Clin Orthop Relat Res (2026) 00:1-9
DOI 10.1097/CORR.0000000000004038

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

Clinical Research

Are Age-based Cutoffs for THA Logically Consistent?

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Received: 12 February 2026 / Accepted: 3 June 2026 / Published online: 23 June 2026

Abstract

Background Although THA is routinely offered to patients age 85 years and older, surgeons might hesitate to operate on patients deemed "too young." This study tests whether such hesitancy reflects a consistent standard.

Questions/purposes (1) How much utility (net benefit) can be expected from THA, as a function of patient age and operation-related clinical variables? (2) What relative cost must be attributed to revision of a THA such that the imposition of this penalty renders the expected utility of the operation too low to justify it in younger people?

Methods A calculator was programmed using a state-transition Markov model to estimate the expected lifetime benefit of THA as a function of patient age and other user-specified parameters. A novel unit of benefit, the joint-adequate life year (JALY), was defined. One JALY is earned in each postoperative year that the patient has an intact prosthesis and adequate clinical outcome. JALYs can also be forfeited when a patient enters a revision state. Thus, previously accumulated JALYs may be partially or completely offset, resulting in a net lifetime total that is lower than the total years of an adequate outcome. Users of the calculator specify patient sex and age at the time of THA (we modeled sex rather than gender in order to be able to derive life expectancy from sex-specific life tables published by the Social Security Administration), the anticipated fraction of patients expected to have a clinically adequate outcome (termed here the "satisfaction fraction"), prosthetic life expectancy, the expected annual risk of revision attributed to catastrophic events such as fracture or infection, and a discount rate, which is used to convert future gains and losses to their net present value. The prosthetic life expectancy parameter was used to calculate an annual risk of needing revision for wear. Users also assign a negative value to the revision state, representing the number of JALYs that a patient would be willing to forgo to avoid that state. This penalty was applied in the first instance the failure state was encountered, and a value 1.5 times this penalty was applied for any subsequent encounter. The model was then interrogated to provide the expected JALYs earned as a function of failure-state penalties ranging from 0 to 40 JALYs. For this calculation, prosthetic life expectancy was set to 15 years, the anticipated satisfaction fraction was set to 90%, the annual rate of catastrophic failure was set to 0.5%, and no temporal discounting was applied. Sensitivity analyses were then performed for different values of prosthetic life expectancy,

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Ethical approval was not sought for the present study.
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satisfaction fraction, catastrophic failure rate, second-revision penalty ratio, and with 2% and 10% temporal discounting applied. Based on the common use of THA in 85-year-old patients (a group with a life expectancy of about 6 years after THA), a benchmark of six JALYs was established, as logically no patient can have more "adequate joint years" than total years of life. We then determined the penalty that must be assigned to the revision state, such that a 45-year-old male's expected benefit would fall below this six-JALY benchmark.

Results A cohort of 45-year-old males can be expected to earn 25 lifetime JALYs under the base case assumptions and a revision penalty of five JALYs. Lifetime JALYs for this cohort do not drop below the threshold of six until the revision penalty reaches 25 JALYs. Sensitivity analysis demonstrated that this finding was robust across wide variation in clinically plausible values for prosthetic life expectancy, satisfaction, failure rates, and discounting.

Conclusion Hesitation to offer THA to 45-year-old patients with impairing hip disease is logically inconsistent with the procedure's broad acceptance in 85-year-old patients. This is because under plausible assumptions of the clinical parameters, 45-year-old patients stand to accrue considerably more lifetime benefit. Indeed, even accounting for the inevitable failures younger patients may encounter (and the penalties these failures impose), such patients can expect to accrue more than six JALYs across their lifetimes unless implausibly large failure penalties are assumed.

Level of Evidence Level II, Economic and Decision Analyses

Introduction

The appropriate lower age limit for THA remains a contentious issue in orthopaedic practice. Surgeons routinely offer THA to octogenarians—and a recent report concluded that "elective THA can be appropriately considered in nonagenarians" [12]—yet many hesitate to operate on patients in their 40s [6]. This discrepancy invites examination of whether current practice reflects evidence, intuition, or inconsistency.

The minimum age for THA depends not only on measured outcomes but also on implicit judgments about how much benefit justifies the surgical risk and other costs [3]. Nonetheless, a principle of logical consistency can clarify that judgment. If surgeons accept a given magnitude of benefit as sufficient justification for THA in older patients, that same magnitude should, in principle, suffice for younger ones. The routine practice of operating on 85-year-old patients accordingly provides a revealed-preference standard for what is already deemed acceptable: By offering THA to patients with approximately 6 years of remaining life expectancy, surgeons demonstrate that this duration of benefit can justify surgery, as death precludes further gain. We used this threshold as a benchmark for evaluating consistency in age-based surgical decision-making. This benchmark should not be interpreted as a cutoff for making decisions about individual patients; rather, it represents a reference point for comparison about choices made for groups.

We theorized that clinical intuition systematically misjudges lifetime benefit for patients of different ages. Some surgeons accept operating on 85-year-old patients, even though death leaves much potential benefit unrealized. By contrast, some surgeons hesitate to operate on 45-year-old patients despite their far greater capacity to accrue benefit, owing to their greater life expectancy, before any revision becomes necessary. To be sure, greater life expectancy also gives 45-year-old patients far greater exposure to prosthetic failure and more years living with its consequences. Thus, the balance is determined by the relative costs and benefits assigned to successful and unsuccessful outcomes considered in the context of both human and prosthetic life expectancy.

To test our proposition, we developed a Markov model based on users' own estimation of clinical parameters to calculate the expected lifetime benefit of THA. This calculation yields the expected benefit as a function of age at surgery, integrating life expectancy, revision probability, and time discounting. The model was then used to address two related questions: (1) How much utility (net benefit) can be expected from THA as a function of patient age and selected operation-related clinical variables? (2) What relative cost must be attributed to revision of a THA such that the imposition of this penalty renders the expected utility of the operation too low to justify it in younger people? If that cost must be implausibly high, current age-based restrictions on THA can be deemed to reflect not evidence-based caution but an inconsistency within prevailing practice patterns.

Materials and Methods

Study Design

This experiment was based on a decision analysis using a Markov model. Decision analysis is a framework that combines the probabilities of clinical events with the value assigned to their outcomes to estimate overall benefit. A Markov model extends this approach by representing patients as transitioning among discrete health states over time, allowing clinical events occurring over successive time cycles to exert their effects at the time of occurrence and to accumulate over the entire time horizon. Model inputs were derived from a combination of external data (such as mortality tables) and user-specified parameters. Sensitivity analyses were performed to assess the robustness of the results across a range of these parameters.

Unit of Benefit

We propose a novel unit of benefit that considers the temporal dimension of clinical effect: the joint-adequate life year (JALY), a joint-specific analog to the quality-adjusted life year (QALY) [11]. A JALY represents 1 year in which the prosthesis remains intact and patient outcome meets a user-defined standard of adequacy. Each year in which this criterion is met contributes one JALY. A consistent threshold of adequacy is specified by the user and applied within the model. Adequacy may be operationalized formally, for example, as achieving a minimum clinically important difference on a hip-specific score [9], or informally as a clinician's subjective determination of success. By aggregating JALYs over the patient's remaining lifetime, the model treats benefit as a time-integrated measure rather than a snapshot of success at a single postoperative interval, such as hip score at year 2 or prosthesis survival at year 10. Notably, the JALY is a unit of currency describing net benefit and can also be forfeited. That is, previously accumulated JALYs may be partially or completely offset when a major complication requiring revision is encountered. This can result in a net lifetime JALY total that is lower than the number of years in which an adequate outcome was experienced. Also, two patients who experience similar early success may yield substantially different numbers of JALYs if the duration of benefit differs. By the same token, two patients may earn the same number of JALYs if they experience the same number of years with an adequate outcome, even if one has a stellar result and the other merely meets the threshold for adequacy. The JALY therefore emphasizes the persistence of adequate benefit rather than distinctions among outcomes that all exceed the threshold.

Model Logic

We developed a cohort-based Markov model to estimate the lifetime expected benefit of THA, expressed in JALYs [5]. The model was built using an AI programming agent (Replit) and implemented in Python. To ensure transparency and reproducibility, both the natural-language instructions used for model construction and the executable Python code are publicly available at https://jalycalculator.com/.

The model functions as a utility-summation calculator using annual time cycles based on user-specified parameters: patient age at time of THA, patient sex, anticipated satisfaction fraction, prosthetic life expectancy, catastrophic failure rate, prosthetic failure cost (PFC; given in JALYs), and discount rate. In this model, "failure" is defined as the state leading to revision or reoperation, irrespective of cause, and is not limited to mechanical implant failure. For example, a prosthesis requiring revision for infection is considered to have failed.

Age and patient sex were used to determine the annual mortality risk for each postoperative year. Sex rather than gender was incorporated into the model because remaining life expectancy was derived from the sex-specific life tables published by the Social Security Administration. Gender-related factors, such as treatment preferences and perceptions of outcome, were not explicitly modeled. The catastrophic failure rate is the annual risk of needing a revision for causes beyond wear—for example, fracture or infection.

Prosthetic life expectancy is specified by the user. In the model, prosthetic life expectancy is taken to represent the time point by which 10% of prostheses have failed. The prosthetic life expectancy also anchors a time-dependent "senescent failure function" representing the annual risk of needing revision because of wear, with early failures being uncommon and the risk of failure increasing with time. The specific derivation of annual failure risk from prosthetic life expectancy is described below.

The PFC is the utility penalty assigned to reaching the state of failure. In clinical terms, it represents the trade-off between obtaining benefit now and avoiding that outcome, expressed as the number of "good years" a patient would be willing to forgo to avoid failure. This trade-off can be made more tangible by asking how long a patient would be willing to delay surgery to avoid failure. Interpreting PFC as the amount of acceptable delay is in fact conservative because each year of delay typically yields less than one JALY sacrificed owing to imperfect satisfaction, competing mortality, and discounting.

The model then progresses through annual state transitions (Fig. 1). Each cycle represents a postoperative year in which JALYs may be earned through an adequate clinical outcome or forfeited through prosthesis failure and revision. Death terminates further accrual and proportionally reduces the surviving cohort for subsequent cycles. Each cycle begins by determining whether the prosthesis remains intact or has failed. The total probability of failure equals the sum of senescent failure risk (that is, attributed to wear) and catastrophic failure risk (from external events such as fracture or infection). The complement of the total failure risk represents the probability of remaining intact.

Senescent failure is modeled using a Weibull distribution [13] anchored to the user-specified prosthetic life expectancy. The distribution is parameterized with shape $k = 3.25$ and scale $\eta = 2 \times$ prosthetic life expectancy, such that the cumulative probability of failure is set at 10% by

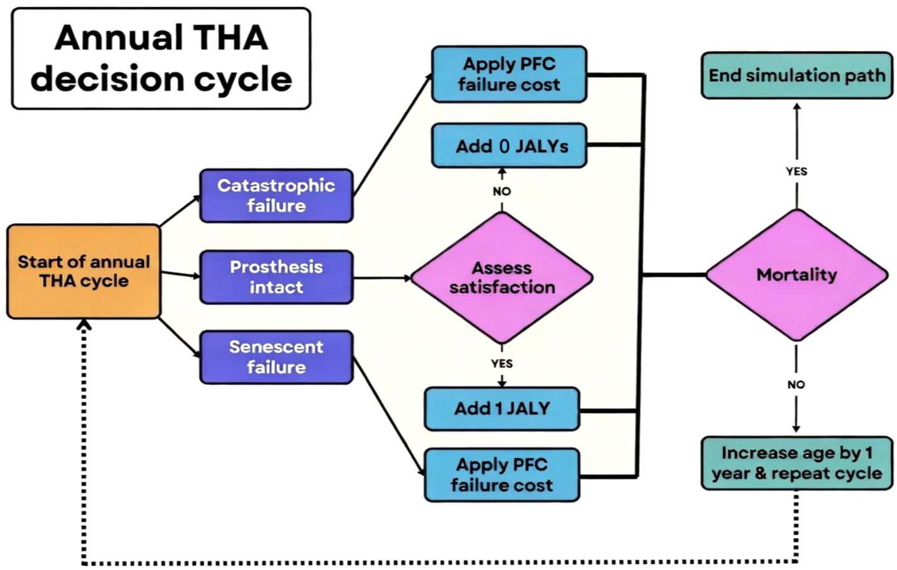

Fig. 1 Markov states and transitions. The process begins with the cohort at the user-specified starting age and the prosthesis age set to 0. In each cycle, the status of the prosthesis is determined: either remaining intact or failing from catastrophic or senescent causes (the complement of these two failure rates gives the probability that the prosthesis remains intact). Each outcome state is assigned the appropriate utility, adjusted for time-preference discounting and cohort size. The cohort size is then reduced according to the age-specific mortality risk, and the cycle repeats with both patient age and prosthesis age incremented by 1 year.

prosthetic life expectancy years and 63% by twice that duration. In a Weibull distribution, a shape parameter > 1 implies an increasing hazard over time; with k = 3.25, failures are uncommon early and become progressively more likely with longer follow-up. This parameterization is a modeling assumption rather than an empirically derived estimate. Catastrophic failure represents an independent, constant annual hazard, as defined by the user.

Upon prosthesis failure, the prosthesis failure cost penalty is applied. If a revised prosthesis were to fail, a second—and presumably higher—user-supplied revision prosthesis failure cost is applied. If the prosthesis remains intact, adequacy is assessed according to the user-specified satisfaction fraction, capturing the probability that a patient with a structurally intact prosthesis experiences an adequate outcome (as some patients with ostensibly normal exam results and radiographs can still be dissatisfied [2]). Next, benefits and penalties are applied. Each patient with an intact prosthesis and an adequate outcome accrues one JALY.

All future JALYs and penalties in the model are discounted to net present value using the user-specified time preference discount rate [14]. For each year, the discounted value equals the nominal value divided by one plus the temporal discount rate raised to the power corresponding to the number of years in the future.

At the end of each cycle, the cohort is reduced by the applicable age-specific mortality rate derived from the US Social Security Administration life tables [15]. If at least 0.1% of the initial cohort remains, the process repeats with both patient age and prosthesis age incremented by 1 year. The simulation continues until 99.9% of the cohort has died.

Unlike conventional decision-analytic studies intended to estimate real-world outcomes, the present model was designed to examine the logical implications of user-specified assumptions. Event probabilities, satisfaction fractions, failure penalties, and discount rates therefore are treated as input parameters rather than quantities derived within the study. The purpose of the model is not to determine the correct values of these inputs, but rather to determine the implications of a given set of assumptions when applied consistently across the age spectrum. In this respect, the validity of the model is similar to that of a retirement calculator. In both instances, users specify the assumptions and the tool produces a result. The validity of both tools depends only on whether they correctly translate those assumptions into their implications; the accuracy of any particular output necessarily depends on the accuracy of the inputs provided. The present study neither determined nor independently validated those inputs, which are specified by the user.

Establishing the Acceptable Minimum Anticipated Benefit

According to the American Joint Replacement Registry graphic [1], approximately 3% of patients undergoing THA are 85 years of age or older. We therefore selected 85 years as an older age consistent with prevailing practice patterns. Based on US Social Security life-table data, male members of an 85-year-old cohort have a remaining life expectancy of 5.75 years, rounded up to 6. To ensure that our threshold was not underestimated, we assumed a satisfaction fraction of 100% and a failure rate of 0 in 85-year-old patients, awarding one JALY for every year of survival, without discounting for satisfaction or failure. (This yields an upper bound on expected benefit, as real-world satisfaction rates are lower than 100% and real-world failure rates are greater than 0, which would yield fewer JALYs.) A willingness to operate on patients of this age thus implies that an anticipated lifetime benefit of approximately six JALYs is considered sufficient to justify surgery.

Determining the Threshold Prosthesis Failure Cost for 45-year-old Patients

The model was interrogated to provide the expected JALYs earned, assuming prosthetic life expectancy of 15 years, as a function of failure-state penalties ranging from 0 to 40 JALYs. For this base-case calculation, the anticipated satisfaction fraction was set to 90%, the annual rate of catastrophic failure was set to 0.5%, and no temporal discounting was applied.

Ethical Approval

Ethical approval for this study was not sought because this paper discusses a mathematical model and did not involve any living organisms.

Sensitivity Analysis

To evaluate the robustness of the model to variation in input parameters, we performed one- and two-way sensitivity analyses on key variables, including prosthetic life expectancy, satisfaction fraction, catastrophic failure rate, revision penalty, and discount rate. Given the high dimensionality of the parameter space (eight inputs, several continuous), only a subset of representative combinations can be presented here. Additional combinations can be explored using the publicly available calculator at https://jalycalculator.com/.

Results

Assuming prosthetic life expectancy of 15 years, a satisfaction fraction of 90%, a catastrophic failure rate of 0.5% annually, and no temporal discounting, a cohort of 45-year-old males can expect to accumulate 30 lifetime JALYs before applying any PFC penalty associated with revision. Increasing the PFC penalty resulted in a near-linear decline in expected JALYs, with each additional unit increase in PFC reducing expected JALYs by roughly one (Fig. 2). Applying a PFC penalty of five JALYs yields approximately 25 lifetime JALYs for the cohort. The six-JALY net benefit benchmark was reached at a PFC of approximately 24 JALYs.

Sensitivity Analysis

The results of the sensitivity analyses (Table 1) show that the primary finding is robust: expected JALYs remain well above the six-JALY benchmark under most plausible assumptions, with the threshold primarily determined by the PFC. Under conservative assumptions including a prosthetic life expectancy of only 10 years and a satisfaction fraction of only 80%, a cohort of 45-year-old males still accumulated substantially more than the six-JALY benchmark. Increasing the catastrophic failure rate to 1% annually likewise did not materially alter the result. Under this assumption, the six-JALY threshold was exceeded even at PFC values of approximately 20.

Temporal discounting reduced JALY accumulation across all values of PFC in the base case. Increasing the discount rate from 0% to 2% or 10% further reduced total JALYs, although the six-JALY threshold was exceeded under most conditions examined. When the penalty for failure of a revised prosthesis was increased substantially (revised PFC [rPFC] = 10 × PFC), threshold behavior became more sensitive to the value of PFC. Under these conditions, expected JALYs exceeded six when PFC = 5, but fell below six when PFC = 10 (and rPFC was accordingly 100). Finally, in the setting of high temporal discounting and large revision penalties, discounting increased net JALYs because the present value of large late failure penalties was reduced more than the value of earlier gains.

Discussion

THA is performed commonly in patients in their mid-80s and beyond, patients whose remaining life expectancy is in the order of 6 years or less. Such patients, because of their limited life expectancy, cannot be expected to accrue, on average, more than six JALYs. By contrast, some surgeons may hesitate to operate on 45-year-old patients whose potential span

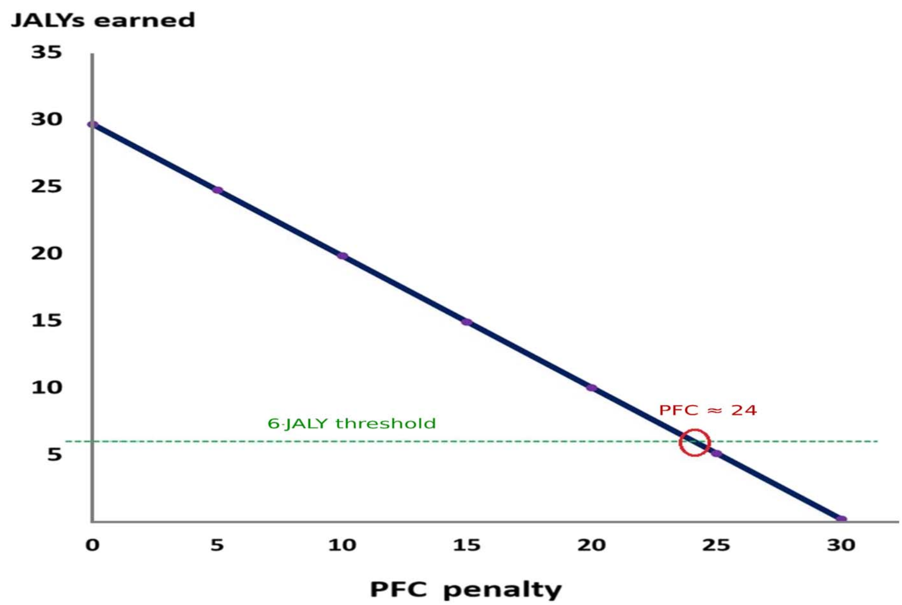

Fig. 2 Graphic representation of total lifetime JALYs expected for 45-year-old males as a function of increasing penalties for reaching the state of needing revision (the PFC). For this scenario, the anticipated satisfaction fraction was set to 90%, the annual rate of catastrophic failure was set to 0.5%, and no temporal discounting was applied.

Table 1. Sensitivity analysis

PFC	Base case[a]	Prosthetic life expectancy 10 years	Catastrophic failure rate of 1% annually	Satisfaction fraction of 80%	Base case with 2% annual temporal discount rate	Base case with 10% annual temporal discount rate	rPFC equal to PFC × 10 with 0% annual temporal discount rate	rPFC equal to PFC × 10 with 2% annual temporal discount rate	rPFC equal to PFC × 10 with 10% annual temporal discount rate
0	30	29	30	26	21	8	30	21	8
5	25	21	24	21	18	7	17	14	7
10	20	12	18	17	15	7	4	7	6
15	15	3	12	12	12	6	-9	0	5
20	10	-5	7	7	9	6	-22	-7	4
25	5	-14	1	2	6	5	-34	-14	3
30	0	-22	-5	-3	3	4	-47	-21	2
35	-5	-31	11	-8	0	4	-60	-28	1
40	-10	-39	-16	-13	-3	3	-73	-35	0

Anticipated lifetime JALYs accumulated as a function of PFC are shown for the base case and across one- and two-way parameter variations. Each cell represents the expected lifetime JALYs for a 45-year-old cohort under the specified parameter combination. Each column represents a separate sensitivity scenario in which a single parameter (or set of related parameters) is varied from the base case. The table is intended as a reference to show how model outputs change across plausible assumptions; no single parameter dominates across all scenarios. Each cell reports net JALYs for the given parameter set. Negative values indicate a net loss of JALYs, meaning that the surgery leaves the patient worse off than not operating. The temporal discount rate is the annual percentage used to convert future outcomes to present value.

[a]45-year-old male, prosthetic life expectancy = 15 years, annual catastrophic failure rate = 0.5%, satisfaction fraction = 90%, rPFC = 1.5 × PFC, temporal discounting = 0%.

of benefit is far greater than six JALYs. Importantly, a net value of six JALYs should not be interpreted as implying only 6 years of successful arthroplasty followed by failure; it represents the lifetime net balance of gains and losses accumulated throughout the patient's remaining lifespan. Indeed, 6 years of adequate function followed by failure would generally yield far fewer than six JALYs because the failure penalty may offset some, all, or more than all of the gains initially accrued. We found that offering THA to 85-year-old patients while hesitating in 45-year-old patients is logically consistent only if very high costs are attributed to prosthesis failure. Indeed, the six-JALY benchmark that implicitly informs decisions in older patients was not reached in the younger cohort until the prosthetic failure penalty rose to 24 JALYs. We assert that this value is implausibly high in clinical practice.

Limitations

Although our model incorporates detailed representations of mortality, revision probability, and time discounting, it remains subject to several limitations. The most fundamental limitation of this study was that the analysis depended on a particular conception of value: that the benefit of arthroplasty is best represented as the accumulation of years with an adequate clinical outcome. Reasonable observers may disagree with this premise. Alternative approaches might treat benefit as a continuous quantity, place greater weight on short-term gains, emphasize avoidance of rare but severe adverse outcomes, or incorporate qualitative aspects not captured by a binary definition of adequacy. The conclusions of this study are therefore contingent not simply on the use of a new metric, but on acceptance of this underlying framework.

This limitation is illustrated by the fact that patients with identical cumulative hip scores over time may earn different numbers of JALYs. For example, if adequacy is defined as a hip score of 80 or higher, a patient scoring 81 in two successive years accrues two JALYs, whereas a patient scoring 79 and 83 accrues only one. Indeed, even if the latter patient scored 79 and 85, that patient would still accrue fewer JALYs despite having a higher total hip score.

More broadly, there is no single definitive measure of the value of arthroplasty. We contend that an integrated measure (technically, a Riemann sum) is an improvement over single snapshot values such as hip score at year 2 or fraction of prostheses intact at year 10, yet this remains, ultimately, a value judgment.

Like all models, the JALY calculator produces outputs that depend on the inputs provided. The aim here was not to establish that the resulting JALY values are correct in an external or empirical sense, but that they are correctly derived from the specified assumptions. The validity of the framework lies in the internal consistency of that mapping, not in the validity of any particular choice of inputs. Parameters such as failure rates, satisfaction, and discounting are specified by the user. Accordingly, the model does not attempt to determine appropriate parameter values or to elicit patient preferences; rather, it makes explicit what follows from whatever assumptions are supplied.

At the same time, certain structural elements are imposed by the model. These include the parameterization of senescent failure using a Weibull distribution, the treatment of catastrophic failure as a constant hazard, and the assumption of a fixed satisfaction fraction over time. These choices were made to render the problem tractable and transparent, but they may not reflect the full complexity of prosthesis performance and patient experience.

A major limitation concerns the treatment of prosthesis-failure cost. While the calculator allows specification of a separate penalty for repeated failures (rPFC), all such failures beyond the first are treated equivalently. In reality, the burden of successive revisions may escalate, particularly in the setting of bone loss, infection, or compromised soft tissue. Additionally, in the present analysis, we specified the penalty for subsequent failures as a fixed multiple of the primary prosthesis-failure cost, namely rPFC = 1.5 × PFC. This choice was not empirically derived and serves as a simplifying assumption for illustrative purposes. Reasonable observers may assign substantially higher penalties to later failures. If so, the magnitude of the observed advantage in younger patients would be reduced, as this cohort of patients spends more time in the postfailure state. Future work should incorporate more nuanced modeling of the revision burden.

It is of course possible that very high values of rPFC apply only to a subset of patients, such that their influence on cohort-level estimates is limited. By construction, cohort-based analysis smooths over individual variation in loss aversion, risk tolerance, and other patient-specific preferences. This remains a limitation of the approach, as the clinical significance of heterogeneity persists despite aggregation. For example, individual patients with sufficiently high aversion to failure may fall outside the range for which THA would be considered appropriate under their own rPFC, even if the inclusion of their values does not materially alter cohort-level estimates. In such cases, THA may not be appropriate for those individuals, even if it remains appropriate at the cohort level. That is, the model evaluates the internal consistency of prevailing practice patterns and does not determine the clinical appropriateness of THA for any specific patient. It provides a population-based consistency analysis, not a patient-level decision tool [8].

Relatedly, the comparison of 45- and 85-year-old patients assumes that all other relevant factors, including disease severity and functional limitation, are comparable [7]. Under those conditions, the model isolates the role of age rather than proposing an indication for surgery. The purpose of the analysis is to assess whether the anticipated benefit standard is applied consistently across age groups, not to determine whether surgery should be offered to any particular patient or group.

Finally, the results presented here are necessarily limited to the comparison of 45- and 85-year-old male patients under the specific parameters employed. Because life expectancy is modestly higher in females, the corresponding benchmark would be slightly higher (on the order of seven JALYs). More broadly, different parameter choices may yield different results, and a comprehensive sensitivity analysis is not feasible. With numerous degrees of freedom in the model (including age, satisfaction fraction, catastrophic failure rate, prosthesis life expectancy, prosthesis-failure cost, and discount rate), even a small set of representative values for each parameter generates thousands of possible combinations. To address this, we provide an accessible version of the calculator that allows users to explore a range of input assumptions.

Discussion of Key Findings

In our model, using clinically plausible assumptions regarding prosthesis performance, a cohort of 45-year-old males falls below the six-JALY benchmark only when the penalty assigned to the state of needing revision exceeds 24 JALYs. This implies a trade-off so extreme that it would require an individual to forgo more than two decades of adequate hip function merely to avoid the eventual prospect of revision. Such a valuation is not consistent with the patient preferences we have observed in clinical practice.

The sensitivity analysis demonstrated that the principal finding was robust across a broad range of assumptions. Even under conservative assumptions regarding prosthetic longevity, satisfaction fraction, and catastrophic failure rates, younger patients generally exceeded the six-JALY benchmark derived from current practice patterns.

Several observations about the sensitivity analysis warrant comment. First, a constant annual catastrophic failure rate of 1% is likely higher than that observed in clinical practice, as it implies nearly 10% cumulative incidence at 10 years. Nonetheless, the principal finding persisted even under this intentionally stringent assumption. Second, there is no consensus regarding the appropriate value of the temporal discount rate. Nonetheless, the six-JALY benchmark was exceeded under most conditions at discount rates of 0%, 2%, and 10%, spanning the range of values likely to be considered plausible in practice.

The analysis also highlights the importance of assumptions regarding revision penalties. When the penalty associated with failure of a revised prosthesis was increased substantially, threshold behavior became more sensitive to the value assigned to prosthetic failure. Such parameter combinations may be uncommon, but they are not implausible for individual patients. This underscores an important limitation of the present study: it was strictly cohort based. As such, it does not incorporate individual variation in risk tolerance and therefore cannot guide shared decision-making at the patient level.

Finally, under conditions of both high temporal discounting and large revision penalties, discounting may increase net JALYs because large late penalties are discounted more heavily than earlier gains. This observation illustrates a broader principle: when important complications are both delayed and costly, assumptions regarding temporal discounting may substantially influence the perceived value of treatment. The role of such assumptions deserves increased attention in orthopaedic surgery.

Conclusion

Our findings suggest that age-based hesitancy is not supported by a benefit-cost framework. Younger patients with severe hip disease warrant consideration for surgery when the same accumulated-benefit standard applied to 85-year-old patients is applied to them. Under plausible assumptions of prosthetic life expectancy and satisfaction fractions, 45-year-old patients can expect substantially greater lifetime benefit from THA than 85-year-old patients, a group for whom the procedure is already accepted practice. The age boundary may be further lowered if the absence of radiographic wear in highly crosslinked polyethylene bearings seen at 25 years [10] translates to even greater prosthetic durability than assumed, a claim supported by the recently reported lower-than-expected revision rates [4]. The magnitude of foregone benefit by not offering THA to younger patients becomes clear at scale. If an additional 30,000 Americans who are 45 years of age underwent THA annually, the aggregate yield would approach 1 million additional person-years of improved hip function. This reflects the simple fact that younger patients live longer and therefore stand to accrue decades of benefit. Younger patients with severely impairing hip disease, whether from dysplasia, Perthes disease, or trauma, have the potential to enjoy decades of adequate function before revision becomes likely, making THA a sound and defensible option. Patients should be offered THA on the basis of their signs and symptoms; they should not be denied THA on the basis of age.

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