A cost-effectiveness analysis for the screening of total hip replacements to detect aseptic loosening

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Summary
The cost-effectiveness of alternative follow-up strategies for patients who have undergone a unilateral primary total hip replacement (THR) is discussed. Using technologies such as electromagnetic autonomous transducers (EMAT), it is possible to measure microscopic migration of hip prostheses. The degree of such migration may be predictive of future symptomatic loosening of the hip.
A Markov model is constructed in which patients are assigned to alternative follow-up strategies depending on the level of loosening risk identified by an EMAT screening procedure one year after the primary THR. A key feature of our model is that the allocation to the different strategies is based on a risk threshold that may be adjusted to achieve optimal cost-effectiveness.
In this study, the model was used to ascertain the "societal value" of the screening procedure when applied to a choice between two follow-up strategies. The alternative strategies considered here were "no follow up" and "annual radiographic review up to a certain age".
It emerged that the societal value of EMAT screening is guaranteed to be positive, and also that this value is very sensitive to the unknown features of the loosening model.

KEY WORDS: *cost effectiveness analysis, incremental cost effectiveness ratio, Markov model, total hip replacement*.

Introduction

Total hip replacement (THR) is a common surgical intervention. The National Joint Registry for England and Wales recorded 24,997 operations in the first nine months of 2003, including 2,325 revision operations (1). The mean age of the patients involved, the majority of whom (60%) were women, was estimated to be 69.7 years. Revision operations are performed for three main reasons: aseptic loosening – this accounted for 76% of revisions recorded in the Swedish Register's 2003 Annual Report (2) –, infection and dislocation, each accounting for about 7%. In Italy, hospital discharge databases show increasing trends for both primary and revision procedures (primary THRs rose from 42,198 in 1999 to 51,448 in 2003). Regular radiographic review may be able to identify patients who need revision surgery for aseptic loosening before they present pronounced symptoms, although opinions differ about the desirability of regular review of hip prostheses (3, 4). An early revision of a loosening hip prosthesis is beneficial insofar as it allows some of the pain and discomfort associated with a failing hip to be avoided, is less likely to be associated with surgical complexities, and has a more favourable long-term prognosis in terms of the patient's quality of life. On the other hand, the potential long-term benefits of an ear-

ly revision are irrelevant unless the patient lives long enough to enjoy them. Moreover, these benefits must be set against the cost of a follow-up strategy based on regular radiographic review. Thus it may be advantageous to reserve the more intensive follow-up strategies for those patients who are most likely to benefit from them.

The purpose of this study was to model alternative follow-up strategies for primary hip replacement patients and, in particular, to evaluate the impact of a screening procedure that can be used to choose between alternative follow-up strategies for individual patients. This procedure uses electromagnetic autonomous transducers (EMAT) to detect microscopic migration of the prosthesis before it is visible on a radiograph. Such migration is detected by measuring the relative positions of small implants inserted into the prosthesis and the surrounding bone at the time of the primary operation. By comparing measurements taken at the time of the operation with those taken at a later time, it is possible to identify those prostheses at greatest risk of future loosening. We aim to determine the "societal value" that may be attached to this type of screening, in order to inform decisions surrounding its possible implementation in practice.

Method

The population dealt with in this study is that of THR patients who have successfully completed normal post-operative procedures and follow up to the end of the first post-operative year. These are the patients for whom the choice of follow-up strategies is to be made. In this study we consider two basic screening strategies:

a) annual radiographic review (ARR)
b) no (planned) follow up (NFU)

In addition, we propose an intermediate follow-up strategy:

c) annual radiographic review up to age X, with no planned follow up thereafter (ARRX)

If the threshold age, X, is chosen properly, this modified review strategy will be more beneficial to patients than ARR, and is also likely to be less costly. Our approach is to identify the age, X, at which the effectiveness of the review strategy will be maximised irrespectively of the costs.

Subsequently, follow-up strategies can be compared using conventional cost-effectiveness analysis. Here, effectiveness is measured in terms of the average number of quality-adjusted life years (QALYs) enjoyed by a patient when a particular strategy is pursued, beginning at the end of the first post-operative year, and ending in death. Costs are measured in monetary terms, and include the direct costs of follow up and all subsequent contingent interventions. A discount rate of 3.5% p.a. is applied throughout to all costs and QALYs as suggested by NICE (5).

As mentioned, if the threshold age, X, is correctly chosen it is likely that the hybrid strategy will actually prove more beneficial than ARR – i.e. ARRX will be both more effective and less costly than ARR. Perfect prediction of whether a THR will or will not become aseptically loose is not possible. Therefore, we assume that the probability of an individual unrevised hip becoming loose in any given interval of time is governed by a risk parameter λ, specific to that hip. In accordance with other researchers (6), we assume that, for small time intervals, the loosening probability increases linearly with the time since primary surgery. Algebraically, the hazard function for aseptic loosening is specified as

$$h_{\lambda}(t) = 2\lambda t,$$

where t is the time (in years) since the primary THR. The mix of λ-values in the patient population may be estimated from hip registry data (i.e. rates of revisions for loosening).

The rationale for screening is based on the idea that EMAT technology can identify the value of λ by assessing the degree of migration one year after the primary THR. Using this information it is then possible to choose the best follow-up strategy for any particular patient. In our model, we concentrate on NFU (no follow up) and ARRX (the hybrid strategy in which annual reviews cease when patients become too old to benefit from early revisions). After EMAT screening, patients with low λ-values are assigned to the NFU strategy and those with high values to ARRX. The threshold value of λ between the low-risk and high-risk groups is chosen on the basis of a maximum cost-effectiveness criterion.

We developed a mathematical model for long-term THR outcomes in patients who successfully reach

the end of the first post-operative year without major difficulties. It serves three purposes:

a) determine the age, X, at which early revision following annual review ceases to be in the best interests of the patient. This is necessary in order to implement the best review strategy, ARRX.
b) To establish the threshold value (λ') of the risk parameter, above which the annual review strategy (ARRX) is more cost-effective than NFU. This is necessary to determine the best implementation of the EMAT screening approach.
c) To calculate the costs and QALYs associated with the three available options – i.e. NFU, ARRX and EMAT (ARR).

The experience of a typical patient will follow the time line depicted in figure 1: the patient has a THR at age A, and dies D years later. During this time, the hip becomes radiographically loose – at time A + T – and, left alone, would become symptomatic at time A + φT, where φ is a constant that is assumed to apply to all patients.

Under ARR, such a patient would be revised at time A + T, and receive D - T years of standard post-early hip revision care. Under NFU, the revision is delayed until time A + φT, and the patient receives D - φT years of standard care following the revision of a symptomatic hip.

This approach remains controversial although, at the time of writing, it has been possible to elicit some (limited) expert surgical opinion concerning a plausible value for φ. This expert opinion supports our use of φ = 1.5 as a "base -case" value, but it does not settle the issue. This remains one of the greatest sources of uncertainty in our model.

Our model has the capacity to examine the impact of screening strategies on patient populations with an arbitrary mix of risk parameters for aseptic loosening – the quantity λ introduced above.

We propose a two-parameter mixing model for λ, namely that the distribution of λ-values in the population of patients has the following density function:

$$f(\lambda) = \frac{1}{\Gamma(\alpha)} \beta^{2\alpha} \lambda^{\alpha-1} e^{-\beta^2 \lambda}, \lambda > 0.$$

In other words, we assume that λ follows a gamma distribution with parameters α and β^2 (both greater than 0) chosen to reflect the characteristics of the patient population. This probability model should be flexible enough to represent most unimodal populations of risk parameters. It results in the following form for the "survival" function of a hip subject to aseptic loosening:

$$S(t) = \left(1 + \frac{t^2}{\beta^2}\right)^{-\alpha}, t > 0.$$

This form is qualitatively consistent with, for example, the estimated survival curves given by the Swedish Hip Register (2). In principle, values for α and β could be estimated from these curves for use in our cost-effectiveness analysis.

The structure of the Markov model

The model describes the progress of a patient who undergoes a successful primary unilateral THR at a fixed age, which we take to be 69 years. Subsequently, the hip may deteriorate to the point at which it has to be revised, and this may happen several times; alternatively the patient may die of other causes before the revision becomes necessary.

A revision operation may be simple or complex, de-

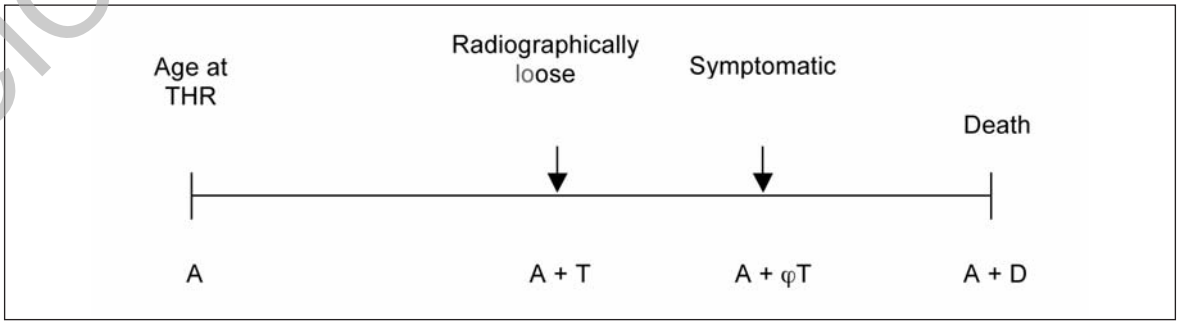

Figure 1. Time-line for a typical patient.

pending on the degree of bone loss that has arisen. Although some first revisions will be complex, many will be simple, especially if the patient is undergoing an active follow-up regime at the time. We assume that any subsequent revision after the first will automatically require a complex operation, and will consequently show an increased cost and probably a reduced effectiveness compared to a simple revision. Thus, two Markov states are needed to represent patients with successfully completed revisions. In order to capture the sequence of events surrounding a revision operation, the years in which a revision takes place are represented by two further states in the formulation of the model.

Death can occur at any stage following THR, mostly from causes unrelated to the hip prosthesis, although there is an additional (peri-operative) risk associated with revisions.

The "primary THR" state is split into two separate states with identical utilities but different costs:

"THR reviewed" represents the case of a patient with a primary THR in a year in which a review is scheduled;

"THR unreviewed" represents the case of a patient with a primary THR in a year in which no review is scheduled.

Similarly, the "simple revision" state is split into two:

"simple revision reviewed" denotes a simple revision occurring in a year in which a review is scheduled;

"simple revision unreviewed" denotes a simple revision occurring in a year in which no review is scheduled.

Figure 2 shows the model structure for the hybrid follow-up strategy (annual review up to age X with

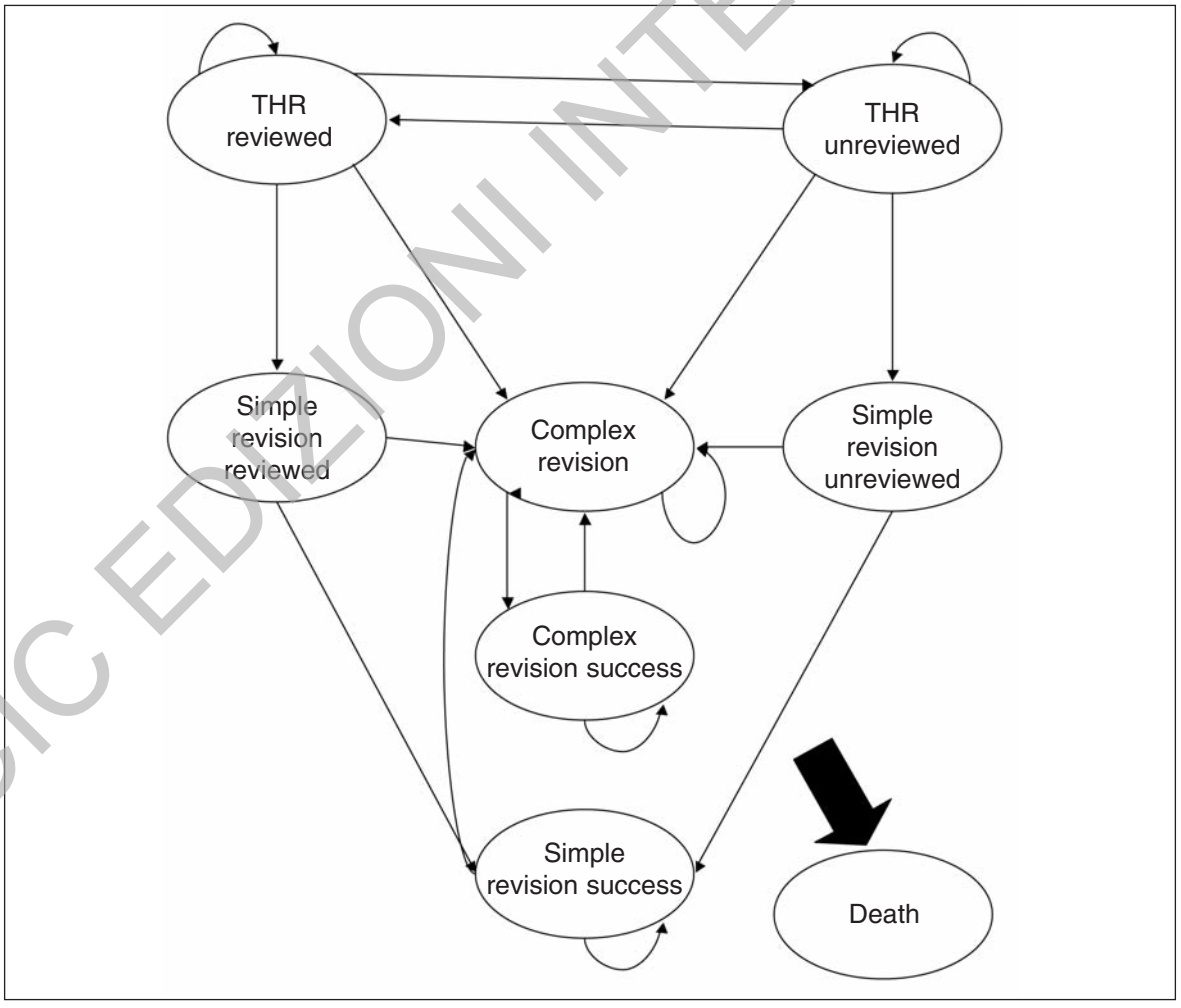

Figure 2. Model incorporating complex review strategies.

no scheduled follow up thereafter) embracing these modifications. The structure encompasses all the review strategies considered here.

Transitions between the model states are possible each year and may be subdivided into two groups:

1. transitions from the primary THR state to a simple or complex revision for aseptic loosening;
2. all other transitions.

Since the purpose of the model is to compare different review strategies employed in cases of aseptic loosening following primary THR, the impact of the review strategy on the first set of probabilities is vitally important and warrants a careful analysis, especially since aseptic loosening is the root cause of the majority of revision operations.

The following events are associated with the second set of transitions:

– (simple) revisions of the primary hip due to dislocation
– (complex) revisions of the primary hip due to infection
– (complex) re-revisions for any cause
– surgical death related to revision operations
– death from other causes (standard mortality).

Age-dependent standard mortality rates derive from current mortality tables (7) and apply to all (live) states in the model. The other transitions in this list are modelled using constant annual probabilities. The structure of the transition probabilities is summarised in Tables 1 and 2.

Costs and Utilities

The cycle-length in the model is one year. Thus each patient-year spent in a given state incurs a cost, defined as the monetary cost incurred by the health service provider (i.e. the NHS) for a patient spending a year in that state. At the same time as the cost is incurred, a utility value is accrued, defined as the number of QALYs associated with a year spent in the given state. The assumed cost structure is shown in Table 3; the current costs are taken from NHS Reference Costs 2003 (8).

Table 1. Structure of the transition probabilities, excluding standard mortality.

	Primary THR	Simple revision	Complex revision	SR, success	CR, success	Death
Primary THR	1-dis-inf-pt	dis + pt × srp	inf + pt × (1-srp)			
Simple revision			(1-sd) × fsr	(1-sd) × (1-fsr)		sd
Complex revision			(1-sd) × fcr		(1-sd) × (1-cr)	sd
SR, success			fsr	1-fsr		
CR, success			fcr		1-fcr	

To obtain the actual probabilities, standard age-specific mortality rates (q_t) must be added to the final column, and the remaining entries in the table adjusted (downwards) by the factor (1- q_t) so that the sum of the entries in each row is 1. Blank entries are to be taken as zero.

Table 2. Sources of transition probabilities.

Parameter	Definition	Value	Source
dis	Rate of revision of THR for dislocation	0.000371	(11)
inf	Rate of revision of THR for infection	0.000996	(12, 13)
pt	Rate of revision of THR for aseptic loosening	Time-dependent rate	-
srp	Proportion of aseptic loosening of simple of THR revisions	1, if under review 0.75, if not under review	-
fsr	Rate of failure of revised simple hips	0.02076	(13, 14, 15)
fcr	Rate of failure of complex revised hips	0.04658	(7)
sd	Peri-operative death probability for revision surgery	0.005	(1)
qt	"All-cause" mortality rate	Age-dependent rate	(8)

Table 3. Markov state costs.

Clinical Event		Cost (£)
Radiographic review	a	87
Outpatient clinic (pre-revision)	b	174
Simple revision of hip	c	5,944
Complex revision of hip	d	7,036
Markov State		**Cost (£)**
THR reviewed	a	87
THR unreviewed	0	0
Simple revision, reviewed	b + c	6,118
Simple revision, unreviewed	b + c	6,118
Complex revision	b + d	7,210
SR, success	a	87
CR, success	a	87
Death	0	0

Quality of life in a given state is measured with reference to the pain (distress) experienced in that state on a four-point qualitative scale – none, mild, moderate, severe – converted to a numerical QALY value in accordance with Laupacis et al., 1993 (9) – i.e. none = 1, mild = 0.82, moderate = 0.52, severe = 0.18. The proportion of patients at each pain level is obtained from a variety of sources, as referenced in the table. The Markov state QALY values are obtained by weighted averaging of the Laupacis scores across the pain categories (Table 4). In the revision states (simple revision reviewed and unreviewed, complex revision), it is assumed that one half of the year is spent awaiting revision ("pre-revision") and the other half enjoying the QALY value associated with a successful revision operation. Thus the QALY values for these states are averages of the values across the two six-month periods.

The quantity p_t in Tables 1 and 2 represents the probability that a previously unrevised hip will undergo a revision for aseptic loosening in the year beginning at time t. Since aseptic loosening is more likely to be detected under a more intensive follow-up regime, it follows that this probability will be sensitive to the review strategy that is in place.

Furthermore, we assume that the complexity of a revision operation for aseptic loosening may be affected by the review strategy (a hip that is discovered to be radiographically loose at a scheduled review is unlikely to be associated with the presence of significant bone loss, such as to necessitate a complex revision operation). On the other hand, a hip that becomes symptomatic outside a scheduled review may have deteriorated to the point at which a complex operation is necessary. According to practising orthopaedic surgeons, this is the likely scenario in around 25% of such cases. Thus the value of the parameter srp (simple revision proportion) in Tables 1 and 2 is taken as 1 in any year in which a scheduled review takes place, and 0.75 in any year without a scheduled review.

Table 4. Markov state utilities.

Markov State	% at Pain Level				QALY value	Source
	None [1] (9)	Mild [0.82] (9)	Moderate [0.52] (9)	Severe [0.18] (9)		
THR reviewed	80	20	0	0	0.964	(16)
THR unreviewed	80	20	0	0	0.964	(16)
SR reviewed						
Pre-revision (× 0.5)	0	0	85	15		(16)
SR, success (× 0.5)	70	30	0	0		(17)
SR unreviewed					0.639	
Pre-revision (× 0.5)	0	0	45	55		Opinion
SR, success (× 0.5)	70	30	0	0		(17)
CR					0.595	
Pre-revision (× 0.5)	0	0	85	15		(16)
CR, success (× 0.5)	33	29	24	13		(18)
SR, success	70	30	0	0	0.946	(17)
CR, success	33	29	24	13	0.716	(18)
Death					0	

Estimates of the hip survival function

The Swedish Hip Register publishes an estimated survival function for revisions performed because of loosening of Charnley hips (2). This non-parametric curve could plausibly be used as a base-case estimate of the function $S_{ARR}(t)$ in our model where $S_{ARR}(t)$ is defined by

$$S_{ARR}(t) = \Pr\{L_{ARR} > t\}$$

L_{ARR} is the time at which the hip would be revised for aseptic loosening when under annual review, and in the absence of other failure modes. t denotes the time that has elapsed since the primary operation.

In accordance with Fitzpatrick et al. (6), we postulate a Weibull model for aseptic loosening under regular review, with a linear hazard rate specific to the hip. We found the Swedish data to be incompatible with a single parameter λ. Instead, this parameter is assumed to follow a two-parameter gamma distribution across the population of hips. This leads to a parametric form of survival function given by

$$S_{ARR}(t) = \int_0^\infty g\left(\lambda;\alpha,\beta^2\right)\exp\left(-\lambda t^2\right)d\lambda = \left(1+\frac{t^2}{\beta^2}\right)^{-\alpha}$$

where $g\left(\lambda;\alpha,\beta^2\right)$ is the probability density function of a gamma distribution with parameters α and β^2 – i.e. $g\left(\lambda;\alpha,\beta^2\right) = \frac{1}{\Gamma(\alpha)}\beta^{2\alpha}\lambda^{\alpha-1}\exp\left(-\beta^2\lambda\right)$. This form of survival function was fitted to the three points on the non-parametric curve published by the Swedish Hip Register (2). Weighted least squares were used for this purpose, with weights equal to the square of the inverse width of the published confidence intervals. The estimates obtained were α = 0.0953 and β = 9.798. The fit to the published figures is shown in Table 5.

Table 5. Hip survival probabilities.

Time since THR (yrs)	Survival Probability: Swedish data (with 95% intervals)	Survival Probability: Fitted value
5	0.978 (0.976 – 0.981)	0.978
10	0.936 (0.930 – 0.942)	0.934
12	0.917 (0.907 – 0.928)	0.916

In the following analyses, we use the parametric form with the estimated α- and β-values to represent the survival function under ARR. The survival function under NPR has an identical parametric form, with β replaced by $\varphi\beta$. The two survival functions are plotted in Figure 3.

Finally, to estimate the robustness of the results, deterministic sensitivity analysis was performed. All analyses were performed using TreeAge DataPro (TreeAge, Williamstown MA, USA).

Results

Three follow-up strategies were compared in a population of women who received a Charnley THR at the age of 69 and successfully completed the first post-operative year, concluding with a successful radiographic review. These three strategies were: annual radiographic review (ARR); no follow up (NFU); and the best (i.e. most effective) hybrid strategy[1] in which annual review is discontinued after the age of 78 – denoted by ARR(78). The results are given in Table 6 and include the incremental cost-effectiveness ratios comparing ARR and ARR(78) with NFU. After ten years it appears that NFU and ARR(78) are about equally effective, although ARR(78) is much

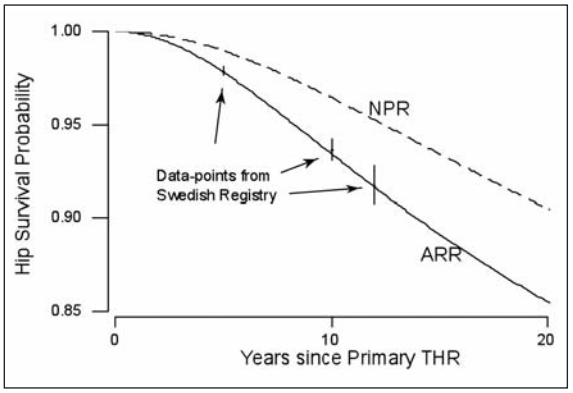

Figure 3. Fitted hip survival functions, including data-points and error bars from The Swedish National Hip Arthroplasty Register (2).

[1] The best age at which to discontinue the annual reviews was determined by running a sensitivity analysis on this parameter.

more expensive. In the longer term, ARR(78) is more effective than NFU, but would be considered cost-effective only at a QALY value of nearly £60,000.
It is to be noted that the best hybrid strategy depends on the mortality profile of the population. For example, it would be different for the male population, whose reviews should be terminated at age 76 for maximal effectiveness. Within this model it will always be best to terminate ARR for women at age 78, whether or not their hips are at increased or reduced risk of loosening. This has implications for the implementation of any screening method (such as EMAT) that aims to stratify the population by loosening risk.

Base-case results from the full screening model

In women who receive a THR at the age of 69 and EMAT screening one year later, it emerges that the optimal (most cost-effective) threshold for the risk parameter is $\lambda' = 0.00366$. According to the Weibull model, a hip at this threshold will have a 91% probability of surviving five years before revision for loosening when under regular review. The high-risk group is comprised of those hips with a worse prognosis than this, and contains 7.7% of the population; in this group the more intensive follow-up strategy, ARR(78), is used. The results in Table 7 extend those in Table 6 to encompass implementation of the screening strategy using this threshold. In a sense, they represent the best that EMAT can do in the base case.
In obtaining these results, no cost was associated with the EMAT screening procedure itself. Thus, if EMAT screening were cost-free, the screening-based strategy would prove cost-effective compared to NFU at a cost of £14,483 per QALY. In practice, there will be costs associated with the screening procedure, estimated to be £451 by Borroff (17) who found (using a somewhat different approach) that screening was not cost-effective at this price. The results in Table 5 show that £84 is the highest price per screening event at which the EMAT strategy would be cost-effective at £30,000 per QALY – i.e. the incremental cost-effectiveness ratio (ICER) becomes 30,000 when £84 is added to the EMAT cost in Table 5. This is well below the realistic screening cost, and less even than Borroff's estimate of the marginal component of that cost.
Corresponding results for the male population aged 69 at the time of THR are presented in Table 6. Here the best (most effective) review strategy ceases at age 76 – a little earlier than in the female population because of higher male mortality rates. The most cost-effective threshold is $\lambda' = 0.00423$ – corresponding to 90% five-year hip survival when under regular review – at which level 6.8% are allocated to the more intensive follow-up programme, ARR(76).

Table 6. Costs and QALYs for the basic review strategies.

	After 10 years		Unbounded time horizon		
	Cost (£)	QALYs	Cost (£)	QALYs	ICER(£/QALY)
NFU	300.19	7.7237	536.34	10.7862	
ARR	1129.77	7.7216	1659.68	10.7869	1.6×106
ARR(78)	976.08	7.7237	1158.92	10.7967	59,293

Table 7. Costs, QALYs and revision rates for three strategies (women, aged 69 at THR).

	After 10 years			Unbounded time horizon			
	Cost (£)	QALYs	Revisions per 100 patients	Cost (£)	QALYs	ICER (£/Q) cf. NFU	Revisions per 100 patients
NFU	300.19	7.7237	5.74	536.34	10.7862		11.03
EMAT	405.44	7.7239	7.99	614.55	10.7916	14,483	11.61
ARR(78)	976.08	7.7237	6.89	1158.92	10.7967		11.71

Table 8. Costs, QALYs and revision rates for three strategies (men aged 69 at THR).

	After 10 years			Unbounded time horizon			
	Cost (£)	QALYs	Revisions per 100 patients	Cost (£)	QALYs	ICER (£/Q) cf. NFU	Revisions per 100 patients
NFU	271.45	7.1657	5.14	429.33	9.2424		8.56
EMAT	331.13	7.1671	5.67	485.63	9.2460	15,639	9.00
ARR(76)	759.77	7.1687	5.77	914.53	9.2498		9.11
(For men, the societal value of EMAT screening is calculated as £51.)							

Thus, for both male and female populations, the threshold screening level should be set at around 90% hip survival at 5 years. Any hip with a poorer prognosis than this should be assigned to the intensive review programme.

Sensitivity analyses

The base-case results are not particularly favourable to EMAT screening, the societal value of which is found to be the same as, or below, the estimated marginal cost of screening. Of course, these results are predicated on certain assumptions about a number of unknown parameters; in particular, the assumed value for φ of 1.5 is based on the flimsiest of evidence. Since this parameter governs the impact of the follow-up regime on revision rates, it may be expected to have a profound effect on the choice of a cost-effective strategy. For this reason, φ was made the subject of a detailed sensitivity analysis.

Sensitivity to φ

Here we focus exclusively on the female population who receive a primary THR aged 69. All aspects of the model's sensitivity to changes in φ are explored, including its impact on the maximum age at review and the optimal risk threshold for EMAT implementation. The results are displayed in the panel of four plots in Figure 4. It is to be noted that the points corresponding to $\varphi = 1$ are not physically feasible – this value implies the same revision rate under all follow-up strategies, although with better outcomes from revisions under annual review. This case is included to show the most favourable possible case for the value of EMAT screening (£670 in this instance).

Since φ measures the extent to which hip revisions are delayed when follow up is withdrawn, one might expect that the best age to discontinue follow up will decrease as φ increases, and this is indeed the case (Fig. 4a). Perhaps surprisingly, the optimal risk threshold for screening does not increase monotonically with φ. In fact, it appears to attain a maximum in the vicinity of the base-case value for φ (Fig. 4b) with the consequence that the base-case value actually corresponds to a minimum in the proportion screening positive. The most plausible explanation for this behaviour lies in the relationship between φ and X, the age at which review is terminated. As φ increases, X decreases and the intensive follow up option ARR(X) becomes less intensive and therefore cheaper. At this point it can become cost-effective to transfer some hips from the "low-risk" NFU group to the "high-risk" ARR(X) group by decreasing the screening threshold. The main point, put simply, is that the review strategies under consideration are themselves changing with φ, leading to unexpected results.

Figure 4d traces the impact of these changes on the societal value – or most cost-effective price – of EMAT screening. It appears that our base-case value is unfortunate in the sense that it falls at the point at which the EMAT value settles into a lower series of values. φ values closer to 1 correspond to much higher valuations for EMAT.

Sensitivity to other parameter values

More conventional sensitivity analyses were conducted around the values of the remaining parame-

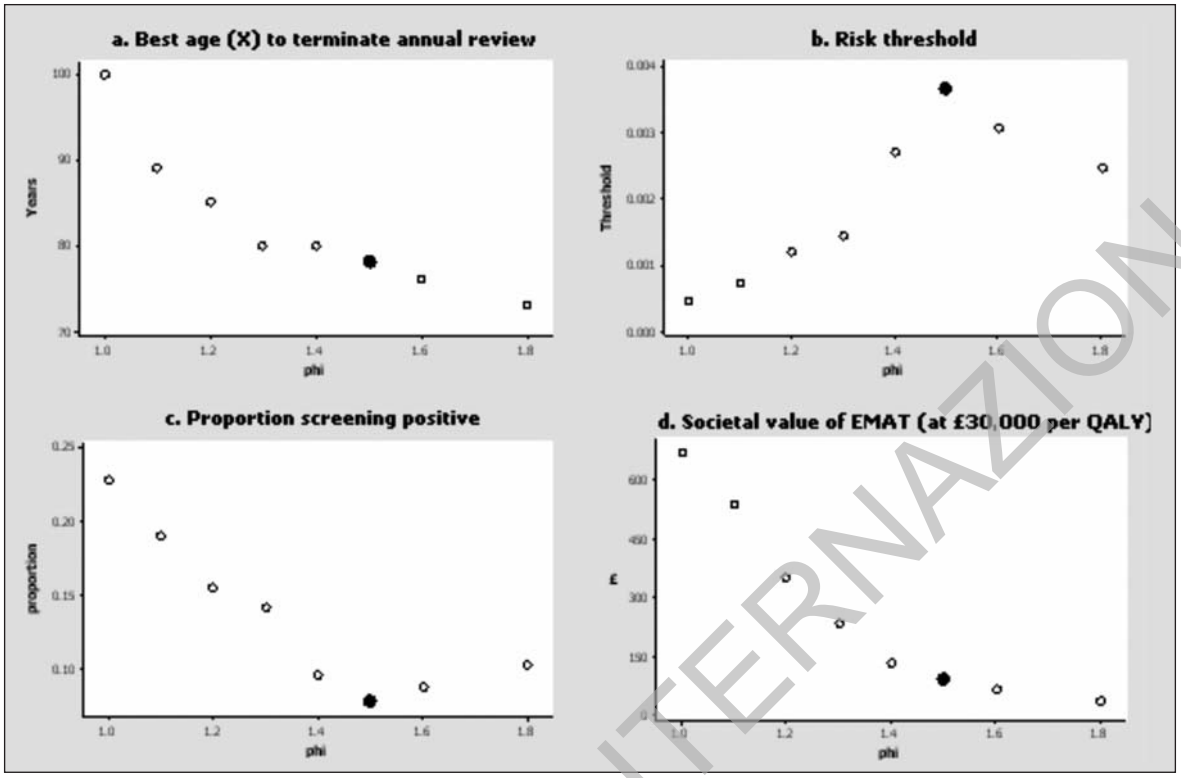

Figure 4. Model sensitivity to changes in φ. The base case ($\varphi = 1.5$) is shown as a solid circle. The open circles arise from complete revisions of the model using different values of φ.

ters, again for 69-year-old women and with φ taken as 1.5. The results are presented in Table 9.

Upper and lower bounds for utilities were set at ±0.01 from the base value. Sensitivity at other values can be deduced from these figures since the EMAT value is linear in cost and utility.

Broadly speaking, none of the parameters considered here appears to have a potential similar to that of φ for improving the value of EMAT screening.

Discussion

It is intrinsic to our approach that the "societal value" of EMAT will always be a positive number of pounds, if only because there will always be some net benefit to be gained by withholding follow up from patients at negligible risk of loosening. The base-case estimates of this value (£51 for 69-year-old men, £83 for 69-year-old women) are not high, and barely cover the estimated marginal cost of screening. Nevertheless, our attempts to quantify this value have shown that it is very sensitive to φ, the parameter about which we have the least reliable information. Values as high as £500 are conceivable (see Fig. 4d) if φ is as low as 1.1.

Furthermore, one might expect to gain more from the screening process were the intensive follow-up arm less expensive. In our model, very few revisions take place in the first couple of years after the screening event, so it might well make sense to reduce radiographic reviews in these years. This is exactly what is seen in the British Orthopaedic Association's recommended follow-up schedule (10), which makes provision for reviews in years 1, 5 and 10. It would be interesting to work through the consequences of applying this review strategy to the high-risk group in our model. Furthermore, it might even be possible to derive a "best" strategy – i.e. a review schedule tailored specifically to a particular patient group. This might be done through our modelling approach, supported by such data as can be obtained on the incidence of hip revisions under alternative follow-up regimes. While the no follow up (NFU) strategy might well be optimal for patients at very low risk of loosening, there is no particular rea-

Table 9. One-way sensitivity analyses for some important parameters.

Probabilities		Value of EMAT (base case £83)
Proportion of unreviewed aseptic loosening revisions of THR that are simple	srp – base value 0.75	
	0.7	147
	0.8	24
Peri-operative mortality rate for revisions	sd – base value 0.005	
	0.001	96
	0.01	71
Utilities		
THR	base value 0.964	
	0.954	107
	0.974	59
SR, success	base value 0.946	
	0.936	51.5
	0.956	114.5
CR, success	base value 0.7208	
	0.7108	92
	0.7308	74
Simple revision (unreviewed)	base value 0.639	
	0.629	89
	0.649	77
Simple revision (reviewed)	base value 0.7075	
	0.6975	74
	0.7175	92
Complex revision	base value 0.595	
	0.585	84.5
	0.605	81.5
Costs		
Radiographic review	base value £87	
	70	92
	102	77
Simple revision	base value £6118	
	5241	95
	6942	74
Complex revision	base value £7210	
	4159	67
	7976	88

son to suppose that ARR(78) – or any other version of the hybrid ARR(X) strategy – is best for any definable group of patients. If EMAT could be used to choose something closer to the optimal follow-up regime for the patient, one may anticipate an enhancement of its estimated societal value.

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