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Computer-Assisted Fluoroscopic Navigation Is Cost Effective Compared to Robotic-Assisted and Manual Surgery in Total Hip Arthroplasty

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Abstract

Total hip arthroplasty (THA) is among the most common surgeries for hip osteoarthritis. Besides the conventional manual technique (mTHA), alternatives such as computer-assisted fluoroscopic navigation (cTHA) and robotic-assisted solutions (rTHA) are available for THA. We aimed to estimate the cost-utility of cTHA compared to rTHA and mTHA in patients undergoing THA from the US healthcare system perspective.

A Markov model was developed to compare costs and utilities of cTHA vs. mTHA, and cTHA vs. rTHA over a 1-year time horizon. Health states were defined based on the occurrence of readmissions with/without revisions due to fracture, dislocation, infection and hip pain. Utilities were presented in quality-adjusted life years (QALYs). Costs included length of stay, operative time and readmissions/revisions. Incremental cost-effectiveness ratio (ICER) was estimated as the incremental cost per QALY change for each pairwise comparison. Inputs were drawn from published literature.

cTHA was associated with a slight QALY gain of 0.001, and estimated savings of $1,595 and $949 per patient compared to rTHA and mTHA, respectively. Results indicated that cTHA was the 'dominant' strategy, i.e. reducing costs and slightly increasing QALYs, compared to both alternatives. Probabilistic sensitivity analysis indicated that cTHA was cost saving in 100% of the 1,000 simulations compared to both rTHA and mTHA.

[*] Contributed to study concept/design, interpretation of data, drafting and revision of publication.
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Using computer-assisted fluoroscopic navigation in THA showed cost savings and a slight improvement in quality of life compared to robotic-assisted and manual THA. Results suggest that computer-assisted fluoroscopic navigation is the preferred strategy for THA mainly due to downstream cost savings by reductions in OR time and readmissions/revisions rates.

1 Background & Objectives

Total hip arthroplasty (THA) is among the most common surgeries performed worldwide for hip osteoarthritis. Besides the conventional manual technique (mTHA), enabling technologies such as computer-assisted fluoroscopic navigation (cTHA) and robotic-assisted solutions (rTHA) are available for primary THA. Such technologies aim to optimize implant positioning and alignment, to restore patients' functional outcomes and quality of life (QoL) (Houcke, Khanduja, Pattyn, & Audenaert, 2017). Each approach can influence patients' QoL and costs, which are crucial aspects for healthcare systems. Previous research showed the cost-effectiveness of rTHA compared to mTHA (Ong, et al., 2024; Maldonado, et al., 2021); however, no study has assessed the cost-effectiveness of cTHA compared to rTHA and mTHA. The objective of this study was to analyze the cost-effectiveness of cTHA compared to rTHA and mTHA among patients undergoing primary THA from the US healthcare system perspective.

2 Study Design & Methods

A Markov state-transition model was developed to compare costs and utilities of cTHA vs. mTHA, and cTHA vs. rTHA over a 1-year time horizon using a cycle length of 3 months. Model population consisted of patients undergoing primary THA, treated with one of the three interventions considered in this analysis: cTHA, rTHA or mTHA. Most model inputs were derived from two published studies (Hamilton, et al., 2023; Bernstein, et al., 2024) based on a real-world hospital billing database from 2016 to 2021. The navigation and robotic technologies included in cTHA and rTHA interventions were representative of the technologies available in 2016-2021. The mean age of the patient cohort was set at 66 years. The health states were defined according to the occurrence of complications leading to readmissions and revisions, which impacted both costs and patients' QoL. All patients started in the "Post-THA" health state, showing they all underwent the procedure, and could either remain in this state (i.e. the patient doesn't experience any complication) or experience a complication, that would lead either to a readmission without revision, or to a readmission with revision. Reasons for readmission/revision included fracture, dislocation, infection and hip pain. Each readmission and/or revision, led to a one-time cost and decrease in QoL. After one cycle, the patient entered the "Post-readmission" or "Post-revision" health state. QoL were measured through utility values, presented in quality-adjusted life years (QALYs) and collected from the literature. Cost components included length of stay, operating room time and readmissions/revisions. The incremental cost of acquiring the equipment for enabling technologies were not included due to challenges in cost estimates, such as different acquisition models (placement, rental, lease, etc.) and the availability of other financial rebates and options from manufacturers. The incremental cost-effectiveness ratio (ICER) was estimated as incremental cost per QALY change for each pairwise comparison. Cost inputs were drawn from published literature. One-way deterministic sensitivity analysis and probabilistic sensitivity analysis were performed to test the robustness of model results. A scenario analysis with 5-year time horizon was tested.

3 Results

cTHA was associated with estimated savings of $1,595 and $949 per patient compared to rTHA and mTHA, respectively (Table 1). Results also showed a slight QALY gain of approximately 0.001 compared to both rTHA and mTHA (Table 1). Results indicated that cTHA was the 'dominant' strategy, i.e. reducing costs and slightly increasing QALYs, compared to both alternative techniques. Compared to rTHA, per-patient cost saving using cTHA was largely attributed to savings in OR time (47%). While cTHA minimally increased OR time cost compared to mTHA, per-patient saving was the most strongly attributed to differences in length of stay. Deterministic sensitivity analysis showed that model cost results were the most sensitive to changes in length of stay and 3-month readmission/revision rates. Probabilistic sensitivity analysis indicated that cTHA was cost saving in 100% of the 1,000 simulations compared to both rTHA and mTHA, indicating the robustness of the results to changes in input parameters (Figure 1). 5-year time-horizon scenario analysis results showed similar QALY gains and increased cost savings ($2,125 vs. rTHA, $1,447 vs. mTHA).

	Group		
Per-Patient Outcomes	**cTHA**	**rTHA**	**mTHA**
Total Costs ($)	11,061	12,657	12,011
Length of Stay	4,960	5,411	5,765
OR Time	5,617	6,362	5,511
Readmissions and Revisions	484	884	735
Cost Difference ($)	-	1,595	949
QALYs	0.9201	0.9188	0.9192
QALY Difference	-	-0.0013	-0.0009
ICER ($/QALY)	-	Dominant	Dominant

Table 1: Per-patient cost and quality of life outcomes.

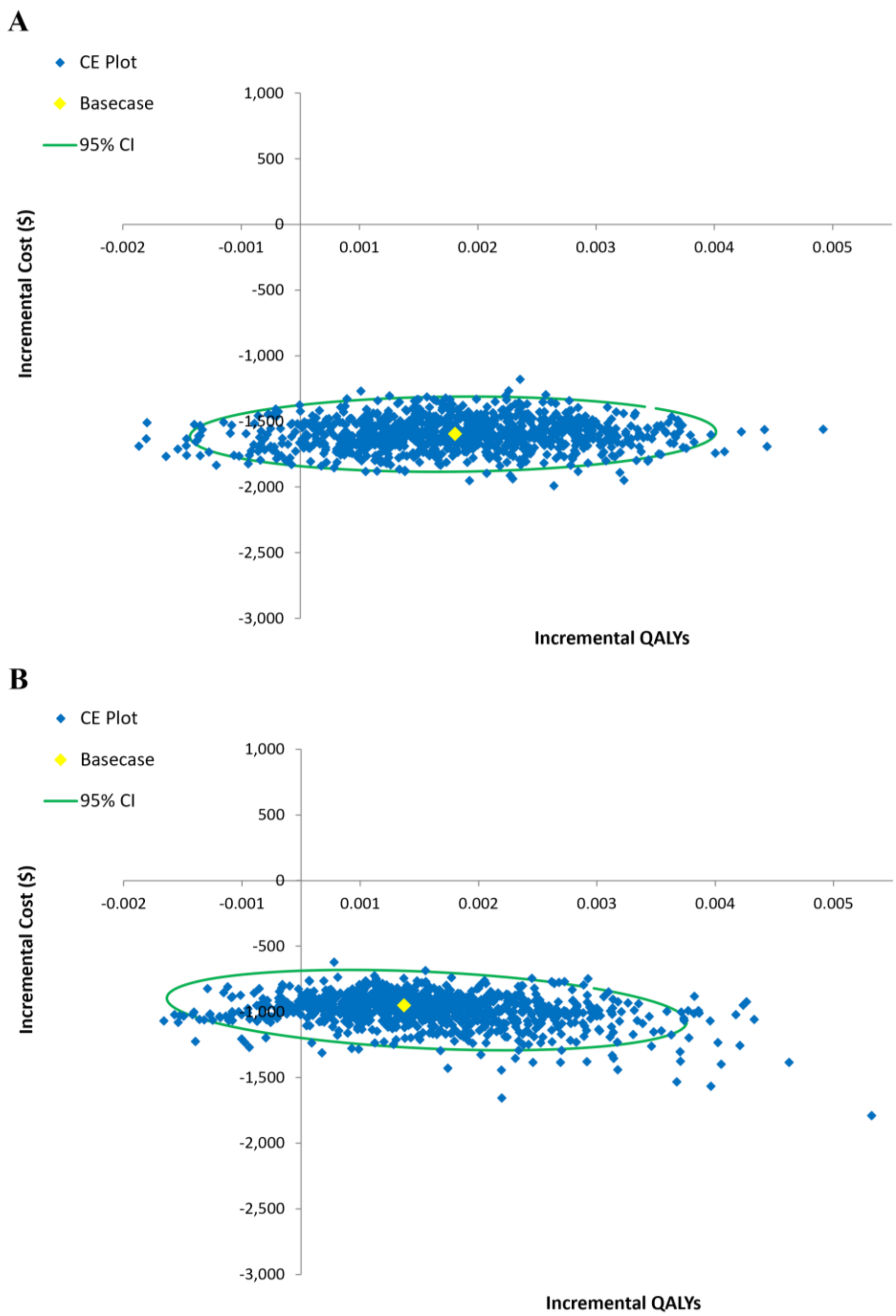

Figure 1: Probabilistic sensitivity analyses: (**A**) cTHA vs rTHA, (**B**) cTHA vs mTHA.

4 Discussion and Conclusions

Using cTHA showed cost savings in addition to a slight improvement in QoL compared to robotic-assisted and manual THA. Several previously published studies investigated the impact of using computer-assisted navigation and robotic technology on patient clinical outcomes (O'Leary, et al., 2022; Goodell, Ellis, Kokobun, Wilson, & Kollmorgen, 2022; Chung, Bin Hazzaa, Hakim, & Zywiel, 2024), and the cost-effectiveness of such enabling technologies compared to manual technique (Li, et al., 2022). However, this study is the first to investigate the impact of computer-assisted fluoroscopic navigation, compared to manual and robotic techniques. Our study results aligned with previously published studies which showed computer-assisted navigation is cost-effective compared to manual technique (Li, et al., 2022), while underscoring the incremental cost-saving benefits compared to the robotic technology for primary THA.

This study has some limitations. Analysis time horizon was 1 year due to the limited availability of inputs beyond 1-year follow-up, though we included a 5-year scenario analysis based on assumption to assess results during a longer time horizon. Results showed minimal QALY gains, and further clinical studies should assess meaningful functional improvements for patients. However, study results are informative regarding the cost burden. This study did not specifically include the cost of enabling technologies, due to the significant variability in acquisition models and cost structures, though it provides useful insights to physicians and healthcare decision makers to compare the technologies in their healthcare setting.

In conclusion, the results of this study suggest cTHA as the preferred strategy for primary THA mainly due to its impact on downstream cost savings incurred by reductions in OR time and readmissions/revisions rates.

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