Impact of Institutional Surgical Volume on the Operative Learning Curve for Robotic-Assisted Total Hip Arthroplasty: An Analysis from the American Joint Replacement Registry

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INTRODUCTION: The adoption of robotic-assisted total hip arthroplasty (RA-THA) has increased in recent years. However, while surgeon-level learning curves have been studied, the influence of institutional surgical volume on the RA-THA learning curve remains underexplored. Understanding how volume impacts learning and efficiency for centers overall can guide resource allocation and training models. This study aimed to evaluate how institutional RA-THA case volume affects the learning curve and surgical efficiency across U.S. centers.

METHODS: A retrospective review of elective primary RA-THA procedures was conducted using the American Joint Replacement Registry from January 1, 2017, to December 31, 2024. Institutions were categorized based on median monthly RA-THA volume into low (<5/month), medium (5–11/month), and high (≥12/month) groups. Operative time trends were analyzed using a centered linear weighted moving average (window=50 cases), and learning curve maturation was assessed using cumulative sum (CUSUM) analysis. Efficiency was defined as achieving a median operative time ≤90 minutes. Statistical comparisons were made using Chi-square, one-way ANOVA, or Kruskal-Wallis testing as appropriate, with significance set at $p<0.05$.

RESULTS: A total of 46,805 RA-THA procedures across 305 institutions were analyzed. Patient demographics across different institution categories are summarized in table 1. Low-volume centers (69.2%) had a mean operative time of 102.8 ± 40.4 minutes, medium-volume centers (20.0%) 90.9 ± 36.0 minutes, and high-volume centers (10.8%) 85.0 ± 48.0 minutes (figure 1). Using the centered linear weighted moving average, we could observe a consistent downtrend in operative time across all three groups. CUSUM analysis revealed high-volume institutions achieved and sustained efficient sub-90-minute operation times after approximately 300 cases, compared to 550 cases in medium-volume centers. Low-volume institutions showed modest improvements but did not maintain performance below the 90-minute benchmark (figure 1). Overall, 78.8% of high-volume institutions achieved operative efficiency of less than 90 minutes, compared to 50.8% of medium- and 38.9% of low-volume institutions.

DISCUSSION AND CONCLUSION: Institutional volume plays a critical role in shaping the RA-THA operative learning curve. Higher-volume centers reached the efficiency threshold of 90 minutes with fewer cases and maintained shorter operative times more consistently. These findings suggest that institutional processes—such as team familiarity, streamlined workflows, and staff training—amplify learning beyond the individual surgeon level. While previous studies reported proficiency at 12–35 cases per surgeon, our results show that institutional proficiency requires 300–550 cases, emphasizing the complexity of system-wide learning. Low-volume centers struggled to sustain efficient operative times. Moreover, nearly 21% of high-volume institutions still failed to reach the target, suggesting that volume alone is necessary but not sufficient alone to achieve overall surgical time of less than 90 minutes. Future research should explore the relationship between operative time and other success metrics such as complications, implant alignment, and long-term outcomes.

	1. Low volume (N=8,680)	2. Medium volume (N=12,979)	3. High volume (N=25,146)	Total (N=46,805)	P Value
Age					
Mean (SD)	65.68 (11.33)	67.06 (10.83)	66.99 (10.76)	66.77 (10.90)	<0.001
Body Mass Index					
Mean (SD)	30.40 (6.25)	30.17 (6.15)	29.85 (6.25)	30.05 (6.23)	<0.001
N (N Missing)	7922 (758)	12102 (877)	22223 (2923)	42247 (4558)	
Hospital Length of Stay					
Mean (SD)	1.35 (1.54)	1.09 (1.65)	1.18 (1.41)	1.19 (1.51)	<0.001
N (N Missing)	8479 (201)	12570 (409)	23973 (1173)	45022 (1783)	
Charlson Comorbidity Index					
0-2	4,193 (48.31%)	5,892 (45.40%)	12,064 (47.98%)	22,149 (47.32%)	<0.001
3-4	3,323 (38.28%)	5,262 (40.54%)	10,215 (40.62%)	18,800 (40.17%)	
5+	1,164 (13.41%)	1,825 (14.06%)	2,867 (11.40%)	5,856 (12.51%)	
Sex					
Female	4,692 (54.07%)	7,155 (55.82%)	13,958 (55.53%)	25,805 (55.13%)	0.027
Male	3,985 (45.93%)	5,662 (44.18%)	11,179 (44.47%)	20,826 (44.50%)	
Missing	3 (0.03%)	162 (1.25%)	9 (0.04%)	174 (0.37%)	
Race/Ethnicity					
Non-Hispanic White	5,979 (77.22%)	9,746 (82.14%)	20,253 (90.23%)	35,978 (76.87%)	<0.001
Non-Hispanic Black	644 (8.32%)	711 (5.99%)	960 (4.28%)	2,315 (4.95%)	
Hispanic	436 (5.63%)	604 (5.09%)	543 (2.42%)	1,583 (3.38%)	
Other	684 (8.83%)	804 (6.78%)	691 (3.08%)	2,179 (4.66%)	
Missing	937 (10.79%)	1,114 (8.58%)	2,699 (10.73%)	4,750 (10.15%)	

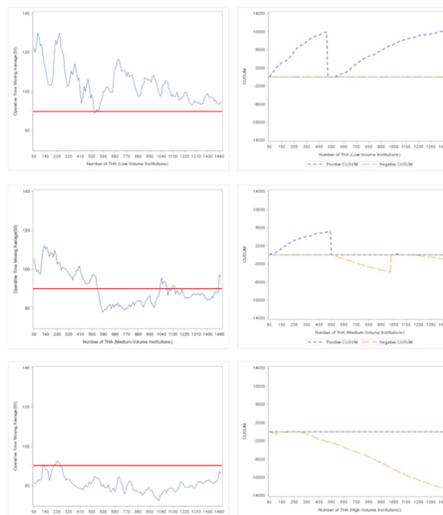Table 1. Patient demographics by institution classification

Figure 1. Learning curve analysis of Robotic Assisted THA surgery using operation time running average (min) (Left) and CUSUM plots (Right).