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Commentary: Recovery Time and Success: A Comparative Study of Robotic and Manual Total Hip Arthroplasty Outcomes

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Introduction

Total hip arthroplasty (THA) is a well-established procedure that has significantly improved the quality of life for patients suffering from end-stage hip osteoarthritis and other debilitating hip conditions[1]. Over the past few decades, robotic-assisted THA (rTHA) utilization has grown significantly, with projections suggesting that rTHA may comprise up to two-thirds of all THA procedures by 2030[2,3]. Thus, these advancements in surgical techniques have led to an ongoing debate between traditional manual THA (mTHA) and rTHA. Manual THA depends heavily on the surgeon’s expertise, experience, and tactile feedback for accurate component placement[4-6]. In contrast, rTHA incorporates computer-guided precision, detailed preoperative planning, and real-time intraoperative adjustments to optimize component alignment, minimize variability, and potentially improve long-term outcomes[7-9]. Despite these theoretical advantages, current comparative studies between mTHA and rTHA have produced mixed findings regarding clinical superiority[7,10-12].

The growing adoption of robotic technology in orthopedic surgery has sparked important discussions around its clinical benefits, cost-effectiveness, and impact on patient recovery. While rTHA offers the promise of enhanced precision, it remains uncertain whether this translates into meaningful improvements in outcomes, particularly in terms of recovery time and overall procedural success. In our original article, “Recovery Time and Success: A Comparative Study of Robotic and Manual Total Hip Arthroplasty Outcomes”[13], we examined these questions by comparing the two surgical techniques in terms of both the achievement of minimally clinically important difference (MCID) and the time required to reach MCID in a cohort of 1,364 THAs (Table 1 and Figure 1). To minimize confounding between the cohorts, propensity score matching was employed and was calculated based on age, sex, body mass index, and Charlson comorbidity index. While we did not apply formal correction for multiple comparisons, we limited our analyses to clinically relevant endpoints to reduce the risk of Type I error. This commentary aims to contextualize the key findings of our article, with a focus on (1) the effect of robotic THA on recovery time, (2) whether increased surgical precision leads to improved clinical outcomes, and (3) the economic implications of incorporating robotic technology into routine practice.

Table 1: Demographic Information Manual and Robotic Total Hip Arthroplasty (THA) Patients

Characteristic	Overall THA (N = 1,364)	Manual THA (N = 1,023)	Robotic THA (N = 341)	*P*-value
Age (year)	65 ± 10.2	65 ± 10.0	65 ± 10.8	0.82
Sex (%)				0.51
Women	772 (56.6)	579 (56.6)	193 (56.6)	
Men	592 (43.4)	444 (43.4)	148 (43.4)	
BMI	28.7 ± 5.5	28.6 ± 5.3	28.9 ± 5.9	0.43
Charlson Comorbidity Index	1.3 ± 1.6	1.3 ± 1.6	1.3 ± 1.6	0.99
Surgical Approach (%)				0.023
Posterior	789 (57.8)	611 (59.7)	178 (52.2)	
Anterior	531 (38.9)	377 (36.9)	154 (45.2)	
Lateral	44 (3.2)	35 (3.4)	9 (2.6)	
Length of stay (days)	1.9 ± 1.4	2.0 ± 1.5	1.7 ± 1.2	< 0.001
Discharge disposition (%)				0.53
Home	1,276 (93.5)	961 (93.9)	315 (92.4)	
Skilled Nursing Facility	64 (4.7)	46 (4.5)	18 (5.3)	
Rehab Facility	24 (1.8)	16 (1.6)	8 (2.3)	
Indicated for Hip Dysplasia (%)	18 (1.3)	12 (1.2)	6 (1.8)	0.41

Bold indicates statistically significant (*P* < 0.05).
Continuous variables are expressed as the mean and standard deviation.
Categorical variables are expressed as the number of patients with the percentage in parentheses.

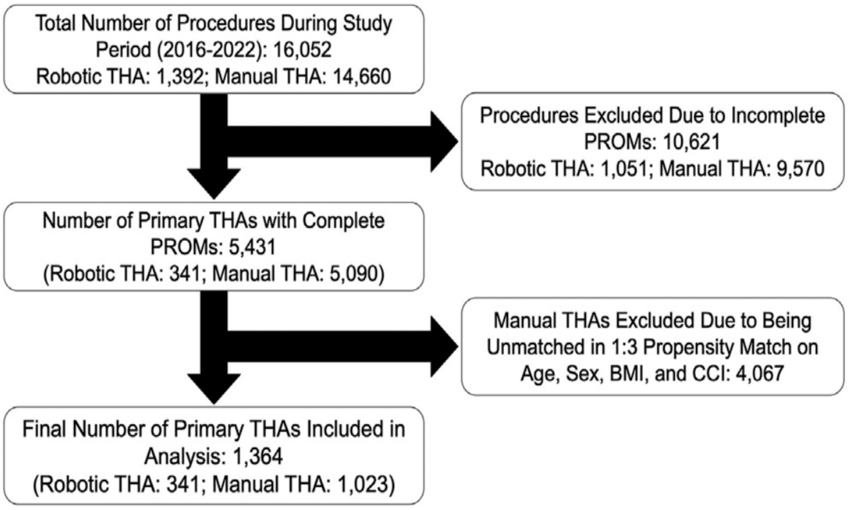

Figure 1: Flow chart of patient inclusion and exclusion.
BMI, Body Mass Index; CCI, Charlson Comorbidity Index; PROMIS, Patient-Reported Outcomes Measurement; THA, Total Hip Arthroplasty.

Robotic THA and Recovery Time: Is Faster Always Better?

Our study found that rTHA may accelerate early recovery, as evidenced by a faster time to achieve MCID for the Hip Disability and Osteoarthritis Outcome Score - Physical Function Shortform (HOOS-PS) (0.67 versus 1.0 months, P < 0.001) (Figure 2). Furthermore, our article also showed earlier achievement of other milestones such as length of stay, consistent with prior studies[14] (1.7 ± 1.2 versus 2.0 ± 1.5, P < 0.001). However, these findings should be interpreted in a broader context, as a larger percentage of mTHA patients ultimately achieved MCID for Patient-Reported Outcomes Measurement Information System (PROMIS) Global Physical (84.1 versus 79.8%, P = 0.003) and HOOS-PS (60.0 versus 44.9%, P < 0.001) (Table 2). This paradox, faster early recovery in rTHA but lower overall MCID attainment, may reflect differences in patient expectations, surgical technique, or patient selection. Notably, the rTHA cohort had a higher proportion of anterior approaches, which may have contributed to the minimized soft-tissue disruption[15]. Our results support existing literature suggesting that less soft tissue trauma associated with the anterior approach may lead to decreased postoperative pain and inflammation, resulting in earlier mobilization[16-18]. As a result, its higher use in the rTHA cohort introduces potential bias that may confound interpretation of the modest benefits in early recovery. Still, the clinical importance of these short-term improvements remains inconclusive and future studies should investigate whether early gains from rTHA lead to sustained functional benefit or greater cost-effectiveness.

To achieve optimal outcomes, surgeons must weigh short-term functional gains against lasting improvements in function, taking into consideration patient-specific factors such as preoperative activity level and patient expectations when deciding which surgical approach and technique[19]. While rTHA shows promise in reducing variability in recovery, its long-term advantages over

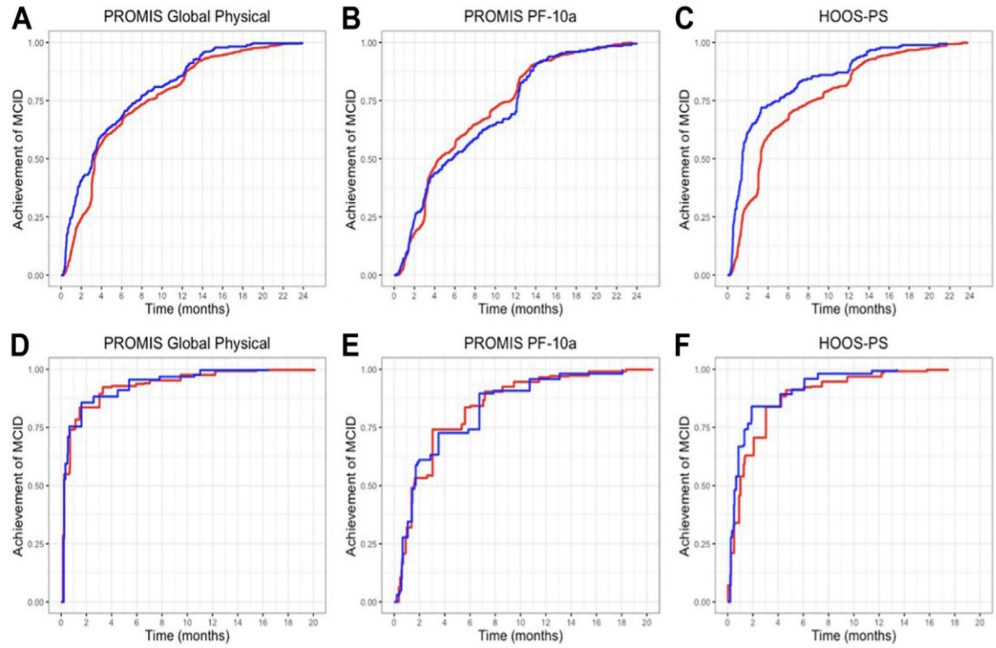

Figure 2: Comparing time to achieve MCID between rTHA and mTHA without interval censoring (A-C) and with interval-censoring (D-F). A) PROMIS Global Physical: rTHA achieved MCID significantly faster in 3.10 months versus 3.50 months for mTHA (*P* < 0.001). B) PROMIS PF-10a: rTHA achieved MCID in 5.80 months versus 5.00 months for mTHA (*P* = 0.83). C) HOOS-PS: rTHA achieved MCID significantly faster in 1.50 months versus 3.30 months for mTHA (*P* < 0.001). D) PROMIS Global Physical with interval-censoring: rTHA achieved MCID in 0.24 months versus 0.70 months for mTHA (*P* = 0.18). E) PROMIS PF-10a with interval-censoring: rTHA achieved MCID in 1.60 months versus 3.03 months for mTHA (*P* = 0.73). F) HOOS-PS with interval-censoring: rTHA achieved MCID significantly faster in 0.67 months versus 1.00 months for mTHA (*P* < 0.001). HOOS-PS, Hip Disability and Osteoarthritis Outcome Score-Physical Function Short Form; MCID, Minimal Clinically Important Difference; mTHA, Manual Total Hip Arthroplasty; PF-10a, Physical Function Short Form 10a; PROMIS, Patient-Reported Outcomes Measurement Information System; rTHA, Robotic Total Hip Arthroplasty; THA, Total Hip Arthroplasty.

Table 2: Comparison of PROMs and MCID Achievement Rates Between Robotic and Manual THA Patients

Characteristic	Overall THA (N = 1,364)	Manual THA (N = 1,023)	Robotic THA (N = 341)	*P*-value
Preop Score[a]				
PROMIS Global Physical	41.1 ± 7.6	41.2 ± 7.5	40.7 ± 7.9	0.31
PROMIS PF-10a	35.8 ± 5.6	35.9 ± 5.5	35.5 ± 5.6	0.27
HOOS-PS	58.2 ± 16.3	58.3 ± 16.3	57.9 ± 16.4	0.72
Achieved MCID (%)[b]				
PROMIS Global Physical	N = 1,327	N = 988	N = 339	0.003
Mean Follow-Up: 1.79 years	1,132 (83.0)	860 (84.1)	272 (79.8)	
PROMIS PF-10a	N = 1,278	N = 947	N = 331	0.085
Mean Follow-Up: 1.78 years	790 (57.9)	599 (58.6)	191 (56.0)	
HOOS-PS	N = 1,169	N = 886	N = 283	< 0.001
Mean Follow-Up: 1.78 years	767 (56.2)	614 (60.0)	153 (44.9)	

[a]Values displayed refer to mean ± standard deviation
[b]The binary outcome of the achievement of the MCID by the end of the study period, based on the available PROM data.
Values are given as mean ± SD or n (%).
Bold values indicate statistical significance (*P* < 0.05).
HOOS-PS, hip disability and osteoarthritis outcome score-physical function short form; PF-10a, physical function short form 10a; PROMIS, patient-reported outcomes measurement information system; THA, total hip arthroplasty

mTHA remain uncertain. Faster early recovery is appealing to both patients and surgeons, but the real-world relevance of a few days' shorter hospital stay or slightly earlier MCID achievement is debatable.

Does Surgical Precision Guarantee Better Clinical Outcomes?

Robotic-assisted THA is often promoted for its ability to achieve highly accurate component positioning and reduce variability in alignment[20]. Studies have demonstrated that rTHA can enhance the accuracy of cup positioning compared to mTHA[9,21]. In theory, improved implant positioning should lead to better hip biomechanics, lower wear rates, and reduced complications such as dislocations or aseptic loosening. However, the key question remains: Does this enhanced precision consistently translate into better clinical outcomes?

While rTHA's precision may appeal to surgeons, evidence linking improved accuracy with superior PROMs remains inconsistent[22]. This raises questions about the utility of enhanced alignment when measurable gains are not observed. Precision may offer the greatest benefit in select cases, such as acetabular deformity or hip dysplasia[23]. Enhanced precision may also improve cup placement accuracy in overweight and obese patients[24]. These advantages are most pronounced when combined with optimized rehabilitation protocols and alignment with patient expectations. This study informs adoption of rTHA and supports nuanced counseling for patients prioritizing faster recovery or when rTHA may offer technical advantages over mTHA. It should be acknowledged that in our original study, HOOS-PS and PROMIS Global Physical were sufficiently powered, but our analysis of PROMIS PF-10a may have been underpowered.

Although studies have reported improved radiological outcomes following rTHA, as indicated by higher rates of cup placement in the Lewinnek safe zone, the long-term benefit remains to be elucidated[7,25,26]. Additionally, several studies have suggested that rTHA is associated with lower dislocation rates likely attributed to improved cup placement[27,28]. In contrast, mTHA has demonstrated excellent implant longevity and clinical outcomes beyond 15 years[29-31]. Therefore, it is important to consider that if well performed mTHAs already achieve high success rates, the incremental benefit of rTHA may be marginal.

Furthermore, the use of rTHA may introduce potential risks such as haptic boundary errors and registration inaccuracies from the overreliance on imaging over intraoperative judgment. While robotic systems enhance reproducibility, precision alone does not ensure better outcomes. A successful THA still depends on clinical judgment, soft tissue management, and individualized care. Future improvements in robotic technology, such as more advanced intraoperative guidance for setting the femoral anteversion, may add further nuance to this question[32].

Cost, Accessibility, and Practical Considerations

At present, one key disadvantage of rTHA is the higher cost compared to mTHA, however, if this increased cost is associated with improved long-term outcomes requires further investigation[33-36]. For many healthcare institutions, the high purchase costs, maintenance fees, and additional supply and personnel costs linked to increased operative time associated with rTHA may outweigh the potential for reduced complications that have been reported in the literature[37-39]. Institutions, particularly those that are not high-resource academic centers, must evaluate these factors carefully, considering real-world practical implications.

In our study, all rTHA procedures were completed using the Mako Total Hip robot (Stryker Corp., Mahwah, New Jersey), which offers CT-based 3D models, haptic feedback, and real-time intraoperative leg length data. While the Mako Total Hip robot is the most used system in the United States, there are other robots such as the ROSA system (Zimmer-Biomet, Warsaw, Indiana) and CORI (Smith & Nephew, Watford, UK) that are currently used in practice[40]. It remains to be determined if there are differences in outcomes based on the technology used, as ROSA relies on preoperative radiographs and CORI utilizes intraoperative "smart mapping" technology without preoperative images.

Another consideration with regards to rTHA is the associated learning curve for surgeons. Previous studies have shed light on this topic and estimate a modest learning curve of 12-17 cases being associated with increased operative time and accuracy of acetabular component placement improving with experience[41,42]. This suggests that adoption of rTHA may temporarily impact operative efficiency, and the relatively short learning curve allows most surgeons to quickly gain proficiency. However, even for high volume surgeons, robotic assistance can still be associated with longer and costlier procedures[43]. In our study, the rTHA cohort consisted of surgeons with a median experience of 5 years compared to 13 years in the mTHA cohort, potentially impacting our results as surgeon experience, age, and volume have been shown to impact MCID achievement[43]. Future research may investigate this question to offer additional understanding of surgeon characteristics and modifiable factors that will lead to maximizing patient and economic value of rTHA procedures. Concurrently, this will allow for enhanced preoperative counseling and equip surgeons with information they can use to address patient perceptions of rTHA[45-47].

Conclusion

As rTHA adoption increases, our study adds nuance to the conversation. Robotic assistance may reduce variability and modestly improve early recovery, but mTHA showed a higher overall rate of MCID. While rTHA offers appealing precision, its long-term superiority and cost-effectiveness remain uncertain. Given mTHA's proven success, it is unclear whether robotics represent true innovation or incremental progress. Future research should focus on long-term outcomes, implant longevity, and value-based impact.

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