EPiC Series in Health Sciences
Volume 7, 2024, Pages 172–180
Proceedings of The 24th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

Fluoroscopy-based Robotic-assisted Total Hip Arthroplasty Resulted in Greater Improvements in Hip-specific Outcome Measures at One-year Compared to CT-based Robotic-assisted Technique

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Abstract

Introduction: Most of the literature on robotic-assisted total hip arthroplasty (THA) outcomes is derived from a single computerized tomography-based robotic (CT-RTHA) platform. The purpose of this study was to compare one-year patient reported outcome measures (PROMs) between a novel, fluoroscopy-based, robotic-assisted (FL-RTHA) system and a CT-RTHA system.

Materials and methods: A review of 85 consecutive FL-RTHA and 125 consecutive CT-RTHA was conducted. All cases were performed via a direct anterior approach by one of two surgeons, during the same time period, for a pre-operative diagnosis of osteoarthritis, avascular necrosis, or rheumatoid arthritis. Outcomes included one-year post-operative Veterans RAND-12 (VR-12) Physical (PCS)/Mental (MCS), Hip Disability and

Osteoarthritis Outcome (HOOS) Pain/Physical Function (PS)/Joint Replacement (JR), and University of California Los Angeles (UCLA) Activity scores. The primary comparative endpoint was the magnitude of improvements between pre- and post-operative scores.

Results: Patients in the FL-RTHA cohort had lower pre-operative VR-12 PCS, HOOS Pain, HOOS-PS, HOOS-JR, and UCLA Activity scores compared to patients in the CT-RTHA cohort. Patients in the FL-RTHA cohort reported significantly greater improvements in HOOS-PS scores (-41.54 vs. -36.55; p=0.028) than patients in the CT-RTHA cohort. Both cohorts experienced similar rates of post-operative complications requiring reoperation/revision surgery (FL-RTHA 0% vs. CT-RTHA 3.20%; p=0.095).

Conclusions: Both robotic techniques produced similar excellent PROM scores at one-year post-operative. However, use of the novel, fluoroscopy-based robotic system resulted in greater improvements in HOOS-PS at one-year relative to the computerized tomography-based robotic technique.

1 Introduction:

The use of robotic assistance for THA (RA-THA) has been associated with improved acetabular cup placement accuracy and precision [1-4] and reduced rates of dislocation [5] relative to manual unassisted technique. While this should theoretically result in improved post-operative patient reported outcome measures (PROMs), the literature remains largely inconclusive in this regard [6-15]. Notably, a majority of published studies have derived PROM outcomes from one design of a computerized tomography-based robotic platform (CT-RTHA) [6-15].

In August 2021, a novel fluoroscopy-based robotic-assistance system for THA (FL-RTHA) received United States Food and Drug Administration approval for use in direct anterior approach (DAA) total hip arthroplasty (THA). The purpose of the present investigation was to compare the one-year PROMs of patients who underwent DAA THA using a FL-RTHA technique, to those who underwent this same procedure through a CT-RTHA technique.

2 Methods:

A comparative cohort analysis of a consecutive series of 85 FL-RTHA and 125 CT-RTHA patients who underwent primary, unilateral, cementless DAA THA during the same time period, for a pre-operative diagnosis of osteoarthritis, avascular necrosis, or rheumatoid arthritis, was conducted. All procedures were performed by one of two high-volume, fellowship-trained arthroplasty surgeons who have been in practice for at least 10 years and use the DAA for THA. All FL-RTHA procedures utilized the Zimmer ROSA® Hip System (Zimmer Biomet, Warsaw IN, USA), while CT-RTHA procedures were performed with the Stryker MAKO® Hip System (Stryker, Kalamazoo MI, USA). Exclusion criteria included revision THA, THA using a posterior approach or cemented component fixation, incomplete pre-operative PROM questionnaires, and patient age <18 years. Institutional Review Board (IRB) approval was obtained prior to the initiation of this investigation.

Patient PROM questionnaires were collected pre-operatively (during pre-operative visits), and one-year post-operatively from the index procedure date. The primary outcome variables for this investigation were one-year post-operative PROMs, and the change in patient PROMs from pre-operative baseline to one-year post-operative (Δ PROMs). Three validated, standardized instruments were used for the collection of PROMs: 1) Veterans RAND 12 (VR-12), Physical (PCS), and Mental (MCS) Component scores [16]; 2) Hip Disability and Osteoarthritis Outcome Score (HOOS) [Pain, Physical Function (PS), and Joint replacement (JR) scores] [17]; and 3) University of California, Los Angeles (UCLA) Activity Scale score [18]. Secondary outcome variables for this investigation were major post-operative complications, defined as those which required reoperation and/or revision surgery.

Based on the previously reported Minimum Clinically Important Difference (MCID) for the HOOS JR, this study fulfilled the minimum cohort size of 60 patients per treatment arm to adequately detect an 18-point difference in HOOS JR scores, at 80% statistical power [19].

3 Results:

Cohorts had similar distributions of patient Body Mass Index (BMI), procedure laterality, and pre-operative American Society of Anesthesiologists (ASA) scores. Patients in the FL-RTHA cohort were younger in age (59.47 vs. 65.84 years), more predominantly male (55.29% vs. 37.60%), less predominantly Caucasian (81.18% vs. 96.80%), and less likely to have a pre-operative diagnosis of osteoarthritis (84.70% vs. 98.40%) compared to patients in the CT-RTHA cohort.

Cohorts had similar pre-operative VR-12 MCS scores. However, patients in the FL-RTHA cohort had lower pre-operative baseline scores VR-12 PCS (26.32 vs. 29.83), HOOS Pain (31.73 vs. 41.32), HOOS-PS (53.95 vs. 44.56), HOOS JR (36.97 vs. 45.65), and UCLA Activity (3.76 vs. 4.39) scores relative to patients in the CT-RTHA cohort. When assessing one-year post-operative PROMs, cohorts had similar scores for all instruments apart from VR-12 MCS, which was lower among patients in the FL-RTHA cohort (50.19 vs. 54.65). The complete comparisons of pre- and post-operative PROMs are provided in **Table 1**.

Average Δ PROMs were similar for all PROM instruments apart from HOOS-PS. Patients in the FL-RTHA cohort experienced an additional benefit of 4.99 points in the HOOS-PS score relative to patients in the CT-RTHA cohort (-41.54 vs. -36.55) which reached statistical significance. Comparisons of all Δ PROMs are provided in **Table 2**.

Overall, major complication rates were similar between the FL-RTHA and CT-RTHA cohorts (0% vs. 3.20%; $p=0.095$).

4 Discussion:

A majority of the existing literature on PROMs following RA-THA has been derived from the use of CT-based robotic techniques, generally with a single platform, leaving little guidance for practitioners who use alternative robotic systems [6-15].

The first significant finding of this investigation was that patients in the FL-RTHA cohort experienced an additional 4.99 points of improvement in Δ PROMs for HOOS-PS. The FL-RTHA platform relies on standard intra-operative fluoroscopic images for pin-less digital navigation [4], while the CT-RTHA platform requires navigation tracker pin insertion, including use of separate incision(s), and physical probe contact with bony points around the acetabular rim [20]. By foregoing the need for pin insertion and physical probe contact, the FL-RTHA system may present a more precise workflow, which could theoretically improve procedure outcomes [1-4].

The second significant finding of our study was that the FL-RTHA and CT-RTHA cohorts experienced similar one-year post-operative PROM scores apart from the VR-12 MCS, as well as similar rates of post-operative complication. This result is significant, given the relative pre-operative PROM deficits reported by FL-RTHA patients, as well as the demographic dissimilarities between cohorts. Racial minorities historically experience diminished PROMs relative to Caucasians [21,22], and patients with a pre-operative diagnosis of avascular necrosis report inferior pain outcomes following THA compared to patients with osteoarthritis [23]. The post-operative scores obtained from this study are similar to those previously reported in the CT-RTHA literature [8-11,24]. The authors hypothesize that the discrepancy in post-operative evaluations of mental health may have been attributable to the demographic dissimilarities that existed between cohorts.

5 Conclusion:

The findings of this study suggest that patients who undergo primary, direct anterior approach THA with the assistance of a novel, fluoroscopy-based robot may experience greater improvements in post-operative HOOS-PS scores at one year, relative to patients who undergo this same procedure using a CT-based robotic alternative.

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Table 1: A comparison of average pre- and post-operative patient-reported outcome measures (PROMs) between cohorts.

	Treatment		
	FL-RTHA	**CT-RTHA**	**p value**
Pre-operative	n = 85	n = 125	
VR-12 PCS	26.32 ± 9.19	29.83 ± 8.59	**0.011***
VR-12 MCS	48.19 ± 13.08	51.43 ± 11.62	0.078
HOOS Pain	31.73 ± 20.89	41.32 ± 16.35	**0.001***
HOOS-PS	53.95 ± 23.39	44.56 ± 15.75	**< 0.001***
HOOS-JR	36.97 ± 19.36	45.65 ± 13.58	**< 0.001***
UCLA Activity	3.76 ± 2.04	4.39 ± 1.81	**0.005***
Post-operative	n = 62	n = 107	
VR-12 PCS	45.21 ± 11.25	46.41 ± 8.94	0.795
VR-12 MCS	50.19 ± 12.42	54.65 ± 8.51	**0.032***
HOOS Pain	84.23 ± 22.12	90.74 ± 12.28	0.363
HOOS-PS	12.76 ± 18.86	7.69 ± 9.65	0.726
HOOS-JR	83.57 ± 19.27	88.59 ± 11.59	0.289
UCLA Activity	5.46 ± 2.18	5.65 ± 1.88	0.447

*Note: FL-RTHA = Fluoroscopy-based Robotic-assisted Total Hip Arthroplasty; CT-RTHA = Computerized Tomography-based Robotic-assisted Total Hip Arthroplasty; VR-12 = Veterans RAND 12; PCS = Physical Component Score; MCS = Mental Component Score; HOOS = Hip Disability and Osteoarthritis Outcome Score; PS = Physical Function Shortform; JR = Joint Replacement; UCLA = University of California, Los Angeles; * = p<0.05*

Table 2: A comparison of the change in patient-reported outcome measures (PROM) scores (Δ PROMs) between the pre-operative baseline and one-year post-operative timepoints.

	Treatment		
	FL-RTHA	**CT-RTHA**	**p value**
	n = 62	n = 104	
VR-12 PCS	18.93 ± 12.86	16.92 ± 10.81	0.159
VR-12 MCS	0.75 ± 14.03	3.20 ± 9.82	0.233
HOOS Pain	54.56 ± 26.27	50.49 ± 18.37	0.139
HOOS-PS	-41.54 ± 25.08	-36.55 ± 17.66	**0.028***
HOOS-JR	46.41 ± 21.52	42.31 ± 16.34	0.219
UCLA Activity	1.77 ± 2.07	1.32 ± 1.88	0.271

*Note: FL-RTHA = Fluoroscopy-based Robotic-assisted Total Hip Arthroplasty; CT-RTHA = Computerized Tomography-based Robotic-assisted Total Hip Arthroplasty; VR-12 = Veterans RAND 12; PCS = Physical Component Score; MCS = Mental Component Score; HOOS = Hip Disability and Osteoarthritis Outcome Score; PS = Physical Function Shortform; JR = Joint Replacement; UCLA = University of California, Los Angeles; * = p<0.05*