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L Vale
L Wyness
K McCormack
L McKenzie
M Brazzelli
S Stearns

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A systematic review of the effectiveness and cost-effectiveness of metal-on-metal hip resurfacing arthroplasty for treatment of hip disease

L Vale[1,2*]
L Wyness[2]
K McCormack[1]
L McKenzie[2]
M Brazzelli[1]
SC Stearns[2]

[1] Health Services Research Unit, Institute of Applied Health Sciences, University of Aberdeen, UK
[2] Health Economics Research Unit, Institute of Applied Health Sciences, University of Aberdeen, UK

[*] Corresponding author

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Executive summary

Background

Disease affecting the hip joint is mainly caused by osteoarthritis, which may be primary or secondary, and the inflammatory arthropathies, of which rheumatoid arthritis is the archetype. Other conditions that cause arthritis and which could be treated by metal-on-metal hip resurfacing arthroplasty are avascular necrosis, congenital dislocation, Paget's disease, ankylosing spondylitis and traumatic arthritis.

The prevalence of osteoarthritis affecting the hip is difficult to estimate. A survey of 28,080 residents of Avon and Somerset (UK), aged 35 years and over, showed that 107 men per 1000 and 173 women per 1000 suffered from hip pain and that 15.2 people per 1000, aged between 35 and 85 years, had hip disease severe enough for surgery. There are fewer data on the incidence and prevalence of hip involvement in rheumatoid arthritis than for osteoarthritis. Hip involvement was found in 20% of patients with rheumatoid arthritis in a Swedish study, 3% of whom were found to have severe hip destruction. Other studies have reported the incidence of hip involvement in rheumatoid arthritis to be between 10% and 40%.

The predominant surgical intervention for the treatment of hip disease in use in England and Wales is total hip replacement (THR) with nearly 50,000 procedures performed annually, of which possibly as many as 7000 are revisions of primary THR. Swedish data suggest that moderate to severe osteoarthritis accounts for over 75% of the indications for THR, trauma for 11.3% and rheumatoid arthritis for 6%.

Aim

To assess the effectiveness and cost-effectiveness of metal-on-metal hip resurfacing arthroplasty compared with watchful waiting, THR, osteotomy, arthrodesis and arthroscopy of the hip joint. Suitable participants were those who would:

- be likely to outlive the life of a THR (i.e. those aged under 65 years)
- not be expected to outlive their prosthesis because of age (i.e. those aged 65 years and over) but who participate in activities predicted to shorten the life of a THR and who would thus outlive its life
- not be suitable for consideration for THR for reasons other than expected survival or activity.

Methods

A structured search of electronic databases, websites and relevant audit databases between 1990 and 2001 was conducted, using free text terms to identify potentially relevant papers evaluating metal-on-metal hip arthroplasty, osteotomy, arthrodesis and arthroscopy. A search was also carried out for randomised controlled trials (RCTs) of THR and systematic reviews of RCTs for THR.

Studies in languages other than English were identified from their abstracts but were not included in the review. Inclusion criteria for metal-on-metal hip arthroplasty studies were: any RCT comparing metal-on-metal hip arthroplasty with any other comparator that reported patient outcome data, and any comparative observational study comparing metal-on-metal hip arthroplasty with any other comparator that had concurrent controls and provided revision rates, clinical assessment or patient-based outcomes. There was no restriction on the length of follow-up. Single prosthesis observational studies of metal-on-metal hip arthroplasty were limited to those that provided revision rates, clinical assessment or patient-based outcomes, with a minimum follow-up of 2 years. For watchful waiting, arthrodesis, arthroscopy and osteotomy, inclusion was restricted to studies that made a relevant comparison or contained any observational data on the specified outcomes, with a minimum follow-up of 5 years (10 years for osteotomy). For THR, inclusion was restricted to RCTs with a minimum follow-up of 5 years and systematic reviews of such trials.

Details of study design, participants, setting and timing, interventions, patient characteristics and outcomes were recorded on a data abstraction form. Included studies were assessed using a

quality assessment form based on a checklist used to assess the quality of studies in orthopaedic research journals. The three systematic reviews included were quality assessed using a form specific to the assessment of the methodology of systematic reviews.

A systematic review of existing economic evaluations comparing metal-on-metal hip resurfacing arthroplasty with any of the comparators was conducted. Identified studies were critically appraised and their results summarised.

A Markov model comparing the comparators was developed, using the results of the review of effectiveness data together with data on costs from previous studies. This model was use to estimate costs and quality-adjusted life-years (QALYs) for up to 20 years following commencement of treatment. Subgroup analysis was conducted to reflect the costs and outcomes of those who would not be expected to outlive the life of a THR.

Results

Number and quality of studies

No studies were found that compared metal-on-metal hip resurfacing arthroplasty with any of the comparators. Data from case series were used as the basis of estimates of effectiveness for metal-on-metal hip resurfacing arthroplasty (five studies), watchful waiting (one study), osteotomy (12 studies), arthrodesis (one study) and arthroscopy (one study). Evidence for THR came from three systematic reviews and one RCT not previously identified by the systematic reviews. Substantial differences between studies were identified for the different interventions in terms of preoperative diagnosis, length of follow-up and outcome measures reported.

Summary of benefits

The evidence with which to assess the benefits of metal-on-metal hip resurfacing arthroplasty compared with the other interventions was very limited. In terms of revisions, over a 3-year follow-up period 0–14% of patients who received metal-on-metal hip resurfacing arthroplasty required a revision. The available data came from a comparatively small number of surgeons. In comparison, those managed by watchful waiting avoided an immediate operation but had a 30% chance of an operation over 3 years. THR (depending on the prostheses used) was associated with revision rates of 10% or less over a 10-year follow-up period, while revision rates for osteotomy were, with one exception, between 2.9% and 29% over a period of 10–17 years. The estimated revision rates for patients receiving arthroscopy were slightly higher than those for metal-on-metal hip resurfacing arthroplasty. No data were available on revision rates following arthrodesis.

Patients who underwent metal-on-metal hip resurfacing arthroplasty experienced less pain than those who were managed by watchful waiting, with data from one study suggesting that 91% of patients were pain free at 4 years. This compares with an estimate of 84% at 11 years for THR, 22% for arthrodesis at 8 years, and fewer patients pain free following arthroscopy. Similar data for osteotomy were not available.

Costs

All costs were estimated from an NHS perspective for the year 2000. The direct healthcare costs of each alternative treatment were estimated using information from a variety of sources, published and unpublished. The cost of metal-on-metal hip resurfacing arthroplasty for a patient aged under 65 years was estimated to be £5515. Other estimated intervention costs were: £4195 for THR, £6027 for revision THR, £951 for arthroscopy, and £2731 for osteotomy. The annual cost per patient for the watchful waiting alternative was estimated at £642.

Cost-effectiveness

Benefits in the economic model were measured in QALYs. Quality-of-life scores were based on assumptions about levels of pain associated with the treatment alternatives and published quality-of-life scores for mild, moderate and severe osteoarthritis of the hip. In the modelling process, these were combined with revision rates and mortality rates to generate QALYs.

For each intervention, the costs, probabilities and quality-of-life data were synthesised using a Markov model run over a 20-year period from initial intervention. Costs were discounted at 6% per annum and quality of life at 1.5%. The resulting present values of cost and quality of life for each intervention were then compared across interventions to calculate the incremental cost per QALY. Results for patients under 65 years at the time of treatment showed that metal-on-metal hip resurfacing arthroplasty was dominated (i.e. was more costly with the same or less benefits) by THR, owing to the assumptions about metal-on-metal revision rates and the lower cost of THR. Metal-on-metal hip resurfacing arthroplasty dominated (i.e. generated cost savings and the same or more benefits) the watchful waiting alternative within a 20-year follow-

up period. Incremental cost per QALY values of £3039 and £366 were estimated for metal-on-metal hip resurfacing arthroplasty relative to osteotomy and arthroscopy, respectively. For patients aged over 65 years, THR dominated metal-on-metal hip resurfacing. Sensitivity analysis revealed that metal-on-metal hip resurfacing arthroplasty was no longer dominated by THR once revision rates were less than 80–88% of THR revision rates. Sensitivity analysis was also performed using different metal-on-metal hip resurfacing arthroplasty operation times and different watchful waiting costs and quality-of-life values.

The economic modelling provided in this analysis was constrained substantially by the lack of data on key parameters for the economic models. The most severe problem was the limited information available for metal-on-metal hip resurfacing arthroplasty revision rates. For example, the alternative methods of metal-on-metal hip arthroplasty were considered as if they were a homogeneous set of procedures. In reality this is unlikely but there is very little evidence to suggest whether or not outcomes for different prostheses are similar. Another critical absence of data was on health outcomes for revision THR following metal-on-metal hip resurfacing arthroplasty.

Conclusions

The incremental cost-effectiveness ratios provided in the analysis illustrate several key points. First, the low quality of life experienced by young people with hip disease who have been advised to delay undertaking THR means that if metal-on-metal hip resurfacing arthroplasty can be proven (i) to have lower revision rates than THR over an extended period and (ii) to result in better outcomes from subsequent THR, then such a procedure could possibly be considered cost-effective or even dominant. Second, if metal-on-metal revision rates are below those for primary THR by a sufficient amount, then metal-on-metal hip resurfacing arthroplasty could possibly be judged cost-effective for older people who are more active and may outlive a primary THR.

The few data available on metal-on-metal hip resurfacing arthroplasty came from a very small number of clinicians. It is not clear whether their results could be replicated in practice. In particular, the available studies describe an evolution of the prostheses over time and also, presumably, surgical technique. To achieve the promising low revision rates indicated by recent unpublished data may require substantial training in the procedure as well as provision of the procedure on a high-volume basis to ensure skills are maintained. Potential increases in the surgical procedure rate as the threshold for treatment changes may require training of additional clinicians in order to avoid increases in waiting lists for orthopaedic procedures.

Information was not available on the quality of life of family and carers. An increase in quality of life for those with hip disease would reduce the burden on family members and carers.

Recommendations for research

All the limited data available and results obtained by modelling these data indicate that metal-on-metal hip resurfacing arthroplasty merits further investigation. The lack of any controlled studies comparing it with any of the comparators (but principally watchful waiting and THR) should be addressed in trials with long-term follow-up. Any comparison with watchful waiting is hampered by the absence of long-term data on metal-on-metal hip resurfacing arthroplasty, health outcome data following revision, and virtually any data on watchful waiting. Research is required to define more clearly what watchful waiting entails and how its outcomes compare with the other comparators, especially metal-on-metal hip resurfacing arthroplasty.

List of abbreviations

BHR	Birmingham hip resurfacing
CDSR	Cochrane Database of Systematic Reviews
CI	confidence interval
DARE	Database of Abstracts of Reviews of Effectiveness
GP	general practitioner
ICER	incremental cost-effectiveness ratio
MMT	Midland Medical Technologies (Ltd)
MOM	metal-on-metal hip resurfacing arthroplasty*
NA	not applicable*
NHS EED	NHS Economic Evaluation Database
NICE	National Institute for Clinical Excellence
NR	not reported*
NSAID	non-steroidal anti-inflammatory drug
QALY	quality-adjusted life-year
RCT	randomised controlled trial
SD	standard deviation
THR	total hip replacement
UCLA	University of California at Los Angeles*
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Measure

* Used only in tables, figures and appendices

Chapter 1

Aim of the review

The aim of the review was to evaluate the effectiveness and cost-effectiveness of metal-on-metal hip resurfacing arthroplasty for the treatment of hip disease in comparison to watchful waiting, total hip replacement (THR), osteotomy, arthrodesis, and arthroscopy for three groups of individuals with hip disease.

- People who would be likely to outlive the life of a THR (e.g. those aged under 65 years).
- People who would not be expected to outlive their prostheses because of age (e.g. those aged 65 years and over) but who participate in activities predicted to shorten the life of a THR and who would thus outlive the life of a THR.
- People who would not be suitable for consideration for a THR for reasons other than expected survival or activity.

Chapter 2
Background

Description of the underlying health problem

Metal-on-metal hip resurfacing, THR, osteotomy, arthrodesis and arthroscopy of the hip joint are all used to alleviate the symptoms of degenerative joint disease of the hip. Non-surgical interventions and medications can also be used to control these symptoms and delay or prevent the need for surgery. Collectively, such non-surgical interventions are given the title of 'watchful waiting' in this review.

The main underlying causes of degenerative hip disease may be osteoarthritis or rheumatoid arthritis. Other conditions that may cause secondary osteoarthritis, and which could be treated by metal-on-metal hip resurfacing arthroplasty, are avascular necrosis, congenital dislocation, Paget's disease, ankylosing spondylitis and traumatic arthritis.[1]

Osteoarthritis

Osteoarthritis is best thought of as a 'group of heterogeneous conditions of multifactoral aetiology' that can affect single or multiple joints, including the hip. It is the most common joint disorder, both in the UK and throughout the world.[2] The first presenting symptom of arthritis of the hip is often pain, accompanied by loss of cartilage, which produces significant morbidity, especially in the elderly.[3]

The prevalence of osteoarthritis affecting the hip is difficult to estimate. A survey of 28,080 residents of Avon and Somerset, aged 35 years and over, provided estimates of the prevalence of self-reported hip pain as 107 per 1000 for men and 173 per 1000 for women.[4] It was further estimated that 15.2 people per 1000, aged between 35 and 85 years, had hip disease severe enough for surgery. These figures must be treated with caution because, if these rates are taken as a proxy for the prevalence of osteoarthritis of the hip, they suggest that at least 4 million people in England and Wales have the condition.[5] The Arthritis and Rheumatism Council Epidemiology Unit has estimated the prevalence of osteoarthritis to be about 1.3 million people in England and Wales.

A prospective study of 500 people recruited consecutively from a rheumatology clinic in Bristol looked at the progression and impact of osteoarthritis over 8 years.[6–8] Only 28 people in this sample (average age, 50 years; standard deviation (SD), 12.1) had osteoarthritis of the hip on entry to the study and, of these, 32% (9) used walking aids at study entry and 41% (12) were using aids 8 years after entry to the study. Furthermore, 50% (14) of patients had undergone surgery by the eighth year of follow-up. Although these data relate to a small number of patients, the results are in accordance with those of the larger sample, those with osteoarthritis in the hand and knee, and at other sites. The results of the larger study showed that an additional 43 of the 270 people who fitted into one of the other three predefined disease groupings for the location of their osteoarthritis at study entry (hand only, knee only, and hand and knee involvement) developed osteoarthritis of the hip.

Rheumatoid arthritis

Rheumatoid arthritis is a systemic inflammatory joint disease of complex pathogenesis, often involving genetic and environmental factors. It mainly presents in the peripheral joints as widespread and persistent inflammation of the synovial lining and tendon[5] but, because of its systemic nature, it is unlikely to affect the hip joint in isolation.

The prevalence of rheumatoid arthritis has been estimated to be 500–1000 per 100,000, with an annual incidence of 20–60 per 100,000. This equates to a prevalence of approximately 250,000–500,000 and an incidence of 10,000–20,000 per year in England and Wales.[9] Rheumatoid arthritis is three times more common in premenopausal women than men, although after menopause the frequency of onset between genders is similar.[10]

Incidence and prevalence data of hip involvement in rheumatoid arthritis are less common than for osteoarthritis. Hip involvement was found in 20% of patients with rheumatoid arthritis in a Swedish study, 3% of whom were found to have severe hip destruction.[11] Other studies have reported the incidence of hip involvement as 10–40%.[12–14]

Current service provision

The predominant surgical intervention for the treatment of severe hip disease used in England and Wales is THR. Data from Sweden, quoted by Birrell and colleagues,[15] suggest that moderate-to-severe osteoarthritis accounts for over 75% of indications for THR, trauma for 11.3% and rheumatoid arthritis 6%.[15,16]

In 1999/2000 in the NHS in England, 46,608 operations were coded as 'total prosthetic replacement of the hip joint (W37–W39)', of which 63% were performed on women. Of these operations, 18% (8389) were performed on individuals aged between 15 and 59 years, 46% (21,440) on those aged 60–74 years and 36% (27,965) on those aged 75 years and over.[17] It was reported in 1989/90 that one in seven of all procedures (5000 out of a total of 35,000) were revisions of THR.[2] Applying this rate to current operation rates provides a crude estimate of 6700 revisions of THR in 1999/2000. In Wales during 1999/2000, 2473 operations were coded as total prosthetic replacement of the hip (W37–W39), of which 61% were performed on women; 16% (396) were performed on people aged between 15 and 59 years, 48% (1195) on those aged 60–74 years and 36% (882) on those aged 75 years and over (Ian Baker, Health Solutions Wales, Cardiff: personal communication, 25 October 2001). Data on the number of revisions performed were not so readily available; however, a previous report suggested that of about 2700 THRs undertaken per year, 2100 are primary THRs and 600 are revisions.[18] More recent data on revisions as a percentage of the total number of THR procedures suggest that in 1998/99 over 10% of all THRs were carried out as revisions.[19]

Figures for the use of metal-on-metal hip resurfacing arthroplasty within the NHS in England and Wales are not readily available. Data contained in the industry submissions to the National Institute for Clinical Excellence (NICE) for this technology suggest that, on average, there could be over 2000 procedures performed per year within the UK.[20–22] It is unclear how many of these procedures are performed within the NHS.

Data for the number of people who have their symptoms managed by pain control and other non-surgical interventions (such as the use of transcutaneous electrical nerve therapy and strengthening exercises) within England and Wales are difficult to ascertain. The evidence reported earlier from a population survey suggested that 15.2 people per 1000, aged 35–85 years, had hip disease severe enough for surgery. This equates to approximately 760,000 people within England and Wales.[4] For osteotomy, arthrodesis and arthroscopy of the hip joint, there are no readily available data relating specifically to their use within the UK, although discussions with clinical experts suggest that these procedures are performed infrequently within the NHS.

Current service cost

The cost of watchful waiting for an individual for whom a THR is contraindicated has been estimated to be approximately £640 per year (for details, see chapter 5). If only one-tenth of the 15.2 people per 1000 who were estimated to experience hip pain severe enough for surgery received medical and/or physical therapy,[4] the cost to the NHS in England and Wales would be of the order of £48 million per year. The cost of THR was £3891, averaged across all NHS trusts for 1999/2000, with the cost for 50% of trusts falling within the range £3404–£4434.[23] In an earlier NICE technology assessment, it was reported that the cost to the NHS per year of THR was £140 million and that each trust spent, on average, some £257,000 on the purchase of hip prostheses in 1998/99.[18]

Description of the new intervention and comparators

Within England and Wales, people who are expected to outlive a primary THR are typically referred for this procedure only when their symptoms (e.g. pain, loss of physical function) become unmanageable by non-surgical means. Prior to deterioration that justifies surgery, these patients are managed by watchful waiting. Metal-on-metal hip resurfacing arthroplasty conserves femoral bone and offers a potential option for treating those patients who are not considered eligible for THR because of their relatively young age or their activities. In addition, metal-on-metal hip resurfacing arthroplasty may be appropriate for those who are ineligible for THR for clinical reasons other than age or activity. The techniques considered in this review are briefly described below.

Metal-on-metal hip resurfacing arthroplasty

Hip resurfacing involves the removal of the diseased or damaged surfaces of the proximal femur and the acetabulum. The prepared femoral

head is then covered and the acetabulum is lined with a pair of metal bearings, which provide an articulating surface that allows mobility of the hip joint.[22] The unstemmed femoral prosthesis may use cement in order to ensure fixation or may have a press-fit design.

The potential advantages of metal-on-metal hip resurfacing arthroplasty over conventional THR include minimum bone resection and conservation of femoral bone, and maintenance of normal femoral loading and stresses by elimination of the conventional long stem on a femoral prosthesis.[21] Stress shielding of the proximal femur occurs when a metallic stem is inserted as part of conventional THR. With hip resurfacing, loading of the existing femoral head occurs and stress shielding is not seen in the proximal femur.[22] As bone is conserved, the joint could be revised if the device failed in use, by using a primary hip prosthesis together with a large diameter modular head, effectively allowing the use of a primary prosthesis in a first revision procedure.[21] It has been suggested that owing to the preservation of most of the underlying femur, there would not be significant shortening of the leg after removal of the prosthesis.[24] Metal-on-metal hip resurfacing arthroplasty may also allow higher levels of post-surgery activity with fewer risks than a conventional stem-type device. If this were the case, then the increased stability would be conducive for sports and work activities in which a more normal range of motion of the hip is required.[25]

Metal-on-metal hip resurfacing prostheses were originally re-designed from older metal-on-polyethylene implants and further developed by D McMinn, an orthopaedic surgeon in Birmingham, in conjunction with Corin Medical (the McMinn Resurfacing Hip). This model was withdrawn in 1996 after manufacturing difficulties and the resurfacing devices now used are the Cormet 2000 (Corin Medical), the Birmingham Hip (Midland Medical Technologies (MMT)), Conserve Plus (Wright Medical, Tennessee) and Wagner Resurfacing (Sulzer Limited).

The two major causes of primary hip failure in conventional THR are component loosening caused by ultra-high molecular weight polyethylene wear-induced osteolysis, and dislocation of the femoral head from the acetabular component. Metal-on-metal articulations may be less prone to loosening than combined polyethylene/metal articulations (i.e. polyethylene acetabulum with metal femoral head). This has been shown to be caused by an inflammatory reaction in response to polyethylene-wear particles.[26] The larger diameter of bearing surface, compared with conventional THR, may enhance joint stability and thus reduce the risk of dislocation.[21]

The major potential complication with metal-on-metal hip resurfacing arthroplasty is avascular necrosis of the femoral head. Other complications that can occur after surgery include loosening of the femoral and acetabular components, and formation of ectopic bone. In contrast with THR, patients with hip resurfacing have an additional risk of developing a fracture of the femoral neck caused by notching of the neck during removal of the femoral head. As extra reshaping of the femoral head is required, the operation may last longer than total hip arthroplasty operations. As a result, there may be a greater potential for haemostasis-related complications[26] and infections.

Watchful waiting

Watchful waiting involves patient monitoring, drug-based treatments and other supportive activities, such as physiotherapy. Current guidelines advocate that young active patients should avoid THR for as long as symptoms allow, in order to delay the need for any revision; hence, watchful waiting is usually used until function deteriorates and the patient is old enough to warrant a THR.[22] Patients often have adverse side-effects to the drugs used, especially if they require high doses over a long period, as is often the case. The main drugs administered are analgesics and anti-inflammatory agents. Their inherent complications include dyspepsia, ulceration and gastrointestinal bleeding. Other rare but possible side-effects include hypertension, congestive heart failure and renal damage. There is some evidence that prolonged use of some anti-inflammatory medications result in bone destruction of the arthritic hip.[27–29] The reduced bone integrity that can occur may make future surgery difficult. Another complication for patients taking anti-inflammatory medications is that they tend to bleed excessively from their wounds at hip replacement. This excessive bleeding and haematoma formation may increase the risk of deep infection.[22]

THR

The aim of THR is the re-establishment of functional joint movements and relief from pain in affected hip joints. To reach this goal, the damaged hip joint is replaced with an artificial prosthesis composed of two or three different components:[30]

- the 'head': a metal ball (stainless steel or cobalt chrome) that replaces the original femoral

head (some prostheses, e.g. the standard Charnley, come as a monobloc as the head is attached to the stem)
- the 'femoral component': a metal stem placed into the femur
- the 'acetabular component': a plastic cup (high-density polyethylene) implanted into the acetabulum.

With constant use, small fragments of components – wear debris – can accumulate in the hip joint. Wear debris is responsible for causing bone destruction (i.e. osteolysis) that, in turn, causes loosening of the replacement hip. To overcome this problem, attempts have been made to manufacture prosthesis components using materials to reduce wear of the femoral head, such as ceramics, titanium, and metal-on-metal bearing combinations. These more durable articular couples have addressed the need for longevity of components in younger patients.

Since the late 1950s, the prostheses may be implanted and fixed using 'bone cement'. Although cement fixation is still widely used, various techniques of cement-free hip replacements have been developed to avoid both the risk of loosening parts and the breaking-off of cement particles. The aim of these cement-free prostheses is to allow patients' bones to grow into the uncemented components. In particular, 'porous coating' prostheses are used to encourage patients' bone to grow into the pores and steadily hold the new components in place. An alternative technique to porous coating is the use of biological products, such as hydroxyapatite, to allow the bone to grow and keep the components tightly in position.[30] In many cases, however, a combination of both cemented and uncemented components is used. Cemented femoral components are believed to perform better than cementless ones, while cemented acetabular components are deemed to be the weakest parts in any hip replacement. The typical 'hybrid' replacement comprises a femoral component fixed with cement and an acetabular uncemented component.[31]

The THR procedure takes between 2 and 3 hours.[30] Full recovery occurs within 3–6 months, depending on the type of surgery and the general health status of the patient. Revisions of primary hip replacements occur in about 10% of people within 10 years of primary surgery, mainly because of loosening or failure of prosthesis components or because of post-operative complications.[30] Younger, more active people who receive a THR may require revision surgery at a higher rate than older or less active people. Revision surgery is more problematic, expensive and difficult to perform than primary replacement, and outcomes are usually less satisfactory.

Possible operative complications of THR include nerve damage, vascular damage, cortical perforation, fracture and leg-length inequality. Types of post-operative problems that may occur are dislocation, urinary, cardiovascular complications (e.g. deep vein thrombosis), haematoma formation and trochanteric problems (e.g. trochanteric bursitis), as well as superficial or deep infection. Long-term complications may include aseptic loosening of the prostheses, fragmentation of bone cement, or wear in the polyethylene part of the prosthesis.

Osteotomy

The aim of osteotomy in dysplastic or osteonecrotic hips is to realign the position of the joint by means of a fixation device. For hips affected by osteonecrosis, the major goal of surgery is to move the necrotic segment away from the weight-bearing area and restore blood supply to the necrotic zone. Various surgical techniques have been proposed to reposition the hip joint (i.e. varus, valgus, flexion, rotational and combined osteotomies). Outcomes of osteotomy depend upon factors such as the age and activity of the patients, the stage and severity of the anatomical deformity of hip components, and the severity of the osteonecrotic or osteoarthrotic process. Osteotomy may be adopted merely as a salvage procedure and not as a restorative solution, in order to delay the point when hip arthroplasty is required, although in certain instances THR may be prevented. The risks of having a THR may be slightly greater following an osteotomy than if an osteotomy had never been performed.[32] Recovery after surgery takes about 6–12 months. Complications following osteotomy can include delayed or non-union, varus angulation, bone fracture and infection. The clinical importance of osteotomy has significantly decreased since the adoption of THR.

Arthrodesis

Arthrodesis is the fusion of the femur to the pelvis. This surgical procedure is primarily indicated in children with unilateral degenerative disease of the hip, who are unresponsive to non-operative measures. Normal conditions of spine, knees and opposite hip are required for this surgical operation to be performed. Arthrodesis is highly successful in controlling pain but leaves the hip joint incapable of any movement and causes inequality of leg lengths. Immobilisation

of the hip and leg-length discrepancy are compensated for by adopting abnormal movements of the knee and spine when walking. These compensatory mechanisms predispose patients to pain in the lower back and ipsilateral knee disorders over time.[33] Severe lower back pain can be the main indication for converting arthrodesis to THR. The conversion of a hip arthrodesis to a THR is technically more difficult than a primary THR as the patient's anatomy will be distorted following the previous surgery, and the joint space cannot be used as a landmark.[34]

Arthroscopy

Hip arthroscopy is a minimally invasive surgical procedure used to investigate and treat both traumatic and non-traumatic disorders of the hip. It is the use of hip arthroscopy as a method of treatment that is focused on here. This is performed by means of an arthroscope introduced into the joint in order to visualise anatomical structures. Arthroscopic instruments can be then inserted to undertake surgical procedures (such as chondral and labral debridement and removal of loose bodies from the joint). In view of the depth and complexity of the hip joint, the direction of the insertion and the position of the port are crucial. A range of arthroscopic techniques have been described in the literature with the patient in supine or lateral position, with or without hip dislocation, and with anterior, anterolateral or lateral port. The main indications for arthroscopic hip surgery, other than diagnosis, include: removal of loose bodies, synovial chondromatosis, osteoarthritis and osteonecrosis debridement, septic arthritis and removal of acrylic cement after THR.

Despite arthroscopic techniques for knee, shoulder, ankle and wrist joints being well established, operative hip arthroscopy is still relatively unpopular, mainly because of the anatomical location and features of the hip joint that allow only limited manoeuvrability of surgical instruments.[35] Recovery time is usually about 3 months. Potential complications that can occur during or after surgery include: infection, venous thrombosis, excessive swelling or bleeding, damage to blood vessels or nerves, and instrument breakage.[36]

Metal-on-metal hip resurfacing resource requirements: personnel, setting, length of treatment and follow-up

Metal-on-metal hip resurfacing is, in many respects, similar to THR. It is likely to involve substantially the same configurations of staff, be performed in a similar setting and, in uncomplicated cases, require the same follow-up. There is some uncertainty and therefore possible differences about the duration of the operation and length of stay. The submission to NICE by MMT suggested a shorter operation time, while Schmalzried and colleagues reported an operation time for a different method of resurfacing some 84% longer[37] on average than the 134 minutes estimated for primary THR. The MMT submission also stated that the length of stay is shorter compared with THR by 2.6 days,[22] although it is unclear whether this reduction pertains to the estimate of 12 days length of stay used in previous studies or to the length of stay of 10 days used in chapter 5 of this report.

The principal well-documented difference between metal-on-metal hip resurfacing arthroplasty and THR is the cost of the prosthesis. The price of a metal-on-metal hip resurfacing prosthesis is between £1730 and £1890, compared with £400 for a conventional cemented THR prosthesis and up to £2000 for a cementless/hybrid THR prosthesis.[38]

Degree of diffusion

It is unclear how many metal-on-metal hip resurfacing arthroplasties are performed annually within the NHS. Data from the industry submissions to NICE suggest that over 2000 may be being performed per annum in the UK.

Chapter 3

Effectiveness

Methods for reviewing effectiveness

Search strategy

A structured search was conducted to identify evidence relating to the clinical effectiveness and cost-effectiveness of metal-on-metal hip resurfacing arthroplasty for treatment of hip disease. This included an electronic search of the following databases and websites:

- Cochrane Database of Systematic Reviews (CDSR)
- Database of Abstracts of Reviews of Effectiveness (DARE)
- Cochrane Controlled Trials Register
- MEDLINE and PREMEDLINE
- EMBASE
- HealthSTAR
- CINAHL
- NHS Economic Evaluation Database (EED)
- Allied or Alternative Medicine (AMED)
- Relevant audit databases
- Worldwide Web.

The initial objective of the search strategies was to identify any randomised or comparative observational studies or systematic reviews comparing metal-on-metal with any of the alternatives. As it was anticipated at the outset that there would be few such data, searches were also conducted to identify other data sources for each of the comparators.

These other search strategies (see appendix 1 for details) were as follows.

1. A free text search to identify any potentially relevant papers evaluating metal-on-metal resurfacing arthroplasty. Free text search terms were used because of the expected scarcity of published literature.
2. A free text search to identify any papers potentially relevant to osteotomy, arthrodesis and arthroscopy.
3. A search for randomised controlled trials (RCTs) and systematic reviews of RCTs for THR using a modified version of the search strategy used for the THR NICE report.[38]

It should be noted that relevant audit databases and the Worldwide Web were also searched and that any duplicate studies were removed in OVID. The initial search was made in MEDLINE and the results compared with subsequent searches in the EMBASE, CDSR, DARE and HealthSTAR databases. At each stage duplicates were identified and removed. CINAHL, AMED and NHS EED were searched separately.

Inclusion criteria

All abstracts identified using the above search strategies were assessed for subject relevance by two researchers. Copies of the full published papers of those considered relevant were then obtained and formally assessed for inclusion. Studies reported in languages other than English were identified from their abstracts but were not included in the review.

Metal-on-metal hip resurfacing arthroplasty

Because of the anticipated lack of data from RCTs, comparative observational studies and single prosthesis observational studies were considered eligible for inclusion in the review of metal-on-metal hip resurfacing arthroplasty. The following criteria were applied.

- Inclusion of RCTs in which metal-on-metal hip resurfacing arthroplasty was compared with any of the other comparators was limited to those that provided patient outcome data and compared metal-on-metal hip resurfacing arthroplasty with other interventions. Studies not reporting patient outcome data, such as laboratory only studies, were excluded. No restriction was placed on the length of follow-up.
- Inclusion of comparative observational studies in which metal-on-metal hip resurfacing arthroplasty was compared with any of the other comparators was limited to those with concurrent controls, in which revision rates, clinical assessment (expressed as a global scale or as a rating of pain or function) or patient-based outcomes were provided. No restriction was placed on the length of follow-up.
- Inclusion of single prosthesis observational studies of metal-on-metal hip resurfacing arthroplasty were limited to those in which revision rates, clinical assessment (expressed

as a global scale or as a rating of pain and function) or patient-based outcomes were provided. A minimum of 2 years follow-up was applied.

Comparators

In the anticipated absence of comparative studies of metal-on-metal hip resurfacing arthroplasty, the types of studies that were considered eligible for inclusion for watchful waiting, THR, osteotomy, arthrodesis or arthroscopy were as follows.

- Watchful waiting: observational data studies of patients for whom watchful waiting was used, with a minimum follow-up period of 5 years.
- THR: RCTs with a minimum of 5 years' follow-up of different methods of THR, and systematic reviews of such trials.
- Osteotomy: observational studies with a minimum follow-up period of 10 years.
- Arthrodesis: observational studies with a minimum follow-up period of 5 years.
- Arthroscopy: observational studies with a minimum follow-up period of 5 years.

Data abstraction

A data abstraction form was developed to record details of study design, participants, setting and timing, interventions, patient characteristics, and outcomes (see appendix 2). The outcomes sought from all included studies were as follows.

A Short-term outcomes

(1) Duration of operation
(2) Conversions
(3) Serious complications (e.g. nerve palsy, infection)
(4) Time in hospital
(5) Time to return to normal activities

B Long-term outcomes

(1) The rate of revision surgery or first operation following conservative treatment
(2) Time to revision surgery or first operation following conservative treatment
(3) Functional result (e.g. Harris, Mayo, Charnley scores)
(4) The percentage of patients pain free (clinician or analyst assessment)
(5) Quality of life
(6) Mortality

Revision surgery was defined as being a second surgical procedure for the same condition. The second procedure could be of the same type as the first procedure: for example, THR followed by revision of THR or metal-on-metal hip arthroplasty revised to another metal-on-metal hip arthroplasty or a different type of surgery (e.g. metal-on-metal hip arthroplasty revised to a THR). Under the same heading, data were sought on the first surgical procedure following conservative management. Two reviewers undertook data abstraction independently. When a difference of opinion existed, the two reviewers consulted an arbiter. The results were based on published data only and authors of study reports were not contacted for clarification.

Assessment of the methodological quality of studies

Two reviewers assessed all the studies that met the selection criteria independently for methodological quality. The system for classifying methodological quality was based on a checklist developed by Morris and colleagues[39] to assess the quality of studies appearing in orthopaedic research journals (see appendix 3). This provided a simple standardised expression of the quality of studies. Groups of studies (RCTs, comparative observational studies, single prosthesis observational studies) were scored in each of the six areas assessed, that is:

- clarity of study question and definition of outcome
- description of prosthesis and fixation
- description of study sample
- control of bias in study design
- duration of follow-up
- statistical and analytical considerations.

The three relevant systematic reviews[1,30,38] were assessed independently for their methodological quality by two reviewers. A quality assessment form specifically for assessing the methodological quality of systematic reviews was used.[40] When a difference of opinion existed in the quality assessment, the two reviewers consulted an arbiter.

Results

Quantity and quality of research available

The numbers of potentially relevant studies identified by the systematic search are shown in *Table 1.*

Description of included studies

A total of 22 published studies satisfied the agreed criteria and were included (*Table 2*). Of these, one was an RCT, 18 were single-intervention observational studies and three were systematic reviews which included THR studies.[1,30,38]

TABLE 1 *Total number of possible studies identified by the systematic review*

Source/database	MOM	THR	Other comparators
CDSR	0	Not searched*	17
DARE	1	Not searched*	8
Cochrane Controlled Trials Registry	28[a]	Not searched*	36[b]
MEDLINE	241	699	1127
EMBASE	82	Not searched*	427
HealthSTAR	0	Not searched*	0
CINAHL	0	Not searched*	72
Allied or Alternative Medicine (AMED)	0	0	177
NHS EED		212 abstracts[c]	
Total	352	699	1864

MOM, metal-on-metal hip resurfacing arthroplasty

* *Recent systematic reviews had already been conducted comparing alternative methods of THR*

[a] *Search terms used: resurfacing; surface replacement; metal; hip/hips*

[b] *Search terms used: osteotomy/osteotomies; arthroscopy/arthroscopies; (fusion/fusion/fused) and (bone/bones); arthrodesis; hip/hips*

[c] *Search covered all comparators and, as a result, these 212 abstracts have not been included in the totals*

TABLE 2 *Number of studies found for each comparator*

Study design	MOM	THR	Other comparators	Total
RCT	0	1	0	1
Comparative observational	0	0	0	0
Published single prosthesis observational	4	0	14	18
Systematic review	0	3	0	3
Industry submission	3	0	0	3
Unpublished single prosthesis observational data	1	0	1	2
Total	8	4	15	27

Unpublished data from three industry submissions,[20–22] one metal-on-metal database (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001) and one arthroscopy database (Villar R, Cambridge Hip and Knee Unit: personal communication, 2001) were also included. Of the published studies, there were four on metal-on-metal hip resurfacing arthroplasty,[24,37,41,42] one on watchful waiting,[6–8] one on THR,[43] 12 on osteotomy[44–55] and one on arthrodesis.[33] No published studies relating to arthroscopy were included. The patients included in these studies had, in the main, a pre-operative diagnosis of osteonecrosis, osteoarthritis or developmental dysplasia.

The four published metal-on-metal studies involved a total of 327 hips from 310 patients.[24,37,41,42] The numbers of hips in each intervention examined ranged from four to 116. Lengths of follow-up ranged from 8.3 months to 50.2 months, with an average of 23 months. The mean ages of the patients ranged from 36 to 48.7 years. The database from the Oswestry Outcome Centre (The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001) contained data on 4455 individuals but had a maximum follow-up of less than 5 years. The mean age of the individuals on this database was 49.2 years.

One study on watchful waiting was included.[6–8] The study was reported in three papers with differing lengths of follow-up. In the first paper, baseline data was reported, the next covered a follow-up period of 3 years, and the third covered follow-up at 8 years. The mean patient age was 50 years. All those included in the study suffered from limb joint osteoarthritis.

A total of 91 patients (91 hips) were included in the THR RCT.[43] The mean follow-up time was 5.2 years. All the patients were aged under 66 years. Relevant THR studies were also found in two previous systematic reviews in *Health Technology Assessment*[1,30] and in a NICE update of those reviews.[18]

The total numbers of patients in the 12 osteotomy studies varied between 570 and 572, the sample size being unclear in one study. The patients were aged between 17.8 and 55 years. The numbers of hips in each study ranged from 14 to 145, with an average of 57 hips. The mean lengths of follow-up ranged from 122 to 204 months. The arthrodesis study involved a total of nine hips in nine patients with a mean age of 13.4 years (range 10.8–17 years). These patients were followed for an average of 106 months (range 25–166 months). The arthroscopy data were obtained from an arthroscopy database (Villar R, Cambridge Hip and Knee Unit: personal communication, 2001), which contained data on 661 people. Data on age of entry into the database were not reported. These patients were followed for a maximum of 11 years, although data for at least 5 years were available for only 104.

Methodological quality of studies

Following a similar approach to Fitzpatrick and colleagues,[30] the methodological quality of the studies was assessed (see summary in appendix 5). The three included systematic reviews[1,30,38] were assessed using a quality assessment form specific to the methodological quality of systematic reviews.[40] Overall, the remaining 24 studies were rated favourably in terms of the clarity of study question and definition of the outcome. The description of prosthesis and fixation was less well rated – seven of the 18 published observational studies and the one published RCT did not adequately describe the procedure.[33,41,48–50,53,55] One concern, relating to the description of the study sample, was that only five (26%) of the 19 published studies adequately described how the sample was selected,[6–8,24,45,46,48] and only six of the 19 (32%) published studies specified the inclusion and exclusion criteria.[6–8,43,45,46,48,52] None of the unpublished studies adequately described the method of selection of the study sample or specified the inclusion and exclusion criteria.

The baseline sample was clearly described in 68% of published studies.[6–8,24,33,37,42,45–48,51,52,54,55] The unpublished single prosthesis baseline data (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001; Villar R, Cambridge Hip and Knee Unit: personal communication, 2001) were not clearly reported. However, two of the industry submissions clearly described the baseline sample,[21,22] although the reviewers were unclear whether the remaining industry submission[20] clearly reported this information. Few studies appeared to assess the co-morbidity of the patients. Only four published studies,[6–8,24,37,42] one industry submission[22] and one unpublished single prosthesis study (Villar R, Cambridge Hip and Knee Unit: personal communication, 2001) had samples that were considered to be homogeneous in terms of disease/diagnosis. The control of bias in study design was generally poor in all studies. In only three published studies was an adequate attempt made to control for confounding factors.[6–8,33,55] The duration and completeness of follow-up varied in all the studies. The effect of patients lost to follow-up was considered in only two studies.[6–8,52] The statistical and analytical considerations in the studies were generally either of low quality or the assessor was unable to judge the quality from the details in the study report. In most studies no statistical calculations were reported. In three published studies (16%), the conclusions were not justified by sufficient evidence.[41,44,50] Of all the unpublished studies, only in one were the conclusions justified with sufficient evidence,[20] and for the remainder the reviewers were either unable to make a judgement on this[21,22] or this criterion was not applicable (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001; Villar R, Cambridge Hip and Knee Unit: personal communication, 2001).

Metal-on-metal hip resurfacing arthroplasty

Of the eight metal-on-metal hip resurfacing arthroplasty studies,[20–22,24,37,41,42] (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001) five gave a clear definition of the study question and outcome[21,22,24,37,42] and six clearly described the procedure.[21,22,24,37,42] The studies were rated poorly in two dimensions: the description of the study sample and the control of bias in the study design. None of the studies had a control group or controlled adequately for confounding factors. The duration and completeness of follow-up was adequately described in six studies.[20,22,24,37,42] (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001) None of the eight studies provided any justifi-

cation for their sample size. Four studies drew conclusions that were supported by the evidence presented.[20,24,37,42]

Watchful waiting

The watchful waiting study[6–8] was rated favourably in terms of the clarity of the study question, definition of outcome, and description of the study sample. Many of the assessment criteria were not applicable to this study. The duration and completeness of the study were rated well, as were the statistical and analytical considerations. The only identified weakness of the study was that the study sample size was unlikely to be adequate, as the number of patients with osteoarthritis of the hip was small (29 people).

THR

The two published *Health Technology Assessment* monographs were of high quality but with some limitations on the comprehensiveness of their literature searches (e.g. English language abstract or article).[1,30] Faulkner and colleagues undertook no meta-analysis and only one reviewer assessed the included studies.[1] In Fitzpatrick and colleagues,[30] only 12 included RCTs, 12 comparative studies and 15 observational studies were quality assessed. Furthermore, the methods for study inclusion were not fully reported.[30] The final systematic review[38] was of much lower quality, although it was based on the two earlier reviews. In particular, the methods were very brief with no details of how the included studies were assessed and how study data from individual studies were combined. One additional THR study was assessed for this review.[43] This study was well rated with regards to the clarity of study question, definition of outcome, and description of the prosthesis and method of fixation. The inclusion and exclusion criteria were reported, but there was no adequate description of the method of sample selection and the basic characteristics of the baseline sample were not reported. This study used an RCT design to control for bias. The duration and completeness of the follow-up period were rated favourably.

Osteotomy

In general, the 12 osteotomy studies clearly defined the study question and outcome, although only seven adequately described the procedure.[44–47,51,52,54] As there are many different types of osteotomy, it is essential that a good description of the procedure is provided. The description of the study sample was generally poor, with the method of selection of the sample being adequately described in only three studies[45,46,48] and the exclusion and inclusion criteria being clearly specified in only four studies.[45,46,48,52] Both the control of bias in study design and the completeness of follow-up were generally poor in all the osteotomy studies because of their uncontrolled nature. In five studies the type of statistical test used was not specified,[45,47,49,50,54] and in two the conclusions were not justified by the evidence presented.[44,50]

Arthrodesis

In the one study about arthrodesis, clear definitions were given of the study question and outcome.[33] The procedure, however, was not well described. The basic characteristics of the sample were reported, although the inclusion and exclusion criteria were not reported, and the sample was not sufficiently homogeneous in terms of disease or diagnosis. The effort to control for bias in the study design proved difficult to assess. The study rated well in terms of duration and completeness of follow-up and statistical and analytical considerations.

Arthroscopy

The purpose of this study and the definition of the outcomes were clear. The functional results were reported as Harris hip scores, although interpretation was made slightly difficult as the scores were separated into one hip score for pain and another for functional ability. The description of the study sample was poor and the ages and genders of the patients were not recorded in the data available, although the study sample was sufficiently homogeneous in terms of diagnosis or co-morbidity. No effort was taken to adequately control for confounding factors. The intervals between surgery and follow-up were clearly reported, although the reasons for losing patients to follow-up were in some cases unclear. It was reported that 25.1% of patients were lost to follow-up, although this included those who had a THR. If patients having THR were excluded, then only 5.9% were lost to follow-up for reasons that were not reported. The statistical and analytical considerations of the quality assessment were not applicable for the arthroscopy database. Complications, time to return to normal activities, percentage of patients pain free and quality of life were not reported as outcomes in the database.

Summary of data available for each intervention

Metal-on-metal hip resurfacing arthroplasty

The studies reporting metal-on-metal hip resurfacing arthroplasty are summarised below and in appendix 6.

Design issues

Four published studies,[24,37,41,42] three industry submissions to NICE,[20–22] and one unpublished report (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001) that investigated metal-on-metal hip resurfacing arthroplasty were identified and, as reported in chapter 2, all involved young patients. The outcomes for more than one prosthesis were reported in all four published studies, two different types of prosthesis were considered in three studies,[24,37,41] and four different prostheses were considered in one.[42] The length of follow-up was less than 5 years for all studies, with one of the groups from the study by McMinn and colleagues,[42] having an average follow-up of 8.3 months. With the exception of the unpublished data from the Oswestry Outcome Centre (n = 4424) and one industry submission (n = 1758),[22] all the studies were small, with the smallest group containing only four patients.[37] The proportions of patients with specific preoperative diagnoses varied markedly between studies.

Outcome measures

- Duration of operation: in only one study was any information reported on this outcome measure.[37] In this study the mean operation time was reported to be 247 minutes (range, 180–370).
- Time to return to normal activities: McMinn and colleagues reported that all patients were mobilised on the first post-operative day and that from one to 12 days all patients had a partial weight bearing of 25 kg on the surgically treated leg. After 12 weeks, weight bearing was increased.[42] In the Wagner & Wagner study, patients spent a median of 21 days in hospital.[24]
- Revision surgery: revision rates to THR were reported in all studies except one,[41] and ranged from 0% to 14.3%. The only two groups to report no revisions to THR were both in the study by McMinn and colleagues.[42] Of the 36 patients who had revision surgery (out of 4455 included in the Oswestry database), 44% (16) were revised to THR during a follow-up period of 4 years. In all, 17% of patients were revised to metal-on-metal hip resurfacing arthroplasty and 8% were coded as dysplasia; 31% were unknown (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001).
- Functional result: a comparison of Harris hip scores for THR and Birmingham hip resurfacing (BHR) found a greater increase from preoperative to 1-year postoperative hip scores for resurfacing (20.3 point increase for THR compared with 29.4 point increase for resurfacing). Over 4 years, this increase was even greater for resurfacing (14.3 point increase for THR compared with 31.9 point increase for resurfacing) (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001).
- Patients pain free: McMinn and colleagues were the only authors of a published study to report the percentage of patients who were pain free, which in this case was 60/66 (91%) after a mean follow-up period of 50.2 months (range, 44–54).[42] In one industry submission,[21] 69 of 97 patients (71.1%) were reported to be pain free after a mean follow-up of 16.9 months.
- Complications: few complications were reported in any of the studies. In one study[41] no complications were reported. Schmalzried and colleagues reported that two of 19 patients (10.5%) had complications.[37] One patient had femoral nerve palsy and another a haematoma. McMinn and colleagues reported three patients with an infection and one with sciatic nerve palsy.[42] In the study by Wagner and colleagues, the only complication reported was a femoral neck fracture, although this was caused by a traffic accident.[24] The complications that were serious enough to require revision surgery in the Oswestry database were mainly fractures (56%) (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001). Two of the industry submissions to NICE reported complications.[20,21] In one, seven complications were reported in 110 patients and, in the other, three in 100 patients. The most common complication in both these studies was loosening.
- Conversions, time spent in hospital, quality of life and mortality outcomes were not reported in any of the metal-on-metal hip resurfacing arthroplasty studies.

Watchful waiting

Only one study was identified in which watchful waiting was considered (appendix 7).[6–8]

Design issues

In this study a sample of people were followed who were referred consecutively to a rheumatology clinic in Bristol in the late 1980s. Of the 500 people recruited to this study, 29 presented with osteoarthritis of the hip; their results are summarised below and in appendix 7.

Outcome measures

- THRs performed: surgery performed increased from nine patients (32%) at 3 years to 14 patients (48%) at 8 years.
- Functional result: the use of walking aids also increased from eight patients (29%) at 3 years to 12 patients (41%) at 8 years.
- Long-term pain: the level of long-term pain showed a slight increase from 3 years to 8 years.
- No data were available on complications and most of the other pre-specified outcomes were not relevant for this comparator.

THR

Three systematic reviews of RCTs[1,30,38] and one recent RCT[43] not included in the earlier systematic reviews were identified. The design and results of these are summarised below and in appendix 8.

Design issues

The patients in the paper by Sharp and colleagues[43] and in the studies included in the systematic reviews[1,30,38] were much older than those included in the metal-on-metal hip resurfacing arthroplasty studies. Only Fitzpatrick and colleagues provided information on preoperative diagnosis.[30] They reported that patients included in the identified studies typically had a diagnosis of osteoarthritis, with relatively few being diagnosed with rheumatoid arthritis.

Outcome measures

The short-term outcomes of duration of operation, conversions, time in hospital and time to return to normal activities were not reported. In the study by Sharp and colleagues, two of 91 patients had a dislocation within 1 year of their operation.[43] No evidence on the extent or nature of complications was reported in any of the systematic reviews.

- Revision rates: it was concluded in the systematic reviews that several designs of prostheses would have good results (less than 10% revision at 10 or more years).[30] A revision rate of 27.5% at a mean follow-up of 5.2 years was reported by Sharp and colleagues.[43]
- Functional results: only Fitzpatrick and colleagues summarised data on this outcome.[30] They reported that a Charnley THR would result in a substantial and sustained improvement in functional score.
- None of the studies reported on quality of life, complications or mortality outcomes.

The general conclusions drawn from the systematic reviews by Fitzpatrick and colleagues[30] and Faulkner and colleagues[1] and from the update of these two reviews by NICE[38] are in accordance with one other. The results of the additional RCT identified are worse.[43] However, this study was investigating a new method of THR (C-Fit uncemented with hydroxyapatite compared with porous coating of components), in which the outcomes were similar to some of the less successful prostheses considered in the earlier reviews.[30] In both the earlier systematic reviews, it was concluded that the available evidence was of poor quality.[1,30] This, together with the frequent changes in prosthesis design over time, makes it very difficult to identify the most effective method of THR.

Osteotomy

The studies reporting osteotomy are summarised below and in appendix 9.

Design issues

The type of osteotomy procedure varies greatly. In the 12 osteotomy studies, none of the procedures investigated was the same. The numbers of hips at the outset of the studies also varied greatly, from 14 to 126. In all the studies, the patients were young, with mean ages ranging from 17.8 years to 55 years. The average follow-up period was more than 10 years for all the studies, ranging from 122 months to 204 months. The preoperative diagnosis was mainly developmental hip dysplasia, avascular necrosis, osteonecrosis and osteoarthritis.

Outcome measures

- Duration of operation: the average duration of the operation, 210 minutes (range, 120–300 minutes) was reported in only one study.[55]
- Return to normal activities: the time to return to normal activities was reported in only one study.[51] Patients in this study began mobilisation with touch weight-bearing and active exercises 3 days after the operation. Walking with a single crutch began 3 months later.
- THR revision: revisions to THR appeared to increase with increasing age. Studies with the youngest patients had the lowest revision rates. Also, the revision rate varied greatly from 2.9%[54] to 90.3%.[48]
- Pain free: the percentages of patients who were pain free were reported in three of the 12 studies. These were 33.3%,[47] 16%[49] and 76%[54] at follow-up of 122, 127 and 204 months, respectively.
- Mortality: mortality rates of 6%[44] and 1.6%[55] were given in two studies, although the deaths were reported to be unrelated to surgery.
- Complications: in more than one study the complications were non- or delayed-union, infection, progression of varus angulation

and fracture. Other complications reported less frequently included deep vein thrombosis, nerve palsy, muscle detachment, labral tear and subluxation. This outcome was not reported in three studies.[48,49,51]

The outcomes of conversions, time in hospital, and quality of life were not reported in any of the studies.

Arthrodesis

One arthrodesis study was identified in this review.[33] The results are summarised below and in appendix 10.

Design issues

The medical records were reviewed of 19 patients who had an arthrodesis of the hip between January 1980 and December 1996 and had a minimum of 2 years follow-up. Nine of these patients agreed to participate in the study. The patients were all very young; the mean age at operation was 13.4 years (range, 10.8–17). Most patients (five) had a preoperative diagnosis of avascular necrosis.[33]

Outcome measures

- Functional result: only postoperative Harris hip scores were reported (mean, 69.5; range, 47–90). No preoperative hip scores were reported.
- Pain free: only two of the nine patients (22%) were pain free after the operation. Seven patients reported back and knee pain.
- Complications: those that were reported were muscle atrophy in the thigh in all nine patients and knee laxity in eight patients. Four fractures were reported in three patients. One patient had an additional operation for limb length discrepancy.
- The outcomes of duration of operation, conversions, quality of life, time in hospital, and time to return to normal activities were not reported.

Arthroscopy

Only one study was identified that considered arthroscopy (Villar R, Cambridge Hip and Knee Unit: personal communication, 2001). The results are summarised below and in appendix 11.

Design issues

The arthroscopy database included in this review was provided by an orthopaedic surgeon.

Outcome measures

- Duration of operation: the average duration of an operation was 23.6 minutes (SD, 48.67).
- Complications: only 0.8% of 661 patients were reported to have had complications. These included bleeding, haematoma, vaginal tear and trochburitis, all of which occurred during the operation. The event-free survival rate at 1-year follow-up was 92%. This decreased and levelled off at 33.5% after 9 years, although at 9 years only 13 patients were being followed-up.
- Time in hospital: the available data revealed that a majority of patients (53.6%) were discharged on the day of their operation. Of all patients, 33.4% (182) spent one night in hospital, 12.8% (70) spent two nights and 0.2% (1) spent three nights in hospital.
- THRs performed: the rate of revision to THR was 19.2%.
- Mortality: three patients were reported to have died during follow-up.
- Neither the percentage of patients who were pain free nor quality-of-life outcomes were reported.

Critical review and synthesis of information

As metal-on-metal hip resurfacing arthroplasty is a comparatively new technique, no studies comparing metal-on-metal hip resurfacing arthroplasty with any of the other comparators were found. Furthermore, few studies reporting case series data were found. From the data that were found, it was difficult to combine or compare results, because of differences in patient characteristics, lack of complete data and consistent outcomes across studies, and the different lengths of study follow-up. In order to provide some information, these limited data have been organised in a series of pairwise comparisons of metal-on-metal hip resurfacing arthroplasty to the alternative treatments.

Metal-on-metal hip resurfacing arthroplasty versus watchful waiting

In the metal-on-metal hip resurfacing arthroplasty and watchful waiting studies, the patients had, in the main, a preoperative diagnosis of osteoarthritis. For the metal-on-metal hip resurfacing arthroplasty studies, the mean ages of patients varied between 36 and 49 years and for the watchful waiting study the mean age of patients was 50 years. Between 0% and 14.3% of patients in the metal-on-metal hip resurfacing arthroplasty studies required revision surgery within 4 years of their initial operation.[20–22,24,37,41,42] (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001) In comparison, 3 years post-operatively, 32% of patients from the one

watchful waiting study identified had had surgery (predominantly THR).[6–8]

The very limited evidence suggests that metal-on-metal hip resurfacing arthroplasty is more effective in terms of better quality of life (measured by pain scores for watchful waiting and hip scores for metal-on-metal hip resurfacing arthroplasty) than watchful waiting over a follow-up period of approximately 3 years. During this follow-up period, individuals undergoing watchful waiting had slight increases in their pain levels,[6–8] whereas the hip scores for metal-on-metal hip resurfacing arthroplasty patients all improved during a similar length of follow-up.[20–22,24,37,41,42] (Oswestry Outcome Centre, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001)

Metal-on-metal hip resurfacing arthroplasty versus THR

The patients in the metal-on-metal hip resurfacing arthroplasty studies were younger than those in the THR studies. Older patients are more likely to have complications during or after surgery, which makes it difficult to compare these interventions. The short follow-up periods of the metal-on-metal hip resurfacing arthroplasty studies also made them difficult to compare with the THR studies, which generally had longer follow-up periods. For example, several prostheses had revision rates of 10% or less at 10 years or more.[30] The lack of long-term data on metal-on-metal hip resurfacing arthroplasty hampered comparison; this is especially important, as Fitzpatrick and colleagues[30] reported that the rates of revision tend to increase significantly after 10 years. It is also unclear whether THR would be as successful for a younger and more active population. Data from the Swedish registry reported by Fitzpatrick and colleagues gave a revision rate of 19% at 14 years for people aged under 50 years at the time of the primary procedure.[30] One primary study was also identified that considered THR in a younger population (mean age 50 years; range 24–64 years).[56] In this study, only a slightly higher rate of revision surgery at a mean follow-up of 9.4 years (112.8 months) was found compared with the metal-on-metal hip resurfacing arthroplasty studies rate of revision surgery at a follow-up of 8.3–50.2 months. The only other outcome that could be compared was the proportion of patients who were pain free at follow-up. In one group of patients in one metal-on-metal hip resurfacing arthroplasty study,[42] this was reported to be 90.9% at 50.2 months follow-up. In their systematic review, Fitzpatrick and colleagues[30] reported a mean of 84.1% (range, 46–100) of patients pain free at 11-year follow-up.

Metal-on-metal hip resurfacing arthroplasty versus osteotomy

In the metal-on-metal hip resurfacing arthroplasty studies, the patient's preoperative diagnosis was mainly osteoarthritis, whereas in the osteotomy studies the main preoperative diagnosis was avascular necrosis or hip dysplasia. The follow-up periods for the osteotomy studies were much longer than for the metal-on-metal hip resurfacing arthroplasty studies. The revision rates to THR in four of the nine osteotomy studies that reported this outcome were within the range of the revision rates of metal-on-metal hip resurfacing arthroplasty to THR. As the osteotomy studies had follow-up periods of over 10 years, this suggests that osteotomy is effective over a quite a long period. Osteotomy may, however, be associated with a comparatively longer recovery period and it appears to be more effective in younger patients, as they were reported to have the lowest revision rates to THR.

Metal-on-metal hip resurfacing arthroplasty versus arthrodesis

The patients involved in the arthrodesis study were very much younger than the patients in the metal-on-metal hip resurfacing arthroplasty studies, and the preoperative diagnoses of the patients in the arthrodesis study differed from those in the metal-on-metal hip resurfacing arthroplasty studies. The arthrodesis study also has a longer follow-up period than the metal-on-metal hip resurfacing arthroplasty studies. These factors made it difficult to consider relative effectiveness. The percentage of arthrodesis patients who were pain free at 8 years post-operatively (22%)[33] was much lower than that for the metal-on-metal hip resurfacing arthroplasty study (90.9%) at approximately 4 years postoperatively.[42] It is unclear whether the pain level for people who received a metal-on-metal hip resurfacing arthroplasty would have deteriorated to such a level after 8 years.

Metal-on-metal hip resurfacing arthroplasty versus arthroscopy

The version of arthroscopy database interrogated for this study did not contain information on the ages of patients. The arthroscopy patients were followed for much longer than the participants in the metal-on-metal hip resurfacing arthroplasty studies. Compared with the metal-on-metal hip resurfacing arthroplasty studies, the THR revision rate for patients having arthroscopy was slightly

higher, although this was over a longer follow-up period. The number of complications with arthroscopy was very low (0.8%), and was lower than the complications reported following metal-on-metal hip resurfacing arthroplasty. The percentages of complications in the metal-on-metal hip arthroplasty studies ranged from 0.8% to 8.2%. When Harris hip scores were compared for metal-on-metal hip resurfacing arthroplasty and arthroscopy, the results suggested that metal-on-metal hip resurfacing arthroplasty resurfacing was more effective.

Summary and conclusions

Although the evidence base for making comparisons between metal-on-metal hip resurfacing arthroplasty and any of the comparators was limited, the following observations can be made. Metal-on-metal hip resurfacing arthroplasty has, from early data, the potential to be an effective technique for the management of hip disease. It is difficult, however, to know whether it is truly more or less effective when compared with any of the comparators. In many cases this is because, in the studies identified, patient populations had many dissimilarities, the outcomes used were not always comparable, and the available data were measured over different periods.

In this review, metal-on-metal hip arthroplasty has been treated as if it were a single homogeneous procedure. In reality, this is not the case as there are different prostheses and different surgical options available. The reviews of THR[1,30,38] indicated that there were considerable differences in the outcomes of different prostheses, and there is no reason to believe that metal-on-metal hip arthroplasty prostheses will be any different. However, in the analysis presented here, there is very limited evidence indicating whether there are differences in the outcomes of different metal-on-metal hip arthroplasty prostheses.

The data on metal-on-metal hip arthroplasty originates from a comparatively small number of surgeons. It is not clear whether their results could be replicated in practice. In particular, the available studies describe an evolution of the prostheses over time and also, presumably, surgical technique.

Although the patients in the metal-on-metal hip arthroplasty and the watchful waiting studies had, in the main, a preoperative diagnosis of osteoarthritis, the effectiveness of these management options remains difficult to assess as the data did not come from comparative studies. As a result it is unclear whether the types of osteoarthritis included, which have different natural histories, were similar. For some interventions (osteotomy) data were available over quite long periods (10 years plus), whereas for others (metal-on-metal hip resurfacing arthroplasty) data were only available for short follow-up periods (less than 5 years).

In this systematic review, an attempt has been made to identify and synthesise data for a number of pre-specified outcomes. Other outcomes could potentially have been specified in order to compare such interventions as the potential for genetic damage from a specific type of prosthesis or operation. However, to identify these data would have required the use of a different set of inclusion criteria.

Attempts were made to identify data relevant to the three subgroups of patients identified in chapter 1, and some data were identified for younger people who might be expected to outlive a primary THR and older people who might outlive a THR because of their desired activity levels. Despite this, no data were identified relevant to those who would not be suitable for consideration for THR for reasons other than expected survival or activity.

As the failure rates for some types of THR prosthesis increase markedly after 10 years,[30] and it is possible that the same could apply to the different types of metal-on-metal hip resurfacing arthroplasty, there is a need for comparative long-term studies of good methodological quality. Such studies should preferably be on a large scale and use standard outcome measures, both pre- and post-operatively. The studies should not only measure revision rates for comparable patients but should also assess the success of revision surgery, in terms of subsequent function and quality of life.

Chapter 4

Systematic review of economic evidence

Methods

Search strategies

Studies that reported both costs and outcomes of metal-on-metal hip resurfacing arthroplasty compared with any of the comparators (watchful waiting, THR, osteotomy, arthrodesis, arthroscopy) were sought from four sources.

1. A systematic identification of studies that reported both costs and outcomes performed alongside relevant RCTs and comparative observational studies.
2. A search for studies reporting single intervention observational studies.
3. A search on NHS EED.
4. The manufacturers' submissions to NICE.

Inclusion and exclusion criteria

In order for studies to be included, metal-on-metal hip resurfacing arthroplasty had to be compared with any of the comparators in terms of their costs and effectiveness. Studies in languages other than English were identified from their abstracts but not included in the review. A single economist assessed all abstracts for relevance. Copies of the full papers were obtained for all those studies that appeared potentially relevant, and these were formally assessed for relevance.

Data abstraction

The following data were extracted for each included study.

1. Study characteristics
   - The research question
   - The study design
   - The comparison
   - The setting
   - The basis of costing
2. Characteristics of the study population or of the populations that formed the basis of the data used in a modelling exercise
   - Numbers receiving or randomised to each intervention
   - Dates to which data on effectiveness and costs related
3. Duration of follow-up for both effectiveness and costs
4. Results
   - Summary of effectiveness and costs (point estimate and, if reported, range or SD)
   - Summary of cost-effectiveness/utility (point estimate and, if reported, range or SD)
   - Sensitivity analysis
5. Conclusions as reported by the study authors

Quality assessment

A single economist assessed the included studies against the 35-point *BMJ* checklist for referees of economic analyses.[57] The questions were set out on a standard form generated before the review.

Data synthesis

No attempt was made to synthesise the studies that were identified quantitatively. Data from any included studies were summarised and evaluated by a single economist in order to identify common results, variations and weakness between studies. These data were then interpreted alongside the results of the systematic review of effectiveness, so that conclusions could be drawn on the relative efficiency of metal-on-metal hip resurfacing arthroplasty compared with any of the comparators (watchful waiting, THR, osteotomy, arthrodesis and arthroscopy).

Results

No studies eligible for inclusion were identified from the review of the literature. Of the three industry submissions to NICE, only one provided an economic evaluation.[22] Hence, the remainder of this chapter provides a summary and critique of that submission.

The unpublished industry submission from MMT included an economic model of BHR (metal-on-metal) compared with watchful waiting and THR. Both a base case and a probabilistic analysis were included. The submission comprised both a text document and supporting Excel™ spreadsheets.

The submission maintained that BHR should only be compared with watchful waiting, as BHR should not be used when THR was appropriate. This claim is, however, contentious as others have argued that THR should be compared with metal-on-metal hip

resurfacing arthroplasty in younger patients whose symptoms are judged to warrant arthroplasty. The submission did, however, provide a comparison with THR for completeness. The submission stated that "it is not anticipated that patient selection for BHR will change to include older patients ... until more clinical data are available, as this group are currently managed well with THR", and that "BHR is and will only be used in younger patients aged 45 to 65 [years]". Despite these statements, the data for BHR effectiveness came from BHR patients aged 15–86 years (with an indication that 95% of BHRs have been carried out on "patients who are too young for a usual THR"). An estimate of the budgetary implications of the technology for the NHS was provided, although it was unclear whether this estimate was only for individuals aged 45–65 years.

The economic evaluation conducted for the two comparators is described and commented on below, with particular attention to the 35 points identified in the *BMJ* guidelines for good economic evaluations.[57] The criteria can be split under three broad headings – those that relate to design issues (criteria 1–7); those that relate to data collection issues (criteria 8–19); and analysis and interpretation of results (criteria 20–35). Summary assessments for each criterion are presented in appendix 12.

Design issues

Issues relating to the research question, importance of the question, viewpoint and rationale for choosing the alternatives were specified by NICE. The perspective of the analyses is that of the health service (e.g. costs to the NHS).

Data collection issues

The submission provides estimates of BHR effectiveness and cost, using industry data and estimates from the literature for the comparators.

Effectiveness of BHR

The main measure of effectiveness, time to revision, was calculated based on data for 1693 BHRs conducted by four surgeons. Patient numbers varied somewhat for the other epidemiological or effectiveness measures provided. One surgeon conducted 1382 (82%) of the procedures; his patients accounted for eight of the nine revisions reported during follow-up. Follow-up was on 66% of patients for 1 year, 38% for 2 years, 21% for 3 years, and 1% (21 patients) for 4 years. Revision rates beyond 4 years were assumed to increase at the same rate as revision rates for THR, based on data from the Swedish national hip register.[16] Base-case revision rates assumed for BHR ranged from 0.5% in year two up to an annual rate of 2.5% from year 11 onwards. Sensitivity analysis allowed the BHR revision rate to increase up to the THR revision rate (1% in year two up to an annual rate of 5% from year 11 onwards). Some additional data on epidemiology, disease, gender distribution, and functional scores were provided. The utility analysis assumed that BHR utility scores before and after surgery (0.19 and 0.81) were the same as those provided in the literature for THR (apparently by Laupacis and colleagues,[59] although the specific source was not indicated). There was no discussion as to whether these data were appropriate, although they had also been used in an earlier HTA review.[30]

Costs of BHR

The cost of BHR used in the submission was obtained by:

(i) taking the Department of Health reference cost for primary THR (£3678, year not indicated)
(ii) adding the amount by which the BHR device costs more than a typical Charnley device (£1730 versus £580)
(iii) subtracting the value of the estimated (shorter) stay differential required for BHR (2.6 hospital bed days valued at £170 based on Personal Social Services Research Unit data)[58] (the data justifying the shorter length of stay were not provided or cited; in the discussion it was also maintained that surgical time is shorter for BHR than for THR but no adjustment was made for this difference).

The final cost for BHR was estimated at £4386. The spreadsheets provided with the submission appeared to use an assumption of a 20% variation around this estimate.

Effectiveness and costs of watchful waiting

The effectiveness of watchful waiting (which involves non-steroidal anti-inflammatory drug (NSAID) therapy and standardised care) was also based on the work of Laupacis and colleagues.[59] Quality of life was estimated to rise from 0.19 before treatment to 0.39 with treatment. The model appeared to assume that people never leave the state of watchful waiting except by dying during hospitalisation. The costs of watchful waiting were based on resource use measures for various services (NSAIDs, other drugs, general practioner (GP) contacts, annual hospitalisations) and associated resource costs from the literature. In addition to variation in the effect variables, the

watchful waiting analysis also allowed for variation in gastro-protective drugs prescribed, incidence of gastrointestinal complaints, incidence of ulcer, GP contacts, laboratory tests, risk of endoscopy for ulcers and hospital use for ulcers. Ranges for minimum and maximum values were specified for various components of resource use and cost.

Effectiveness and costs of THR

As noted earlier, the submission to NICE used estimates of THR revision rates from the Swedish national hip register data[16] (1% in year two up to an annual rate of 5% from year 11 onwards) for the base-case estimate, and utility scores of 0.19 and 0.81 were assumed before and after THR surgery. A quality-adjusted life-year (QALY) reduction of 0.62 was assumed during the year of the revision for both THR and BHR. Utility increased back to 0.81 even after a revision THR; this assumption is problematic, in the sense that revision THR may not achieve the same utility as is obtained through initial THR. Department of Health standard reference costs (year not provided) were set at £3678 for a primary THR (either as the initial operation or as a revision following BHR) and at £5688 for a revision THR following primary THR.

Analysis issues

The incremental cost-effectiveness ratios (ICERs) for cost per QALY, for up to 20 years following the initial treatment decision, were provided for both a base-case analysis and a probabilistic analysis. The probabilistic analysis allowed for variation in the following variables: revision rates, cost of surgical procedures and risk of pain (including utility scores for severe pain and no pain), although the basis for the variation was not provided. The text of the submission also did not specify the distributions that were assumed for the effectiveness and cost variables. In the study, it was noted that the life expectancy of patients aged 45 and 65 years (33 and 24 years, respectively) exceeded their 20-year estimation framework. The submission indicated at one point that costs were discounted at 0% and 6%, although elsewhere in the text and spreadsheets a discount rate of 5% was reported. Outcomes were discounted at 0% and 1.5%. In the main base-case results from the submission to NICE, shown in *Table 3*, there was no indication which discount rates had been used.

Modelling of cost-effectiveness of BHR versus watchful waiting

The base-case analysis presented in *Table 3* shows that BHR provides a substantial improvement in QALYs over watchful waiting at each point in time. This result is not surprising since people do not appear to leave the state of watchful waiting because of subsequent receipt of a procedure or death. The submission to NICE indicated a low death rate (0.13%) from admissions for treatment of ulcers but neither the submission nor the accompanying spreadsheets incorporated all-cause mortality. The net costs were positive (BHR costs more than watchful waiting) for the first 15 years but, by year 20, BHR costs were less than watchful waiting, apparently due to the accumulation of repeated watchful waiting costs over the years. Thus, the cost per additional QALY for BHR instead of watchful waiting decreased over time to the point where BHR dominated watchful waiting (i.e. had lower costs and better effectiveness) at year 20.

TABLE 3 *Cost and utility analysis of BHR compared with THR and watchful waiting: based on 1000 patients using base-case data*[*]

Difference from BHR (based on BHR minus comparator): based on 1000 patients				
	Year 5	**Year 10**	**Year 15**	**Year 20**
QALYs gained by BHR compared with:				
THR	29	59	86	112
Watchful waiting	2,499	4,816	6,967	8,963
Extra cost with BHR compared with:				
THR	£378,511	£86,598	–£142,124	–£321,333
Watchful waiting	£2,752,517	£1,479,703	£482,420	–£298,977
ICER (£/QALY) with BHR compared with:				
THR	£13,125	£1,476	BHR dominates	BHR dominates
Watchful waiting	£1,101	£307	£69	BHR dominates

[*] *Reproduced from the submission to NICE by MMT*[22]

In the probabilistic analysis, the BHR revision rate, BHR costs, risk of pain and costs of watchful waiting were allowed to vary. The text of the submission to NICE indicated that BHR always dominated watchful waiting at the 20-year follow-up in the probabilistic analysis.

Modelling of cost-effectiveness of BHR versus THR

The data presented in *Table 3* indicate that BHR provided a very small improvement in QALYs over THR at each point in time. This gain apparently occurred because, although the same utility values were assumed for BHR and THR, the higher revision rate assumed for THR resulted in a more frequent reduction in QALY score during follow-up. Costs were higher when the initial surgery was BHR instead of THR for at least the first 10 years of follow-up but, beyond year 12, the cumulative costs of the THR strategy exceeded the BHR strategy (because of the combined influences of the lower revision rate assumed for BHR and the assumption that the initial revision following BHR cost less than revision following THR). Thus the BHR strategy dominated the THR strategy by having better effectiveness and lower costs from year 13 onwards. The submission to NICE also indicated that under a worst-case scenario (BHR revision rates equal THR revision rates), BHR never dominates but only costs £200 more per person than THR. In this situation, THR would be dominant as it is less costly and supplies the same number of QALYs. The 'break-even' point of equal cost at 20-year follow-up is obtained when BHR revision rates were 85% of THR revision rates for a 55-year-old patient.

The probabilistic analysis allowed effects and costs to vary by amounts specified in the submission spreadsheets (e.g. 20% variation around base-case cost and 10% around base-case effects). The analysis results indicated that by year 20, BHR dominated 57% of the time, THR dominated 15% of the time, BHR was less effective and less costly 28% of the time, and BHR was more effective and more costly 0% of the time. The last two results are surprising since the base-case result assumed that BHR was more effective and less costly, but they may be due to the most optimistic assumption being used in the base-case model – that annual BHR revision rates were half those for THR.

Summary comments

The MMT industry submission to NICE concluded that, "there are probably serious equity issues associated with denying these [younger] patients BHR if the only recommended alternative is watchful waiting with agents that do not work." Indeed, the evidence of gains in utility at reasonable cost within 5 years of BHR instead of watchful waiting (ICER = £1101) seems quite strong. Yet there were two critical assumptions in the models that imply a need for caution in accepting the full results of the analysis. First and foremost, no evidence was presented on revision rates from BHR beyond 4 years, and the 4-year estimate provided in the submission was based on only 21 patients. Second, the model assumed that people remained in watchful waiting, exiting only by death during hospitalisation (a low probability event); a more realistic model would have assumed that most people eventually become candidates for THR or some alternative treatment either by further disease progression or increasing age. Variations in these assumptions (e.g. a substantial increase in revision rates beyond 4 years) could eliminate the dominance of BHR in the 20-year follow-up period.

The MMT submission to NICE did make several assumptions that were 'conservative' with respect to BHR. It maintained that BHR surgery takes less time (albeit without providing any evidence) but, conservatively, did not adjust BHR costs downwards. It used a relatively inexpensive THR prosthesis and also assumed that revision THR provides the same utility as an initial THR. All of these assumptions mean that the analysis of BHR versus THR was not as favourable for BHR as it might otherwise have been. Yet the paucity of data on a number of factors argues for caution in accepting the submission indication that BHR should be preferred to primary THR in younger or more active patients. Aside from the lack of data on BHR revision rates beyond 4 years, no data were provided for revision rates for primary THR following BHR. If revision rates of primary THR following BHR are higher than revision rates for initial THR (i.e. if the first THR following BHR does not last as long as an initial primary THR without BHR), the dominance of BHR in the base case could be lost. Dominance or additional benefits judged to be worth additional costs from BHR could similarly be eliminated if the estimated QALYs differed between the procedures. Within the model, BHR, revision of BHR, primary THR and revision of THR were all given the same utility score. A situation may exist in which primary THR following BHR results in lower QALYs than primary THR without BHR.

One further qualification with respect to the analysis is that the submission was based on

"patients who present with severe hip joint pain and negligible problems with other joints". The submission correctly indicated that patients with multiple joint involvement have "less reduction in global pain". The submission went on to say that "cost-effectiveness ratios will be higher in multiple joint patients", and that "it would be perverse that BHR (or THR) is cost-effective in patients with only hip joint damage but not in patients with more widespread disease". From a wider perspective, however, it would seem that the absolute increase in QALYs is what should be used to make resource allocation decisions.

While most of the data in the analysis appeared to have come from persons aged under 65 years, some data did come from older (or substantially younger) patients. Whether parameters such as the estimated revision rate following BHR vary by age simply is not known. The precision in the cost estimates used in the submission is probably fairly high but the revision rates and associated QALY estimates were, in many places, assumptions based on limited data. The contradiction in the submission between the statement that "BHR is and will only be used in younger patients aged 45 to 65 [years]" and the use of data for a broader age range of patients who received BHR was not addressed or resolved.

In total, the industry submission represents a reasonably complete economic evaluation of BHR versus watchful waiting and THR. As indicated in appendix 12, attempts were made to address most of the key considerations advocated by the *BMJ* for economic evaluations.[57] Some assumptions were difficult to follow in the text and/or spreadsheets, justification for certain assumptions was not provided (e.g. the variance assumed on the key effect and cost parameters) and, in some cases, important considerations were not addressed (e.g. exiting from watchful waiting to THR). Despite these points, the evaluation was fairly thorough, although the assumption that people do not eventually leave the state of watchful waiting for some form of surgery is dubious. The most important limitation of this evaluation is undoubtedly the limited evidence base available for the effectiveness of BHR (and metal-on-metal hip resurfacing arthroplasty more generally). It is this same lack of any evidence on the effectiveness of metal-on-metal hip resurfacing arthroplasty beyond 4 years following surgery that limits the economic evaluation reported in the next chapter.

Chapter 5

Economic modelling

Markov model framework and key parameter estimates

The aim of the economic evaluation was to assess the cost-effectiveness of metal-on-metal hip resurfacing arthroplasty relative to the alternative interventions for patients with hip disease. The evaluation was based on a Markov model, which was run using a hypothetical cohort of patients. A Markov model is composed of a set of defined states of health between which a patient can move over successive periods. Transition probabilities are used to allow a patient to move within and between these states of health. A patient can be in only one state of health at any time and can make only one transition per cycle. A cycle is a discrete period spent in each state of health before transition to a successive state of health. A relevant period is chosen for the length of a cycle and the cycles then link together to create a 'Markov chain.' In this study, the cycle length used was 1 year. Length and quality of life may vary across the different states. The total cost is determined by the occurrence or recurrence of different states and the lengths of time spent in each of the various states.

In this study, the economic model was designed to estimate a typical patient's costs and outcomes for the alternative treatments over a 20-year follow-up period. This period was chosen to facilitate comparison with the industry submission. The four main treatment approaches to hip disease are summarised in *Figure 1*. The interventions are not considered in the same order as the rest of the report because this is the clearest way of describing the model structure. Each option resulted in a simplified Markov model, as depicted in subsequent figures. These focus on the main treatment pathways and do not reflect the full set of complications that could arise with each procedure and, as explained below, complications following operations have not been explicitly modelled.

The Markov model for the most frequently used treatment, THR, is summarised in *Figure 2*. This figure is identical in structure to the Markov model used in an earlier report in *Health Technology Assessment* on THR by Fitzpatrick and colleagues.[30]

The Markov model for the treatment that is the focus of this study, metal-on-metal hip resurfacing arthroplasty, is summarised in *Figure 3*. For the purposes of this study, it was assumed that an initial decision to use metal-on-metal hip resurfacing arthroplasty was ultimately followed by a decision to use THR, unless death occurred before the need for other treatment. Too few data were available to consider modelling a decision to have a revision metal-on-metal resurfacing, although this is a clinical possibility that may merit future study.

Bone-conserving alternative treatments (osteotomy, arthrodesis, or arthroscopy) are represented in the third node of *Figure 1*. Separate models are not

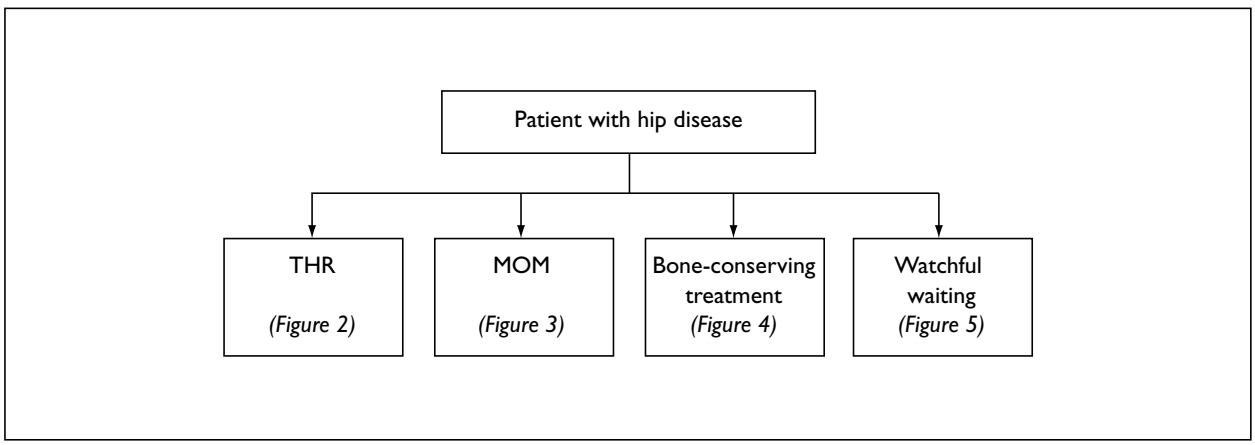

FIGURE 1 *Decision tree for treatment alternatives for hip disease*

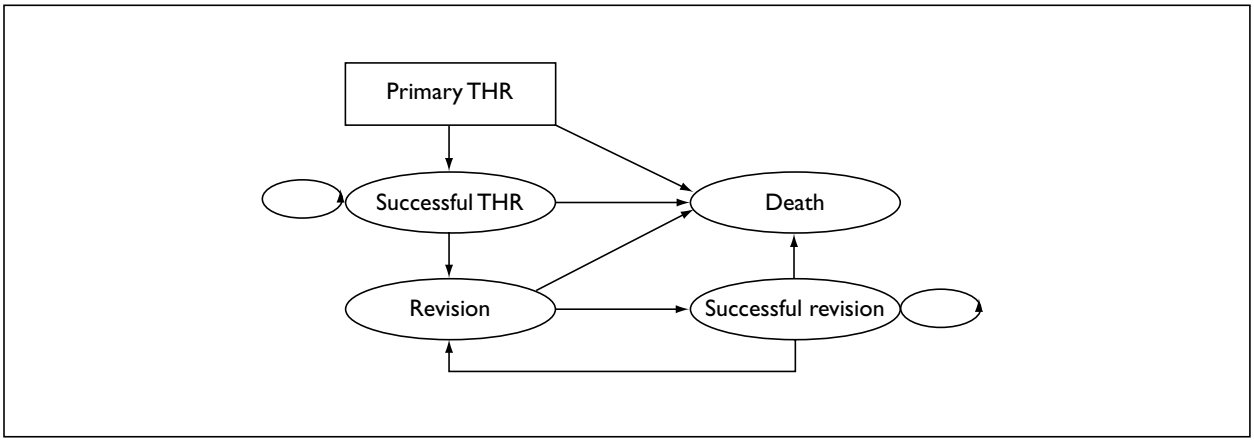

FIGURE 2 *Markov model for an individual receiving a THR as their initial replacement procedure*

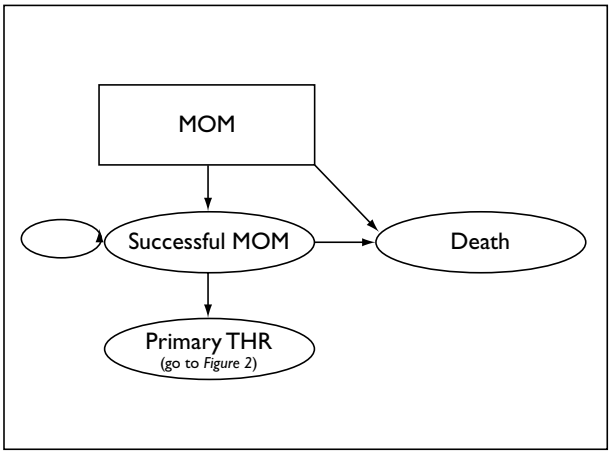

FIGURE 3 *Markov model for an individual receiving a metal-on-metal hip resurfacing arthroplasty as their initial replacement procedure*

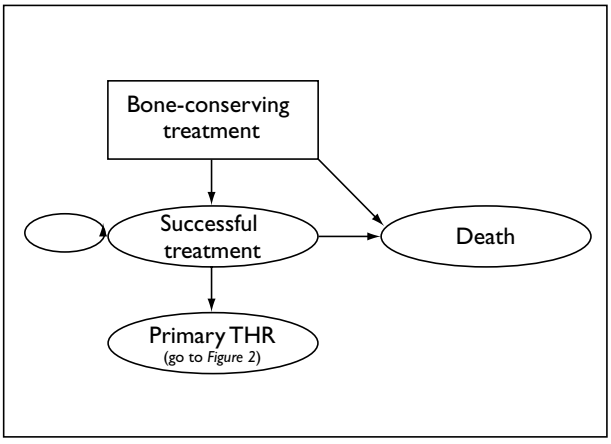

FIGURE 4 *Markov model for an individual receiving bone-conserving treatment as their initial replacement procedure*

depicted for each of the bone-conserving treatments, as the process for each treatment was assumed to be the same (see *Figure 4*). Because there were too few data on revision rates and health outcomes for arthrodesis, economic modelling of this bone-conserving alternative was not undertaken. The model assumed that an initial decision to use a bone-conserving treatment was ultimately followed by a decision to use THR, unless death occurred before the need for the procedure, as represented in *Figure 4*. Once THR is used, the Markov model is identical in structure to that for primary THR (*Figure 2*), although the probabilities, quality of life, and calculated total cost may vary. In theory, metal-on-metal hip resurfacing arthroplasty could be used as an alternative to THR but, for simplicity and to keep the comparison of other bone-conserving treatments to metal-on-metal hip resurfacing arthroplasty pure, this possibility was not included in the figure.

Watchful waiting is represented in *Figure 5*. The model assumes that an initial decision to use watchful waiting was ultimately followed, once quality of life declined to an unacceptable level, by a decision to use THR unless death occurred before the need for other treatment, as represented in *Figure 5*. Once THR was used, the Markov model for THR (*Figure 2*) is identical in structure to those for primary treatments, although once again the probabilities, quality of life, and calculated total cost may vary as the data allow. As noted earlier, the simplified figures do not reflect complications that could arise, such as hospitalisations caused by adverse drug reactions to therapy provided as part of watchful waiting. Also, metal-on-metal hip resurfacing or a bone-conserving treatment could be used in lieu of THR; however, the models presented in this analysis do not incorporate these possibilities.

While the model structures permitted variation in the parameters of the treatment-specific

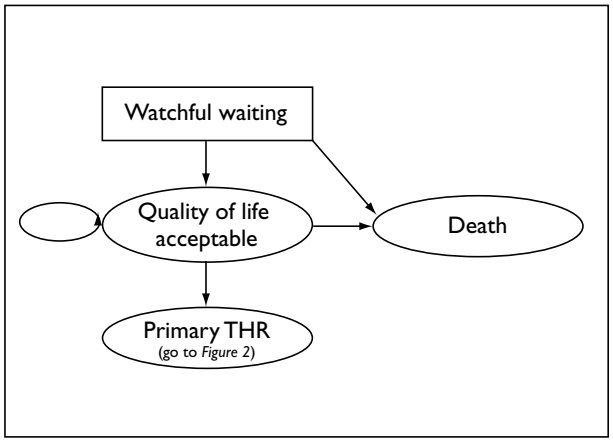

FIGURE 5 *Markov model for an individual undergoing watchful waiting*

Markov models across each of the nodes in theory, in practice it was necessary, because of a lack of available evidence, to assume that many parameters were identical across the different branches.

Models for each treatment alternative outlined in *Figures 2–5* were developed and applied using DATA software (©TreeAge Software Inc.) (see appendix 13). Separate models were estimated for younger individuals (e.g. aged 45–50 years on entry) and more active elderly people (e.g. aged 65–70 years on entry). The costs, probabilities and outcome estimates (e.g. length or quality of life within a state) that were incorporated into the estimation of the models are described below.

Cost estimation

The following equation was used for estimating the present value of costs:

$$PVC_A = TC_A + \sum_{t=0}^{n} [(P_{xt})(P_{yt})C_r] \;/\; (1 + 0.06)^n$$

where:
PVC_A = present value of the cost of treatment alternative 'A' over n years ($t = 0, \ldots n$)
TC_A = total cost of initial operation/approach
P_{xt} = probability of being alive in year t
P_{yt} = probability of revision operation in year t
C_r = costs of revision operation
0.06 = discount rate for healthcare costs[18]

Total procedure costs included operation costs, hospital ward costs, and follow-up costs. In all cases, the costs for any procedure included, where relevant, the components outlined in *Table 4*.

THR and revision THR costs

The costs of THR and revision THR were taken directly from those published in a previous *HTA* report,[30] with prices updated to year 2000 NHS prices.[58] Based on clinical opinion, it was considered that the length of stay for THR patients used in the earlier review was no longer valid as patients can now usually be discharged sooner. Hence, the current length of hospitalisation after THR was assumed to be shorter at roughly 10 days, rather than the 12 days used in the earlier review.[30] This approach gave a cost for THR of £4076 and for a revision hip replacement of £5908 (*Table 5*). Previous studies had not included post-hospital costs (e.g. for community health services) but, for this review, the follow-up costs incurred during the first year after discharge were considered to be important and, hence, were included. A typical patient was assumed to have two outpatient visits, one of which would include having an X-ray. Follow-up costs for these services in the year after the operation were estimated to be £119.

Metal-on-metal hip resurfacing arthroplasty costs

The cost of the prosthesis used in metal-on-metal hip resurfacing arthroplasty was obtained by contacting the relevant manufacturers. Of four companies contacted, two replied with details of their prices for a metal-on-metal prosthesis. The figures quoted were £1730 for an acetabular cup and femoral head set (Hatton J, Managing Director, MMT: personal communication, 2001)

TABLE 4 *Cost components for surgical interventions*

	Cost components	
Surgery	**Hospitalisation**	**Community healthcare**
Prosthesis cost	Cost per day	GP visits
Scheduled theatre time	Length of stay	Physiotherapy
Recovery room time	Ward overheads	Relevant prescriptions
Staff in theatre and recovery		
Staff salaries		
Consumables/drugs/tests (e.g. X-rays)		
Theatre overheads		

and £1890 for a Conserve™ plus femoral head and acetabular component (Fry J, Wright Cremascoli Ortho: personal communication, 2001).

After discussions with local clinical experts, it was considered reasonable to assume that the theatre time and theatre staff required for metal-on-metal hip resurfacing arthroplasty would be similar to those for primary THR. Most of the other resource quantities used in the earlier review of THR[30] were considered appropriate for the purposes of the current study. The exception was length of stay – a shorter average length of stay of 10 days was considered to be more reasonable than the previously used value of 12 days for a primary THR. The costs of follow-up during the first year after discharge for the metal-on-metal hip resurfacing arthroplasty were calculated using the method described above for THR. The estimated costs using the 10-day hospitalisation assumption are presented in *Table 5*. Using the lower of the two prostheses costs, the total cost for a metal-on-metal procedure was estimated at £5396. In the earlier review,[30] a procedure time of 134 minutes was used for THR. Based on local clinical opinion, this length of time was considered to be appropriate. However, since a longer operation time had been identified in the literature review and a shorter operation time was claimed by one of the industry submissions,[22] the impact of both shorter and longer operation times was explored in the sensitivity analysis.

Bone-conserving treatment costs

The costs for osteotomy and arthroscopy were taken from the NHS national schedule of reference costs.[23] Although the figures are not broken down into their component parts, they included all costs relevant to a patient's stay in hospital (i.e. direct costs and overheads for surgery, and stay in hospital post-operatively). Follow-up events after

TABLE 5 *Estimated costs for THR procedures*

	1996 prices[a]				2000 prices[b]			2000 prices	
	Primary THR		Revision THR		Primary THR		Revision THR	MOM	
	(units)	(£)	(units)	(£)	10-day LOS (£)	12-day LOS (£)	(£)	8-day LOS (£)	10-day LOS (£)
Theatre overheads (minutes)	134	655	195	954	731.41	731.41	1,065.29	731.41	731.41
Theatre staff									
Surgeon	–	66	–	97	73.70	73.70	108.32	73.70	73.70
Anaesthetist	–	66	–	97	73.70	73.70	108.32	73.70	73.70
Registrar	–	31	–	45	34.62	34.62	50.25	34.62	34.62
Nurse, F grade	–	24	–	35	26.80	26.80	39.08	26.80	26.80
Nurse, F grade	–	24	–	35	26.80	26.80	39.08	26.80	26.80
Nurse, E grade	–	21	–	30	23.45	23.45	33.50	23.45	23.45
Number of X-rays	6	134	6	134	149.63	149.63	149.63	149.63	149.63
LOS (days)	12	2,412	14	2,814	2,244.47	2,693.37	3,142.26	1,795.58	2,693.37
Number of outpatient visits	3	252	3	252	281.40	281.396	281.40	281.40	281.396
Prostheses costs									
Charnley	1	306	1	676	341.70	341.70	754.86	–	–
Cement	2	61	4	122	68.12	–	136.23	–	–
From MMT	–	–	–	–	–	–	–	1,730.00	1,730.00
Total cost per patient	**–**	**4,052**	**–**	**5,291**	**4,075.78**	**4,456.56**	**5,908.21**	**4,947.09**	**5,395.98**
First year follow-up costs									
Two outpatient visits, including one X-ray	–	–	–	–	118.74	118.74	118.74	118.74	118.74
Total cost per patient	**–**	**NA**	**–**	**NA**	**4,195**	**4,575**	**6,027**	**5,066**	**5,515**

[a] *Taken from Fitzpatrick* et al., Table 6[30]
[b] *Inflation index = 1.1167*
LOS, length of stay

TABLE 6 *Estimated costs for bone-conserving treatments*

National schedule of reference costs NHS Executive data	Costs (£)	Units	Notes
Osteotomy, code H19	2425		Primary osteotomy of pelvis for correction of congenital deformity of hip
Arthroscopy, HRG 10	575	Day case	No separate costs by joint involved and no distinction made between diagnostic and therapeutic use
	832	2-day stay	

discharge for a 'typical' patient undergoing bone-conserving treatment were those suggested by local clinical contacts.

All costs are listed in *Table 6*. The NHS national reference costs for bone-conserving treatments were £2425 for osteotomy and £832 for arthroscopy. While variation in costs between THR and metal-on-metal hip resurfacing arthroplasty may be minimal, such costs may be substantially different for some of the bone-conserving treatments. It was assumed that patients who had undergone osteotomy would most probably have three outpatient visits in the first year after their operation; patients having an arthroscopy would have one outpatient visit in the first year of follow-up. All patients would undergo an X-ray at one of these visits.

Watchful waiting costs

The costs of care for patients with hip disease who were not given one of the above interventions but were, instead, in a watchful waiting group are based on estimated physiotherapy requirements, GP visits and painkilling medication during the course of a year. Information on the nature and amount of this healthcare was obtained through discussions with local medical staff. Patients taking long-term courses of painkilling medication are prone to side-effects with varying degrees of severity. Little information was available in the literature to estimate the nature or cost of such side-effects in detail. The submission to NICE by MMT provided an account of these costs. In the absence of better information, this information was used in the evaluation.[22]

It was difficult to obtain an accurate picture of the treatment of people managed by watchful waiting that would be relevant to this study, because of the absence of a suitable database and the diversity of underlying conditions among the patients attending physiotherapy clinics. It was assumed that a typical patient undergoing watchful waiting might receive eight physiotherapy sessions at an outpatient clinic, together with three additional community physiotherapy sessions in a year, and that GP visits related to hip disease would be necessary, on average, twice per year. Depending on the degree of severity, typical medication would be either paracetamol, a low-dose NSAID such as ibuprofen or, in the more severe cases, an opioid analgesic such as co-codamol. Since details of the range or distribution of patients taking these alternative painkilling treatments were unavailable, it was assumed that most patients would take medium strength pain relief medication, namely ibuprofen, and that they would do so (based on the estimate in the MMT submission to NICE) for 270 days per year on average (see *Table 7*).

TABLE 7 *Estimated cost per patient with moderate osteoarthritis of watchful waiting*

Area of resource use	Quantity of resource use	Unit cost (£)	Annual cost per patient (£)	Source
Physiotherapy sessions – outpatient	Eight sessions per annum	37	296	PSSRU[58]
Physiotherapy in the community	Three sessions per annum	16	48	PSSRU[58]
Medication (assume 270 days per year):				
Ibuprofen	1.2 g daily	(0.6 g x 84 tabs = 3.66)	23.53	BNF[60]
GP visits	Two per annum	18	36	PSSRU[58]
NSAID events			238	MMT[22]
Total			**641.53**	

PSSRU, Personal Social Services Research Unit; BNF, British National Formulary

The MMT estimate provided an 'overall average cost' for treating these side-effects of £238 per patient.[22] Adding this to the estimated cost of physiotherapy, GP visits and medication gave an estimated total cost per patient of £641.53 per year. As discussed below, alternative values have been applied in the sensitivity analyses, in view of the potential uncertainty in this cost estimate.

Event probabilities

The event probabilities for the model were mortality rates, complication rates and revision rates (e.g. the annual probability that following initial use of a treatment alternative, a revision to a second procedure is necessary). Revision rates – the key probability driving the results – are described separately for each treatment alternative, after a brief description of mortality and complication rates.

The models used annual rates of mortality in 5-year age bands over the 20-year time horizon of the model. These mortality rates were taken from those published by the Office of National Statistics per 1000 population for England and Wales for the year 2000.[61] For the purposes of this study, the mortality rates for the general population were used due to the difficulties of identifying rates for specific disease subgroups (e.g. separate rates for those with osteoarthritis versus congenital hip disease). An average of the rates for males and females for entry to the models at either 45 or 65 years of age on entry was used. The mortality rates are detailed in appendix 14. The models also included an additional 1% operative mortality risk at the time of each surgical intervention, consistent with the model for THR.[30]

Branches for complications with associated revision probabilities, outcomes and costs could be added to the models depicted in *Figures 1–5* if appropriate data were found. The review did not give any indication that the effect of such extensions would be substantial. For simplicity, it was assumed that most complications during the operations were reflected in the average cost and quality-of-life adjustments associated with each of the interventions.

The revision rate for any intervention is defined as the risk of a patient requiring an alternative intervention some time after the original treatment. The models were run over a 20-year follow-up period to make the results comparable to the industry submissions to NICE. Hence, it was necessary to make assumptions about the longer-term risks of revision. In the absence of long-term data for most interventions, as discussed in more detail below, it was decided to apply the available annual equivalent risk data to the full follow-up period. Such an assumption is clearly tenuous and all results need to be considered in this light.

THR revision rates

Numerous studies have been published that show the rates of revision for patients after THR.[1,30,38] The available systematic reviews were deemed to be the best sources of effectiveness data for THR. The data, available for follow-up periods of up to 14 years, indicated that the revision rate is relatively low for the first 5 years following surgery but that it subsequently increases and becomes much more substantial between 10 and 14 years of follow-up. Fitzpatrick and colleagues[30] considered three possible models for the revision rate (hazard): a constant hazard, a linearly increasing hazard and a quadratic hazard. They found that the linearly increasing hazard fitted their data best overall but did not assess the appropriateness of the various functions by age group, even though they presented data separately for three age groups (under 50, 50–70 and greater than 70 years of age). Visual inspection of their figures suggests that the constant hazard may actually fit the observed data best for the first 10 years of follow-up, both overall as well as for the data by age group. The use of a constant hazard is discussed below.

Since the analysis was concerned with revision rates for younger persons or more active elderly persons, the main estimates of revision rates for THR were derived using data for persons aged 50 years or younger,[30] which resulted in an estimated annual equivalent revision rate of 1.36%. The annual equivalent revision rate for those aged 50–70 years was calculated to be slightly lower at 1.14% (possibly owing to lower activity levels in this age group). A recent study of a group of patients with an average age of 50 years and a mean follow-up period of 9.4 years, however, yielded annual equivalent revision rates of 1.59% and 2.02% for the two methods of THR investigated.[56] Hence, a range of revision rates were investigated in the sensitivity analyses.

Metal-on-metal hip resurfacing arthroplasty revision rates

The review process found very little evidence on metal-on-metal hip resurfacing arthroplasty revision rates, largely because this is a fairly new procedure. The reviewed metal-on-metal studies reported in appendix 6 showed revision rates of between 0% and 14.3% over different periods.

These figures were used to estimate the annual rate that would fit an increasing linear function to give a corresponding cumulative rate of revision at the end of the specified follow-up period of 20 years. From the available evidence, the data published by McMinn and colleagues was chosen.[42] The other published studies either had a very small sample size ($n = 21$)[37] or included a particularly young patient group who had had many previous operations and considerable deformity.[24]

The results of the McMinn study were given for four groups of patients, according to precise type of metal-on-metal hip resurfacing arthroplasty prosthesis.[42] There were no revisions in two groups (follow-up periods were 40.2 and 8.3 months). The group with the longest follow-up period (50.2 months) had a cumulative revision rate of 12.1%. The base-case value used in the modelling was 1.52%, which was derived by taking the weighted average of the annual equivalent revision rates from the four groups. This approach generated a cumulative rate at 20 years of approximately 30%. It should be noted that the 4-year rate from the published study[42] is higher than the revision rates provided as part of the MMT submission to NICE, which is based on substantially more cases for at least 3 years of follow-up and may reflect more recent experience following refinements to the technique as well as greater experience. Furthermore, aggregate data obtained from the Oswestry Outcome Centre (The Robert Jones and Agnes Hunt Orthopaedic and District Hospital: personal communication, 2001) also suggested the possibility of a lower metal-on-metal hip resurfacing arthroplasty revision rate. Because of the limited nature of this evidence on metal-on-metal hip resurfacing arthroplasty revision rates, sensitivity analyses were conducted on this parameter.

Arthroscopy revision rates

Data from the arthroscopy database (Villar R, Cambridge Hip and Knee Unit: personal communication, 2001) were analysed to find the percentage of patients who, following arthroscopy, under went a primary THR within the follow-up period. The cumulative revision rate at the end of the 11-year follow-up period was 19.2%. The average length of follow-up was 3 years. It was considered that the data would only be reliable for the first 5 years because of the increasing proportion of patients being lost to follow-up. A mean annual equivalent risk of revision of 8.53% was estimated using data from the first 5 years and then applied for the full follow-up period.

Osteotomy revision rates

An average annual rate of revision was obtained from the observational study that reported data in sufficient detail on the percentage of patients who had a THR over the period of follow-up after osteotomy.[44–55] The annual rates from each of the osteotomy studies included in the review ranged from 0.17%[54] to 2.69%.[44] These annual rates were combined by weighting the annual rate from each study by the size of the study. The weighted average annual equivalent risk of revision was estimated to be 0.83%. Details of how this risk was calculated are given in appendix 15.

Watchful waiting revision rates

For watchful waiting or waiting-list patients, the risk is the probability of undergoing a surgical intervention at a given time after entering the watchful waiting situation. Estimates of the annual risk of a primary THR for someone in the watchful waiting group were difficult to obtain, especially from good quality studies. Only one study was found in which details of outcomes were included for patients in the watchful waiting group – the outcomes were reported at 3 and 8 years.[6–8] The average annual equivalent probability of having surgery from the two different follow-up results was calculated to be 8.33%.

Health outcomes and quality-of-life estimates

A range of outcome measures was available for hip disease, including the Harris hip score, the Merle d'Aubigne or Charnley score, and the Western Ontario and McMaster Universities osteoarthritis measure (WOMAC) score. Most reviewed evidence provided effectiveness data in terms of hip scores or percentages of patients by severity of pain. Some studies assessed outcomes in terms of the percentages of patients with varying degrees of pain both pre- and post-operatively. All such measures are disease-specific, however, and only very limited evidence was found to facilitate a translation of any of the individual measures into a global quality-of-life score.

One study of quality-of-life scores for patients undergoing THR did report, along with disease-specific outcome measures, the results of a time trade-off study for alternative states of osteoarthritis of the hip pre- and post-THR.[59] A group of patients with osteoarthritis of the hip were asked to consider hypothetical scenarios that were designed to reflect patients having mild, moderate and severe osteoarthritis of the hip. The patients were then asked to state how many years in each of these hypothetical states they would give up to achieve

a certain number of years in perfect health. Their answers were mapped on a utility scale from 0 to 1, where 0 represented death and 1 represented perfect health. The resulting quality-of-life values for a patient 2 years after THR were estimated as 0.82, 0.52 and 0.18, for patients experiencing mild pain, moderate pain, or severe pain, respectively. A quality-of-life value of 1 was assumed for patients who were pain free 2 years post-THR. In the absence of better information, these data were used to define quality-of-life scores for each of the health states in the models (NB: these values are referred to below as 'time trade-off values').

To enable QALY scores to be estimated in the models, the quality-of-life values from the study by Laupacis and colleagues[59] were applied to the alternative health states in the models according to the assumed percentages of patients with no pain, or mild, moderate or severe pain. This method of calculating quality-of-life values for health states was used in an earlier report, in which it was assumed that 20% of patients would experience mild pain and 80% no pain following THR, thereby generating a quality-of-life score of 0.964 ($(0.20 \times 0.82) + 0.8$).[30] The quality-of-life adjustment figure was used to weight the length of time spent in each state of health. The summation of time spent in each health state provided life expectancy, and this time was weighted with the quality-of-life weights corresponding to the treatment received to obtain QALYs.

The models assumed that all patients were in the same underlying health state prior to treatment or entry to the 'model'. Based on the study by Laupacis and colleagues,[59] the time trade-off value for severe osteoarthritis of the hip was 0.19. The assumption that all patients were in the same health state prior to treatment or entry into the model is problematic, as the patient populations in the primary studies were not homogeneous in terms of pain levels, and hence quality of life, before treatment. This is an important caveat when interpreting the results of the evaluation.

For patients who had either metal-on-metal resurfacing, primary THR or arthroscopy, it was assumed that 20% would have mild pain and 80% no pain. Applying this to the time trade-off values gave a quality-of-life score of 0.964. The same assumption was also used for revision THR because of the lack of any data on quality of life following revision THR, although clinical indications are such that patients in this state probably do have reduced function and quality of life. There were also no data on function or quality of life for persons with revision THR following initial metal-on-metal hip resurfacing arthroplasty. The quality-of-life score following osteotomy was similarly derived using an assumption that 30% of patients would experience mild pain after osteotomy and 70% no pain. This gave a quality-of-life score of 0.946. For the watchful waiting state, the quality-of-life value was estimated using outcome information from Dieppe and colleagues[7] who reported the proportions of patients experiencing no pain, or mild, moderate or severe pain. Using this information, an average quality-of-life value of 0.5034 was estimated for patients in the watchful waiting group.

A simplifying assumption used in the model was that at the time of any transition involving a surgical intervention, a patient was assumed to lose 50% of their pre-operative quality-of-life value for the cycle in which the transition appears, before returning to the relevant post-operative quality-of-life state. This utility loss was incorporated in order to allow for the deterioration in quality of life in a patient requiring surgery, along with loss of quality of life during the recovery period following surgery. When the transition was to 'death', all of the pre-state quality of life was lost, implying a quality of life of zero for the year of death.

Discounting, subgroups, and sensitivity analyses

As specified in the guidelines for conducting health technology assessments,[18] discount rates of 6% and 1.5% per annum were applied in the model to costs and health-related quality-of-life values, respectively. Thus all costs and benefits that would occur in the future were given less weight than costs and benefits occurring now.

The Markov models were estimated using alternative values for two main patient types (subgroups). The first subgroup was 'younger people' aged 45 years at entry (using THR revision rates for those under 50 years of age and initial mortality rates for those aged 45 years). The second subgroup was 'more active elderly people' aged 65 years at entry. For this group, THR revision rates for those under 50 years of age were used, since it was assumed that the higher activity level of these people would result in the higher revision rate of the younger people, although the mortality rates were for people aged 65 years. It was expected that a model for a third patient group, 'people who would not be suitable for consideration for THR for reasons other than expected survival or activity', would be required

but, as no relevant data were identified, this model could not be populated.

The Markov models for 'younger people' were estimated for comparisons of metal-on-metal hip resurfacing arthroplasty to four alternative treatments: watchful waiting followed by THR (the most plausible alternative for this age group), THR, osteotomy and arthroscopy (both of the latter followed by THR). The Markov model for 'more active elderly people' was only estimated for metal-on-metal hip resurfacing arthroplasty compared with THR, as THR is the most common intervention for people aged 65 years or over.

Once the results of the basic models for the subgroups had been estimated, the model for young people, aged 45 years at entry, was re-run using alternative values for certain event probabilities and component costs estimates. The variables selected for sensitivity analysis were primarily chosen on the basis that the underlying data were poor. These variables included revision rates for metal-on-metal hip resurfacing arthroplasty and THR, and cost estimates for watchful waiting and metal-on-metal hip resurfacing arthroplasty.

Results

The model parameter estimates for costs, event probabilities, and quality of life are summarised in *Table 8*. The information on costs, event probabilities and quality of life was entered into the appropriate Markov models using the DATA software package. The present values of costs and QALYs (discounted at 6% and 1.5%, respectively) for each intervention were calculated by running the model for 20 cycles (i.e. for a 20-year follow-up period). The main cost-effectiveness and sensitivity analysis results are presented here in terms of incremental cost per QALY estimates.

Main results

The analysis results for the 'younger people' subgroup are shown in *Table 9*. The first part of the table provides information on the costs and QALY results for the various procedures. Costs for surgical procedures increased relatively slowly over time, as the main procedure costs occurred during the first year and costs in subsequent years were caused by the need for revision. In contrast, costs for watchful waiting increased more uniformly over time to a highest level at 20 years, since the treatment costs accrue to people on watchful waiting for each year of the estimation. Watchful waiting and arthroscopy resulted in the lowest level of QALYs at each point in time.

The middle part of *Table 9* provides information on net costs and QALYS for metal-on-metal hip resurfacing arthroplasty versus other procedures. Negative values for either net costs or net QALY change result in dominance of one procedure versus another, reflected by a negative ICER.

Metal-on-metal hip resurfacing arthroplasty ultimately dominated watchful waiting followed by THR. The initial costs of metal-on-metal hip resurfacing arthroplasty were greater than the costs of watchful waiting for a number of years, but the cumulative discounted costs of watchful waiting followed by THR eventually exceeded the metal-on-metal hip resurfacing arthroplasty costs. The gain in utility from metal-on-metal hip resurfacing arthroplasty was substantial, because of the low quality of life experienced during watchful waiting. The changes in incremental cost per QALY gained for metal-on-metal hip resurfacing arthroplasty compared with watchful waiting, over the full 20-year time horizon of the model, are shown in *Figure 6*. The incremental cost per QALY diminished until approximately 14.5 years post metal-on-metal hip arthroplasty, beyond which metal-on-metal hip arthroplasty was dominant over watchful waiting.

In contrast, the THR strategy dominated metal-on-metal hip resurfacing arthroplasty throughout the 20-year follow-up period, owing to THR being assumed to cost less and to have a slightly lower revision rate. It is important to note that the difference in utilities from metal-on-metal hip resurfacing arthroplasty and THR was so small because of the similarity in the revision rates and, more critically, because there were no data for the quality of life (or functional outcomes) for those receiving revision THR following metal-on-metal hip resurfacing arthroplasty or THR. Many clinicians acknowledge that functional outcomes for revision THR following primary THR may not be as good. No published information on quality of life following secondary (revision) THR was available, though Fitzpatrick and colleagues[30] did attempt to model this using estimates of pain differences. It is possible that primary THR following metal-on-metal hip resurfacing arthroplasty could result in better function, and hence higher utility (compared with revision THR following primary THR), because metal-on-metal hip resurfacing arthroplasty is bone-conserving relative to THR. Since no data were available, however, no difference in utilities could be incorporated in the analysis. Finally, the incremental costs per QALY for metal-

TABLE 8 *Summary of variables used in analysis*[*]

Costs	Definition	Value[**]	Source/notes
C1	MOM procedure cost (including follow-up costs)	£5515	See *Table 5* for further details
C2	THR procedure cost (including follow-up costs)	£4195	See *Table 5* for further details
C3	Revision THR procedure cost (including follow-up costs)	£6027	See *Table 5* for further details
C4	Annual cost of watchful waiting	£642	See *Table 7* for further details
C5	Arthroscopy procedure cost (including follow-up costs)	£951	NHS reference costs Follow-up costs from *Table 6*
C6	Osteotomy procedure cost (including follow-up costs)	£2731	NHS reference costs Follow-up costs from *Table 6*
Probabilities			
p1	MOM revision risk	0.01516	Average value from McMinn *et al.*[42]
p2	THR revision risk	0.01357	Derived from data for patients aged < 50 years in Fitzpatrick *et al.*[30]
p3	Osteotomy revision risk	0.0083	Weighted average from reviewed studies (see appendix 15)
p4	Arthroscopy revision risk	0.0853	Averaged from database (see appendix 11)
p5	Annual probability of THR for watchful waiting patients	0.0833	Based on mean time to surgery in Dieppe *et al.*[6,7]
p6	Mortality (all causes) for patients aged 45–50 years at outset in 5-year age bands. Includes 1% operative mortality where appropriate		See appendix 14
p7	Mortality (all causes) for patients aged 65–70 years at outset in 5-year age bands. Includes 1% operative mortality where appropriate		See appendix 14
Quality of life			
Q1	MOM	0.964	Based on assumed percentage patients by degree of pain and 'time trade-off' values given in Laupacis *et al.*[59]
Q2	THR (including revision THR)	0.964	As above
Q3	Watchful waiting	0.503	Based on percentage patients by degree of pain in Dieppe *et al.*[6,7] and 'time trade-off' values as above
Q4	Arthroscopy	0.964	As MOM and THR
Q5	Osteotomy	0.946	As above but with fewer patients pain free
Q6	Death	0	

[*] *Technical notes about how these data were used in the model are provided in appendix 16*
[**] *All costs are per patient in 2000 £(UK)*

on-metal hip resurfacing arthroplasty relative to osteotomy and arthroscopy were estimated to be £3028 and £344, respectively, for the 20-year follow-up period.

All the assumptions used in the analysis in *Table 9* were used in *Table 10,* except that higher mortality rates were incorporated to enable an assessment of the implication of using metal-on-metal hip resurfacing arthroplasty instead of watchful waiting or THR in somewhat older individuals, for example, those aged 65 years or over. For essentially the same reasons that relate to the results shown in *Table 9,* THR dominated metal-on-metal hip resurfacing arthroplasty for all of the follow-up period.

Sensitivity analysis results

The dominance of THR over metal-on-metal hip resurfacing arthroplasty in the main results for

TABLE 9 *Incremental cost-effectiveness results for metal-on-metal hip resurfacing arthroplasty versus comparators: base case 'younger person' scenario*

	Year 5	Year 10	Year 15	Year 20
Total costs				
MOM	£5,891	£6,078	£6,215	£6,297
Watchful waiting followed by THR	£3,937	£5,414	£6,189	£6,476
THR	£4,513	£4,721	£4,862	£4,940
Osteotomy	£2,784	£2,906	£2,996	£3,051
Arthroscopy	£2,960	£3,612	£3,966	£4,090
QALYs				
MOM	5.34	9.37	12.99	16.20
Watchful waiting followed by THR	3.36	6.48	9.58	12.46
THR	5.35	9.38	13.00	16.22
Osteotomy	5.17	8.95	12.27	15.12
Arthroscopy	4.31	6.74	8.66	10.17
Extra cost for MOM versus:				
Watchful waiting followed by THR	£1,953	£664	£26	–£179
THR	£1,378	£1,357	£1,353	£1,357
Osteotomy	£3,107	£3,173	£3,219	£3,245
Arthroscopy	£2,930	£2,466	£2,249	£2,080
QALYs gained by MOM versus:				
Watchful waiting followed by THR	1.98	2.89	3.41	3.73
THR	–0.01	–0.01	–0.01	–0.02
Osteotomy	0.17	0.42	0.72	1.07
Arthroscopy	1.03	2.63	4.33	6.04
Incremental cost per QALY for MOM versus:				
Watchful waiting followed by THR	£986	£230	£8	MOM dominates
THR	THR dominates	THR dominates	THR dominates	THR dominates
Osteotomy	£17,959	£7,554	£4,458	£3,039
Arthroscopy	£2,856	£938	£519	£366

Note: Costs in 2000 £(UK) are discounted by 6% per year over 20 years. QALYs are discounted by 1.5% per year over 20 years. The estimated annual revision rates are 0.01516 for MOM and 0.01357 for THR

both younger and more active elderly persons resulted from:

(i) limited evidence that THR revision rates are lower than metal-on-metal hip resurfacing arthroplasty revision rates (where the limited evidence is primarily for metal-on-metal)
(ii) reasonably strong evidence that metal-on-metal hip resurfacing arthroplasty costs more than THR (due to assumptions that the THR prosthesis costs less and the procedure time and subsequent resource use are approximately the same).

While the utility gain from metal-on-metal hip resurfacing arthroplasty in lieu of watchful waiting drives the model results, variations in the rate at which patients in watchful waiting are transferred to THR or in the quality of life under watchful waiting may also potentially affect whether watchful waiting is dominated by metal-on-metal hip resurfacing arthroplasty. Additional sensitivity analyses are presented here on these issues and assumptions. All the sensitivity analyses presented pertain to the younger age group, as the results were very similar to those for the older age group.

Variations in revision rates

As noted earlier, the use of a constant average annual revision rate for THR and metal-on-metal hip resurfacing arthroplasty meant that the rates were relatively high, especially in the early years

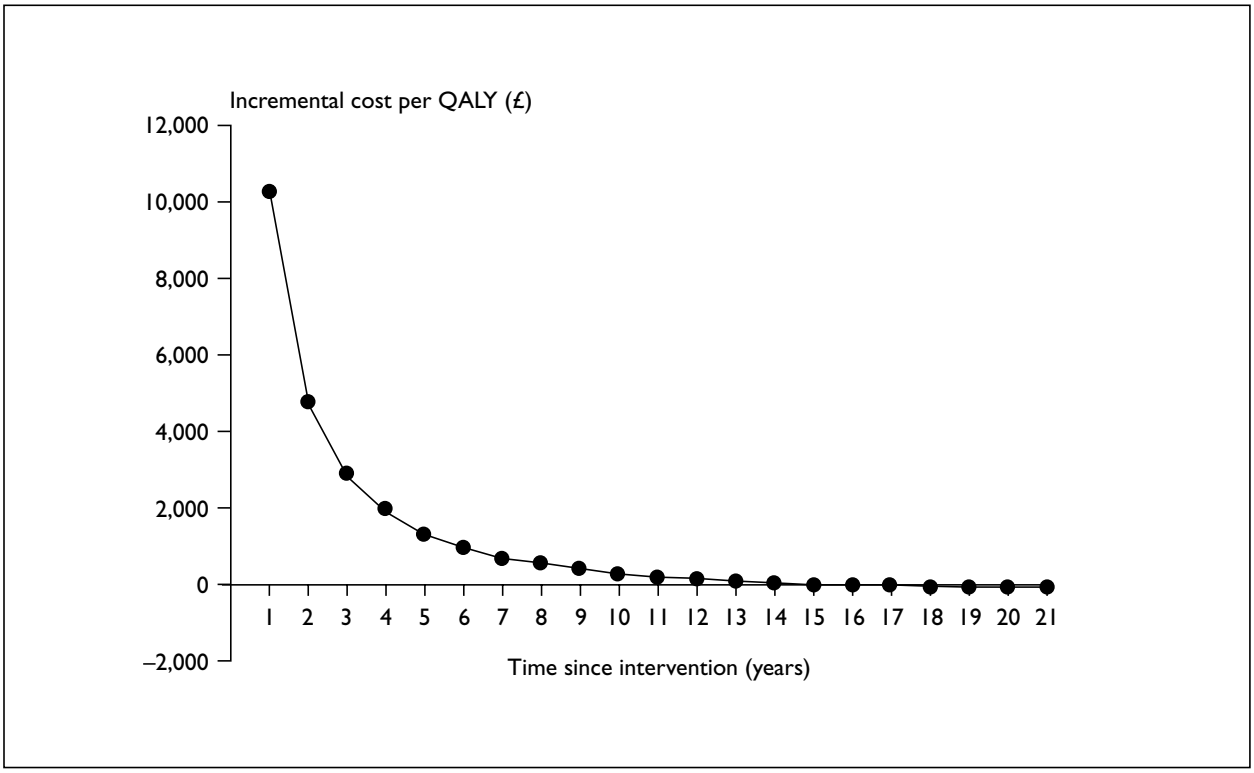

FIGURE 6 *Incremental cost per QALY for metal-on-metal hip resurfacing arthroplasty compared with watchful waiting over the complete follow-up period*

TABLE 10 *Incremental cost-effectiveness results for metal-on-metal hip resurfacing arthroplasty versus comparators: base case 'more active elderly person' scenario*

	Year 5	Year 10	Year 15	Year 20
Total cost: MOM	£5,880	£6,040	£6,137	£6,180
Total cost: THR	£4,500	£4,677	£4,777	£4,818
Total QALYs: MOM	5.05	8.38	10.81	12.31
Total QALYs: THR	5.06	8.39	10.83	12.33
QALYs: MOM versus THR	–0.01	–0.01	–0.02	–0.02
Extra cost: MOM versus THR	£1,380	£1,363	£1,360	£1,362
Incremental cost per QALY: MOM versus THR	THR dominates	THR dominates	THR dominates	THR dominates

Note: Costs in £(UK) are discounted by 6% per year over 20 years. QALYs are discounted by 1.5% per year over 20 years. Revision rates are the same as in Table 9 *(0.01516 for MOM and 0.01357 for THR) but a higher mortality rate is assumed to assess the implications of conducting MOM in an older population*

of the 20-year simulation. Yet what drove the model results were largely the relative rates. Hence, sensitivity analyses were undertaken, holding the THR revision rate constant while varying the metal-on-metal resurfacing rate, and vice versa. Rates for a range of different values were used to achieve two goals. The first was to identify the switching points (i.e. the point at which dominance of THR over metal-on-metal hip resurfacing arthroplasty occurs). The second was to illustrate the range of relative rates at which metal-on-metal hip resurfacing results in a level of cost per additional QALY that may be deemed to be affordable by society. The 20-year ICER results for these two scenarios are presented in *Table 11*. The first line of this table represents the base case for younger persons (presented in *Table 9*) in which THR dominates. Subsequent rows indicate that metal-on-metal hip resurfacing arthroplasty may become cost-effective as the revision rate of THR increases or the revision rate of metal-on-metal hip resurfacing arthroplasty decreases.

TABLE 11 *Sensitivity analysis varying the revision rates for THR and metal-on-metal hip resurfacing arthroplasty*

Sensitivity analysis: MOM revision rate held constant at 0.01516 while varying THR rate		Sensitivity analysis: THR revision rate held constant at 0.01357 while varying MOM rate	
Increasing THR revision rate	**20-year ICER MOM versus THR**	**Decreasing MOM revision rate**	**20-year ICER MOM versus THR**
0.01357	THR dominates	0.01516	THR dominates
0.01516	THR dominates	0.01230	THR dominates
0.01800	THR dominates	0.01000	£92,725
0.02000	£101,757	0.00500	£13,713
0.02500	£29,220	0.00100	£8,839

In the first two columns of *Table 11,* by increasing the THR revision rate, metal-on-metal hip resurfacing arthroplasty ceases to be dominated when its rate is roughly 80% of the THR rate (i.e. when the THR revision rate is roughly 0.019). In the third and fourth columns, by decreasing the metal-on-metal hip resurfacing revision rate, the procedure ceases to be dominated when the revision rate is roughly 88% of the THR rate (i.e. when the metal-on-metal rate is roughly 0.0120). As the revision rate of metal-on-metal hip resurfacing arthroplasty fell relative to THR, the ICERs also fell.

Since the MMT industry submission to NICE[22] showed that metal-on-metal hip resurfacing arthroplasty dominated THR at 20 years, it is insightful to investigate the results obtained when revision rates similar to those used in the industry submission are considered. Based on this, average annual equivalent rates of revision of 0.0178 and 0.0356 were calculated for metal-on-metal hip resurfacing arthroplasty and THR, respectively. Using these rates in the model (which differs from the industry submission model, as described above), it was found that, for a 20-year follow-up period, the incremental cost per QALY was £9735 gained with metal-on-metal hip resurfacing arthroplasty compared with THR. It is important to emphasise, however, that the THR revision rate is double that of the rate for metal-on-metal hip resurfacing arthroplasty and that, within the submission, and effectively under the assumption of a constant hazard rate, the pattern of increase in rates over time was identical.

The incremental costs per QALY of metal-on-metal hip resurfacing arthroplasty relative to watchful waiting at different revision rates for metal-on-metal resurfacing are shown in *Figure 7.* When the cumulative risk of revision for metal-on-metal hip resurfacing arthroplasty increased beyond approximately 43%, then resurfacing was no longer dominant. However, the incremental cost (not shown) and the incremental cost per QALY remained modest. The negative ICER values shown in *Figure 7* have been included only to illustrate those points at which metal-on-metal hip arthroplasty was dominant.

Variations in treatment costs

Two sensitivity analyses were conducted with respect to treatment costs: changes in the costs of watchful waiting and the effect of changes in the operation times for metal-on-metal hip resurfacing arthroplasty. As shown in *Figure 8,* when the annual cost of watchful waiting falls below approximately £620 per patient per annum, metal-on-metal hip resurfacing arthroplasty will no longer be dominant. Such a situation could arise if the care provided during watchful waiting was less intense, as may pertain to people with lower pain or impairment (who would also have a higher quality of life) or if there were fewer side-effects associated with medical therapy.

The incremental costs per QALY for metal hip resurfacing arthroplasty relative to watchful waiting are shown in *Figure 9* at different operation times for metal-on-metal hip resurfacing arthroplasty. This analysis also embodied different metal hip resurfacing arthroplasty revision rates. As shown in the figure, metal-on-metal hip resurfacing arthroplasty dominated the watchful waiting alternative at operation times greater than 134 minutes up to 20-year cumulative revision rates of approximately 30% (an average annual rate of approximately 0.015). When the operation time for metal-on-metal hip resurfacing arthroplasty was assumed to be 230 minutes (similar to the mean operation time reported by Schmalzried and colleagues[37]) the incremental cost per QALY relative to watchful waiting ranged from £84, at a 10% cumulative revision rate, to £448, at a 70% cumulative revision rate after 20 years.

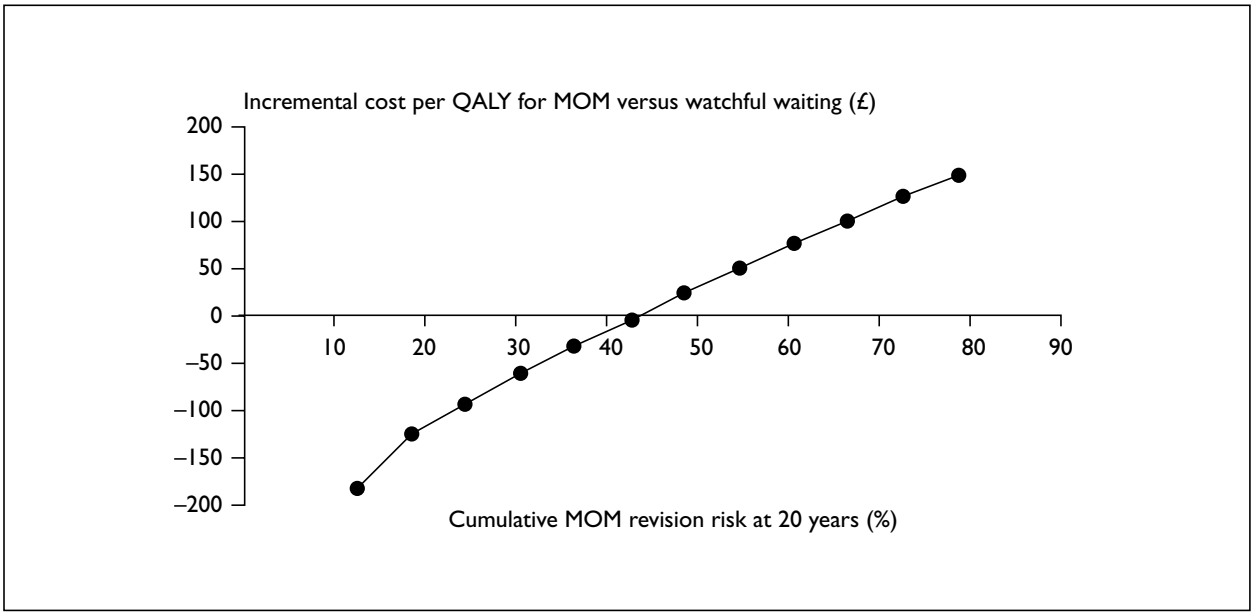

FIGURE 7 *Incremental cost per QALY at different metal-on-metal hip resurfacing arthroplasty revision risks*

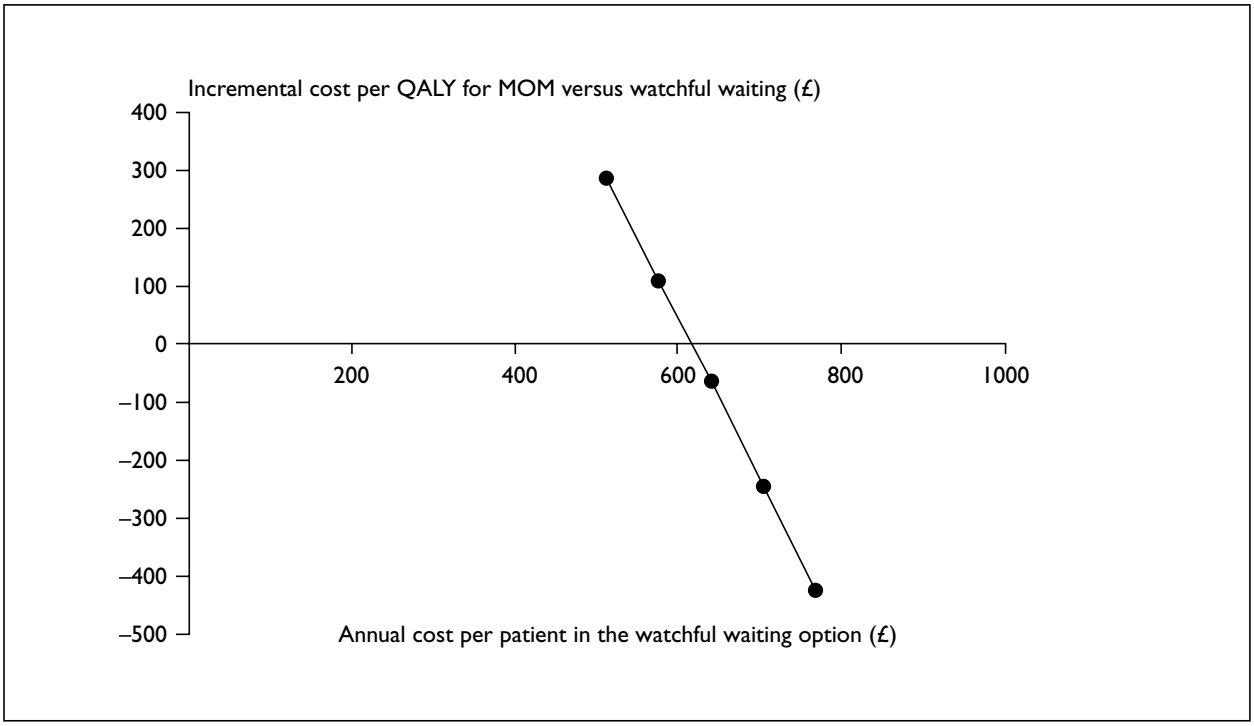

FIGURE 8 *Incremental cost per QALY of metal-on-metal hip resurfacing arthroplasty compared with watchful waiting for different annual costs per patient on watchful waiting*

Variations in quality of life

An additional sensitivity analysis was conducted in which a range of higher values for quality of life was assumed while in watchful waiting. Metal-on-metal hip resurfacing arthroplasty continued to dominate watchful waiting over a 20-year follow-up period for values all the way up to 0.963%, owing to the higher cumulative costs of watchful waiting.

Discussion

The economic modelling provided in this analysis was constrained substantially by too few data on key parameters for the economics models and it was not possible to estimate a model for 'people who would not be suitable for consideration for THR for reasons other than expected survival or

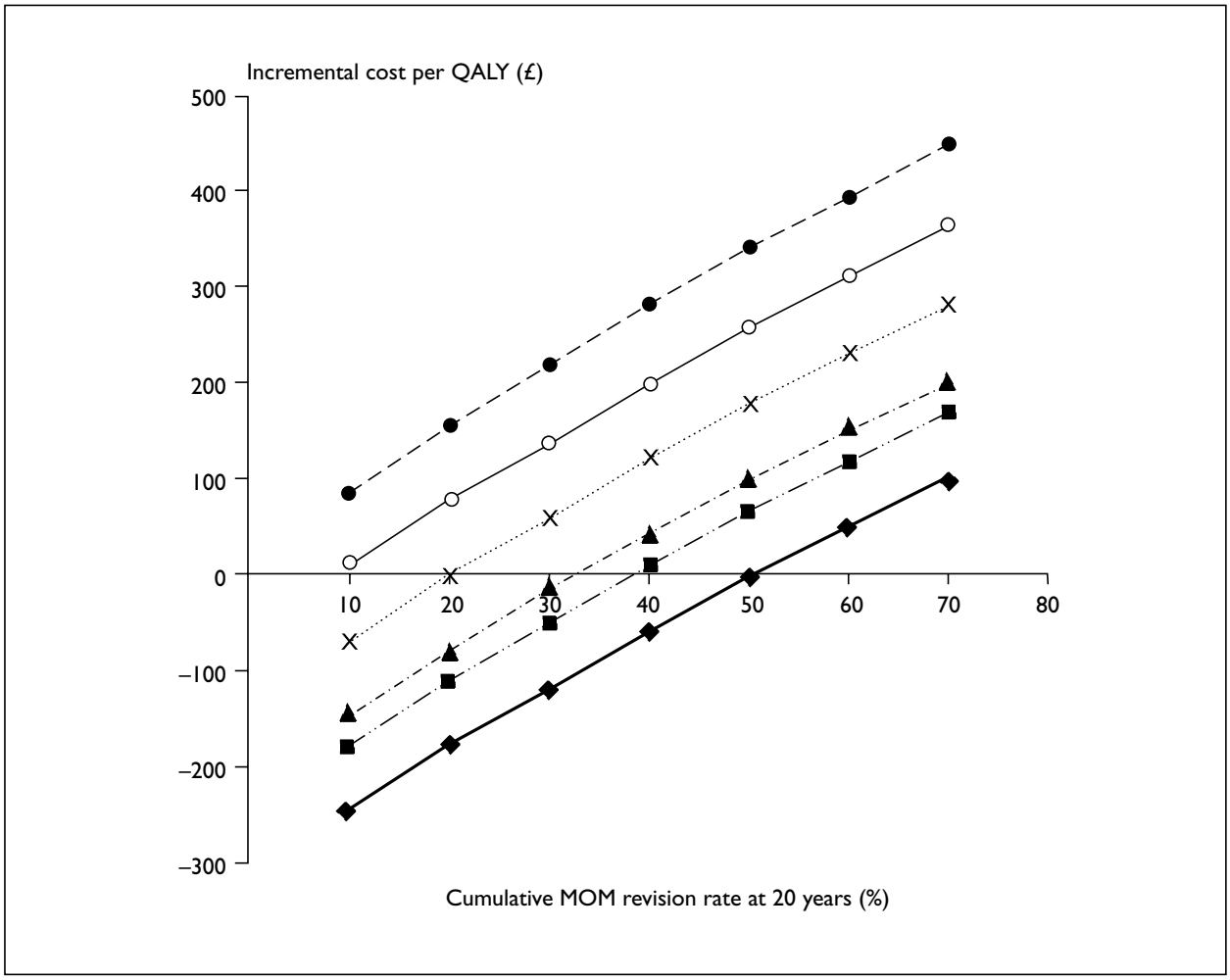

FIGURE 9 *Incremental cost per QALY for metal-on-metal hip arthroplasty versus watchful waiting at different metal-on-metal hip arthroplasty operation times and metal-on-metal hip arthroplasty revision rates (—◆—, 100 minutes; –··–■–··–; 134 minutes; – · –▲– · –, 150 minutes; ·····X·····, 190 minutes; —○—, 230 minutes; – –●– –, 270 minutes)*

activity'. The most severe problem pertained to the limited information available for metal-on-metal hip resurfacing arthroplasty revision rates. Even using the larger and more recent sample provided within the MMT industry submission to NICE, revision rates could only be calculated reliably for the 3 years following the procedure. It is simply not known whether revision rates for metal-on-metal hip resurfacing arthroplasty will follow a similar (or better or worse) trajectory than revision rates for primary THR. Furthermore, the metal-on-metal hip resurfacing arthroplasty revision rates from the industry submission were lower than the metal-on-metal hip resurfacing arthroplasty revision rates taken from the published studies. This reduction in revision rates may very well reflect improvements in the metal-on-metal hip resurfacing arthroplasty technique that have occurred over time. Yet it was not clear that the THR revision rates were calculated for a similar set of patients (e.g. younger patients) or that the THR rates were similarly calculated using the most effective or cost-effective form of THR.

The periods of reliable follow-up available for the treatments were variable and, crucially, virtually no data were available with which to assess the revision rate beyond 4 years for metal-on-metal hip resurfacing arthroplasty. Hence, the analysis was simplified using the average annual equivalent rate for the observed data for each treatment. The annual equivalent risk rates were slightly higher than the constant hazard rate needed to achieve a cumulative risk at the end of an observation period. This approach was also necessary because only aggregate data on revision rates for all the treatments were available; hence it was not possible to control specifically for a person's age, gender, or baseline disease severity in determining appropriate and comparable rates for any of the procedures. This assumption effectively meant that the revision rates used in the model

were higher than the actual revision rate during the early years of follow-up and lower than the actual revision rate during the later years of follow-up (which are more heavily discounted). While such an approach is unfavourable to an individual treatment in the immediate follow-up period (for example, within the first 5 years), all treatment alternative revision rates were treated equally. This may be the fairest approach given the lack of long-term follow-up data on so many of the treatments.

Another critical absence of data related to information on health outcomes for revision THR following metal-on-metal hip resurfacing arthroplasty. It could be hypothesised that, because metal-on-metal hip resurfacing arthroplasty is bone-conserving relative to THR, revision THR following the resurfacing procedure would result in better outcomes than revision THR following primary THR. While such speculation merits further scientific investigation, it was not considered worthwhile to estimate all the possible scenarios in the absence of any data. Further qualifications about the need for data from an RCT (or patient data enabling better matching in observational studies) and for better measures of health outcomes and quality of life also apply.

The assessment of cost-effectiveness of metal-on-metal hip resurfacing arthroplasty compared with osteotomy and arthroscopy was restricted because the data on both effectiveness and cost were limited. The cost data were based on national reference costs, which often aggregate similar procedures together. For arthroscopy this meant that no distinction was made for arthroscopy of different joints or arthroscopy for therapeutic as opposed to principally diagnostic purposes. Thus, the costs of arthroscopy may be underestimated.

Owing to the absence of data on those people who would not be suitable for a THR for reasons other than expected survival or activity, the relative cost-effectiveness of metal-on-metal hip resurfacing arthroplasty could not be estimated. The relative cost-effectiveness of metal-on-metal hip resurfacing arthroplasty to arthrodesis was also not estimated because of the lack of data on revision rates. Data from the national reference costs suggest that arthrodesis would have a similar cost to osteotomy. In terms of quality of life, pain may be alleviated but mobility would be reduced. Thus, arthrodesis may have a similar incremental cost per QALY to osteotomy.

Given the paucity of information available, the analysis was not presented using frameworks that are often helpful in policy decision-making, such as the use of a net benefit approach or acceptability curves. Yet point estimates of cost-effectiveness ratios should also be interpreted with great caution, as they neither solve the problem of the lack of long-term follow-up data on metal-on-metal hip resurfacing arthroplasty nor reflect the stochastic variation that undoubtedly characterises the outcomes of the procedure. By providing ICERs, however, several key points have been illustrated. First, the low quality of life experienced by young people with hip disease, who have been advised to delay THR, means that if metal-on-metal hip resurfacing arthroplasty could be proven to: (i) have lower revision rates than THR over an extended period, and (ii) result in better outcomes from subsequent THR, then such a procedure may provide an incremental cost per QALY that is judged acceptable or possibly even be dominant (that is, generate cost savings and the same or greater QALYs). Second, if metal-on-metal hip resurfacing arthroplasty revision rates are below primary THR revision rates by a sufficient amount, then metal-on-metal hip resurfacing arthroplasty could possibly be judged to be cost-effective by society for older people who are more active and who may outlive a primary THR.

The model used for THR in this study was identical in structure to that used in a previous review by Fitzpatrick and colleagues.[30] Their model was validated against additional data and gave consistent predictions. It was not possible in this study to conduct similar tests of validity for the models, owing to a lack of suitable additional data with which to test model predictions.

Chapter 6

Implications for other parties

Quality of life for family and carers

On the basis that the quality-of-life values used in the evaluation are valid, metal-on-metal hip resurfacing arthroplasty offers younger patients an earlier improvement in quality of life than would be the case if they were managed using the watchful waiting alternative. There is little evidence about whether metal-on-metal hip resurfacing arthroplasty is any better than THR for younger patients (that is, the failure rate could be equal and revisions could be no more successful). Hence, in the economic evaluation presented in chapter 5, it was assumed that a revision from metal-on-metal hip resurfacing arthroplasty to THR would result in a quality of life equal to that obtained after a primary THR. Although no information was available on the quality of life of family and carers, an increase in the quality of life of an individual with hip disease would most likely reduce the burden of care for family members and carers.

Financial impact on the patient and others

Since quality of life for a person suffering from osteoarthritis of the hip is likely to reflect their levels of pain and mobility, then an improved quality of life would probably be associated with higher levels of activity. This may enable a patient to be more economically active, and perhaps less reliant on other family members, than would be the case if the patient was in a watchful waiting treatment group. Such implications were not, however, substantiated in this evaluation by any available data.

Chapter 7

Factors relevant to the NHS

Training

Relatively few orthopaedic surgeons within the UK are currently undertaking metal-on-metal hip resurfacing arthroplasty. A decision to pursue the widespread adoption of this technique would require training sufficient numbers of surgeons. Furthermore, because most of the data on the effectiveness of the resurfacing procedure were provided by a small number of specialists, it is unclear whether metal-on-metal hip resurfacing arthroplasty would achieve the same level of success were it to be adopted in routine practice.

The adoption of metal-on-metal hip resurfacing arthroplasty may increase the number of people eligible for surgical interventions, particularly to the extent that those people who are currently managed by watchful waiting may be considered eligible for earlier surgery. Providing surgical services to these people without increasing waiting times for other orthopaedic procedures would require training of additional orthopaedic surgeons during an initial transition period and, ultimately, on a permanent basis, assuming that the total rate of surgical procedures for the population increases.

Fair access and equity issues

Currently, metal-on-metal hip resurfacing arthroplasty is predominantly available to those who are willing and able to pay for the procedure. Less wealthy individuals do not have this opportunity and, unless the NHS provides the procedure, they are unlikely to receive it. Additional equity implications may relate to age. Clinical opinion varies with respect to the suitability of THR for younger individuals because of concern about outcomes from subsequent THR revision. Further determination of benefits and costs of metal-on-metal hip resurfacing arthroplasty may enable an expansion of the choice of treatments available to younger individuals.

The reduction in the threshold for surgery that may follow the introduction of metal-on-metal hip resurfacing arthroplasty would, in the absence of additional resources, result in reductions in other types of care provided by orthopaedic surgeons. Thus, individuals who require other types of surgery may lose out as the numbers of other types of orthopaedic procedures performed are reduced or the time spent on waiting lists is increased.

Resource transfers between primary and secondary care

Even if metal-on-metal hip resurfacing arthroplasty is less costly in the long term than watchful waiting, a significant portion of the care of watchful waiting is provided in primary care. Most of the NHS costs for providing metal-on-metal resurfacing arthroplasty fall in secondary care. Hence, in the absence of additional funds, resources would need to be transferred from primary care to secondary care in order to prevent reductions in other activities carried out in secondary care.

Budgetary impact on the NHS

Without precise estimates on effectiveness it is difficult to estimate the budgetary impact on the NHS. In chapter 2, the current NHS cost of conservative management was estimated to be £48 million per annum, if one-tenth of those people believed to experience severe hip disease were in receipt of management similar to that defined for watchful waiting. Similarly, the cost of THRs to the NHS has been estimated at £140 million per annum. Given that the procedure costs were estimated to be £5066 for metal-on-metal hip resurfacing and £4195 for THR, and that the annual cost of watchful waiting was estimate to be £642 per patient, then the additional costs to the NHS in the short to medium term (less than 10 years) might be quite large. This is dependent upon THR and watchful waiting being not very much less effective and metal-on-metal hip resurfacing arthroplasty being not very much more effective than the data identified suggest.

Chapter 8
Discussion

Effectiveness

Metal-on-metal hip resurfacing arthroplasty has, from early data, the potential to be an effective technique for the management of hip disease. As only short-term data are available, it is difficult to know how much more or less effective it is in relation to any of the comparators. In addition, no data were available with which to assess the relative effectiveness of, notably, metal-on-metal hip resurfacing arthroplasty for those people not suitable for THR for reasons other than expected survival or activity.

Extensive searching was conducted to identify studies eligible for inclusion in this technology assessment. Despite this effort, however, little high-quality information was found on which to base estimates of relative effectiveness. For example, no RCTs or prospective comparative studies were identified in which metal-on-metal hip resurfacing arthroplasty was compared with any of the other interventions considered. Furthermore, for some of the interventions, notably metal-on-metal hip resurfacing arthroplasty, no long-term data were identified. This is a serious limitation that precludes the ability to make reliable estimates of effectiveness. In the presentation of the data on metal-on-metal hip arthroplasty, it has been assumed that the alternative methods of metal-on-metal hip arthroplasty have a homogeneous set of procedures. In reality this is unlikely to be the case but there is very little evidence to suggest whether the outcomes for different prostheses are similar or not. The data available on metal-on-metal hip resurfacing arthroplasty came from a very small number of clinicians. It is not clear whether their results could be replicated in practice. In particular, the available studies described an evolution of prostheses over time and also, presumably, surgical techniques. To achieve the promising low revision rates indicated by recent unpublished data may require substantial training in procedures, as well as provision of the procedure on a high-volume basis to ensure that skills are maintained.

In terms of the comparators to metal-on-metal hip resurfacing arthroplasty, data were limited to only a very small number of patients for watchful waiting and arthrodesis. Given that watchful waiting is, in practice, the main option available for people who are deemed too young for a THR, the lack of data on these patient groups is a major limitation of the available evidence base.

In terms of watchful waiting, it is also important to know how quickly an individual's quality of life deteriorates until surgery is necessary. The data reported in the effectiveness chapter and used in the model related to just 29 people and were of only limited use in assessing any deterioration in quality of life. Although not fulfilling the criteria for inclusion in the study, a short-term study of 99 people in London, Ontario, Canada, by Bourne and colleagues,[62] reported that the health-related quality of life deteriorated significantly ($p < 0.05$) between referral for a THR and the surgical procedure (average time, 5.6 months ± 5.0). The methods used to measure health-related quality of life were the distance walked in 6 minutes and the WOMAC osteoarthritis measure components of pain, stiffness and physical function.

Owing to the limitations of the evidence available, pooled estimates of relative effectiveness were not derived. Very crude aggregation could have been performed and, indeed, has been in the economics chapter, where the pooled estimates for single interventions were used as the basis of the sensitivity analysis. As measures of effectiveness, however, such estimates would be difficult to interpret reliably because of the heterogeneous nature of the study populations, intervention (e.g. different types of osteotomy) and setting.

A final factor limiting the ability to make comparisons between studies is that the assessment of some outcomes was hampered by the lack of standardised measures, even between studies of the same intervention. For example, functional status was measured in a variety of different ways (e.g. Harris, Mayo, and Charnley hip scores). This lack of consistency in the method of measurement used between studies makes it difficult to make comparisons, even for outcomes that are widely assessed.

Costs

Most of the cost estimates (and especially those for THR) are fairly robust. Assumptions regarding some issues, such as follow-up care after a procedure, were, in some cases, more tenuous but also pertained to what is likely to be a relatively smaller amount of resources. One important assumption was used to estimate a procedure cost for metal-on-metal hip resurfacing arthroplasty. In accordance with clinical advice, it was assumed that the operation times for metal-on-metal hip resurfacing arthroplasty would be similar to those for THR. In contrast to this, the submission to NICE by MMT[22] suggested that the procedure operating costs and length of stay might be lower. However, in the study by Schmalzried and colleagues,[37] operating times were reported that were 80% longer than those estimated (and used in the evaluation presented here) by Fitzpatrick and colleagues[30] for THR.

Procedure costs may, of course, vary substantially between surgeon and/or institution. While the main need for better data pertains to effectiveness measures (revision measures and quality of life), better data on metal-on-metal hip resurfacing arthroplasty procedure resource use would enable a more accurate determination of the differential cost of metal-on-metal hip resurfacing arthroplasty versus alternative treatments.

Cost-effectiveness

The economic modelling illustrated several key points. First, the low level of quality of life experienced by young people with hip disease who have been advised to delay THR means that if metal-on-metal hip resurfacing arthroplasty could be proven to (i) have lower revision rates than THR over an extended period, and (ii) result in better outcomes from subsequent THRs, then such a procedure may provide an incremental cost per QALY that might be judged acceptable, or possibly may even be dominant (i.e. generate cost savings and the same or greater values of QALY). Second, if metal-on-metal hip resurfacing arthroplasty revision rates are lower than primary THR revision rates by a sufficient amount, then metal-on-metal hip resurfacing arthroplasty could possibly be judged cost-effective by society for older people who are more active and may outlive a primary THR.

This evaluation has relied in some parts on very limited data. In particular, the estimated revision rates for metal-on-metal hip resurfacing arthroplasty came from a single study with only a short-term follow-up period. In order to reflect the uncertainty relating to these rates, a sensitivity analysis was performed using the rates from other sources (notably the industry submissions to NICE). In order to run the model over a 20-year time horizon, it was necessary to assume that the annual equivalent revision rate taken from the short-term trial data would apply over the full follow-up period of 20 years. This assumption must be treated with considerable caution.

The models included mortality risk from all causes, and separate rates were not included for the specific disease group (e.g. osteoarthritis, rheumatoid arthritis) in question. The assumption was made that the mortality risk would not vary markedly between people with different underlying causes of hip disease who commonly required the interventions considered in this study.

Effectiveness was measured in terms of quality of life to enable QALY scores to be estimated. Quality-of-life values were based on limited information from the reviewed studies since most such studies relied on measuring outcomes in terms of hip scores. Quality-of-life scores were therefore based on secondary data. With the exception of watchful waiting, quality of life was measured by using assumptions about the proportions of patients experiencing different levels of pain. (For the watchful waiting group, quality of life was included in the reviewed study as a specific outcome measure.) These pain distributions were translated into quality-of-life scores using data from published results of a time trade-off study that produced utility scores for patients with mild, moderate and severe arthritis of the hip. To derive these scores, it was necessary to assume the proportions of patients in each treatment group with and without pain. No data on quality of life following revision THR (after either primary THR or primary metal-on-metal hip resurfacing arthroplasty) were available.

An important caveat of the study is that patients are assumed to be at the same base-line quality-of-life level at the start of the treatment process, regardless of the treatment alternative. Such an assumption is unlikely to be reflected in the patient samples in the reviewed studies from which other data were taken.

The validity of each of the models used in the study was not tested. Given that the model for THR was identical in structure to that used in a

previous study,[30] which was found to have both internal and external predictive validity, it could be assumed that similar validity would be true of the model for THR used in the current study. However, external additional data were not available to conduct similar tests of validity for the other models used in this study and their validity remains uncertain.

Chapter 9
Conclusions

Implications for the NHS

- Under the conservative assumptions of the base analysis, THR is both less costly and more effective than metal-on-metal hip arthroplasty but plausible changes in the revision rate for THR could change this.
- If further research shows that metal-on-metal hip resurfacing arthroplasty is sufficiently more effective than THR (i.e. has a sufficiently lower revision rate and sufficiently better outcomes following revision), then:
  - the use of metal-on-metal hip resurfacing instead of watchful waiting in younger persons could decrease the net costs for some patients in the watchful waiting group or may result in increases in QALYs at a cost deemed to be affordable
  - the use of metal-on-metal hip resurfacing in lieu of THR in more active elderly patients may result in additional QALYs at a cost that may be considered affordable to society (although the effectiveness would have to be substantially higher to achieve cost savings – which are therefore deemed unlikely).
- The net effect of the two considerations above imply a potential increase in surgery rates, although without better data on effectiveness, it is too speculative to develop a reliable estimate of budgetary impact.
- The increase in surgery rates may have implications for the number of clinicians to be trained and the need to train established clinicians in a new procedure, and for waiting lists for orthopaedic procedures.

Implications for patients and carers

- If metal-on-metal hip resurfacing arthroplasty revision rates are substantially lower than those for THR, then patients deemed too young or too active for THR (as well as the carers of these patients) could benefit from metal-on-metal hip resurfacing arthroplasty. There were too few data available, however, to determine whether such benefit is likely over an extended follow-up period.
- No data are available with which to determine the effectiveness and cost-effectiveness of metal-on-metal hip resurfacing arthroplasty for those who are not suitable for THR for reasons other than expected survival or activity levels.

Recommendations for research

- All the data and modelling results indicate that metal-on-metal hip resurfacing arthroplasty merits further scientific investigation.
- The lack of any controlled studies comparing metal-on-metal hip resurfacing arthroplasty with any of the comparators (but principally watchful waiting and THR) needs to addressed. Reiterating the recommendation of Fitzpatrick and colleagues,[30] such studies must have long-term follow-up periods.
- Any comparison of metal-on-metal hip resurfacing arthroplasty with watchful waiting is hampered by the absence of long-term data on metal-on-metal hip resurfacing arthroplasty, of health outcome data following revision, and of virtually any data on watchful waiting. Research is required to more clearly define what watchful waiting entails and how its outcomes compare with the other comparators, notably with metal-on-metal hip resurfacing arthroplasty.

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Contributions of authors

Kirsty McCormack, Laura Wyness and Miriam Brazzelli completed the review of effectiveness. Lynda McKenzie conducted the economic evaluation. Sally Stearns conducted the review of economic evaluations and provided supervision, advice and critical comment. Luke Vale supervised the conduct and completion of the project.

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Appendix 1

Search strategies

Metal-on-metal search strategy

Search terms

1 (resurfac$ adj25 hip$).tw.
2 (surface adj5 replacement$ adj25 hip$).tw.
3 (resurfac$ adj25 prosthesis adj25 hip$).tw.
4 (surface adj5 replacement$ adj25 prosthesis adj25 hip$).tw.
5 (resurfac$ adj25 femoral head$).tw.
6 (surfac$ adj5 replacement$ adj25 femoral head$).tw.
7 (metal adj1 metal adj25 hip$ adj25 surface).tw.
8 (metal adj1 metal adj25 hip$ adj25 resurfac$).tw.
9 (cup adj25 resurfac$).tw.
10 (cup adj25 surface adj5 replacement$).tw.
11 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
12 animal/
13 human/
14 12 and 13
15 12 not 14
16 11 not 15

THR search strategy

Search terms

1 controlled clinical trial.pt.
2 randomised controlled trial.pt
3 randomised controlled trials/
4 random allocation/
5 double blind method/
6 single blind method/
7 or/1-6
8 (animal not human).sh.
9 clinical trial.pt.
10 exp clinical trials/
11 (clin$ adj25 trial$).ti,ab.
12 ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).ti,ab.
13 placebos.sh.
14 placebo$.ti,ab.
15 random$.ti,ab.
16 reseach design.sh.
17 or/9-16
18 7 or 17
19 18 not 8
20 hip prosthesis/
21 prosthesis failure/
22 cementation/
23 reoperation/
24 exp prosthesis design/
25 prosthesis-related infections/
26 prosthesis fitting/
27 20 or 21 or 22 or 23 or 24 or 25 or 26
28 19 and 27
29 limit 28 to yr = 1999–2001

Comparators search strategy

Search terms

1 arthrodesis/ or arthroscopy/ or osteotomy.tw.
2 (hip or hips).tw.
3 (fem$ or head$).tw.
4 2 or 3
5 1 and 4
6 (bone$ adj1 (fusion or fusing or fused)).tw.
7 (joint$ adj1 (fusion or fusing or fused)).tw.
8 6 or 7
9 4 and 8
10 (arthroscop$ or osteotom$ or arthrodes$).tw.
11 4 and 10
12 5 or 9 or 11
13 limit 12 to yr = 1998–2001 [limit not valid in: DARE; records were retained]

Appendix 2

Data abstraction form

Reviewer ID: _____

Study details	
Study ID:	**Refman ID:**
Authors:	
Title:	
Publication year or date of interim data collection:	
Publication source:	

Study design						
RCT	☐	**Comparative observational study**	☐	**Single prosthesis observational study**	☐	
Other:						

Participants				
Number of participants randomised or included in study:				
Criteria for inclusion:	**Criteria for exclusion:**			
Relevance to principal question:				
Were participants	**Yes**	**No**	**Unclear**	**Not applicable**
(a) Likely to outlive the life of a THR?	☐	☐	☐	☐
(b) Unlikely to outlive the life of a THR?	☐	☐	☐	☐
(c) Unsuitable for THR?	☐	☐	☐	☐

Setting and timing
Setting of study: _____
Recruitment period: _____
Were the majority of procedures performed by the principal researcher? **Yes** ☐ **No** ☐
If Yes, what proportion of procedures did the principal researcher perform? _____

Intervention		
	Surgical technique	**No. of patients**
Intervention 1		
Intervention 2		
Intervention 3		
Intervention 4		

Patient characteristics				
	Intervention 1	**Intervention 2**	**Intervention 3**	**Intervention 4**
Age (years)[a]				
Sex (male/female)				
Primary osteoarthritis (%)				
Secondary osteoarthritis (%)				
Rheumatoid arthritis (%)				
Comments:				

Outcomes					
	Follow-up period	**Intervention 1**	**Intervention 2**	**Intervention 3**	**Intervention 4**
Short-term outcomes					
Duration of operation (minutes)[a]					
Conversions (number& specify)					
Time in hospital (days) [a]					
Time to return to normal activities (days) [a]					
Serious complications (specify) e.g. dislocation, infection, reoperation with in 6 months, nerve palsy					
Long-term outcomes					
Number and rate of revision surgery					
Number and rate of operation (conservative treatment groups only)					
Functional result (e.g. Harris, Mayo, Charnley scores)					
Percentage of patients pain free					
Quality of life (e.g. Short Form 36)					
Mortality					
Other:					

[a]Mean (SD) and/or median (IQR)

Comments

Contact with author

Date: ……/……/…… **Signature: ……**

Appendix 3

Quality assessment form

Study ID:

Assessment item	Yes	No	Unable to judge	Not applicable	No agreed rating
Clarity of study question and definition of outcome Is the purpose of the study clearly stated? Is the definition of prosthesis failure clear? Is there a clear definition of primary outcome(s)? Are standardised outcome measures used? Are the outcome measures used appropriate for the purpose of the study?					
Description of prosthesis and method of fixation Is the prosthesis design adequately described? Is the method of fixation adequately described?					
Description of study sample Is the method of selection of the sample adequately described? Are the study exclusion and inclusion criteria stated? Is the baseline sample clearly described in terms of basic characteristics (age, sex, etc.)? Is the study sample sufficiently homogeneous in terms of disease/diagnosis? Is the study sample sufficiently homogeneous in terms of co-morbidity?					
Control of bias in study design Is the method of allocation random? Is the method of masking the patient to the intervention allocated stated? Were outcome assessors blind to intervention allocation? Are baseline values for groups compared? Has the study adequately controlled for confounding factors?					
Duration and completeness of follow-up Are intervals between surgery and follow-up assessment clearly stated? Are reasons for loss of patients at follow-up stated? Are those lost to follow-up compared with the rest of the sample? Is there an appropriate length of follow-up? Is the length of follow-up at least 5 years?					
Statistical and analytical considerations Has the study sample size been justified? Are the data clearly presented? Was the data analyst masked to interventions? Has type of statistical test and actual probability value been stated? Are statistical tests appropriate to study? Have the data been analysed by intention-to-treat? Is the sample on which failures are assessed adequate? Are conclusions justified by evidence?					

Appendix 4

Quality assessment form for the THR systematic reviews

Reviewer:

First author:

1. Were the search methods used to find evidence (primary studies) on the primary question(s) stated?

No	
Partially	
Yes	

Comments:

2. Was the search for evidence reasonably comprehensive?

No	
Partially	
Yes	

Following done:	
Language restrictions	Yes/No
Handsearching	Yes/No
Reference lists	Yes/No
Authors contacted	Yes/No

Comments:

3. Were the criteria used for deciding which studies to include in the review reported?

No	
Partially	
Yes	

Author specifies:	
Type of study	Yes/No
Participants	Yes/No
Intervention(s)	Yes/No
Outcome(s)	Yes/No

Comments:

4. Was bias in the selection of articles avoided?

No	
Partially	
Yes	

Author specifies:	
Explicit selection criteria used	Yes/No
Independent screening of full text by at least two reviewers	Yes/No

Comments:

5. Were the criteria used for assessing the validity of the studies that were reviewed reported?

No	
Partially	
Yes	

Author specifies:	
Criteria used to assess methodological quality	Yes/No

Comments:

6. Was the validity of all of the studies referred to in the text assessed using appropriate criteria (either in selecting studies for inclusion or in analysing the studies that are cited)?

No	
Partially	
Yes	

Author specifies:	
Assessments of included studies using explicit criteria reported	Yes/No

Comments:

7. Were the methods used to combine the findings of the relevant studies (to reach a conclusion) reported?

No	
Partially	
Yes	

	Author specifies:	
Meta-analysis	Outcome of interest	Yes/No
	Model used	Yes/No
	Test for heterogeneity	Yes/No
Qualitative	Why meta-analysis inappropriate?	Yes/No
	How then made sense of data?	Yes/No
Both	Sensitivity analysis	Yes/No

Comments:

8. Were the findings of the relevant studies combined appropriately relative to the primary question the review addresses?

No	
Partially	
Yes	

Interventions homogeneous	Yes/No
Outcome measures homogeneous	Yes/No
Participants homogeneous	Yes/No
How unit analysis errors were handled	Yes/No
Settings comparable	Yes/No

Comments:

9. Were the conclusions drawn by the author(s) supported by the data and/or the analysis reported in the review?

No	
Partially	
Yes	

Conclusions consistent with results	Yes/No
Conclusions do not go beyond the data	Yes/No
No evidence not interpreted as no effect	Yes/No
Strength of recommendations for practice consistent with level of evidence (uncertainty)	Yes/No
Recommendations for research consistent with identified shortcomings	Yes/No

Comments:

10. Overall, how would you rate the scientific quality of this review?

Extensive flaws		Major flaws		Minor flaws		Minimal flaws
1	2	3	4	5	6	7

Comments:

Appendix 5

Summary of the quality assessment of the 24 assessed studies

Assessment item	Yes	No	Unable to judge	Not applicable	No agreed rating
1. Clarity of study question and definition of outcome					
a. Purpose of the study clearly stated?	21	2	1	–	–
b. Definition of prosthesis failure clear?	9	3	–	12	–
c. Clear definition of primary outcome(s)?	19	5	–	–	–
d. Standardised outcome measures used?	20	3	1	–	–
e. Outcome measures used appropriate for the purpose of the study?	21	1	2	–	–
2. Description of prosthesis and method of fixation					
a. Prosthesis design adequately described?	14	8	–	2	–
b. Method of fixation adequately described?	7	2	–	15	–
3. Description of study sample					
a. Method of selection of the sample adequately described?	5	16	1	2	–
b. Study exclusion and inclusion criteria stated?	6	16	1	1	–
c. Baseline sample clearly described in terms of basic characteristics (age, gender, etc.)?	15	8	1	–	–
d. Study sample sufficiently homogeneous in terms of disease/diagnosis?	6	5	13	–	–
e. Study sample sufficiently homogeneous in terms of co-morbidity?	3	1	20	–	–
4. Control of bias in study design					
a. Method of randomisation adequate?	–	11	1	7	–
b. Method of masking the patient to the intervention allocated specified?	–	14	2	6	–
c. Outcome assessors blind to intervention allocation?	–	6	11	7	–
d. Baseline values for groups compared?	–	4	1	19	–
e. Study adequately controlled for confounding factors?	3	19	2	–	–
5. Duration and completeness of follow-up					
a. Intervals between surgery and follow-up assessment clearly specified?	14	10	–	–	–
b. Reasons for loss of patients at follow-up given?	6	9	2	7	–
c. Those lost to follow-up compared with the rest of the sample?	2	12	3	7	–
d. Appropriate length of follow-up?	22	2	–	–	–
e. Length of follow-up at least 5 years?	17	7	–	–	–
6. Statistical and analytical considerations					
a. Study sample size justified?	–	22	1	1	–
b. Data clearly presented?	19	5	–	–	–
c. Data analyst masked to interventions?	–	7	15	2	–
d. Type of statistical test and actual probability value specified?	10	6	1	7	–
e. Statistical tests appropriate to study?	10	1	1	12	–
f. Sample on which failures are assessed adequate?	6	2	13	1	–
g. Conclusions justified by evidence?	13	3	6	2	–

Appendix 6

Studies on metal-on-metal hip replacement

Observational studies

Study	Study setting	Prosthesis	Number of hips at outset	Mean duration of follow-up (range), months	Mean patient age (range), years	Revision rate (unless otherwise stated)	Hip score pre-operation	Hip score post-operation	Number of patients pain free	Preoperative diagnosis
Amstutz, 2000[41]	Specialist orthopaedic hospital (USA)	Cemented, modified McMinn acetabular	7	22 (NR)	40 (NR)	NR	NR	NR	NR	All patients had stage four osteonecrosis
		Conserve Plus	29							
McMinn *et al.*, 1996[42]	Three Birmingham hospitals (UK)	Uncemented, uncoated	70	50.2 (44–54)*	48.7 (NR)	8/66 patients (12.1%)	Pain 3.1[a] Mobility 3.1[a] Walking 3.1[a]	Pain 5.3[a] Mobility 5.3[a] Walking 5.3[a]	60/66 (90.9%)	Osteoarthritis (73.62%); secondary arthritis (10.64%); inflammatory (8.51%); avascular necrosis (7.23%)
		Uncemented, hydroxyapatite coating	6	40.2 (38–42)*		0/6 patients (0%)	Pain 3.0[a] Mobility 3.1[a] Walking 2.7[a]	Pain 5.5[a] Mobility 6.0[a] Walking 5.7[a]	NR	
		Cemented acetabular	43	33.2 (23–38)*		4/39 patients (10.3%)	Pain 2.9[a] Mobility 3.0[a] Walking 3.2[a]	Pain 5.4[a] Mobility 5.4[a] Walking 5.4[a]	NR	
		Cemented acetabular, hydroxyapatite coating	116	8.3 (1–19)*		0/109 patients (0%)	Pain 3.0[a] Mobility 3.2[a] Walking 3.2[a]	Pain 5.7[a] Mobility 5.7[a] Walking 5.7[a]	NR	
Schmalzried *et al.*, 1996[37]	Specialist orthopaedic hospital (USA)	Cementless Wagner	4	16 (10–25)	42 (22–64)*	1/19 patients (5.3%)	Pain 4[b] Walking 6[b] Function 6[b] Activity 4[b] NB: Results of groups reported together	Pain 9[b] Walking 9[b] Function 9[b] Activity 7[b] NB: Results of groups reported together	NR	Osteoarthritis (33%); developmental dysplasia (14%); posttraumatic arthritis (9.5%); juvenile rheumatoid arthritis (9.5% – same patient); arthro-katadysis (9.5% – same patient); slipped capital femoral epiphysis (9.5%); failed hemisurface replacement (5%); tuberculosis with secondary arthritis (5%); osteonecrosis (5%)
		Cemented McMinn	17							
Wagner & Wagner, 1996[24]	Specialist orthopaedic hospital (Germany)	Two titanium pins on cup shell	12	20 (6–54)	36 (15–64)*	5/35 patients (14.3%)	32 (5–51)[c] NB: Results of groups reported together	94 (72–100)[c] NB: Results of groups reported together	NR	Patient groups mostly young with numerous previous operations and considerable deformity
		Press fit version	23							

* *Median (range);* [a] *Charnley hip score;* [b] *UCLA hip score;* [c] *Harris hip score*

Industry submissions

Study	Study setting	Prosthesis	Number of hips at outset	Mean duration of follow-up (range), months	Mean patient age (range), years	Revision rate (unless otherwise stated)	Hip score pre-operation	Hip score post-operation	Number of patients pain free	Preoperative diagnosis
Corin Group Ltd, 2001[21]	Four hospitals, one clinic (UK; three surgeons)	Cormet 2000	CIC	21.36[a]	50.8 (26–69)[a]	CIC	NR	NR	69/97 (71.1%)[a]	NR
Wright Cremascoli Ortho Ltd, 2001[20]		Conserve Plus	100	NR (24–51.6)	NR	3/100 hips (3%)	NR	NR	NR	NR
MMT, 2001[22]	Hospitals in Birmingham, Southampton and Liverpool (UK) and Belgium	BHR	(1761 patients)	NR	49.2 (15–86)	8/1382 hips (0.6%)	NR	NR	NR	Osteoarthritis 74–95%; dysplastic hips 0–10%; rheumatoid arthritis 1–4%; avascular necrosis 0–7%; post trauma 0–2%; other 4–7%

[a] *Data from subset of 97 patients (110 hips); CIC, data marked "commercial-in-confidence" in industry report*

Oswestry Outcome Centre data

Outcomes of hip-resurfacing operations performed between 01.07.97 and 03.08.01

Prosthesis	Number of operations	Average age of patients, years*	Revision rate	Harris hip score					Merle-score				
				Pre-operative	Postoperative				Pre-operative	Postoperative			
					1 year	2 years	3 years	4 years		1 year	2 years	3 years	4 years
McMinn *et al.*, 1996[42]	1378	53.1	7/1378 (0.5%)	66.2	95.6	95.4	94.4	98.1	Pain 3.8 Mobility 4.4 Movement 3.7	Pain 5.7 Mobility 5.8 Movement 5.5	Pain 5.7 Mobility 5.8 Movement 5.5	Pain 5.7 Mobility 5.7 Movement 5.4	Pain 5.7 Mobility 6.0 Movement 5.9
All consultants	4424	49.2	34/4424 (0.77%)	61.3	89.0	86.8	93.5	95.9	Pain 3.6 Mobility 4.0 Movement 3.4	Pain 5.4 Mobility 5.6 Movement 4.8	Pain 5.4 Mobility 5.4 Movement 4.9	Pain 5.7 Mobility 5.8 Movement 5.3	Pain 5.9 Mobility 5.8 Movement 5.2

* *Average age of patients on day of operation*

Outcomes of hip-resurfacing operations performed between 30.07.97 and 10.09.01

Number of operations	Average age of patients, years	Revision rate	Reason for revision (%)	Revised to (%)
4455	49.2	36/4455 (0.8%)	Avascular necrosis 4 (11%) Dislocation 1 (3%) Fracture 20 (56%) Infection 4 (11%) Loosening 7 (19%)	BHR 6 (17%) Dysplasia 3 (8%) THR 16 (44%) Uunknown 11 (31%)

Appendix 7

Watchful waiting studies

Study*	Study setting	Number of patients (hips) at outset	Mean duration of follow-up (range)	Mean age of patients (SD), years	Patient's pain level		Surgery performed	Use of walking aids	Notes
					At baseline	At follow-up			
Dieppe *et al.*, 1997[6]	Single orthopaedic unit (UK)	84 (NR)	37.6 months (31–41)	50 years (12.1)	None, 7% Mild, 48% Moderate, 31% Severe, 10%	None, 4% Mild, 50% Moderate, 32% Severe, 14%	9 patients (32%) 8 patients (29%) at 3-year follow-up	9 patients (32%) at baseline	All patients had symptomatic limb joint osteoarthritis
Dieppe *et al.*, 2000[7]	Single orthopaedic unit (UK)	29 patients (29 hips)	NR (36–96 months)	50 years (12.1)	None, 7% Mild, 48% Moderate, 31% Severe, 10%	None, 3% Mild, 34% Moderate, 48% Severe, 14%	14 patients (48%)	12 patients (41%) at 8-year follow-up	All patients had symptomatic limb joint osteoarthritis

* *Both studies included the same population but for different periods of follow-up*

Appendix 8

Summary of THR studies

RCTs of at least 5 years' duration

Study	Study setting	Prosthesis	Number of hips at outset	Mean duration of follow-up (range), months	Mean patient age (range), years	Revision rate[a,b]	Hip score pre-operation	Hip score* post-operation (patients)	Hip pain pre-/post-operation	Allocation details	Blinding of out-come	Loss to follow-up	Preoperative diagnosis
Sharp *et al.*, 2000[43]	Two hospitals (UK) NB: only one centre randomised	C-Fit uncemented with hydroxyapatite coating	91 in total for both groups	5.2 years (1 month–8 years)	< 66	25/91 (27.5%)	NR	12–20 (35)	NR	Yes	Not clear	4/91 (4.4%)	NR
		C-Fit uncemented with porous coating					NR	21–30 (13) 31–40 (12) 41–50 (1) 50–60 (2)	NR				

[a] *Revision rate at latest follow-up point and crude survival rate based on all patients*
[b] *Results reported by patient number on entry to trial (i.e. intention-to-treat)*
* *Oxford hip score*

Systematic reviews

Study	Fitzpatrick *et al.*, 1998[30]	Faulkner *et al.*, 1998[1]	NICE, 2001[38]
Number of studies and years searched	11 RCTs (mean sample 168 patients); 18 comparative observational studies including two very large studies based on Scandinavian registry data; 159 observational studies Searches on MEDLINE and EMBASE, 1980–95; 11 journals handsearched	17 RCTs; 61 comparative studies; 145 observational studies Not clear what total sample of hips this represented Searches on: MEDLINE 1980–95, EMBASE 1990–96	Two systematic reviews[1,30] and four RCTs (1144 hips in total); ten prospective comparative observational studies (5404 hips) plus Swedish Registry data Studies additional to systematic reviews were from 1995 to November 1999
Operation time, time in hospital, serious complications and return to usual activities, mortality	NR	NR	NR
Revision rates (all results for Charnley THR with mean follow-up of 11 years (range 2–20)	Adjusted revision rate per 100 person years at risk, 0.37 (± 0.02)	Cemented designs showed good survival at 10–15 years	A number of prostheses achieved a revision rate of 10% or less after follow-up of 10 or more years
Functional result	NR	NR	NR
Long-term pain (as revision rates)	84.1% (range 46–100) patients receiving Charnley prosthesis are pain free at mean follow-up of 11 years (range 2–20); mean improvement 39.3	Thigh pain in 0–25% of cases after 2–7 years; rates higher with cementless implants	NR
Quality of life (as revision rates)	Mean hip score on 0–100 scale, 86 (range 59–95)	NR	NR
Quality of evidence	Paucity of evidence on which to base treatment choices; Charnley design has changed over time so relevance of evidence unclear	Most studies from specialist orthopaedic centres which limits generalisability Methodological quality of studies generally poor	Few RCT or comparative observational studies with 5- or 10-year follow-up Changes in design of prostheses and differences in process of care limit interpretation

Appendix 9

Osteotomy observational studies with follow-up of 5 years or more

Study (setting)	Procedure	Number of hips at outset	Mean duration of follow-up (range), months	Mean patient age (range), years	THR rate (unless otherwise stated)	Hip score (range)		Number of patients pain free	Unselected cases	Preoperative diagnosis
						Preoperative	Post-operative			
Gallinaro & Masse, 2001[44] (Teaching hospital, Italy)	Flexion inter-trochanteric osteotomy	46	122 (48–144)	NR	9/33 patients (27.3%)	Pain 3[a] Walking 4[a] Mobility 5[a]	Pain 5[a] Walking 5[a] Mobility 5[a]	NR	NR	Avascular necrosis
Inao *et al.*, 1999[45] (Teaching hospital, Italy)	Trans-trochanteric rotational osteotomy	14	158 (120–212)	36 (24–58)	3/14 hips (21.4%) 2/12 patients (25%)	NR	Pain 5.5[a] Walking 5.6[a] Mobility 4.5[a]	NR	NR	Avascular necrosis
Ito *et al.*, 1999[46] (Teaching hospital, Italy)	Varus inter-trochanteric osteotomy	26	150 (84–228)	36 (25–50)	4/26 hips (15.4 %)	46 (26–75)[b]	85 (80–100)[b]	NR	Hip flexion < 90° and 25° of abduction	Osteonecrosis
Lengsfeld *et al.*, 2001[47] (Teaching hospital, Germany)	Femoral valgus and lengthening osteotomy	15	122 (102–147)	25.8 (13.3–49)	1/15 patients (6.6%)	7.3 (pain and walking only)[a]	8.9 (pain and walking only)[a]	5/15 (33.3%)	NR	Avascular necrosis
Mellerowicz *et al.*, 1998[49] (Teaching hospital, Germany)	Chiari-osteotomy	48	127	17.8	NR	NR	NR	6/37 (16%)	NR	Developmental hip dysplasia
Menschik *et al.*, 1998[50] (Teaching hospital, Austria)	Rotational sugioka osteotomy	51	NR	43 (SD, ± 8)	8/41 patients (29%)	NR	Excellent/good, 24 patients Fair, 10 Poor, 7[b]	NR	NR	Osteonecrosis
McGrory *et al.*, 1998[48] (Teaching hospital, USA)	Inter-trochanteric osteotomy	67	NR	55 (29–75)	49/61 patients (90.3%)	NR	NR	NR	Avascular necrosis	Developmental dysplasia (31%); osteoarthritis (19%); advanced destructive changes preventing diagnosis (10%); miscellaneous (12%)
Morita *et al*, 2000[51] (Teaching hospital, Japan)	Valgus-extension femoral osteotomy	33	152 (120–204)	45 (24–57)	NR	Pain 17[b] Gait 16[b] ROM 3.9[b]	Pain 33 (at 12 years) Gait 19 (at 12 years) ROM 3.7 (at 10 years)[b]	NR	NR	Osteoarthritis of hip secondary to acetabular dysplasia

continued

Study (setting)	Procedure	Number of hips at outset	Mean duration of follow-up (range), months	Mean patient age (range), years	THR rate (unless otherwise stated)	Hip score (range)		Number of patients pain free	Unselected cases	Preoperative diagnosis
						Preoperative	Post-operative			
Nakamura *et al.*, 1998[52] (Teaching hospital, Japan)	Rotational acetabular osteotomy	145	156 (120–276)	28 (11–52)	7/145 hips (4.8%)	Pain 3.9[a] Gait 4.9[a] Mobility 5.4[a]	Pain 5.2[a] Gait 5.3[a] Mobility 4.9[a]	NR	NR	Hip dysplasia
Ohashi *et al.*, 2000[53] (Teaching hospital, Japan)	Chiari pelvic osteotomies	126[*]	199.8 (12–444)	27.5 (6–54)	5/91patients (5.5%)	Japanese scoring system used	Japanese scoring system used	NR	NR	Subluxation of the hip and osteoarthritis
Schramm *et al.*, 1999[54] (Single setting, Germany)	Spherical acetabular osteotomy	38	204 (120–300)	25 (12–50)	1/34 patients (2.9%)	NR	NR	29/38 (76%)	NR	Residual dysplasia and secondary osteoarthritis
Siebenrock *et al.*, 1999[55] (Orthopaedic unit, Switzerland)	Bernese peri-acetabular osteotomy	75	135.6 (120–165.6)	29.3 (13–56)	12/63 patients (19%)	Pain 3.9[a] Ambulation 4.9[a] Motion 5.8[a] NR[b]	Pain 5.3[a] Ambulation 5.6[a] Motion 5.4[a] 93 (65–100)[b]	NR	NR	Hip dysplasia

[a] *Merle d'Aubigne hip score;* [b] *Harris hip score;* [*] *Discrepancy in number of patients included,* n = *91 and* n = *93 both reported*

ROM, range of movement

Appendix 10

Arthrodesis observational study

Study (setting)	Prostheses	Number of hips at out-set	Mean duration of follow-up (range), months	Mean patient age (range), years	Hip score post-operative mean (range)	Patients' pain at follow-up	Notes
Karol *et al.*, 2000[33] (Children's hospital, USA)	Intra-articular arthrodesis	9	106 (25–166)	13.4 (10.8–17)	69.5 (47–90)*	Pain free 2/9 (22%) Slight pain 3/9 (33%) Mild pain 1/9 (11%) Moderate pain 3/9 (33%)	Preoperative diagnosis: avascular necrosis (5 patients) idiopathic chondrolysis (2 patients) Legg–Calve–Perthes disease (1 patient) septic hip dislocation (1 patient)

* *Harris hip score had, in this case, a maximum of 90 points, as areas of score relating to motion and deformity omitted*

Appendix 11

Arthroscopy data from Cambridge Hip and Knee Unit database*

Arthroscopy data

Main procedures and numbers of patients	Previous surgery on hip	Operating time (range), minutes	Days in hospital (number of patients)	Revision rate	Steroids used	Anaesthesia used	Complications	Loss to follow-up
Irrigation: 198 Partial labrectomy: 143 Debridement: 67 Loose body retrieval: 35 N/A: 28 Synovial biopsy: 20 Biopsy: 17 Chondroplasty: 15	15.7%	Mean: 23.6 (1–1000)	0 (292) 1 (182) 2 (70) 3 (1)	19.2% THR	31%	82%	0.8%	25.1%**

** *Including patients who had THR; excluding THR, 5.9%*

Patients receiving arthroscopy primarily for diagnosis

	Pre-operative	At 6-week follow-up	At 6-month follow-up	At 1-year follow-up	At 5-year follow-up	At 10-year follow-up
Mean hip pain score HHSPN (number of patients)	18.7 (84)	26.8 (73)	25.5 (65)	27.5 (56)	33.4 (31)	27.0 (2)
Mean functional ability score HHSFUN (number of patients)	33.8 (73)	36.7 (55)	35.8 (68)	35.7 (47)	42.0 (12)	47.0 (2)

Patients receiving arthroscopy for diagnosis and treatment

	Pre-operative	At 6-week follow-up	At 6-month follow-up	At 1-year follow-up	At 5-year follow-up	At 10-year follow-up
Mean hip pain score HHSPN (number of patients)	19.8 (450)	33.0 (433)	27.5 (357)	28.4 (281)	31.1 (78)	30.0 (4)
Mean functional ability score HHSFUN (number of patients)	36.7 (568)	37.5 (346)	39.4 (317)	41.8 (257)	40.7 (67)	43.5 (4)

Functional status of patients

	Pre-operative	At 6-week follow-up	At 6-month follow-up	At 1-year follow-up	At 5-year follow-up	At 10-year follow-up
Mean hip pain score HHSPN (number of patients)	19.3 (534)	29.9 (506)	26.5 (422)	28.0 (337)	32.3 (109)	28.5 (6)
Mean functional ability score HHSFUN (number of patients)	35.3 (641)	37.1 (401)	57.3 (385)	56.6 (304)	41.4 (79)	45.3 (6)

* Supplied by R Villar

HHSP, Harris hip score, pain; HHSFUN, Harris hip score, function

Survival without revision to THR for patients who initially received an arthroscopy

Year of follow-up	Number followed-up	Number of events	Number of withdrawals	Event-free survival without THR (%)	Cumulative risk of THR per year (%)
1	353	28	0	92.07	7.93
2	267	62	24	69.68	30.32
3	208	11	48	65.52	34.48
4	146	7	55	61.65	38.35
5	104	6	36	57.35	42.65
6	71	5	28	52.32	47.68
7	38	2	31	47.67	52.33
8	21	3	14	37.45	62.55
9	13	1	7	33.51	66.49
10	7	0	6	33.51	66.49
11	2	0	5	33.51	66.49

Appendix 12

Quality assessment of MMT submission to NICE

This quality assessment is based on the 35-point *BMJ* guidelines for reviewers of economic evaluations,[57] of which a summary is given overleaf.

Study	Checklist items											
	1	2	3	4	5	6	7	8	9	10	11	12
MMT submission[22]	Yes	Yes	Yes	Yes	Not clear	Yes	Yes	Yes	No	NA	Yes	No

Study	Checklist items											
	13	14	15	16	17	18	19	20	21	22	23	24
MMT submission[22]	No	NA	No	Yes	Yes	Yes	Yes	Not clear	Not clear	Yes	Yes	Not clear

Study	Checklist items										
	25	26	27	28	29	30	31	32	33	34	35
MMT submission[22]	Not clear	No	Not clear	No	Yes	Not clear for watchful waiting	Yes	Yes	Yes	Not clear	Not clear

Summary of *BMJ* guidelines for reviewers of economic evaluations[57]

1. Research question stated
2. Importance of question stated
3. Viewpoint of analysis stated and defined
4. Rationale for choosing alternative programmes or interventions compared stated
5. Alternatives being compared clearly defined
6. Form of economic evaluation used stated
7. Choice of form of economic evaluation justified in relation to question addressed
8. Source(s) of effectiveness estimates stated
9. Details of design and results of effectiveness study given (if based on single study)
10. Details of methods of synthesis or meta-analysis of estimates given (if based on overview of a number of effectiveness studies)
11. Primary outcome measure(s) for economic evaluation clearly stated
12. Methods to value health states and other benefits stated
13. Details of subjects from whom valuations were obtained given
14. Productivity changes (if included) reported separately
15. Relevance of productivity changes to study question discussed
16. Quantities of resources reported separately from their unit costs
17. Methods for estimation of quantities and units costs described
18. Currency and price data recorded
19. Details of currency and price adjustments for inflation or currency conversion given
20. Details of any model used
21. Choice of model used and key parameters on which it is based justified
22. Time horizon of costs and benefits stated
23. Discount rate(s) stated
24. Choice of rate(s) justified
25. Explanation given if costs and benefits are not discounted
26. Details of statistical tests and confidence interval given for stochastic data
27. Approach to sensitivity analysis given
28. Choice of variable for sensitivity analysis justified
29. Ranges over which variables are varied stated
30. Relevant alternatives compared
31. Incremental analysis reported
32. Major outcomes presented in an aggregated as well as a disaggregated form
33. Answer to study question given
34. Conclusions follow from data reported
35. Conclusions accompanied by appropriate caveats

Appendix 13

Decision models to assess costs and benefits of various procedures

Each of the models depicted in this appendix has a very similar structure, so only the metal-on-metal hip resurfacing model is described here. Markov models can be used to estimate costs and consequences that occur over a series of years (in this study up to 20 years). At the start of the first year a patient receives a MOM and, hence, a probability of 1 is attached. At the end of the first year there is a chance (depicted as ○) that a patient could have died, or needed a revision of their MOM or that their MOM is still successful. The chance of a patient dying is p6 (see *Table 8* (page 34) and appendix 14). The chance of the MOM needing to be revised to a THR is p1 (see *Table 8*). Thus, the chance of the MOM being successful is equal to 1 – (p1 + p6).

As an individual is followed over a number of years, this process continues. At the end of each year there is a chance that the MOM will have needed revision or that the patient will have died during that year. In the model it has been assumed that the probability that the MOM will need revising does not change over time. However, as people grow older it is more likely that their chances of dying will increase. In order to reflect this, the chance of death (p6) changes each year. So at the end of each year (or stage) in the model, a different risk of death is used (see appendix 16).

If the patient needs a revision to THR, they move to the 'revision to primary THR' part of the model. Once here they follow essentially the same process. The only exception is that if the primary THR fails then they need a revision THR, which means that they move to the third main branch of the Markov model.

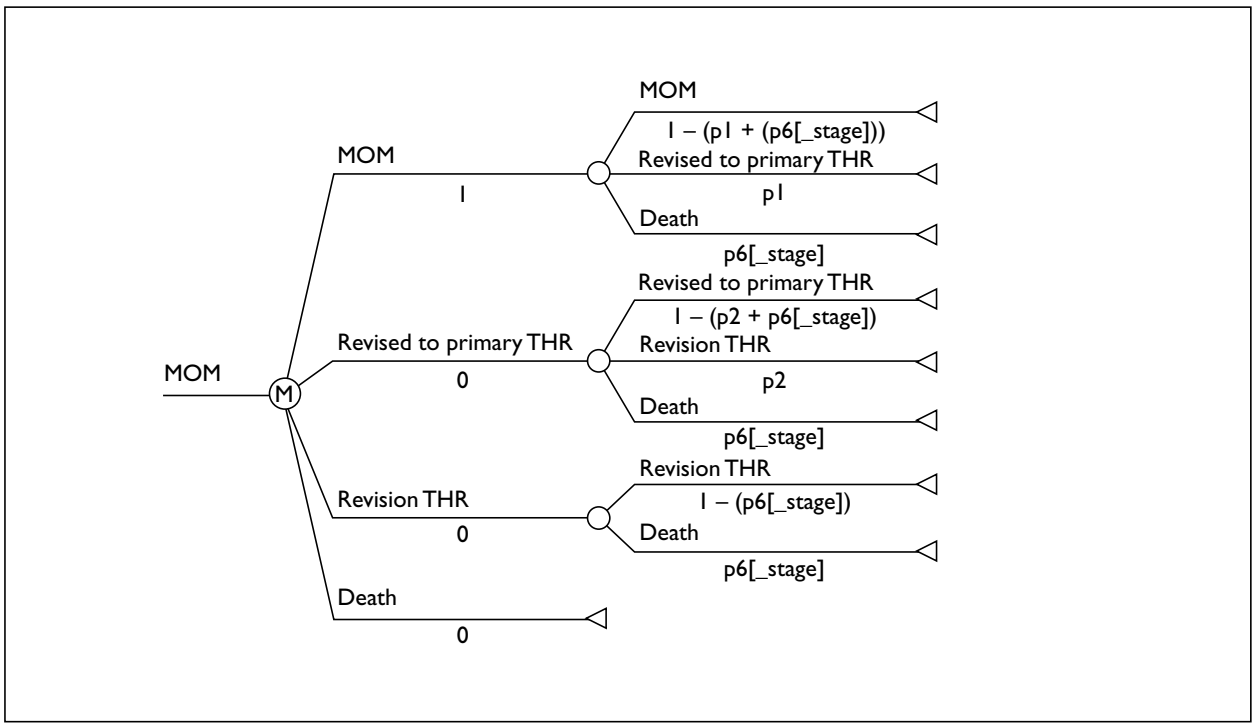

FIGURE 10 *Decision model to assess costs and benefits of metal-on-metal hip resurfacing arthroplasty (M, Markov)*

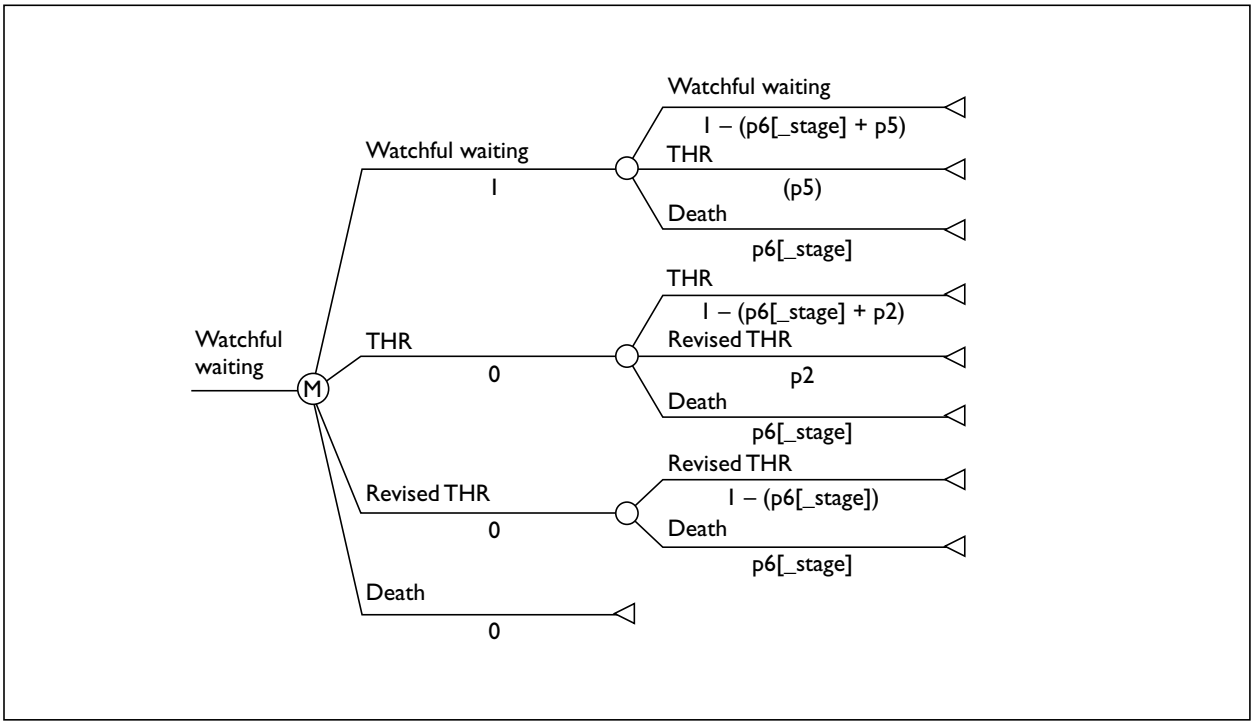

FIGURE 11 *Decision model to assess costs and benefits of watchful waiting (M, Markov)*

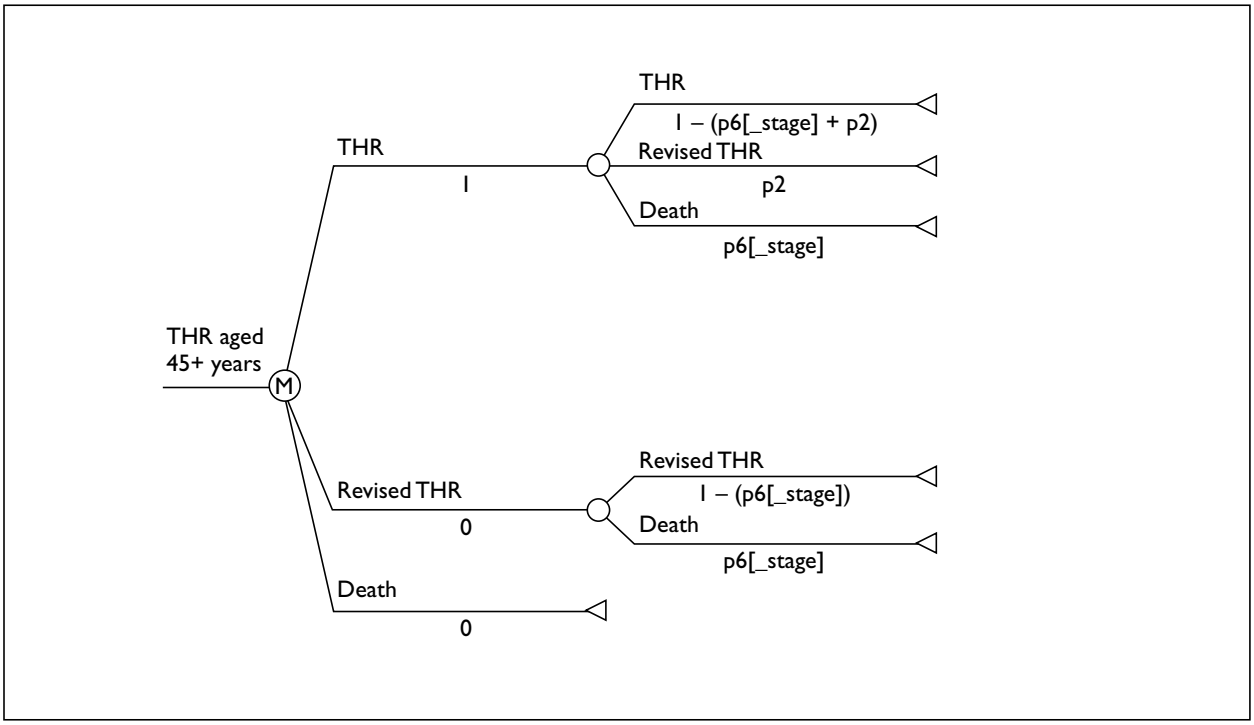

FIGURE 12 *Decision model to assess costs and benefits of THR (M, Markov)*

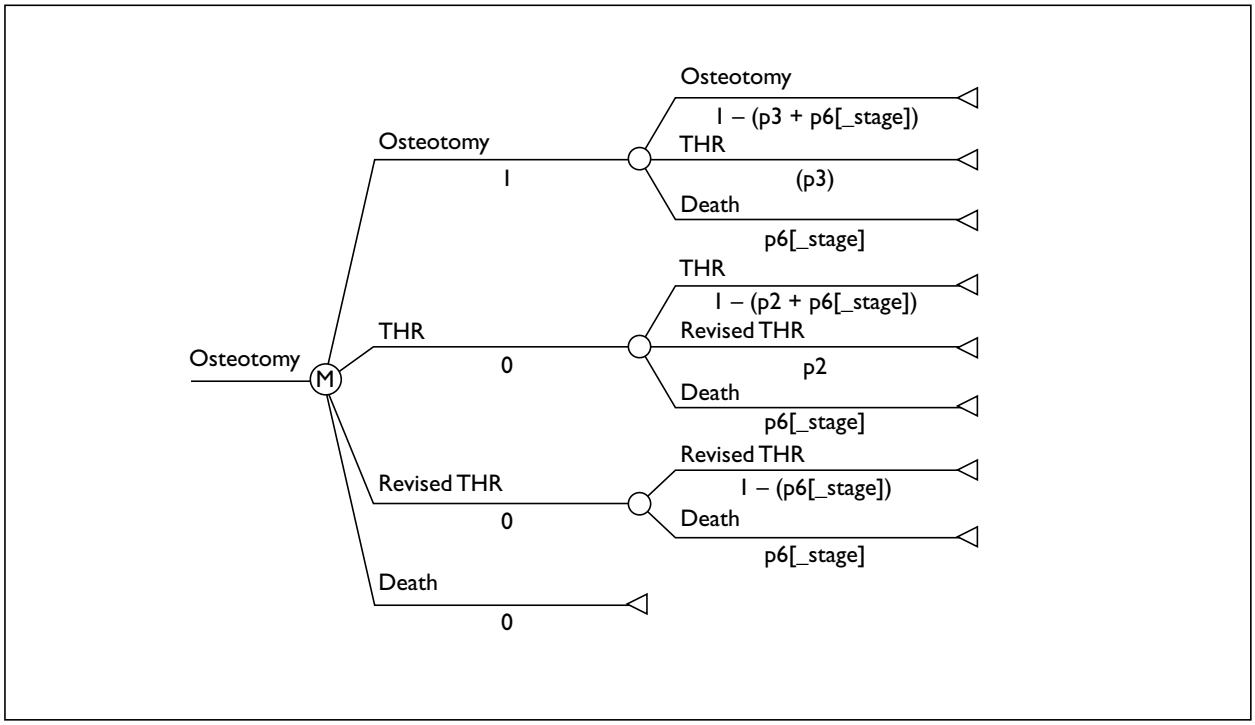

FIGURE 13 *Decision model to assess costs and benefits of osteotomy (M, Markov)*

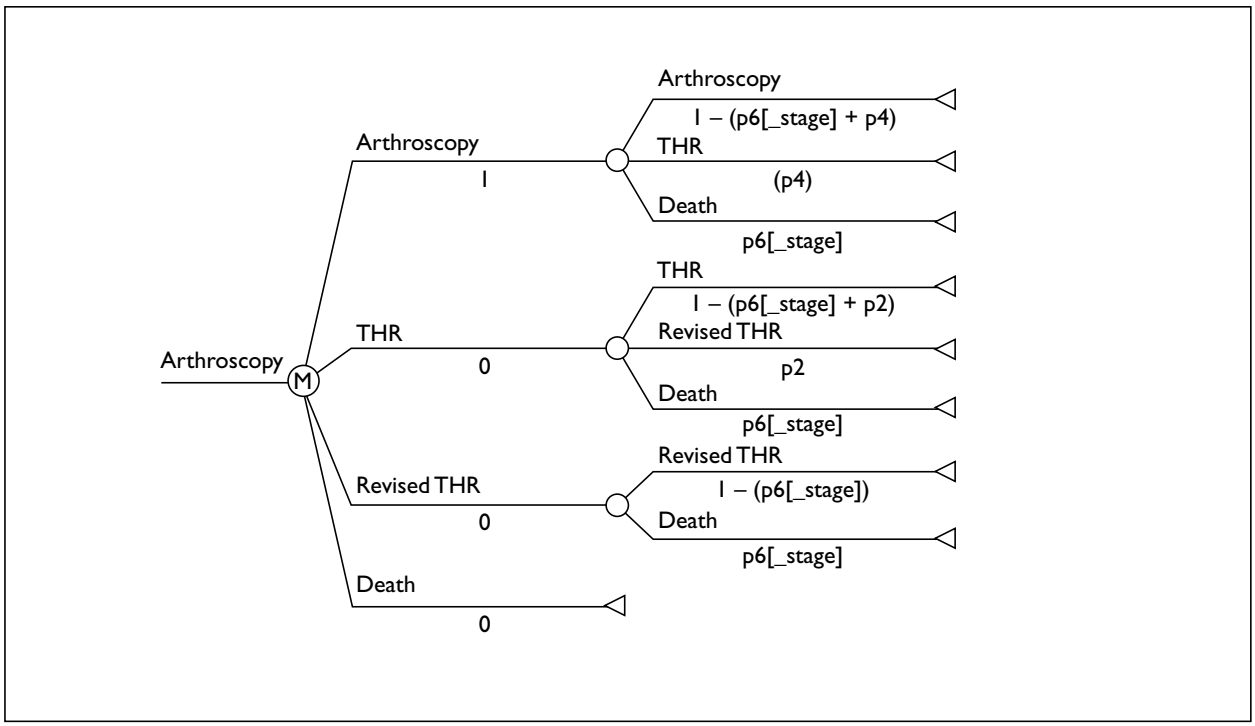

FIGURE 14 *Decision model to assess costs and benefits of arthroscopy (M, Markov)*

Appendix 14

Mortality data used in the models

Mortality rates from age 45 years

Year	Males	Female	Average of male and female	From ONS[61] All
0	0	0	0	0
1	0.013	0.012	0.0125	0.01385
2	0.003	0.002	0.0025	0.00385
3	0.003	0.002	0.0025	0.00385
4	0.003	0.002	0.0025	0.00385
5	0.003	0.002	0.0025	0.00385
6	0.0047	0.0032	0.00395	0.00385
7	0.0047	0.0032	0.00395	0.00385
8	0.0047	0.0032	0.00395	0.00385
9	0.0047	0.0032	0.00395	0.00385
10	0.0047	0.0032	0.00395	0.00385
11	0.0081	0.0052	0.00665	0.01060
12	0.0081	0.0052	0.00665	0.01060
13	0.0081	0.0052	0.00665	0.01060
14	0.0081	0.0052	0.00665	0.01060
15	0.0081	0.0052	0.00665	0.01060
16	0.0135	0.0081	0.0108	0.01060
17	0.0135	0.0081	0.0108	0.01060
18	0.0135	0.0081	0.0108	0.01060
19	0.0135	0.0081	0.0108	0.01060
20	0.0135	0.0081	0.0108	0.01060

Mortality rates from age 65 years

Year	Males	Female	Average of male and female	From ONS[61] All
0	0	0	0	0
1	0.0325	0.0234	0.02795	0.0399
2	0.0225	0.0134	0.01795	0.0299
3	0.0225	0.0134	0.01795	0.0299
4	0.0225	0.0134	0.01795	0.0299
5	0.0225	0.0134	0.01795	0.0299
6	0.0385	0.0232	0.03085	0.0299
7	0.0385	0.0232	0.03085	0.0299
8	0.0385	0.0232	0.03085	0.0299
9	0.0385	0.0232	0.03085	0.0299
10	0.0385	0.0232	0.03085	0.0299
11	0.0621	0.0388	0.05045	0.0775
12	0.0621	0.0388	0.05045	0.0775
13	0.0621	0.0388	0.05045	0.0775
14	0.0621	0.0388	0.05045	0.0775
15	0.0621	0.0388	0.05045	0.0775
16	0.1086	0.0709	0.08975	0.0775
17	0.1086	0.0709	0.08975	0.0775
18	0.1086	0.0709	0.08975	0.0775
19	0.1086	0.0709	0.08975	0.0775
20	0.1086	0.0709	0.08975	0.0775

Appendix 15

Estimation of the osteotomy failure rate

Study	Number of patients in study	Mean follow-up period (years)	Rate of revision to THR (%)	Revision rate per year* (%)	Weighted revision rate† (%)
Gallinaro & Masse, 2001[44]	33	10.17	27	2.69	0.21
Inao *et al.*, 1999[45]	12	13.17	25	1.90	0.05
Ito *et al.*, 1999[46]	26	12.50	15	1.23	0.08
Lengsfeld *et al.*, 2001[47]	15	10.17	7	0.65	0.02
Mellerowicz *et al.*, 1998[49]	48	10.58	NR	Not estimated	Not estimated
Menschik *et al.*, 1998[50]	51	Unclear	29	Not estimated	Not estimated
McGrory *et al.*, 1998[48]	67	Unclear	90	Not estimated	Not estimated
Morita *et al.*, 2000[51]	33	12.67	NR	Not estimated	Not estimated
Nakamura *et al.*, 1998[52]	145	13.00	5	0.37	0.13
Ohashi *et al.*, 2000[53]	91	16.65	6	0.33	0.07
Schramm *et al.*, 1999[54]	34	17.00	3	0.17	0.01
Siebenrock *et al.*, 1999[55]	63	11.28	19	1.68	0.25
Combined weighted annual revision rate					**0.83**

* *Rate of revision divided by number of years*
† *Annual revision rate from each study weighted by size of study*

Appendix 16

Further notes on the methods used to run the Markov models

All decision trees are based on Markov models and can be 'solved' using the 'Markov analysis' command in the *Analysis* menu of DATA©. Detailed information on the use of the software is given in the DATA manual (DATA 3.0 User Manual: TreeAge Software; 1997). In DATA, the preferences for the calculation method are set at cost-effectiveness, with payoff 1 as costs and payoff 2 as effectiveness, the latter being measured in QALYs. Costs were measured in £UK.

The variables used in the analyses are listed in *Table 8* (page 34). With the exception of the watchful waiting model, the initial costs of a procedure (including follow-up costs for the first year after the operation) are included in the model as 'Prior costs'.

The costs and quality-of-life adjustment for each cycle, in this case for each year after the year of the intervention, are specified in the reward sets in the Markov state information for each of the appropriate interventions in the tree. Changes in quality of life when moving from one state to a different state are specified in the model as transition rewards. When a transition is to the state 'death', the transition quality of life is a loss of all quality of life in the previous state. Quality-of-life values for each intervention are given in *Table 8* (Q1–Q6).

All interventions except watchful waiting have a zero annual cost after year 1. For watchful waiting, the annual cost of £641.53 (C4 in *Table 8*) is included in the Markov state information.

The discount rates for costs and QALYS are specified as part of the initial Markov state information, using the option 'UtilDiscount'.

The probabilities, p1–p7, represent the revision risks for each intervention and mortality rates. The values for p1–p5 are included as variables, while the mortality rate values, p6 and p7, were included in the model as tables. Different values for any of the variables, such as revision rate or quality of life, could readily be incorporated into these models by editing the appropriate values in the Markov state information or by changing the value of a probability variable.

Note that in the case of the tree for the watchful waiting alternative, the model was first specified with three options for interventions that could occur after a patient went to watchful waiting, namely, metal-on-metal hip arthroplasty, THR or a bone-conserving technique. While such a range of alternatives would be a feasible model, the results included in the report have used the model in which THR is the only surgical intervention that could occur after a patient enters watchful waiting.

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Professor Kent Woods
Director,
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Professor of Therapeutics
University of Leicester

Professor Bruce Campbell
Consultant General Surgeon
Royal Devon & Exeter Hospital

Professor Shah Ebrahim
Professor of Epidemiology
of Ageing
University of Bristol

Dr John Reynolds
Clinical Director
Acute General Medicine SDU
Oxford Radcliffe Hospital

Dr Ron Zimmern
Director, Public Health
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Strangeways Research
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Consultant in Nuclear
Medicine & Radiology
Royal Cornwall Hospitals Trust
Truro

Mrs Joan Webster
Former Chair
Southern Derbyshire
Community Health Council
Nottingham

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We look forward to hearing from you.

Copies of this report can be obtained from:

The National Coordinating Centre for Health Technology Assessment,
Mailpoint 728, Boldrewood,
University of Southampton,
Southampton, SO16 7PX, UK.
Fax: +44 (0) 23 8059 5639 Email: hta@soton.ac.uk
http://www.ncchta.org

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