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HIP

Economic evaluation of robotic-assisted versus manual total hip arthroplasty: a systematic review of cost and clinical outcomes

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- *Introduction:* Total hip arthroplasty (THA) is a widely performed, cost-intensive procedure with growing demand due to an aging population. While manual THA (mTHA) offers reliable outcomes, robotic-arm-assisted THA (RATHA) has emerged as a technologically advanced alternative with potential clinical advantages. However, its economic value remains uncertain due to high capital and maintenance costs. This systematic review aimed to compare the economic and clinical outcomes of RATHA versus mTHA.
- *Methods:* A systematic search of MEDLINE, Embase, and Cochrane Library was conducted (1990–May 2024) following PRISMA guidelines. Studies comparing RATHA and mTHA in adult populations were included. Quality was assessed using the Newcastle–Ottawa scale, and data on costs, clinical outcomes, and patient-reported outcome measures (PROMs) were extracted and synthesized.
- *Results:* Seven studies (two Markov models, one prospective cohort, and four retrospective analyses) covering over 1.3 million patients were included. RATHA was associated with higher procedural costs but often yielded lower total 90-day care costs due to shorter hospital stays, fewer readmissions, and reduced rehabilitation needs. Cost-utility analyses showed favorable incremental cost-effectiveness ratios (ICERs), particularly in high-volume centers. Clinical outcomes were comparable or slightly better for RATHA, with some evidence of improved PROMs.
- *Conclusion:* RATHA may be cost-effective in high-volume settings, with potential for long-term clinical and financial benefits. However, variation in cost methodologies and healthcare models, along with high initial investment, highlights the need for further high-quality studies with standardized economic reporting and patient-centered outcomes.

Keywords: robotic THA; cost-effectiveness; cost comparison

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Introduction

Total hip arthroplasty (THA) remains a cornerstone in the management of advanced hip arthritis, offering substantial improvements in mobility, pain relief, and overall quality of life for millions of patients globally (1). With the aging of global populations and the continued rise in the prevalence of obesity, the demand for THA is anticipated to increase markedly, thereby imposing significant financial and operational burdens on healthcare systems (2, 3, 4).

While manual total hip arthroplasty (mTHA) has consistently demonstrated reliable clinical outcomes, robotic-arm-assisted total hip arthroplasty (RATHA) has emerged as a promising technological advancement. Several studies have reported benefits associated with RATHA, including improved implant positioning, potentially lower revision rates, and enhanced functional outcomes (1, 2, 3, 4, 5, 6). However, the adoption of robotic systems introduces considerable economic considerations. These include substantial upfront capital investment, increased per-procedure costs, and the need for specialized training for surgical teams – factors that raise important questions regarding the overall efficiency, cost-effectiveness, and long-term sustainability compared to conventional approaches (6, 7).

A central challenge in assessing the feasibility of RATHA is understanding its economic impact relative to mTHA. Certain studies argue that RATHA may lead to long-term cost savings by reducing the incidence of complications, hospital readmissions, and implant failures (7, 8). Conversely, critics highlight the financial strain of acquiring and maintaining robotic systems, along with the extended operative times often associated with robotic procedures (8, 9, 10, 11, 12, 13). Economic evaluations comparing RATHA and mTHA vary widely across healthcare systems and methodological approaches. Notably, these economic evaluations differ in scope and methodology. For instance, some studies focus mainly on resource utilization, capturing only direct hospital costs, such as the surgical procedure and inpatient stay, but often excluding the substantial fixed and variable costs associated with robotic systems, including acquisition, maintenance, and staff training (9, 10). In contrast, cost-utility analyses combine overall costs with patient-reported outcomes, as well as complication rates, revision surgeries, and rehabilitation (14, 15). However, findings across the literature remain inconsistent. While some studies suggest that RATHA may deliver long-term financial benefits through shorter hospital stays, reduced complication rates, and longer implant survival rates, others question its financial viability due to substantial upfront and ongoing costs of purchasing, maintaining, and operating robotic systems. This creates a complex evidence base that requires careful economic consideration and analysis (7, 8, 13). This systematic review aims to deliver a comprehensive economic comparison between robotic and manual THA across a range of healthcare systems.

Methodology

This systematic review was designed and executed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The eligibility criteria were established prior to commencing the search. The study was prospectively registered in the PROSPERO Database (CRD 42024549190).

Search strategy and study selection

A thorough and detailed literature search was performed on three databases (Cochrane Library, Embase, and MEDLINE) for studies that were published from January 1990 to May 2024 that compared economic evaluations of RATHA with mTHA.

The search strategy employed encompassed Medical Subject Headings (MeSH) and free-text terms that delineate the exposure variable as well as the population of interest. Only studies that were published in English or had English as their primary language were included.

Following the removal of duplicates, two independent reviewers (CD and RP) assessed the titles, abstracts, and full texts of the identified studies. Any differences and discrepancies that existed between the two reviewers were resolved by further reviewers (AF and WW) prior to data extraction.

Eligibility criteria and outcome measures

The following inclusion criteria were used: (i) studies that compared economic evaluations between mTHA and RATHA and (ii) patient population aged over 18 years.

We included randomized controlled trials (RCTs), cohort studies, case–control studies, case series, and model-based economic evaluations. Technical notes, letters to the editor, expert opinions, review articles, meta-analyses, conference abstracts, and case reports were excluded from the review.

The primary focus of this review was the comparison of costs between RATHA and mTHA. In addition, clinical outcomes, such as complication rates, revision rates, and patient-reported outcome measures (PROMs), were evaluated to assess whether any differences in costs were associated with differences in clinical outcomes. Some of the included studies examined costs alone, whereas others conducted full health

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economic evaluations, including quality of life (QoL) assessments.

Risk-of-bias assessment of the included studies

The Newcastle–Ottawa scale (NOS) was utilized to assess the quality of the studies (retrospective cohort, prospective cohort, and economic evaluations) (11). This tool consists of three dimensions, encompassing a total of eight items: four items assessing the selection of the study population, one item evaluating comparability between the groups, and three items related to outcome measurement. Except for the comparability item, which can score a maximum of two points, each item is scored up to one point, yielding a total possible score ranging from zero to nine points. Higher overall scores indicate higher methodological quality of the study. We categorized the studies into three quality levels: low (<2 points, high risk of bias), medium (2–5 points, unclear risk of bias), and high (6–9 points, low risk of bias). Only studies with moderate-to-high quality scores, as determined by these criteria, were included in the final analysis.

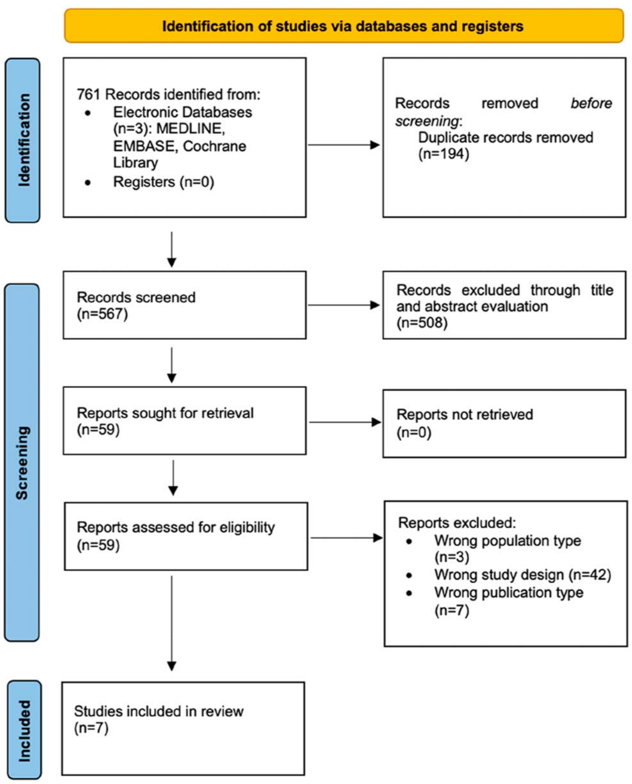

Figure 1

PRISMA flow chart. Notes: Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Results

Literature search results

The initial database searches (MEDLINE/PubMed, Embase, and Cochrane Library) identified a total of 761 records. After the removal of 194 duplicates, 567 records underwent title and abstract screening, resulting in 59 articles eligible for full-text assessment. Of these, 52 studies were excluded for reasons including inappropriate study designs, irrelevant populations, insufficient data, or inadequate follow-up. Ultimately, seven studies met all eligibility criteria for inclusion in this systematic review. The study selection process is illustrated in the PRISMA flow diagram shown in Fig. 1 (12, 14, 15, 16, 17, 18, 19).

Characteristics of included studies

The seven included studies comprised two Markov model analyses (14, 16), four retrospective analyses (12, 15, 17, 18), and one prospective cohort study (19). A cumulative total of 1,337,801 patients were analyzed, of which 10,148 underwent RATHA and 1,327,653 underwent mTHA. Patients were predominantly female, with overall mean ages ranging between approximately 60 and 67 years across studies. Details of patient demographics are presented in Table 1.

Risk-of-bias assessment

Risk of bias was assessed using the Newcastle–Ottawa scale (NOS) for the seven studies, with results summarized in Table 2. All included studies demonstrated a low risk of bias, with total scores ranging from 7 to 9. Clement *et al.* (19) received 3 out of 4 stars for selection and 2 out of 3 for outcome, primarily due to its limited sample size and the use of two distinct data sources (private sector vs National Health Service (NHS)), which affected the study's homogeneity. Both Ong *et al.* (16) and Maldonado *et al.* (14), which utilized Markov model analyses, each lost one point in the selection domain due to indirect comparability inherent in their modeling-based methodologies.

Economic outcomes and cost-effectiveness

Cost resource utilization (index procedure, 90-day episode of care)

Four studies reported data on direct costs related to RATHA and mTHA (12, 15, 17, 18). Constantinescu *et al.* (12) reported higher immediate procedural costs for

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Table 1 Characteristics of included studies.

Study	Year	Design	Age (years)	Gender		Number of cases		Robotic system	Outcome summary
				Male	Female	RATHA	mTHA		
Barsoum *et al.* (15)	2023	RCS	–	5,298	5,094	1,732	8,660	MAKO	Lower LOS & 90-day EOC cost for RATHA
Maldonado *et al.* (14)	2021	MM	59.2 ± 9.7	257	298	555		MAKO	Cost savings & modest QALY gain
Clement *et al.* (19)	2022	PCS	58.9 (RATHA), 67.5 (mTHA)	267	293	48	512	MAKO	RATHA cost-effective (£1,910/QALY)
Constantinescu *et al.* (12)	2024	RCS	~65.6	561,552	757,511	6,010	1,313,053	Not stated	Higher cost, lower fracture/delirium in RATHA
Kirchner *et al.* (18)	2021	RS	64.5/64.8	650	866	758	758	MAKO	No difference in complications; RATHA had lower LOS & cost
Ong *et al.* (16)	2022	MM	60.5 ± 14.1	57	50	107		Not stated	RATHA cost-effective at 1 & 5 years
Pierce *et al.* (17)	2021	CA	–	2,330	3,278	938	4,670	MAKO	$785 lower 90-day cost for RATHA

RATHA, robotic-arm-assisted total hip arthroplasty; mTHA, manual total hip arthroplasty; LOS, length of stay; EOC, episode of care; QALY, quality-adjusted life year; RCS, retrospective cohort study; PCS, prospective cohort study; MM, Markov model; RS, registry study; CA, claims analysis.

RATHA compared to mTHA ($17,729 versus $15,977) (12). This finding is consistent with Kirchner *et al.* (18), who similarly observed significantly increased direct inpatient hospital costs associated with RATHA ($20,046 versus $18,250; $P < 0.001$) (18).

Conversely, other studies highlighted overall economic advantages associated with RATHA. Pierce *et al.* noted that despite slightly higher initial index procedural costs (US$12,827 versus US$12,665; $P = 0.0487$), RATHA resulted in lower total costs over a 90-day episode of care (US$19,734 versus US$20,519; $P = 0.0095$), with savings being primarily driven by reduced postoperative rehabilitation requirements (17).

Barsoum *et al.* also demonstrated significant overall cost savings associated with RATHA, reporting a mean reduction of $1,573 in total costs for the index procedure and subsequent 90-day episode of care compared to mTHA ($35,436 versus $37,009; $P < 0.0001$) (15). Specifically, the RATHA group incurred significantly lower index procedure costs, saving an average of $1,297 ($31,507 versus $32,804; $P < 0.0001$). Additionally, although the RATHA group exhibited lower post-discharge hospital utilization costs within the 90-day episode of care ($3,929 versus $4,205; difference: $276), this difference did not reach statistical significance ($P = 0.1086$). These authors also reported that the RATHA cohort required significantly fewer inpatient care interventions, with 31.7% fewer patients requiring such care ($P = 0.0203$), resulting in a 35.9% reduction in hospital readmissions ($P = 0.0204$) (15). Moreover, they observed significantly lower utilization of hospital outpatient services, with 7.85% fewer patients requiring these services ($P = 0.0038$). This corresponded to a 22.3% reduction in total outpatient encounters ($P = 0.0002$).

Length of hospital stay and utilization of healthcare resources post the 90-day EOC

Four studies reported shorter hospital stays and higher rates of home discharges associated with RATHA (12, 15, 17, 18). Constantinescu *et al.* observed slightly reduced length of stay (LOS) for RATHA (1.8 ± 1.2 days vs 1.9 ± 1.2 days; $P < 0.05$) compared to mTHA, as well as higher rates of home discharges (87.6 vs 85.7%; $P < 0.05$) (12). Kirchner *et al.* also reported reduced LOS in the RATHA group compared to the mTHA group (2.69 ± 1.25 vs 2.82 ± 1.18; $P < 0.001$) (18). Barsoum *et al.* also demonstrated a shorter LOS compared with mTHA (1.51 vs 1.71 days; $P < 0.0001$) (15).

Table 2 Risk-of-bias assessment using the Newcastle–Ottawa scale.

Study	Selection (★/4)	Comparability (★/2)	Outcome (★/3)	Total stars	Risk of bias
Barsoum *et al.* (15)	★★★★	★★	★★★	9	Low
Clement *et al.* (19)	★★★	★★	★★	7	Moderate
Constantinescu *et al.* (12)	★★★★	★★	★★★	9	Low
Ong *et al.* (16)	★★★	★★	★★★	8	Moderate
Pierce *et al.* (17)	★★★★	★★	★★★	9	Low
Maldonado *et al.* (14)	★★★	★★	★★★	8	Moderate
Kirchner *et al.* (18)	★★★★	★★	★★★	9	Low

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One-day stays were more frequently seen among RATHA patients (65.24 vs 58.98%; $P < 0.0001$), while stays of three or more days were significantly less prevalent (7.97 vs 11.34%; $P < 0.0001$) (15, 18).

Pierce *et al.* reported a significant reduction in the utilization of post-index rehabilitation services among RATHA patients compared to mTHA. Specifically, RATHA patients were 76.1% less likely to require inpatient rehabilitation ($P < 0.0001$) and 16.8% less likely to need skilled nursing facility care ($P = 0.0041$). In contrast, RATHA patients were 12.4% more likely to require home health agency visits compared to mTHA patients (72.9 vs 64.9%; $P < 0.0001$) (17).

Cost-utility analysis and incremental cost-effectiveness ratio (QALY and ICER)

The cost-utility analysis using quality-adjusted life years (QALYs) revealed positive economic justifications for RATHA. Maldonado *et al.* used a Markov model analysis to report mean direct cost savings of approximately $945 for Medicare (15,355 ± 115 vs 14,410 ± 40) and $1,810 for private payers (17,022 ± 204 vs 15,212 ± 82) over a five-year period for RATHA (14). This study also demonstrated slightly higher QALYs associated with RATHA patients (2.96 ± 0.58 vs 2.92 ± 0.57), making RATHA a cost-effective intervention.

Another Markov model analysis noted that RATHA patients accumulated lower total costs at both 1-year ($20,865 ± 9,897.52 vs $21,661 ± 9,909.15, $P < 0.001$) and 5-year intervals ($23,124.57 ± 10,045.48 vs $25,756.42 ± 10,091.84; $P < 0.001$), alongside increased QALYs at both 1-year (0.901 ± 0.117 vs 0.888 ± 0.114; $P < 0.001$) and 5-year intervals (4.455 ± 0.563 vs 4.384 ± 0.537; $P < 0.001$) (16). The incremental cost-effectiveness ratio (ICER) also favored RATHA at 1-year (ICER: −$61,210.77) and at 5-year follow-ups (ICER: −$37,068.31), highlighting that RATHA was more cost-effective and yielded greater utility compared to mTHA (16).

Similarly, Clement *et al.* demonstrated superior cost-effectiveness for RATHA compared to mTHA (19). After adjusting for confounders, RATHA was associated with meaningful QALY gains over time. The cost per QALY for RATHA was £1,910 over a 10-year horizon and £980 over a lifetime horizon, increasing modestly to £2,349 and £1,432, respectively, when applying a 5% annual discount rate. The cost-effectiveness improved notably with surgical volume; for centers performing 50 RATHAs per year, the cost per QALY was approximately £3,000, while for those performing 200 procedures annually, this figure decreased to £1,000. All cost per QALY values remained well below the commonly accepted National Institute for Health and Care Excellence (NICE) threshold of £20,000 to £30,000 per QALY in the UK.

Clinical outcomes

Clinical outcomes, including complications and PROMS, were also analyzed to assess their potential relationship with cost differences between mTHA and RATHA. Constantinescu *et al.* highlighted a significantly lower incidence of intraoperative fracture (0.22 vs 0.39%, $P < 0.05$), delirium (0.1 vs 0.2%, $P < 0.05$), and postoperative anemia (14.4 vs 16.7%, $P < 0.05$) in RATHA patients compared to mTHA (12). However, RATHA exhibited slightly increased occurrences of myocardial infarction (0.13 vs 0.08%, $P < 0.05$), wound dehiscence (0.02 vs 0.01%, $P < 0.05$), renal failure (1.7 vs 1.6%, $P < 0.05$), and blood transfusion (2 vs 1.9%, $P < 0.05$). No significant differences were noted in terms of respiratory complication (0.8 vs 0.8%, $P > 0.05$), gastrointestinal complication (0.1 vs 0.1%, $P > 0.05$), pulmonary embolus (0.1 vs 0.1%, $P > 0.05$), DVT (0.1 vs 0.1%, $P > 0.05$), hematoma/seroma (0.00 vs 0.04%, $P > 0.05$), and overall mortality (0.03 vs 0.03%, $P > 0.05$).

Conversely, Kirchner *et al.* found no significant differences in major perioperative complications between robotic and manual cohorts in their matched sample (3.3 vs 2.24%, $P = 0.729$) (18). Minor complication rates appeared higher for RATHA (21.6 vs 12.8%, $P = 0.004$); however, these differences lost significance after multivariate adjustment, suggesting that the likelihood of experiencing a minor complication was similar between groups (OR = 1.294, 95% CI = 0.938–1.785).

Finally, Clement *et al.* reported that patients undergoing RATHA demonstrated significantly greater postoperative EQ-5D utility scores compared to those receiving mTHA (19). The mean postoperative EQ-5D score was significantly higher in the RATHA group (0.905 ± 0.139) than in the mTHA group (0.754 ± 0.263) at 12 months follow-up, with a mean difference of 0.148 ($P < 0.001$). However, the unadjusted overall change in EQ-5D from baseline was not statistically different between groups ($P = 0.078$). After adjusting for confounding variables, including age, sex, and baseline EQ-5D, the RATHA group demonstrated a statistically significant additional improvement of 0.091 (95% CI: 0.009–0.173; $P = 0.029$), indicating a clinically meaningful advantage in health-related quality of life.

Discussion

This systematic review examines and compares the economic and clinical outcomes associated with mTHA and RATHA across different healthcare contexts. Although THA has evolved remarkably over recent decades, achieving implant survival rates exceeding 95% at 10 years and around 80% at 20 years, challenges such as suboptimal implant positioning and component alignment continue to be relevant concerns, with

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implications for long-term implant performance and revision rates (20, 21).

From a financial perspective, the evidence for RATHA's cost-effectiveness remains mixed but promising in certain contexts. While RATHA inevitably involves higher upfront costs due to the capital investment required for robotic systems, as well as ongoing expenses for maintenance, software, disposables, and staff training, some studies suggest that these costs may be offset by potential downstream savings, particularly in high-volume centers (12, 18). This is largely driven by reduced downstream costs associated with postoperative care, lower complication rates, and improved functional outcomes (15, 17). For instance, Barsoum *et al.* and Pierce *et al.* demonstrated that despite higher index procedural costs, RATHA patients had lower total 90-day episode-of-care costs compared to those who underwent mTHA – by $1,573 and $785, respectively – primarily due to reduced utilization of inpatient rehabilitation services, hospital readmissions, and skilled nursing facilities (15, 17). These short-term savings suggest that, from a payer or bundled-payment perspective, RATHA may offer a better return-on-investment and economic value when case volumes are sufficient (22, 23).

Long-term economic modeling also provides cautious optimism. Clement *et al.*, through a UK-based cohort, reported a favorable ICER of £1,910 per QALY at a 10-year horizon and £980 over a lifetime horizon, well within NICE thresholds of £20,000–£30,000 per QALY (19). Even better ratios have been reported in centers performing high volumes of robotic procedures, with the ICER dropping to approximately £1,000 per QALY in centers performing 200 RATHAs annually, indicating that procedural volume impacts economic viability (19). Similarly, Ong *et al.* and Maldonado *et al.* found positive ICERs for RATHA in US-based Markov model analyses, suggesting potential cumulative savings over multiyear timeframes (ICERs of −$61,210.77 and −$37,068.31 at one- and five-year intervals, respectively) (14, 16). However, it is important to note that these projections depend on assumptions regarding surgical volume, complication rates, implant longevity, and healthcare reimbursement models that may not apply universally. Centers with lower case volumes may not achieve the same scale of financial benefits, limiting the extent to which initial investments are recouped over time.

Importantly, studies such as those by Constantinescu *et al.* and Kirchner *et al.* highlight the balance between higher intraoperative costs and potential savings through operational efficiencies (12, 18). While these studies observed increased surgical costs for RATHA, they also noted slightly shorter LOS and higher rates of discharge to home, which could help contain costs across the broader perioperative and post-acute care pathways (12, 15, 18). These findings suggest that RATHA may support more efficient patient rehabilitation and reduce the burden on post-acute care resources. However, although the financial case for RATHA appears promising under certain circumstances, inconsistency in cost reporting and limited transparency around additional expenses – such as maintenance contracts, software upgrades, and ongoing staff training – make it challenging to draw firm conclusions about its overall economic impact across different healthcare systems.

It is also necessary to recognize that the included studies differ in the type and scope of economic evaluation they used. Barsoum *et al.* and Pierce *et al.* primarily examined resource utilization, focusing on direct hospital costs and short-term savings within a defined episode of care but often did not capture all fixed and variable costs, such as the capital outlay for robotic systems, ongoing maintenance, or staff training (15, 17). Other studies, such as Clement *et al.*, Ong *et al.*, and Maldonado *et al.*, conducted more long-term cost-utility analyses, combining overall costs with patient-reported outcomes to calculate cost per QALY gained, offering a more holistic view of value for money over time (14, 16, 19). This distinction highlights why findings on the cost-effectiveness of RATHA can vary: short-term savings alone may not reflect the true economic impact if key costs are overlooked. A better understanding of how these different approaches affect real-world decisions is essential for healthcare systems evaluating whether the theoretical benefits of RATHA translate into sustainable, long-term value.

Beyond the economic considerations, the clinical evidence for RATHA reflects both potential advantages and limitations. Robotic systems have been shown to consistently improve implant positioning and component alignment compared to manual techniques (22, 24, 25). Konishi *et al.* demonstrated improved accuracy in cup orientation and positioning with RATHA compared to the mTHA (26), while Emara *et al.* reported significantly superior radiographic outcomes in favor of RATHA, including improved cup orientation, more accurate femoral stem alignment, greater femoral canal fill, and optimized combined offset (27). This improved accuracy may potentially translate into better implant longevity and lower risks of malposition-related complications, which could support cost savings over time (26, 28).

However, the impact of these technical improvements on patient outcomes – including complication rates, revision surgeries, and patient-reported outcome measures (PROMs) – remains less clear. Constantinescu *et al.* reported lower rates of intraoperative fractures and delirium in patients undergoing RATHA compared to those receiving mTHA (12). Conversely, Kirchner *et al.* observed slightly higher rates of minor complications with RATHA, although this difference was not statistically significant after multivariate adjustment, and they found no significant differences in major complications between the two groups (18). Clement *et al.* also demonstrated higher EQ-5D scores in favor of RATHA, suggesting a potential benefit in patient-reported

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quality of life (19). Findings across the literature further underscore these results (29). Ruangsomboon *et al.*, in a systematic review and meta-analysis of RCTs, found no significant differences in overall complications, revision rates, or PROMs between RATHA and mTHA, although they did observe improvements in lower limb length discrepancy favoring RATHA (30). Wang *et al.*, in another meta-analysis involving 18 studies, reported that RATHA demonstrated better outcomes in terms of leg-length discrepancy, stem alignment, cup inclination, total complications, and intraoperative complications; however, they noted that mTHA had a lower dislocation rate (24). These results highlight that while robotic-arm assistance appears to offer technical precision, translating these technical gains into consistent, clinically meaningful improvements remains an area that requires further high-quality research. Finally, while some studies suggest that robotic systems may improve operational efficiency and potentially enhance patient satisfaction by supporting more predictable outcomes and recovery pathways, these aspects also warrant more robust investigation (25, 31).

Finally, it is important to note that a common limitation of many systematic reviews and meta-analyses in the literature is the pooling of evidence and data from multiple robotic systems – including CT-guided and imageless platforms – which can differ significantly in their technical performance, clinical impact, and associated costs. Therefore, we recommend that future studies assess and individualize cost-efficacy for each specific robotic system rather than generalize findings across all platforms.

Our review is subject to certain limitations. The included studies exhibit substantial heterogeneity in terms of study design, definitions of cost, and duration of follow-up. Many analyses did not comprehensively account for all fixed and variable costs associated with robotic systems, such as maintenance contracts, software updates, and disposable instruments. Additionally, two of the included studies did not specify the type of robotic system used, making it more difficult to draw definitive conclusions about cost-effectiveness across different technologies. Finally, differences in healthcare systems introduce challenges in interpreting the financial data. Most of the included studies were conducted in the US or UK, where healthcare systems differ significantly from those in countries with alternative funding structures and reimbursement models.

In conclusion, while RATHA involves a higher upfront financial burden, our review suggests that it has the potential to be a cost-effective intervention over time, particularly in high-volume settings. The combination of potential clinical benefits, reduced long-term care costs, and operational efficiencies may support its economic viability. However, to guide informed decision-making, future research should provide more comprehensive financial data and include detailed investment analyses that account for real-world costs, such as maintenance, training, and system upgrades. Moving forward, high-quality, long-term studies with transparent cost reporting and robust, patient-centered outcome measures will be critical to determine whether the advantages of RATHA consistently translate into sustainable, meaningful benefits for patients and healthcare systems alike.

ICMJE Statement of Interest

FS Haddad has served as a consultant for Smith & Nephew, Corin, MatOrtho, and Stryker; has received payment for lectures, including service on speakers' bureaus for Smith & Nephew and Stryker; and has received royalties from Smith & Nephew, MatOrtho, Corin, and Stryker; all of these activities were outside the submitted work. P Putzeys reports being a consultant for Stryker Education. The other authors did not receive any financial support and did not have any conflicts of interest.

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Author contribution statement

WW, CD, and AF prepared the manuscript. RP collected the data. MB and PP conceived the study and prepared the manuscript. FSH supervised the study and prepared the manuscript.

References

1 Learmonth ID, Young C & Rorabeck C. The operation of the century: total hip replacement. *Lancet* 2007 **370** 1508–1519. (https://doi.org/10.1016/s0140-6736(07)60457-7)

2 Chen AG, Sogbein OA, McClure JA, *et al.* Total hip arthroplasty in patients aged 40 to 60 years old: a population-based study. *J Arthroplast* 2023 **38** S83–S88.e2. (https://doi.org/10.1016/j.arth.2023.04.027)

3 Chen B, Clement ND, MacDonald D, *et al.* Cost-utility analysis of total knee arthroplasty using 10-year data from a randomised controlled trial: implant design influences quality-adjusted life year gain. *Knee* 2023 **44** 79–88. (https://doi.org/10.1016/j.knee.2023.07.002)

4 Shichman I, Askew N, Habibi A, *et al.* Projections and epidemiology of revision hip and knee arthroplasty in the United States to 2040–2060. *Arthroplast Today* 2023 **21** 101152. (https://doi.org/10.1016/j.artd.2023.101152)

5 Fontalis A, Kayani B, Plastow R, *et al.* A prospective randomized controlled trial comparing CT-based planning with conventional total hip arthroplasty versus robotic arm-assisted total hip arthroplasty. *Bone Joint Lett J* 2024 **106-b** 324–335. (https://doi.org/10.1302/0301-620x.106b4.Bjj-2023-1045.R1)

6 Sugano N, Maeda Y, Fuji H, *et al.* Accuracy of femoral component anteversion in robotic total hip arthroplasty. *Bone Joint Lett J* 2024 **106-b** (3 Supplement A) 104–109. (https://doi.org/10.1302/0301-620x.106b3.Bjj-2023-0840.R1)

7 Bullock EKC, Brown MJ, Clark G, *et al.* Robotics in total hip arthroplasty: current concepts. *J Clin Med* 2022 **11** 6674. (https://doi.org/10.3390/jcm11226674)

EFORT Open Reviews (2026) **11** 553–560
https://doi.org/10.1530/EOR-2025-0179

8 Coulomb R, Cascales V, Haignere V, *et al.* Does acetabular robotic-assisted total hip arthroplasty with femoral navigation improve clinical outcomes at 1-year post-operative? A case-matched propensity score study comparing 98 robotic-assisted versus 98 manual implantation hip arthroplasties. *Orthop Traumatol Surg Res* 2023 **109** 103477. (https://doi.org/10.1016/j.otsr.2022.103477)

9 Goh GS, Haffar A, Tarabichi S, *et al.* Robotic-assisted versus manual unicompartmental knee arthroplasty: a time-driven activity-based cost analysis. *J Arthroplast* 2022 **37** 1023–1028. (https://doi.org/10.1016/j.arth.2022.02.029)

10 Gregory DA, Coppolecchia A, Scotti DJ, *et al.* A 90-day episode-of-care analysis including computed tomography scans of robotic-arm assisted versus manual total knee arthroplasty. *J Knee Surg* 2023 **36** 1077–1086. (https://doi.org/10.1055/s-0042-1749083)

11 Wells GA, Shea B, O'Connell D, *et al*. *The Newcastle–Ottawa Scale (NOS) for Assessing the Quality of Nonrandomised Studies in Meta-Analyses*. 2011. (http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp)

12 Constantinescu DS, Costello JP 2nd, Yakkanti RR, *et al.* Varying complication rates and increased costs in technology-assisted total hip arthroplasty versus conventional instrumentation in 1,372,300 primary total hips. *J Arthroplast* 2024 **39** 1771–1776. (https://doi.org/10.1016/j.arth.2023.12.019)

13 Remily EA, Nabet A, Sax OC, *et al.* Impact of robotic assisted surgery on outcomes in total hip arthroplasty. *Arthroplast Today* 2021 **9** 46–49. (https://doi.org/10.1016/j.artd.2021.04.003)

14 Maldonado DR, Go CC, Kyin C, *et al.* Robotic arm-assisted total hip arthroplasty is more cost-effective than manual total hip arthroplasty: a markov model analysis. *J Am Acad Orthop Surg* 2021 **29** e168–e177. (https://doi.org/10.5435/jaaos-d-20-00498)

15 Barsoum W, Gregory D, Needham K, *et al.* Advantages of robotic arm-assisted total hip arthroplasty: a 90-day episode-of-care clinical utility and cost analysis. *J Comp Eff Res* 2023 **12** e220208. (https://doi.org/10.57264/cer-2022-0208)

16 Ong KL, Coppolecchia A, Chen Z, *et al.* Robotic-arm assisted total knee arthroplasty: cost savings demonstrated at one year. *Clinicoecon Outcomes Res* 2022 **14** 309–318. (https://doi.org/10.2147/ceor.S357112)

17 Pierce J, Needham K, Adams C, *et al.* Robotic-assisted total hip arthroplasty: an economic analysis. *J Comp Eff Res* 2021 **10** 1225–1234. (https://doi.org/10.2217/cer-2020-0255)

18 Kirchner GJ, Lieber AM, Haislup B, *et al.* The cost of robot-assisted total hip arthroplasty: comparing safety and hospital charges to conventional total hip arthroplasty. *J Am Acad Orthop Surg* 2021 **29** 609–615. (https://doi.org/10.5435/jaaos-d-20-00715)

19 Clement ND, Gaston P, Hamilton DF, *et al.* A cost-utility analysis of robotic arm-assisted total hip arthroplasty: using robotic data from the private sector and manual data from the National Health Service. *Adv Orthop* 2022 **2022** 5962260. (https://doi.org/10.1155/2022/5962260)

20 Pivec R, Johnson AJ, Mears SC, *et al.* Hip arthroplasty. *Lancet* 2012 **380** 1768–1777. (https://doi.org/10.1016/s0140-6736(12)60607-2)

21 Gwam CU, Mistry JB, Mohamed NS, *et al.* Current epidemiology of revision total hip arthroplasty in the United States: national inpatient sample 2009 to 2013. *J Arthroplast* 2017 **32** 2088–2092. (https://doi.org/10.1016/j.arth.2017.02.046)

22 Berwick DM, Nolan TW & Whittington J. The triple aim: care, health, and cost. *Health Aff* 2008 **27** 759–769. (https://doi.org/10.1377/hlthaff.27.3.759)

23 Dixit SK. Strategic management in hospitals – theory and practice: orthopedic and spine services. *Int J Healthc Manag* 2016 **9** 181–189. (https://doi.org/10.1179/2047971915Y.0000000004)

24 Wang Y, Wang R, Gong S, *et al.* A comparison of radiological and clinical outcomes between robotic-assisted and conventional total hip arthroplasty: a meta-analysis. *Int J Med Robot* 2023 **19** e2463. (https://doi.org/10.1002/rcs.2463)

25 Zhang J, Ndou WS, Ng N, *et al.* Robotic-arm assisted total knee arthroplasty is associated with improved accuracy and patient reported outcomes: a systematic review and meta-analysis. *Knee Surg Sports Traumatol Arthrosc* 2022 **30** 2677–2695. (https://doi.org/10.1007/s00167-021-06464-4)

26 Konishi T, Sato T, Hamai S, *et al.* Robotic arm-assisted system improved accuracy of cup position and orientation in cementless total hip arthroplasty for dysplastic hips: a comparison among groups with manual placement, computed tomography-based navigation, and robotic surgery. *Arthroplast Today* 2024 **28** 101461. (https://doi.org/10.1016/j.artd.2024.101461)

27 Emara AK, Samuel LT, Acuña AJ, *et al.* Robotic-arm assisted versus manual total hip arthroplasty: systematic review and meta-analysis of radiographic accuracy. *Int J Med Robot* 2021 **17** e2332. (https://doi.org/10.1002/rcs.2332)

28 Ng N, Gaston P, Simpson PM, *et al.* Robotic arm-assisted versus manual total hip arthroplasty: a systematic review and meta-analysis. *Bone Joint Lett J* 2021 **103-b** 1009–1020. (https://doi.org/10.1302/0301-620x.103b6.Bjj-2020-1856.R1)

29 Sweet MC, Borrelli GJ, Manawar SS, *et al.* Comparison of outcomes after robotic-assisted or conventional total hip arthroplasty at a minimum 2-year follow-up: a systematic review. *JBJS Rev* 2021 **9** e20.00144. (https://doi.org/10.2106/jbjs.Rvw.20.00144)

30 Ruangsomboon P, Ruangsomboon O, Osman K, *et al.* Clinical, functional, and radiological outcomes of robotic assisted versus conventional total hip arthroplasty: a systematic review and meta-analysis of randomized controlled trials. *J Robot Surg* 2024 **18** 255. (https://doi.org/10.1007/s11701-024-01949-z)

31 Kayani B, Fontalis A, Haddad IC, *et al.* Robotic-arm assisted total knee arthroplasty is associated with comparable functional outcomes but improved forgotten joint scores compared with conventional manual total knee arthroplasty at five-year follow-up. *Knee Surg Sports Traumatol Arthrosc* 2023 **31** 5453–5462. (https://doi.org/10.1007/s00167-023-07578-7)