

Robotic Assisted Versus Manual Total Hip Arthroplasty Using the Direct Anterior Approach: A Comparative Analysis of Operative Time and Radiation Exposure

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INTRODUCTION: The direct anterior approach (DAA) for hip arthroplasty (THA) continues to increase in popularity. Fluoroscopic guidance is commonly employed to assess bone preparation and component positioning during manual DAA procedures. Robotic-assisted THA (RA-THA) potentially offers enhanced accuracy in component placement with less fluoroscopy; however, the added technology may increase surgical time. Surgical times and radiation exposure are important factors to consider, in adopting additional technologies for DAA. This study aims to compare surgical times and radiation exposure between RA-THA and manual THA (M-THA) to assess differences in operating room workflow associated in DAA.

METHODS: This was a prospective study at a single-high volume institution from January to March 2025. Consecutive DAA THAs performed by six clinical fellows under the supervision of four attending orthopedic surgeons were included. A total of 50 cases were analyzed: 25 RA-THAs using a CT-based robotic platform and 25 M-THAs performed with fluoroscopic guidance. For each procedure, total operative time and thirteen distinct intraoperative steps were individually recorded, including four key robotic-specific steps. Radiation exposure was assessed by collecting intraoperative fluoroscopy in the manual cohort as well as preoperative CT scan data in the robotic cohort. This approach enabled a comprehensive evaluation that distinguished between radiation exposure affecting the operating room staff and the overall radiation burden experienced by the patient. T-tests and Chi-square or Fisher's exact tests evaluated the impact of robotic assistance on surgical times and radiation exposure. Assumptions of normality and variance were assessed using Shapiro-Wilk and Levene's tests.

RESULTS: RA-THA was associated with a modest increase in total operative time (79.2 ± 11.9 minutes) compared to M-THA (71.2 ± 12.4 minutes; $P < 0.05$). Total preoperative set-up time was significantly longer in RA-THA, averaging 14.3 ± 2.1 minutes, compared to 10.6 ± 2.5 minutes in M-THA ($p < 0.001$), driven by the addition of the robotic device setup, which required 4.3 ± 1.3 minutes. The initial phase (incision & exposure) was significantly longer in RA-THA compared to the M-THA (11.4 ± 2.2 vs. 8.2 ± 1.9 minutes; $P < 0.001$), with the addition of pin placement contributing 2.1 ± 0.8 minutes to the overall duration. Leg length and offset registration did not significantly prolong the femoral neck cut phase in RA-THA. However, acetabular registration significantly extended the acetabular preparation time in RA-THA (6.3 ± 1.8 minutes) compared to M-THA (3.3 ± 2.1 minutes; $p < 0.001$). However, reaming time was significantly reduced in the RA-THA group (1.6 ± 0.7 minutes) versus M-THA (3.2 ± 1.2 minutes; $P < 0.001$), as well as during acetabular shell impaction (1.5 ± 0.6 vs. 3.1 ± 1.6 minutes; $P < 0.001$). Finally, fluoroscopy time and radiation exposure to the surgical team were significantly lower in RA-THA (0.3 ± 0.3 mGy vs. 2.6 ± 1.4 mGy; $P < 0.001$), although patient exposure increased by 857.9 ± 75.1 mGy due to the preoperative CT requirement.

DISCUSSION AND CONCLUSION: RA-THA via the DAA modestly prolongs operative time but confers notable efficiency gains during key surgical phases: reaming & shell-impaction. RA-THA also significantly reduces intraoperative radiation exposure for OR personnel. These benefits, however, are accompanied by an increase in patient radiation exposure due to preoperative CT imaging. These findings highlight the need to balance procedural precision and staff safety with operative duration and patient-specific radiation burden when adopting robotic systems in THA.

Figure 1. Intraoperative Time Comparison Between RA-THA and M-THA. With Highlighted Robotic-Specific Steps

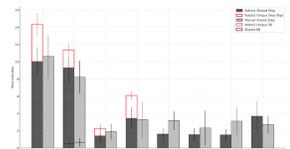


Table 1. Demographic differences between M-THA and RA-THA groups

Characteristic	Manual THA (n=25)	Robotic THA (n=25)	P Value
Age (Years)	66.3 ± 10.5	65.8 ± 12.1	>0.05
Body mass index (kg/m ²)	28 ± 4.4	27.5 ± 5.2	>0.05
Side of intervention			>0.05
Right	12 (48%)	14 (56%)	
Left	13 (52%)	11 (44%)	
Gender			>0.05
Male	9 (36%)	7 (28%)	
Female	16 (64%)	18 (72%)	

Table 2. Stepwise comparison of Intraoperative Times Between M-THA and RA-THA

Surgical Step	Manual THA (n=25)	Robotic THA (n=25)	P-value
Operations Room Setup	10.62 ± 2.49	10.05 ± 1.87	
Robotic Device Setup	0 ± 0	4.29 ± 1.34	
Total Preoperative Setup Time	10.62 ± 2.49	14.33 ± 2.07	<0.001
Pin Placement	0 ± 0	2.09 ± 0.83	
Incision	0.67 ± 0.48	0.52 ± 0.38	
Exposure	7.56 ± 1.91	8.79 ± 1.26	
Initial Phase (pin placement + incision + exposure)	8.23 ± 1.97	11.41 ± 2.17	<0.001
Leg Length & Offset Registration	0 ± 0	0.85 ± 0.43	
Femoral Neck Cut	1.93 ± 0.91	1.43 ± 0.68	
Total Femoral Neck Cut Phase (Registration + Cut)	1.93 ± 0.91	2.28 ± 0.87	>0.05
Acetabular Registration	0 ± 0	2.62 ± 0.83	
Total Acetabular Preparation (registration + preparation)	3.27 ± 2.12	3.46 ± 1.28	
Reaming	2.2 ± 1.1	1.62 ± 0.72	<0.001
Cup Preparation	2.3 ± 1.2	1.57 ± 1.11	<0.05
Acetabular Shell Impaction	2.13 ± 1.6	1.54 ± 0.65	<0.001
Final Cup Position (prep + imp)	2.7 ± 1.08	3.71 ± 1.27	
Cup Placement (prep + impact + fixation)	8.14 ± 2.02	6.82 ± 2.64	>0.05
Total Surgical Time	71.2 ± 12.4	79.24 ± 11.9	<0.05

Table 3. Differences in radiation exposure between M-THA and RA-THA

Variable	Manual THA	Robotic THA	P-value
Patients undergoing intraoperative fluoroscopy	25 (100%)	13 (52%)	<0.001
Fluoroscopy time	21,884.56	4,064.3	<0.001
Number of intra-operative images	32,081.53	3,776.4	<0.001
Intraoperative radiation dose (mGy)	2,641.39	0.334626	<0.001
Patients undergoing preoperative CT	0 (0%)	25 (100%)	<0.001
CT (mGy)	0	872,687.14	<0.001
Cumulative radiation dose to patients (mGy)	2,641.39	873,020.53	<0.001
Cumulative radiation dose to operating room staff (mGy)	2,641.39	0.334626	<0.001