standard tariff values[13] were applied to these responses at each time point to provide EQ-5D-3L quality of life values. Quality-adjusted life-years (QALYs) were calculated as an "area under the curve" and form the main outcome measure of the study. Where comparisons between the RSA and THA arms are based on non-imputed data, a two-sample t-test assuming equal variances is used.

Resource use and valuation

The costs of THA and RSA treatments were considered across six broad categories – the costs of the initial operation, of inpatient care post-discharge, of outpatient care, of primary/community care, and of medications, and aids/adaptations required whilst in the community. The analysis considered inpatient and outpatient attendances for all reasons, and requested details of other resource usage only where it related to pain or hip surgery.

All RSA patients received a Cormet metal-on-metal resurfacing (Corin Group, Cirencester, UK), whilst THA patients received their surgeon's preference of prosthesis. For the patients having RSA this was a Cormet resurfacing implant (Corin Group, Cirencester, UK). For the patients having THA the prosthesis type was identified from patient records, with three types of bearing surface (ceramic femoral head on ceramic socket, metal-on-metal and metal-on-polyethylene) accounting for 95% of cases. The University Hospitals Coventry and Warwickshire NHS Trust Finance Department provided implant costs list prices for both the resurfacing implant and representative cost figures for these three types of prosthesis. In the remaining 5% of cases, implant type was treated as missing and were imputed to fall in one of these groups.

The current Healthcare Resource Group v.4 (HRG4) reference costs include the cost of prosthesis across all ages, and in most cases this will be a THR as HRG4 does not include a single category for primary replacements (as appeared in previous versions). Identified national-level HRG4 frequencies for primary hip replacements are available[14] and these are used to calculate an average cost, average length of stay, and average cost per excess bed day. By deducting the expected THA cost from the average cost, we obtain a non-prosthesis average cost, to which it is possible to add the appropriate prosthesis cost relevant to each individual. From here, an average cost of the initial hospitalisation is calculated for each patient by adjusting for each patient's length of stay (as a number of bed days from the mean). In this way, a person admitted for the average length of stay would be assigned the average cost of treatment, with those staying shorter and longer periods assigned lower and higher costs, respectively.

Data regarding length of stay and implant received were obtained from hospital records, with the remainder of the costing information obtained from patient-reported data. Resource usage was assessed alongside other outcomes at 3 months, 6 months and 12 months. For the 3 month data, the recall period was since discharge from hospital. For the other cases, it was since the last questionnaire was due to be completed. The questionnaires included sections on further inpatient care following the initial operation (speciality and length of stay/day case), outpatient care, primary and community care, aids and adaptations provided by the NHS/social services, and medication (pain relief and other NHS medication). Medicines usage was estimated based on mean dosage when used and average usage within the three budgetary periods (discharge to 3 months, 3-6 months, 6-12 months). In order to convert resource usage figures into costs, unit cost figures were assigned from NHS Reference costs[15], PSSRU unit costs[11], NHS Electronic Drug Tariff[16], and reported unit costs of acupuncture and chiropractic from previous studies. Individual resource items and unit prices, including for aids and adaptations, are available in Tables provided as a Web Extra. Where statistical tests analyse resource usage data, t-tests are used to test for differences in expected usage (assuming equal variance and non-imputed data).

Data on personal costs (out of pocket medicine usage and time off work for either the patient or a carer) were also collected. NHS unit costs were used to provide an indicative figure for private medicines costs, whilst 2009 median gross weekly earnings from full time jobs (£488.70) was used to identify a daily productivity cost of £97.74. These are used in the sensitivity analysis considering societal costs.

Missing data

Where data was incomplete we used multiple imputation via chained equations (ice)[17] to complete missing data using STATA 11 (StataCorp 2009, TX, USA). [18 19] Missing cost data was predicted in terms of QALYs, treatment received, length of stay (LOS), age, gender, height, weight, and baseline clinical scores (Oxford Hip Score, Harris Hip Score); missing QALY data was predicted in terms of this same list (excluding QALYs), plus each of the cost items; missing LOS was predicted using the same list as for QALYs, with QALYs included. In order to remove implausible data, missing cost data was constrained to be positive and length of stay was constrained to be at least three days post-imputation. A total of 50 imputations were used to inform each item of missing data. Where tests are conducted to detect significant differences in mean values between the RSA and THA groups based on imputed data (i.e. incremental costs and QALYs), the analysis uses an OLS regression within the STATA's mim command.

<u>Cost-effectiveness</u>

Using the methods identified above, total costs and QALY figures were calculated for all patients including imput~~at~~ed data. For the cost-effectiveness analysis, we identified the differences between costs and QALYs between the two arms, dividing the former by the latter to compute an incremental cost-effectiveness ratio (ICER). When compared against the marginal trade-off for the NHS as a whole – the cost-effectiveness threshold – the ICER gives a broad indication of whether spending additional money on hip arthroplasty appears efficient. The ICER figure is not presented with a confidence interval due to difficulties in interpreting a ratio of two random variables. Instead, we assume that each QALY is valued at £20,000 and subtract costs from this 'monetised' QALY in order to obtain a net monetary benefit (NMB). Any treatment with an ICER below £20,000 will have a positive NMB, with higher NMB figures unambiguously better and lower NMB figures unambiguously worse. As before, a 95% confidence interval is formed for NMB using linear regression using STATA's mim command.

<u>Scenarios/univariate sensitivity analyses</u>

Key uncertainties in the scenarios considered were explored using univariate sensitivity analyses. The results for complete cost and quality of life data (i.e. those with no missing data) were provided to identify the impact of missing data on the analysis. A strict per-protocol analysis of the data is also used to reflect any sensitivity to protocol violations. A societal perspective was also explored by adding the patient medicines and productivity costs outlined above to the NHS + PSS costs. As patients might also recover function within the first three months (rather than continuously to three months), a quicker initial recovery was explored in QALY calculations, where each patient's quality of life was assumed to reach its observed 3-month level at 6 weeks post-operatively. The cost assumptions in the analysis were modified by assessing the impact of assuming the least expensive (metal on polyethylene) THA implant was used throughout with no effect on observed outcomes, to reflect the potential concern that the THA arm might not reflect cost-effective practice. The recent (after the trial)current recommendations against the use of metal on metal THA prostheses are briefly considered by setting all 'metal on metal' implants to missing, estimating which THA prosthesis (i.e. metal on polyethylene or ceramic on ceramic) each patient will receive using multiple imputation, and considering the cost implications within these alternative estimates.

Adjustment for potential baseline differences

The base case analysis was conducted to allow for comparability between this within-trial analysis and the reporting of the main RCT[12]. These quality of life and gender-based analyses are conducted as *sensitivity* analyses to allow comparability with the main RCT, which did not find a significant difference in baseline quality of life and did not test for an interaction between efficacy and gender. Given that these issues may be important within the economic evaluation, they are considered as sensitivity analyses.

As the baseline randomisation did not stratify by quality of life, tThe impact of potential baseline differences in quality of life are corrected for using regression analysis within a sensitivity analysis. The number of QALYs received (average quality of life over 12 months) is assumed to be a normal distribution, conditional on trial arm (RSA or THA))and baseline EQ-5D-3L value. Total cost over 12 months is assumed to be lognormal, so that the natural logarithm of costs is a normal distribution, conditional on trial arm, baseline EQ-5D-3L.

QALYs and (log-)costs for each person are estimated using ordinary least squares regression (using STATA's mim command to handle imputed data). As any relationship between uncertainty in the extra costs and benefits associated with RSA is important when assessing the likelihood of cost-effectiveness, we use a seemingly unrelated regression to do this.. By using a Cholesky Decomposition of the variance-covariance matrix, (log-)costs and QALYs are modelled as if they come from a multivariate normal distribution. Uncertainty in the value of other items in the regression is ignored. From here, costs are estimated as if all patients receive THA, and incremental costs are calculated as a proportion of the average THA cost. In this way, a distribution is built up for incremental costs and incremental QALYs that can be analysed using cost-effectiveness acceptability curve (CEAC) can be formed for this analysis. [21] This CEAC indicates the likelihood that RSA will be cost-effective at different 'values' for a QALY.

As gender so heavily affects the clinical use of RSA, this analysis was re-run for both male patients only and female patients only. This allows the effects of RSA to be assessed separately for men and women, with this figure presented as the likelihood of that RSA would be cost-effective at a threshold value of £20,000 per QALY.

Results

Trial recruitment

The trial[12] recruited a total of 126 patients (RSA=60; THA=66) between May 2007 to February 2010. Two patients from each arm of the study did not have surgery and provided only baseline quality of life/demographic data, leaving a total of 58 and 64 patients in each arm. The sample was representative of the broader population undergoing resurfacing in the UK during the period of recruitment; no significant differences were identified between those who took part and those who were eligible but chose not to take part. Further details on both the ethical approval for the study and the demographics of the patients are provided in the clinical paper.[12] As the analysis estimates data on costs and outcomes conditional on baseline quality of life, these patients cannot contribute any data to our analysis and are excluded from the analyses here.

Quality of life

Table 1 summarises quality of life estimates at the four time points and calculates QALY estimates both with and without data imputation in the two arms. Overall, those in the RSA group started in worse health (as measured by the EQ-5D-3L) and received 0.033 more QALYs within the 12 months of the trial (n=118 observations). When the small amount of missing data is imputed, the estimated benefit remains very similar at 0.032 (95%CI, -0.054, 0.119). Within the trial, the difference in quality of life between the RSA and THA arms of the trial appears to increase at each post-operative time point.

Costs and resource usage

Overall, NHS and social care costs were significantly higher amongst the RSA group with an average of £564 more spent within the first 12 months from the operation (Table 2), of which the majority is due to the higher cost of implants and length of stay following the initial operation (£184), subsequent inpatient care (£279) and outpatient care (£84). The deflated cost of the RSA implants including operative consumables used in this study was £1,826 vs. an average of £1,700 for THA operations, based on imputed data. THA implants differed in costs, with the most expensive being ceramic on ceramic implants (£2,042) and those using metal on metal implants costing slightly less than RSA implants (£1,625). Implants and consumables in metal on polyethylene operations (£843) were associated with only 40% of the cost of ceramic on ceramic implant. Whilst the resurfacing implants were more expensive, they were also associated with a slightly longer length of stay (5.7 vs. 5.5 days), although this difference was not statistically significant (P = 0.536; imputed data).

Those in the RSA arm had significantly more outpatient visits than those in the THA arm (5.155 vs. 3.063, P = 0.0054; non-imputed data). Here, both the number of physiotherapy sessions and the use ofdeep vein thrombosis assessments were significantly higher amongst this group (P = 0.002, P = 0.011; non-imputed data). For inpatient care, only subsequent inpatient attendances (0.155 vs. 0.047, P = 0.066; non-imputed data) approached significance, with the only significant difference (P = 0.009) in aids and adaptations favouring RSA. For full details on individual resource use items and their unit costs, please see the tables available as a Web Extra.

The private costs to patients following arthroplasty surgery are considerable, although relatively little of this is due to the purchase of medication. There are no significant differences in medication usage between the RSA and THA arms, and the total costs of this treatment is similar (£12 RSA vs. £9 THA, P = 0.667). RSA patients report an average of 73 days off work, as against 57 days for THA patients (P = 0.333). Whilst surgery results in a large number of days off work for the patient, carers tend to take very few days off work (2.1 days RSA vs. 1.6 days THA; P = 0.595). Overall, RSA patients report costs valued at £5,917, as against £5,853 in the THA arm (imputed data). This difference is small but highly uncertain, such that there is no significant difference in costs from a societal perspective (£629 higher costs in RSA, 95%CI: -£2,456 -£3,713).

Cost-effectiveness and sensitivity analyses

Whilst RSA is expected to cost more over the first 12 months following an operation, it appears to provide a difference in quality of life. Here, the incremental cost-effectiveness ratio (ICER) for RSA is £17,451 per QALY (£564/0.032 QALY). Within most of the sensitivity tests explored here, the figure appears to remain within or below the £20k-£30k per QALY range used by the National Institute for Health and Clinical Excellence as its estimate of the cost-effectiveness threshold, except where cheaper THA implants are used in place of surgeon's preference, which was mostly MOM THA within the trial -(Table 3). If the cheaper (metal-on-polyethylene) implants are used, the increased cost of RSA vs. THA implants is enough to raise the average cost difference above £1,000 which, given the small quality of life difference observed here, is enough to prevent RSA being cost effective. However, if we consider *both* types of non-MOM implants (ceramic-on-ceramic and metal-on-polythene), this difference disappears entirely as the non-MOM implants were slightly more expensive on average than the MOM ones. ~~As is normally the case in economic evaluations, however, t~~The confidence interval for net benefit in every analysis spans zero (Table 4) so that the findings do not reach statistical significance. As clinical trials are very rarely designed with the power of cost-effectiveness conclusions in mind, very little can be inferred from this lack of significance.

Adjustment for baseline differences

Once baseline differences in EQ-5D-3L are considered, the QALYWAT estimates for the first 12 months appear to change. QALYs are higher generally amongst those who are healthier at baseline (EQ-5D-3L; P=0.000), with those treated in the RSA arm receiving 0.053 more QALYs than those treated with THA (P=0.119). Likewise, log-costs appear to be affected by baseline health (P=0.034), with costs 7.1% higher (95%CI: 1.7%-12.9%) for those who received RSA after bootstrapping.

Whilst correcting for baseline differences leaves the incremental costs largely unchanged (£473; 95%CI: 107-840), the estimated QALY benefit almost doubles (0.053, 95%CI: -0.014-0.120). Consequently, the ICER is around half as large (£8,905 per QALY) as the non-adjusted case. In 79% of cases investigated, RSA is recommended when valuing health at £20,000 per QALY – suggesting quite high confidence that RSA is the more cost-effective option within the first 12 months of treatment across the £20k-£30k range used by NICE (Figure 1). Where this analysis is re-run for male patients only (n = 71), neither incremental costs nor incremental QALYs reach statistical significance and the ICER falls to £5,519 per QALY. For female patients (n=51), the ICER is about three times as large as for males (£16,272 per QALY) due to higher costs and lower benefits, with the latter exacerbated by a much lower baseline quality of life (female 0.257, male 0.389; P=0.032). Within the scenarios used here, RSA is only 54% likely to be cost-effective for female patients at £20,000 per QALY, compared to an 86% likelihood for male patients.

Discussion

In comparison to standard total hip arthroplasty, hip resurfacing arthroplasty appears to provide a modest QALY gain for a modest sum within the first 12 months from surgery; whilst the additional costs of RSA are statistically significant, the additional benefits are not. The higher costs of RSA treatments are largely due to slightly higher costs for the initial operative and recovery periods, and higher usage of outpatient services. Whilst the RSA group achieves slightly better health outcomes and requires more services, this may be due to heterogeneity in outcomes; if resurfacing works well for most but poor for some, then this could produce this type of phenomenon. If so, this emphasises the need to follow patients up in the longer term.

The analysis presented here analyses the data by considering potential confounding due to both gender and baseline quality of life, and this nearly doubles the estimate of RSA effect size. Whilst the main analysis of the trial data[12] found no statistically significant difference in hip function between the RSA and THA groups at 12 months, it seems likely that some short term difference in quality of life exists favouring RSA and that – again within 12 months – there is enough evidence to suggest that it may be cost-effective.

Within the first 12 months of treatment, the main caveat to our results deals with the comparator THA arm. The pragmatic nature of the trial data used here [12] is one of its key strengths, since it reflects current practice. Any changes to this practice may affect cost-effectiveness though, so that RSA may become more/less cost-effective as less/more cost-effective THA implants are used. A recent (US) analysis of registry data suggests that more expensive implants do not provide a substantive age-adjusted advantage over less expensive prostheses.[22] Where the sensitivity analysis assumed the use of the cheapest metal-on-polyethylene implants (without incorporating a possible impact on quality of life), RSA was no longer cost-effective within-trial. However, these implants were used relatively rarely in practice, and the ~~this is somewhat unrealistic to assume, as the~~ main alternative to metal on metal THA implants ~~appears to be~~ was the more expensive ceramic on ceramic type. Restrictions in the use of MOM THA implants within the UK are likely to lead to ~~more~~

~~of these (likely) less cost-effective~~ more costly THA implants being used, and so a net ~~n~~ increase in the cost-effectiveness of resurfacing by comparison ~~implants~~.

Beyond the issues surrounding the choice of THA, the trial is inevitably unable to consider all possible cost items. The trial did not explicitly consider any differences in operative time between the RSA and THA arms; no difference was expected and an informal analysis of the data suggests very similar operative times between the arms. This evaluation was also unable to consider the impact of variation in cost within each type of prostheses (i.e. within the three types of THA, or beyond the single RSA used in the trial) as this information is not generally available. The clinical trial upon which this analysis is based used a single type of Cormet prosthesis that has been used in the UK for around 15 years. ~~As such, our findings are not necessarily generalisable to other types of resurfacing and we cannot identify the most cost-effective type of resurfacing as this is beyond the scope of the trial.~~ Whilst the list price of the Cormet prosthesis is similar to other prostheses available locally, prices are hospital-specific and so some caution is warranted when seeking to generalise findings to other locations. We note also that our findings are not necessarily generalizable to other types of resurfacing, including emerging technologies such as ceramic on ceramic resurfacings. Whilst the cost-effectiveness of these newer treatments may differ from standard resurfacings, we cannot identify the most cost-effective type of resurfacing as this was beyond the scope of the trial and relatively little data exists on which to base even a preliminary estimate. To the degree that this may prove possible, it is an issue for subsequent decision analytic modelling.

Clearly, the cost-effectiveness of resurfacing is likely to require assessment over a longer period of time – as is typically the case for any health economic analysis of trial data.[23] Importantly, the higher revision rates reported for resurfacing arthroplasty suggest that the additional costs of RSA may be higher if a longer period is considered. On the benefit side of the equation, the impact of extending the time period is unclear as RSA may improve quality of life in the short term but lead to a quicker deterioration once revisions are necessary, or require additional monitoring or revisions by virtue of its 'metal-on-metal' nature. One method to explore these questions may be decision analytic modelling.[23] The trial provides an estimate of short term clinical benefits from hip function and quality of life (conditional on EQ-5D-3L), with longer follow up series (from trials or registry data) needed to model implant survival for both RSA and THA.

As THA revision surgery may be surgically more complex, financially more costly, and less effective than a primary THA, a key question when interpreting this study is the prognosis for patients after their RSA is revised. An Australian registry analysis suggests poor implant survival amongst patients receiving a revision of only the acetabular RSA component, and some evidence of higher revision risks among other types of RSA revisions such as where both components are revised.[24] It is unclear, however, whether a revised RSA is more similar, in terms of quality of life, to a primary THA or a revision THA. Further research is necessary to assess the likely impact of this and other questions to guide future research, and the findings of this paper are by no means a complete answer to the decision problem.

Registry data reveals that women represent 61% of primary THA patients in the UK but make up only 25% of RSA patients.[3] These figures reflect relevant gender differences from both a clinical and a health economic perspective as women appear to obtain higher quality of life gains from THA, and face an increased revision rate from RSA.[4 25] This trial may also suggest a lower benefit from RSA relative to THA amongst women, although the finding was not statistically significant (or powered to be so). Despite the conclusions of the within-trial analysis, it seems clear that until such work is done and further data is available, the cost-effectiveness of resurfacing arthroplasty in a UK context remains potentially promising but as yet unproven.

Table 1. EQ-5D-3L quality of life at each measurement and converted into QALYs (missing data imputed)

Quality of life	RSA (SD) n =58	THA (SD) n =64	Difference[+] (95% CI)
Baseline	0.308 (0.338)	0.356 (0.335)	-0.048 (-0.168, 0.073)
3 months	0.722 (0.229)	0.698 (0.284)	0.023 (-0.711, 0.118)
6 months	0.796 (0.244)	0.747 (0.287)	0.050 (-0.046, 0.146)
12 months	0.795 (0.282)	0.727 (0.319)	0.067 (-0.042, 0.177)
QALYs (n = 118)	0.716 (0.216)	0.683 (0.252)	0.033 (-0.053, 0.120)
QALYs[*] (n = 122)	0.713 (0.216)	0.681 (0.251)	0.032 (-0.054, 0.119)

* With imputed data

Table 2. Costs by type, summed across trial period (missing data imputed)

Costs	% imputed	RSA (SD) n =58	THA (SD) n =64	Difference (95% CI)
Initial	7%	£6275 (557)	£6091 (532)	£184 (-18, 386)
Subsequent	11%	£470 (956)	£191 (558)	£279 (-11, 569)
Outpatient	11%	£360 (294)	£276 (210)	£84 (-13, 181)
Primary/community	11%	£63 (98)	£49 (67)	£14 (-17, 45)
Aids and	11%	£21 (33)	£21 (40)	£0 (-14, 14)
Medication	11%	£27 (43)	£24 (41)	£3 (-13, 19)
NHS + PSS Costs	--	£7217 (1320)	£6653 (917)	£564 (144, 985)
Private costs	61%	£5917 (5145)	£5853 (5520)	£64 (-3017, 3146)
Societal cost	--	£13,134 (5146)	£12,506 (5568)	£629 (-2456, 3713)

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Societal cost	--	£13,134 (5146)	£12,506 (5568)	£629 (-2456, 3713)

Table 3. Incremental cost effectiveness

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Scenario	Incremental costs (95%CI)	Incremental QALYs (95%CI)	ICER (per QALY)
Base case (BC)	£564 (144, 985)	0.032 (-0.054, 0.119)	£17,451 ~~per~~
Per protocol	£528 (85, 970)	0.024(-0.066, 0.113)	£22,227 ~~per~~
Complete case data (N=98)	£721 (286, 1157)	0.053 (-0.042, 0.149)	£13,443 ~~per~~
Societal costs	£629 (-2456, 3713)	0.032 (-0.054, 0.119)	£19,435 ~~per~~
Metal/polyethylene THA implants	£1271 (859, 1684)	0.032 (-0.054, 0.119)	£39,318 ~~per~~
No metal on metal THA implants	£522 (76, 968)	0.032 (-0.054, 0.119)	£16,137 ~~per~~
Quicker initial recovery	£564 (144, 985)	0.039 (-0.048, 0.127)	£14,310 ~~per~~
~~Adjustments for quality of~~	£473 (113, 853)	0.053 (-0.014-0.120)	£8,905 ~~per~~
~~Adjustments for~~ QoL adjustments	£402 (-82, 916)	0.073 (-0.012, 0.158)	£5,519 ~~per~~
~~Adjustments for quality of life~~QoL	£598 (64, 1172)	0.037 (-0.070, 0.144)	£16,272 ~~per~~

Table 4. Net Monetary Benefit

Scenario	NMB (95%CI)*
Base case (BC)	£82.46 (-1795, 1960)
Per protocol	-£53 (-2011, 1905)
Complete case data (N=98)	£353 (-1719, 2426)
Societal costs	£19 (-3641, 3680)
Metal/polyethylene THA implants	-£625 (-2515, 1265)
No metal on metal THA implants	£125 (-1750, 1999)
Quicker initial recovery	£224 (-1658, 2107)
Adjustments for quality of life	£590 (-834, 2014)
Adjustments for quality of life, males	£1055 (-843, 2954)
Adjustments for quality of life, females	£137 (-1988, 2262)

QALYs valued at £20k each

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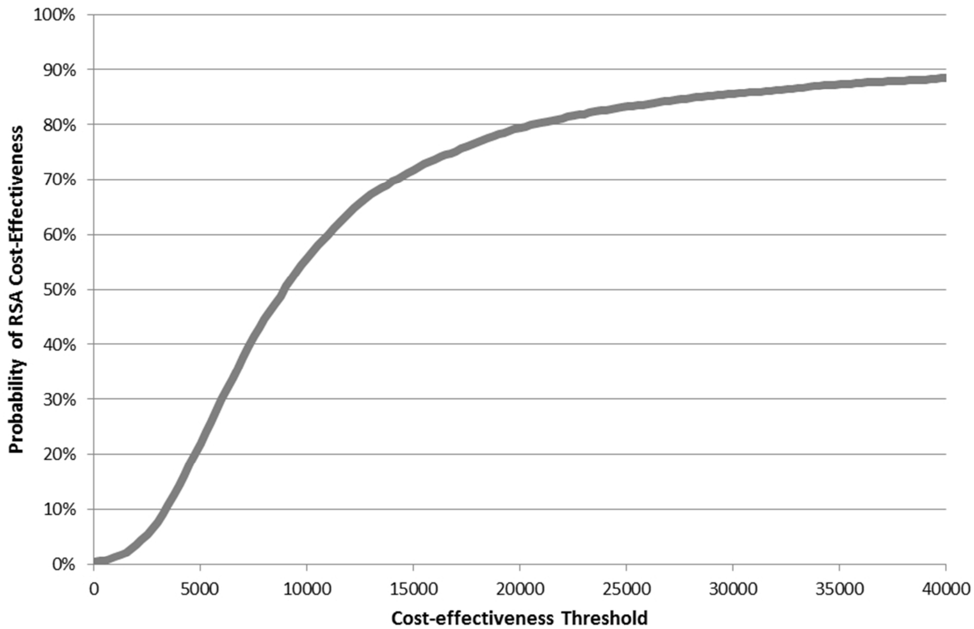

Figure 1: Cost-Effectiveness Acceptability Curve for Resurfacing Arthroplasty (vs. THA)
258x168mm (96 x 96 DPI)

Web Extra: Table 1 – Unit cost of resources

Item	Cost	Source
Initial Operation		
Cost for average THA	£6381	Uses weighted average of outcomes from HB11B, HB11C, HB12A, HB12B, HB12C.*
Average LOS for THA	6.57 days	
Adjustment per day ± av. LOS	£296	
THA: implant + consumables	£2,042	Ceramic femoral head, ceramic socket
	£1,625	Metal femoral head, metal socket
	£843	Metal femoral head, polyurethane socket
	£1,738	Weighted average of THA implants + consumables
RSA: implant + consumables	£1,850	Cormet resurfacing
Subsequent Inpatient Care		
Inpatient (orthopaedics)		
Day case	£874	TPCTDC. Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Cost for average LOS	£1,888	TPCTEI: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Average LOS	1.98 days	TPCTEI: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Adjustment per day ± av. LOS	£340	TPCTEIXS: Minor Hip Procedures for non Trauma Category 1 without CC (HB16C)*
Inpatient (other)		
Elective, non-investigational	£668	Average across all day cases (TPCTDC)*
Elective, investigational	£243	Average cost radiotherapy inpatient, PSSRU 2010
Acute surgical/medical	£535	Average across all non-elective (short stay) cases (TPCTNEI_S)
Outpatient care		
Orthopaedics	£96	OPATT: Trauma & Orthopaedics: Non-Trauma (110N)*
Haematology	£128	OPATT: Clinical Haematology (303) *
Pathology or radiology	£114	Average cost per outpatient radiotherapy contact, PSSRU 2010
Ophthalmology	£80	OPATT: Ophthalmology (130) *
Orthotics	£96	OPATT: Trauma & Orthopaedics: Non-Trauma (110N)*
Physiotherapy	£39	OPATT: Physiotherapy Total Attendances - Adult (19 and Over (650A)*
Chiropractor	£17	Ongoing treatment session from UK BEAM trial http://www.bmj.com/content/329/7479/1381.full costed at £12.17 in 2000 base year. Reflated using NHS Pay and Prices Index.
Dermatology	£92	OPATT: Dermatology (330)*
Acupuncture	£30	Ongoing treatment session from RCT http://www.bmj.com/content/333/7569/626.full costed at £24 in 2002-3 base year. Reflated using NHS Pay and Prices Index.
Accident and Emergency	£113	OPATT: Accident and Emergency (180)*
DVT assessment service	£129	TPCTDC. Deep Vein Thrombosis (QZ20Z)*
Heart specialist/cardiologist	£124	OPATT: Cardiology (320)*
Urology	£99	OPATT: Urology (101)*
Neurophysiologist/neurologist	£166	OPATT: Neurology (400)*
Eye clinic	£80	OPATT: Ophthalmology (130) *
Oncologist	£107	OPATT: Clinical Oncology (800) *
Dietician	£32	PSSRU 2009-10: Cost per hour in clinic, incl. qualifications

Item	Cost	Source
Dentist	£100	OPATT: Dental Medicine Specialties (450) *
Thoracic	£216	OPATT: Thoracic Surgery (173) *
Primary and community care		
In surgery/clinic		
GPs	£28	Cost per surgery consultation, PSSRU Unit Costs 2010
Practice Nurse	£9	Cost per surgery consultation, PSSRU Unit Costs 2010
District nurse	£22	Cost per 15.5 minutes community nurse, PSSRU Unit Costs 2010
Physiotherapist	£15	Cost per clinic visit, PSSRU Unit Costs 2010
Occupational therapist	£15	Cost per surgery visit, PSSRU Unit Costs 2010
At home		
GPs	£94	Cost per home visit, PSSRU Unit Costs 2010
Practice Nurse	£13	Cost per home visit, PSSRU Unit Costs 2010
District Nurse	£37	Cost per home visit, community nurse, PSSRU Unit Costs 2010
Physiotherapist	£41	Cost per home visit, PSSRU Unit Costs 2010
Chiropodist	£20	Cost per home visit, PSSRU Unit Costs 2010
Dermatologist	£92	As for outpatient. OPATT: Dermatology (330)*
Aids and adaptation		
Walking stick	£8.02†	http://www.mobilitysmart.cc/sticks-crutches-canes/walking-sticks-canes/metal-sticks-canes/economy-ergonomic-walking-stick-p-16711.html
Crutches	£25.03†	http://www.mobilitysmart.cc/sticks-crutches-canes/crutches/closed-cuff-crutches/coopers-elbow-crutches-plastic-handles-p-13037.html
Wheelchair	£146.54†	http://www.mobilitysmart.cc/wheelchairs/self-propelled-wheelchairs/lightweight-self-propelling-wheelchair-p-14090.html
Insoles	£22.15†	http://www.mobilitysmart.cc/footcare/insoles-heel-pads/cosyfeet-orthaheel-workforce-p-17086.html
Zimmer	£44.29†	http://www.mobilitysmart.cc/walkers-shoppers/walkers-zimmer-frames/folding-walking-zimmer-frame-with-wheels-p-10599.html
Toilet seat	£12.84†	http://www.mobilitysmart.cc/toileting/toilet-seat-cushions/padded-toilet-seat-with-rim-vinyl-cover-p-671.html
Sock aid	£4.01†	http://www.mobilitysmart.cc/by-activity/getting-dressed/sock-stocking-aid-p-14742.html
Grabber	£5.89†	http://www.mobilitysmart.cc/home-garden-aids/reachers-grabbers/reacher-grabber-pick-up-tool-p-13495.html
Shoe horn	£3.85†	http://www.mobilitysmart.cc/plastic-shoe-horn-p-9955.html
Trolley	£28.53†	http://www.mobilitysmart.cc/trolleys-steps-stools/trolleys/tri-wheeled-shopping-trolley-p-10107.html
Perching stool	£43.33†	http://www.mobilitysmart.cc/trolleys-steps-stools/perching-

Item	Cost	Source
		stools/standard-perching-stool-p-765.html
Frame	£44.29†	http://www.mobilitysmart.cc/walkers-shoppers/walkers-zimmer-frames/folding-walking-zimmer-frame-with-wheels-p-10599.html
Clothes aid	£11.08†	http://www.mobilitysmart.cc/comfort-dressing/dressing-aids/dressing-stick-p-300.html
Medications (price per tablet /tube) related to hip/hip pain		
Co-codamol	£0.05†	30mg/500mg capsules (from pack of 100)
Codeine	£0.04†	30mg tablets (from pack of 28)
Paracetamol	£0.03†	500mg capsules (from pack of 32)
Tramadol	£0.04†	50mg capsules (from pack of 30)
Amitriptyline	£0.03†	25mg tablets (from pack of 28)
Dihydrocodeine	£0.03†	30mg tablets (from pack of 100)
Diclofenac	£0.28†	50mg tablets (from pack of 21)
Ibuprofen	£0.02†	400mg tablets (from pack of 84)
Naproxen	£0.06†	500mg tablets (from pack of 28)
Aspirin	£0.01†	300mg tablets (from pack of 32)
Warfarin	£0.03†	5mg tablets (from pack of 28)
Zopiclone	£0.05†	7.5mg tablets (from pack of 28)
Flucloxacillin	£0.10†	500mg capsules (from pack of 28)
Morphine	£0.09†	10mg tablets (from pack of 56)
Hydrocortisone	£3.44†	Cream 1% tube (from single tube)
Furosemide	£0.03†	40mg tablets (from pack of 28)
Buprenorphine	£0.24†	400μg tablets (from pack of 7)
Omeprazole	£0.20†	10mg tables (from pack of 28)
Productivity costs		
Day off work	£97.74	As 20% of £488.70; Median Gross Weekly Earnings from Full Time, Pay Unaffected by Absence, Office of National Statistics 2009 Annual Survey of Hours and Earnings. http://www.ons.gov.uk/ons/rel/ashe/annual-survey-of-hours-and-earnings/2009-results/stb-ashe-2009.pdf

* 2009-10 Reference Costs
† Figure shown is inflation adjusted.

Web Extra: Table 2 - Resource use by patients according to the arm intervention

	Mean Usage (SD)		P-value*
	RSA (n =58)	THA (n =64)	
Subsequent Inpatient Care			
Orthopaedics	0.155 (0.410)	0.047 (0.213)	0.066
Elective, non-investigational	0.034 (0.184)	0 (0)	0.136
Elective, investigational	0 (0)	0.016 (0.125)	0.343
Acute surgical/medical	0.086 (0.283)	0.063 (0.302)	0.656
Outpatient care			
Orthopaedics	1.569 (1.464)	1.672 (1.196)	0.670
Haematology	0.121 (0.378)	0.109 (0.475)	0.885
Pathology or radiology	0.397 (1.388)	0.234 (0.660)	0.405
Ophthalmology	0 (0)	0.016 (0.125)	0.343
Orthotics	0.017 (0.131)	0 (0)	0.295
Physiotherapy	2.534 (4.096)	0.656 (2.169)	0.002
Chiropractor	0.103 (0.552)	0 (0)	0.136
Dermatology	0.172 (0.131)	0 (0)	0.295
Acupuncture	0.052 (0.394)	0 (0)	0.295
A and E	0.052 (0.223)	0.047 (0.213)	0.903
DVT assessment service	0.155 (0.410)	0.016 (0.125)	0.011
Heart specialist/ cardiologist	0.034 (0.263)	0.094 (0.635)	0.510
Urology	0 (0)	0.047 (0.278)	0.201
Neurophysiologist/neurologist	0.017 (0.131)	0.016 (0.125)	0.945
Eye clinic	0.0344 (0.263)	0.063 (0.393)	0.648
Oncologist	0.017 (0.131)	0 (0)	0.295
Dietician	0.172 (0.131)	0 (0)	0.295
Dentist	0.172 (0.131)	0.031 (0.25)	0.703
Thoracic	0 (0)	0.016 (0.125)	0.343
Primary and community care			
In surgery/clinic			
GPs	1.224 (2.193)	0.938 (1.833)	0.434
Practice Nurse	0.345 (1.101)	0.516 (1.553)	0.489
District nurse	0.034 (0.263)	0 (0)	0.295
Physiotherapist	0.103 (0.788)	0.125 (1)	0.896
Occupational therapist	0 (0)	0.016 (0.125)	0.343
At home			
GPs	0 (0)	0.047 (0.278)	0.201
Practice Nurse	0.103 (0.447)	0.047 (0.035)	0.067
Chiropodist	0.034 (0.263)	0 (0)	0.295
District Nurse	0.155 (0.951)	0.031 (0.175)	0.308

		Mean Usage (SD)		P-value*
		RSA (n =58)	THA (n =64)	
Physiotherapist		0.121 (0.796)	0 (0)	0.228
Dermatologist		0.052 (0.292)	0.016 (0.125)	0.368
Aids and adaptation				
Walking stick		0.269 (0.597)	0.259 (0.902)	0.946
Crutches		0.431 (0.901)	0.421 (0.826)	0.950
Wheelchair		0.017 (0.131)	0 (0)	0.295
Insoles		0.034 (0.184)	0 (0)	0.136
Zimmer		0.017 (0.131)	0 (0)	0.295
Toilet seat		0.103 (0.307)	0.125 (0.333)	0.712
Sock aid		0.017 (0.131)	0.031 (0.175)	0.621
Grabber		0 (0)	0.109 (0.315)	0.009
Shoe horn		0 (0)	0.031 (0.175)	0.178
Trolley		0 (0)	0.031 (0.25)	0.343
Perching stool		0 (0)	0.047 (0.278)	0.201
Frame		0.017 (0.131)	0.016 (0.125)	0.945
Clothes aid		0.017 (0.131)	0 (0)	0.295
Medications				
Co-codamol	30mg/500mg	77.51 (141.29)	84.02 (172.51)	0.821
Codeine	30mg tablets	6.62 (33.08)	0 (0)	0.130
Paracetamol	500mg capsules	53.07 (148.95)	46.54 (136.14)	0.811
Tramadol	50mg capsules	54.98 (169.59)	17.88 (63.05)	0.124
Amitriptyline	25mg tablets	2.30 (16.45)	8.04 (33.61)	0.270
Dihydrocodeine	30mg tablets	7.42 (53.00)	1.51 (11.46)	0.409
Diclofenac	50mg tablets	44.67 (121.91)	38.15 (103.72)	0.764
Ibuprofen	400mg tablets	54.63 (146.76)	25.44 (100.35)	0.224
Naproxen	500mg tablets	21.34 (106.88)	13.59 (77.87)	0.662
Aspirin	300mg tablets	6.94 (34.69)	0 (0)	0.130
Warfarin	5mg tablets	13.76 (98.25)	0 (0)	0.288
Zopiclone	7.5mg tablets	2.30 (11.53)	0.97 (7.37)	0.467
Flucloxacillin	500mg capsules	6.94 (34.69)	3.05 (23.23)	0.489
Morphine	10mg tablets	0 (0)	5.06 (27.06)	0.184
Hydrocortisone	cream 1%	0 (0)	0.02 (0.13)	0.351
Furosemide	40mg tablets	0 (0)	3.05 (23.24)	0.351
Buprenorphine	400μg tablets	0 (0)	4.73 (35.99)	0.351
Omeprazole	10 mg tablets	7.12 (50.81)	6.26 (47.64)	0.927

* P-value, based on a two-sample t-test assuming equal variance

EVEREST STATEMENT / BMJ Checklist

Item	Y/N	Where?
(1) The research question is stated	Y	Page 4 "Perspective"
(2) The economic importance of the research question is justified	Y	Page 3 "Introduction"
(3) The viewpoint(s)of the analysis are clearly stated and justified	Y	Page 4 "Perspective"
(4) The rationale for choosing the alternative programmes or interventions compared is stated	Y	As a within trial analysis, this is determined by the trial design. This is varied in sensitivity analyses.
(5) The alternatives being compared are clearly described	Y	Page 3 "Introduction"
(6) The form of economic evaluation used is stated	Y	Page 4 "Perspective"
(7) The choice of form of economic evaluation is justified in relation to the questions addressed	Y	Page 4 "Perspective"
(8) The source(s) of effectiveness estimates used are stated	Y	Within trial, plus Methods section
(9) Details of the design and results of effectiveness study are given (if based on a single study)	Y	Within trial, plus Methods section. Findings of the main trial have been added.
(10) Details of the method of synthesis or meta-analysis of estimates are given (if based on an overview of a number of effectiveness studies)	NA	
(11) The primary outcome measure(s) for the economic evaluation are clearly stated	Y	Page 4-5, "Quality of life"
(12) Methods to value health states and other benefits are stated	Y	Page 4-5, "Quality of life"
(13) Details of the subjects from whom valuations were obtained are given	Y	Uses standard UK tariff to value EQ-5D outcomes, see "Quality of life"
(14) Productivity changes (if included) are reported separately	Y	These are reported in brief as a sensitivity analysis.
(15) The relevance of productivity changes to the study question is discussed	Y	Page 5-6, "Resource use and valuation". Brevity prevents this being included in depth
(16) Quantities of resources are reported separately from their unit costs	Y	Within Web Extra tables
(17) Methods for the estimation of quantities and unit costs are described	Y	Pages 5-6, "Resource use and valuation"
(18) Currency and price data are recorded	Y	Page 4 "Perspective"
(19) Details of currency of price adjustments for inflation or currency conversion are given	Y	Page 4 "Perspective"
(20) Details of any model used are given	NA	
(21) The choice of model used and the key parameters on which it is based are justified	NA	
(22) Time horizon of costs and benefits	Y	Page 4 "Perspective"
(23) The discount rate(s) is stated	NA	
(24) The choice of rate(s) is justified	NA	
(25) An explanation is given if costs or benefits are not discounted	Y	Justification is given by virtue of a 1-year timeframe.
(26) Details of statistical tests and confidence intervals are given for stochastic data	Y	Confidence intervals are inappropriate for ICERs but confidence intervals are provided for NMB. Detail on statistical tests are given throughout the methods (pp.4-8, and more detail is given

		specifically within the section on "Missing data" (p6) and "Adjustment for baseline differences" (p8)
(27) The approach to sensitivity analysis is given	Y	See Pages 7, "Cost-effectiveness", pp7-8 "Scenarios/Univariate sensitivity analysis", and p.8 "Adjustment for baseline differences"
(28) The choice of variables for sensitivity analysis is justified	Y	See Pages 7, "Cost-effectiveness", pp7-8 "Scenarios/Univariate sensitivity analysis", and p.8 "Adjustment for baseline differences"
(29) The ranges over which the variables are varied are stated	Y	We do not use one-way sensitivity analyses, and so this is not massively relevant (as are many parts of this checklist in 2012). The analyses relate more to specific changes to assumptions than arbitrary values for potentially key parameters.
(30) Relevant alternatives are compared	Y	Page 3 "Introduction"
(31) Incremental analysis is reported	Y	Page 10, "Cost-effectiveness and sensitivity analyses", Table 3
(32) Major outcomes are presented in a disaggregated as well as aggregated form		Table 1 provides disaggregated quality of life data, Table 2 provides cost data by general area, Web Extras provide disaggregated resource data.
(33) The answer to the study question is given	Y	Pages 10-11 provide firstly results where no adjustments are made for baseline differences, and then with this adjustment.
(34) Conclusions follow from the data reported	Y	Page 11-13, "Discussion" follows on from themes introduced in results
(35) Conclusions are accompanied by the appropriate caveats	Y	Page 12-13, Particularly with respect to time and the choice of THA implant.