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ORIGINAL ARTICLE

A cemented cup with acetabular impaction bone grafting is more cost-effective than an uncemented cup in patients under 50 years

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ABSTRACT

Purpose: Acetabular deficiencies in young patients can be restored in several ways during total hip arthroplasty. Currently, cementless cups are most frequently used. Impaction bone grafting of acetabular defects is a more biological approach, but is it cost-effective in young patients on the long term?

Methods: We designed a decision model for a cost-utility analysis of a cemented cup with acetabular impaction bone grafting versus an uncemented cup, in terms of cost per quality-adjusted life year (QALY) for the young adult with acetabular bone deficiency, in need for a primary total hip arthroplasty. Outcome probabilities and effectiveness were derived from the Radboud University Nijmegen Medical Centre and the Norwegian Hip Register. Multiple sensitivity analyses were used to assess the contribution of the included variables in the model's outcome.

Results: Cemented cups with impaction bone grafting were more cost-effective compared to the uncemented option in terms of costs per QALY. A scenario suggesting equal primary survival rates of both cemented and uncemented cups still showed an effect gain of the cemented cup with impaction bone grafting, but at higher costs.

Conclusions: Based on this model, the first choice of treatment of the acetabular bone deficient osteoarthritic hip in a young patient is reconstruction with impaction bone grafting and a cemented cup.

Keywords: Acetabular defect, Cost-effectiveness, Impaction bone grafting, QALY, Total hip replacement, Young patients

Introduction

Cost-effectiveness of orthopaedic procedures is of growing importance. Total hip arthroplasty (THA) has proven to be a very cost-effective procedure (1, 2). However, young patients often outlive their implant. Particularly in these young patients, we need techniques and hip prostheses with a favourable long-term outcome (3) as they are at great risk for revision. The outcome of both primary and revision surgery plays an important role in the cost-effectiveness of treatment of these patients. Clearly, the cup is the weakest link of THA (4, 5). Young patients with hip osteoarthritis often have acetabular bone stock defects at their primary surgery due to underlying diseases, which may hamper the longevity of the cup even more. Uncemented hip designs have gained worldwide popularity and are the first choice of treatment in young patients at the moment, also in cases with acetabular defects. Impaction bone grafting in combination with a cemented cup is another treatment option for these young patients (6) in which the deficient acetabular bone stock is restored. Excellent long-term survival data of this technique are reported (7-10) including long-term data of revision cases (11-13).

We hypothesise that for young patients with acetabular bone stock defects, the efforts of acetabular impaction bone grafting and a cemented cup in primary THA are beneficial and justified on the longer term compared to the use of uncemented cup designs without grafting.

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Methods

Economic modelling

We designed a decision model (Fig. 1) to determine the cost-effectiveness of acetabular impaction bone grafting. The model has 2 modalities for the young patient with an

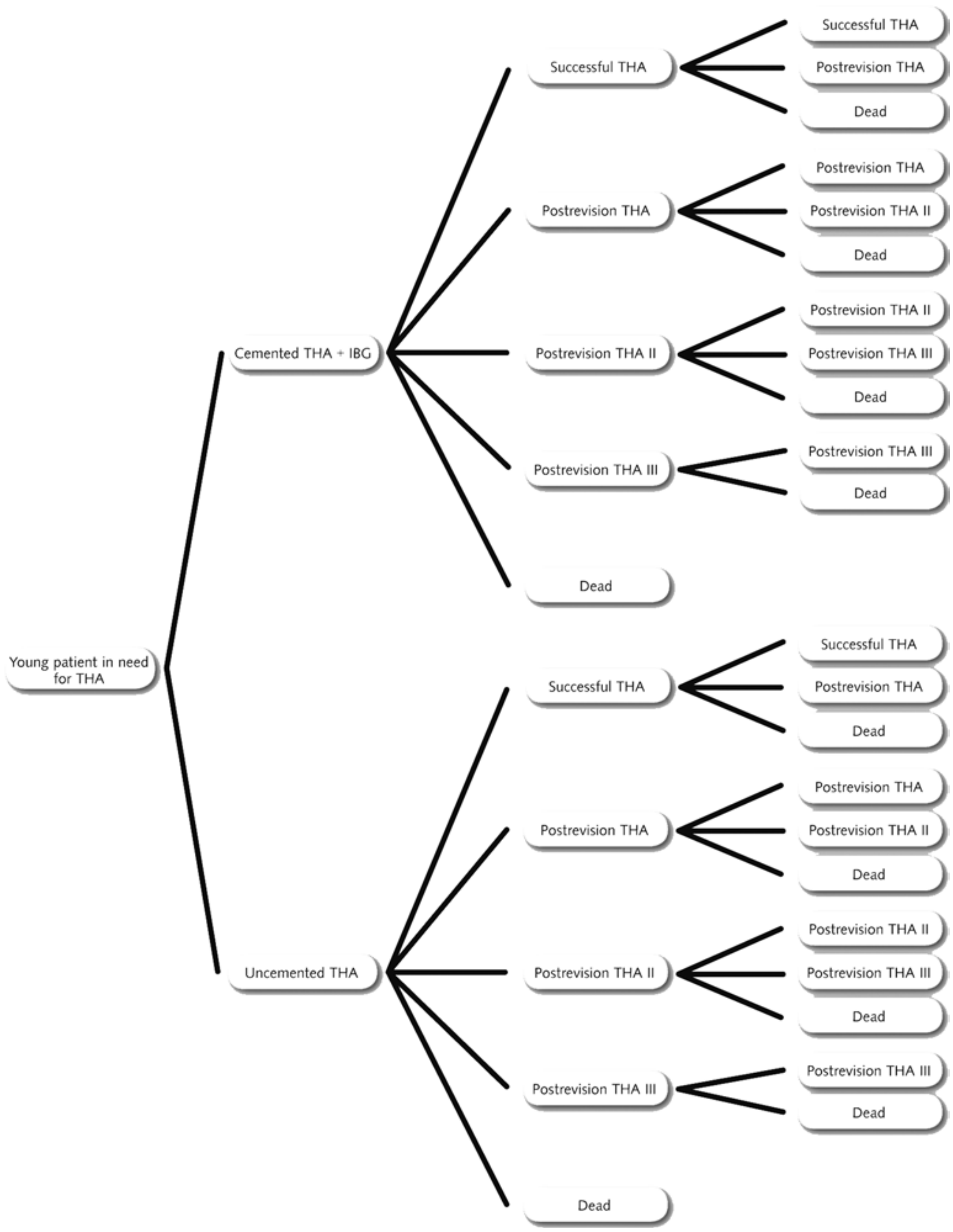

Fig. 1 - Decision model for the young patient with hip osteoarthritis. Markov model with cycles of one year to estimate QALYs and costs accumulating over a time period of 15 years.

acetabular defect and hip osteoarthritis: a cemented cup with acetabular impaction bone grafting versus an uncemented cup. We have expressed our findings in terms of costs, quality-adjusted life years (QALYs) and incremental costs per QALY gained. In the Netherlands, an incremental cost-effectiveness ratio (ICER) of less than €80.000 is generally thought to be cost effective by policy makers, depending on the burden of the underlying illness (14).

We have constructed a discrete-state Markov model and modified the model to approach the actual situation of a young adult in need for a THA. The model has cycles of 1 year to estimate QALYs and costs accumulating over a time period of fifteen years from a hospital perspective, discounted at a standard annual rate of 3% for both QALYs and costs. The first 2 treatment branches consist of a cemented cup with impaction bone grafting and an uncemented cup. The branching points thereafter represent transition to a different health state (prosthesis survival, post revision THA, post revision THA II, post revision THA III and death).

Overall, through our model we considered a hypothetical population aged 37 years or older in need for a hip replacement. We have constructed our model in TreeAge pro Suite 2009 (Williamstown, USA) and assessed it by 2-D Monte Carlo simulation. We ran our model for 16 cycles. We calculated the time spent in each health state and by attributing costs and quality of life weights to each health state. Total costs and QALYs were established for each of the treatment options.

TABLE I - Input parameters

Input parameter	Value	Source (ref)
Survival		
Survival rates primary cemented cups with impaction bone grafting	See Table IIA	Busch et al (7)
Survival first cemented cup revision with impaction bone grafting	See Table IIB	Schreurs et al (13)
Survival primary uncemented cups	See Table IIA	Norwegian Arthroplasty Register
Survival first uncemented cup revision	See Table IIB	Norwegian Arthroplasty Register
Survival 2nd revision/year (cemented and uncemented THA)	0.035	Lie et al (15)
Costs (€)		
Material costs cemented treatment	See Table III	Cost prices at our hospital
Material costs uncemented treatment	See Table III	Obtained from manufacturers of 3 common uncemented THAs
Hospital admission costs/day	575	Dutch Guidelines to Costs in Medical Care (17)
Miscellaneous		
Probability of perioperative death (primary operation)	0.0034	Chang et al (19)
Probability of perioperative death (revision operation)	0.012	Chang et al (19)

Input parameters for the decision model mentioning value and source.

As we were interested in long-term results of both techniques, we have incorporated survival of revision surgeries with accompanying costs.

Uncertainty

Our model took into account the uncertainty around several input parameter point estimates, which are listed in Table I. We ran our model a 1000 times, established through estimation of 2-D Monte Carlo simulation, running random trials and each time randomly selecting simultaneously a value for all the stochastic parameters. We calculated mean costs and mean QALYs by averaging across all 1000 simulations. We did a sensitivity analysis to test the impact of the discount rate on the ICER. We also explored a scenario where primary survival of uncemented cups is made equal to cemented cups with impaction bone grafting.

Survival data

Survival data were gathered of acetabular components in patients younger than 50 years at the time of primary surgery (Tab. IIA). For the cemented option with impaction bone grafting we used data of a previously reported series of 42 acetabular reconstructions with a mean age of 37 years at the time of operation (7). Survival at 15 years was 84% (95% CI, 72%-96%) with failure for all reasons as the endpoint. For the first revision in our model, we have used survival data of 62 acetabular revisions in 58 patients with a mean age of 59 years (13). Survival at 15 years was 84% (95% CI, 70%-92%) (revision for any reason). For the uncemented option in the model, data were obtained from the Norwegian Arthroplasty Register (Tab. IIB). Unpublished data of 1,289 patients younger than 50 years with primary hip osteoarthritis, who had received an uncemented cup, were analysed and survival rates were determined (Tab. IIA). The most commonly used cups were Trilogy (Zimmer), Tropic (Landos), Duraloc (DePuy) and Reflection uncemented (Smith & Nephew). The probability of survival of primary uncemented cups was 61% (95% CI, 57%-65%) at 15 years. Survival of the first uncemented cup revision was based on 76 patients and was 52% (95% CI, 35%-67%) at 15 years (Tab. IIB). As survival rates of the cup solely were not available for the second revision, we used the same data for both cemented and uncemented revisions as presented by Lie et al in 2004 (15), with a survival rate of 59.5% (95% CI, 54%-65%) at 10 years. Using power root transformation the yearly survival was calculated at 0.035. This was extrapolated to obtain a 15-year survival rate for the second revision.

Costs

The costs of an intervention consisted of material costs, costs of operation theatre and costs of hospital admission. The material costs are based on a total cemented or total uncemented hip arthroplasty. For calculation of the costs of the cemented option with acetabular impaction bone grafting, we used data of 79 most recently operated patients younger than 50 years in the period 2007-2010 at the Radboud University Nijmegen Medical Centre (Tab. III). A specification of costs is given in the legends of Table III.

Costs of the uncemented option were calculated as if they were performed at the Radboud University Nijmegen Medical Centre. To minimise the possibility of selection bias regarding costs of uncemented hip arthroplasty, we have averaged the registered prices of 3 very commonly used uncemented total hip designs in the Netherlands (Tab. III). The mean operation time of cemented hip arthroplasty using impaction bone grafting was 123 minutes and we assumed that an uncemented hip arthroplasty at our hospital would take 40 minutes less (20 minutes for the impaction bone grafting

TABLE IIA - Transition rates primary cups

Cemented cup with acetabular impaction bone grafting		Uncemented cup	
Follow up (years)	**Probability of survival**	**Follow up (years)**	**Probability of survival**
1	0.999250562	1	0.992262513
2	0.973678425	2	0.992670263
3	0.999150722	3	0.984153261
4	0.998951101	4	0.984019486
5	0.999000999	5	0.977123523
6	0.971897783	6	0.965153817
7	0.998552099	7	0.972251185
8	0.969980231	8	0.948415917
9	0.998452399	9	0.967455365
10	0.998153416	10	0.946107059
11	0.96874379	11	0.957199658
12	0.967623698	12	0.944124718
13	0.997406742	13	0.936720462
14	0.96499208	14	0.943993804
15	0.963727695	15	0.932704963

Transition rates for 15 years of primary cups calculated from survival data of both cemented and uncemented cups.

TABLE IIB - Transition rates revision cups

Cemented cup with acetabular impaction bone grafting		Uncemented cup	
Follow up (years)	**Probability of survival**	**Follow up (years)**	**Probability of survival**
1	0.993739442	1	0.949016676
2	0.99290076	2	0.942351298
3	0.992161921	3	0.932667282
4	0.991620804	4	0.966830284
5	0.97311066	5	0.866132348
6	0.99000099	6	0.951919181
7	0.989707047	7	0.907243594
8	0.968902401	8	0.939232149
9	0.987703096	9	0.929612731
10	0.963835319	10	0.920987316
11	0.936607051	11	0.985901607
12	0.956665824	12	0.98400984
13	0.954551432	13	0.983477577
14	0.980969198	14	0.980969198
15	0.979527868	15	0.979527868

Transition rates for 15 years of revision cups calculated from survival data of both cemented and uncemented cups.

TABLE III - Costs (€)

	Cemented	**Uncemented**
Material costs primary THA (range)	2,086 (1,633-2,784)*	2,675 (2,112-3,355)
Material costs revision THA (range)	3,086	4,382 (3,816-4,703)
Theatre costs primary THA	1,623	1,096
Theatre costs revision THA	1,980	1,452

Calculated costs of both the cemented and uncemented option to treat a young patient with hip osteoarthritis.
*The mean material costs calculated from a series of 79 young patients treated with a cemented THA and acetabular impaction bone grafting. Mean costs of the cemented prosthesis including disposables were €1,633; costs of a rim mesh €410; costs of a kreuzschale (cross shell) with 4 screws €252; mean costs of a femoral head €488.

procedure, 2 × 10 minutes for cementation). This assumption was made for both primary and revision operations. The costs of all revisions were assumed to be equal.

Mean duration of hospital admission for a cemented hip arthroplasty using impaction bone grafting at our institute was 7.2 days as we have calculated from the group of 79 patients. We assumed that the length of stay in hospital of patients with an uncemented hip arthroplasty was 5 days, which is in concordance with previous data (16). Hospital admission time was set at 10 days for all revision cases. Hospital costs were adapted from the Dutch Guidelines to Costs in Medical Care (17). We assumed that other costs (indirect costs) like visits to outpatients' clinic, radiological review, laboratory testing and physiotherapy were equal for both cemented and uncemented treatments and we have decided not to include these in our model.

Utilities

Effectiveness is expressed in QALYs gained. Health-related quality of life was determined by a functional class as being used by the American College of Rheumatology (18). Harris Hip Scores were converted to the functional classes by the system described by Chang et al (19). The following assumptions were made: patients with successful cemented or uncemented implants have the same utility or QALY value after the initial postoperative period. The mortality rates of patients who survived their hip surgery do not differ from the age-adjusted mortality rates of patients without a hip prosthesis implanted, as calculated by Statistics Netherlands (CBS) life-tables (20). Mortality rates of the life-tables were used starting at the age of 37.5 and 59.5 for the primary surgery and the first revision, respectively. These numbers are based on mean ages at surgery of the patients in our cemented series as described above. For the second revision, data starting at the age of 74.5 was used. Probability of death was assumed equal for both the cemented and the uncemented branch. Regarding determining infection rate (21) after primary and revision arthroplasty, we assumed there was no difference

TABLE IV - Incremental cost-effectiveness ratio

Scenario	Strategy	Costs (€)	Incremental cost (€)	Effectiveness (QALYs)	Incremental effectiveness (QALYs)	ICER (€/QALY)
Basecase	Cemented cup	9,500		11.491	0.451	dominates
	Uncemented cup	10,900	1400	11.040		dominated
Equal survival	Cemented cup	9,526	986	11.4906	0.0236	41765
	Uncemented cup	8,540		11.4670		

Table IV shows the details of determining the incremental cost-effectiveness ratio for both scenarios.

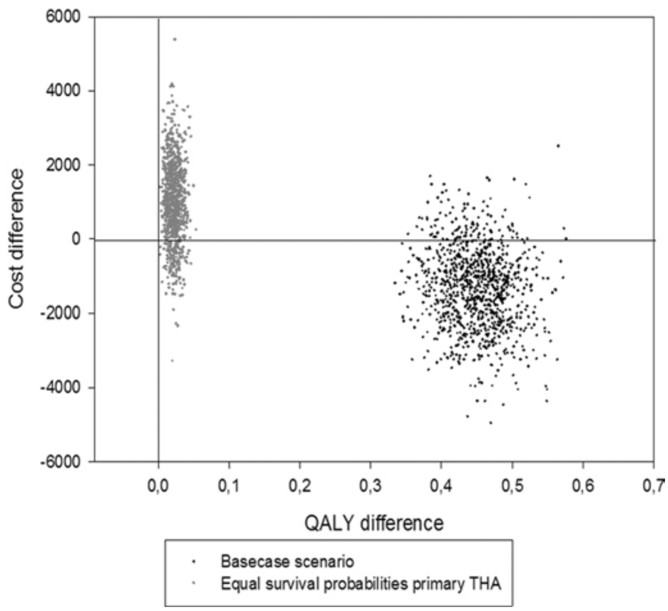

Fig. 2 - Incremental cost-effectiveness plane. Incremental cost-effectiveness plane showing 2 scenarios. In the baseline scenario (black dots), almost 90% of the simulated ICERs lay in the southeast quadrant meaning that cemented plus impaction bone grafting is more cost-effective than the uncemented option. The second scenario with equal survival rates for both options (red dots) still shows an effect gain (higher QALY) for cemented plus impaction bone grafting but at higher costs.

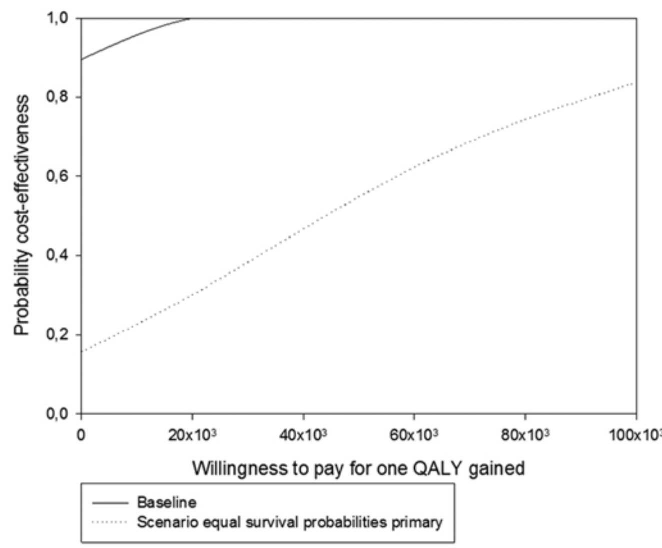

Fig. 3 - Cost-effectiveness acceptability curves. Cost-effectiveness acceptability curves showing that in the baseline scenario, if 'policymakers' are willing to pay a small amount of money for a QALY gained (>€0) they can be 90% confident that cemented plus impaction bone grafting is the most cost-effective option. The second scenario shows that the willingness to pay has to be in excess of €80.000 for policymakers to be about 80% confident that cemented THA with impaction bone grafting is the most cost-effective option.

between older and younger patients and no difference between cemented and uncemented prostheses.

Results

The point estimate of the incremental cost-effectiveness ratio (ICER) in the baseline scenario showed that a cemented cup with impaction bone grafting was more cost-effective compared to the uncemented option, in terms of costs per QALY. When exploring the scenario in which survival rates of primary uncemented cups were made equal to primary cemented cups with impaction bone grafting, the point estimate of the ICER became €43.500 per QALY gained (Tab. IV). Through incorporating uncertainty in the analyses, the results of both scenarios are presented as an incremental cost-effectiveness plane (Fig. 2) and as a cost-effectiveness acceptability curve (CEAC) (Fig. 3). In the baseline scenario, almost 90% of the simulated ICERs lay in the southeast quadrant meaning that a cemented cup plus impaction bone grafting is the most cost-effective option (Fig. 2).

The second scenario suggesting an equal survival of cemented and uncemented cups still showed an effect gain for cemented cups plus impaction bone grafting, however at an extra cost. So, patients still had a rise in QALYs on the longer term but at higher costs compared to an uncemented cup.

Figure 3 shows in the baseline scenario that if 'policymakers' are willing to pay a small amount of money for a QALY gained (more than €0) policymakers can be 90% confident that a cemented cup plus impaction bone grafting is the most cost-effective option. The other scenario shows that the willingness to pay has to be more than €80.000 for policymakers to be about 80% confident that a cemented cup plus impaction bone grafting is the most cost-effective option. Varying the discount rate in the baseline scenario over the range (0.5%) showed that cemented plus impaction bone grafting option kept dominating the uncemented option and was still the most cost-effective option. In the alternative scenario, the

ICER was sensitive to alterations in the discount rate. A higher discount rate resulted in a worse outcome (higher ICER).

Discussion

By designing a model with 2 treatment modalities for the bone deficient osteoarthritic hip in a young patient, we were able to compare a cemented cup with impaction bone grafting versus the use of an uncemented cup. We found that on the longer term, a cemented cup with grafting was the most cost-effective option.

The current trend to use uncemented cups in young patients seems not to be supported in literature (4). We have studied all relevant literature on outcome of cemented or uncemented total hip arthroplasty in patients younger than 50 years at the time of operation and searched for reports with a survival rate of 90% or more at 10 years of follow-up. Although uncemented hip implants are widely used in young patients, at the time of this study we found only 2 reports that fulfil the criteria. Cemented implants have been in use for a longer period with many studies meeting the survival criteria. We had to conclude that at the time of this study, the highest survival rates were related to cemented implants.

Regarding costs, a recent study on data of the National Joint Registry shows that a possible cost saving to the NHS of more than £18 million per year can be made if cemented instead of uncemented hip designs were used in England and Wales (22). Another recent study on cost-effectiveness of different types of total hip replacements in older patients concludes that uncemented prostheses do not improve health outcomes sufficiently to justify their higher costs (23). These studies confirm our findings in the way that uncemented hip designs are less cost-effective compared to cemented total hip prostheses.

A strength of our study is that in our model we acknowledge the fact that the technique of impaction bone grafting takes additional time and materials and we have included these costs in our model. We also have incorporated 3 revisions with accompanying costs in our model and we have used advanced statistical software (TreeAge pro Suite 2009) to construct our model. A point of criticism on our study could be that the survival rates of primary uncemented cups were worse than the rates of cemented cups. However, these numbers were derived from the reliable Norwegian Arthroplasty Register and constitute a consecutive series of young patients treated with uncemented cups. We are aware of the fact that our study is based on hip designs used several years ago and that nowadays articulations with highly cross-linked polyethylene are more commonly used than conventional polyethylene. However, long-term results of uncemented cups with highly cross-linked polyethylene are not available but this limitation of old types of polyethylene also is a disadvantage for the cemented cups. To overcome criticism on these limitations in our model, we have explored a scenario in which the survival rates of primary uncemented cups were made equal to primary cemented cups with impaction bone grafting. In this scenario, an effect gain for a cemented cup with impaction bone grafting was still seen, but at higher costs. So, even with equal survival rates for both acetabular options, reconstruction of an acetabular defect with impaction bone grafting and a cemented cup seems to be beneficial on the long term. Another limitation of our study might be that costs of treatments and materials may differ between hospitals and that some hospitals may have arranged lower prices. We realise this could be a limitation in applying the conclusions of this study to other hospitals. Nevertheless, costs were calculated as if all prostheses were placed in our hospital without any discounts, to have a baseline comparator of the 2 techniques. Another assumption that can be questioned is that costs of all revisions are made equal. Of course this is not the case but the fact that we don't have exact data on these costs is forcing us not to assume any differences between the 2 options to limit confounders in our model. Many assumptions in this model can be questioned and we think that is necessary to improve our model and our understanding and knowledge on this subject. The advantage of this model is that the input can be updated with new information in the future.

We have optimised the parameters of the uncemented option by not taking into account any additional material costs for dealing with bone defects or periprosthetic fractures, which are more common using uncemented designs or at uncemented revision operations. Also the estimation of length of stay is in favour of uncemented hip arthroplasty. We think the assumption that patients stay longer after impaction bone grafting is valid because rehabilitation may take longer than after primary uncemented THA, mainly because of the partial weight-bearing. Besides this, we have compared survival data of cemented cups in difficult cases with acetabular defects to data of uncemented cups without the need for acetabular reconstruction, which might be of positive influence on the outcome of the uncemented treatment. Even using these data, cemented THA with impaction bone grafting was still more cost-effective than the uncemented option in young patients.

We realise that the first step in our model is based on a small group of 42 cemented cases with acetabular impaction bone grafting and that results of 2 single series of patients are compared with data of a national arthroplasty register. We also are aware of studies that show less favourable results of acetabular impaction bone grafting, especially those evaluating reconstruction of larger acetabular defects (24). This means that the outcome of this model might not be translated to other institutions where the technique and circumstances are different. On the other hand, other reports show high success of the same technique (11, 12). Reported survival rates vary, as survival rates of other techniques like uncemented series do.

Cost effectiveness analysis of orthopaedic treatments may be a helpful tool in clinical decision-making for hospitals and health policy makers. In the present study, cemented cups with acetabular impaction bone grafting were more cost-effective than uncemented cups in terms of costs per QALY for the young patient in need for a hip replacement with an acetabular defect.

Disclosures

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Conflict of interest: None.

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