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Kamal Bali was involved in conception, study design, and manuscript editing and provided content expert input.

Thomas J Wood was involved in study design, manuscript editing, and provided content expert input.

ABSTRACT

Purpose: To characterise the learning curve of robotic-assisted total hip arthroplasty (RA-THA) using the direct anterior approach (DAA) through operative time and radiographic accuracy, and to compare acetabular component positioning with a contemporaneous manual THA (M-THA) cohort.

Methods: This was a retrospective review of 85 primary THA procedures (45 RA-THA, 40 M-THA) performed by a single high-volume surgeon using the DAA. The learning curve was assessed by operative time and by deviation of achieved from planned cup position across sequential cases. Acetabular inclination and anteversion were measured by two independent assessors, and component position was compared between groups and against the pre-operative plan. The mean age was 63.1 ± 13.1 years, 62.4% of patients were women, and mean body mass index was 28.4 ± 5.8.).

Results: No learning curve was identified for operative time or radiographic accuracy. Mean inclination did not differ between groups (42.1 ± 4.2° vs 42.9 ± 7.4°, $P = .535$). Inclination variance was significantly lower following RA-THA ($P = .007$), with more cups within the Lewinnek zone (73.3% vs 50.0%, $P = .043$). Anteversion did not differ between groups ($P = .490$). Achieved inclination closely reproduced the plan. Achieved anteversion was 9° greater than planned.

Conclusion: RA-THA using the DAA performed by an experienced surgeon demonstrated significantly lower variance in acetabular inclination than manual THA, without a demonstrable learning curve. High-quality, prospectively designed studies are warranted to define the clinical value of robotic-assisted THA.

Keywords: robotic-assisted, total hip arthroplasty, learning curve, component positioning, radiographic outcomes

LOE: III

INTRODUCTION

Robotic-assisted total hip arthroplasty (RA-THA) has been adopted with increasing frequency [1]. One of the notable benefits of RA-THA is improved reproducibility of acetabular component positioning and restoration of native hip biomechanics [2]. Malposition of the acetabular component has long been associated with instability, impingement, accelerated wear, and revision [3, 4]. Robotic assistance addresses the variability inherent to manual technique, with comparative studies demonstrating more accurate cup placement and fewer positioning outliers than manual THA [5, 6]. Recent systematic reviews confirm these findings, including superior radiographic accuracy and lower complication rates with robotic assistance [7, 8]. Nonetheless, drawbacks of RA-THA include longer operative time and no consistent improvement in short-term clinical outcome scores. Improved radiographic accuracy has therefore not reliably translated into demonstrable clinical benefit, and the value of robotic assistance during early adoption remains unclear.

The safe adoption of any new surgical technology depends on characterising its learning curve, both in operative efficiency and in the preservation of component accuracy. For RA-THA, the available evidence suggests that operative time and workflow improve with experience, whereas radiographic accuracy is often maintained from the outset [7]. Early single-surgeon series described a decrease in acetabular outliers and operative time with accumulating experience [9]. Subsequent cumulative summation analyses have reported learning curves ranging from 12 to 35 cases for operative time and workflow, depending on the metric assessed, without a corresponding learning curve for cup positioning accuracy [7, 10, 11]. This pattern is in keeping with the more mature robotic total knee arthroplasty literature, in which the learning curve is achieved within a small number of cases while implant-positioning accuracy is

preserved throughout [12]. Despite these findings, the literature surrounding the RA-THA learning curve remains limited and is further compounded with respect to the robotic platform and surgical approach utilised. Of particular interest is the direct anterior approach (DAA), which continues to gain adoption and presents with several benefits, including decreased soft-tissue violation, decreased post-operative pain, and potentially decreased dislocation risk [13, 14].

Given the increasing adoption of RA-THA and the limited evidence pertaining to both its learning curve and its use with the DAA, understanding the learning curve in this context is of particular clinical relevance. The purpose of this study was to characterise the learning curve of robotic-assisted direct anterior THA at a single institution, assessed through operative time and radiographic accuracy, and to compare component positioning with a contemporaneous manual THA cohort.

METHODS

This study was conducted with approval from the local Research Ethics Board (HiREB ID XX) and is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [15].

Study Design and Setting

This was a retrospective cohort study of patients who underwent primary, elective total hip arthroplasty (THA) by a single, high-volume arthroplasty surgeon (XX) at a Canadian academic institution (XX) between August and December 2024, during the immediate period following acquisition of a robotic-assisted surgical platform. Patients undergoing RA-THA using the MAKO system (Stryker, Kalamazoo, Michigan, United States) were compared with patients undergoing manual THA (M-THA) via a direct anterior approach over the same period. Patient demographics, operative data, and radiographic measurements were obtained through a de-identified retrospective chart review.

Participants

Eligible patients had undergone primary, elective DAA THA via either the robotic-assisted platform or manual technique, with available follow-up between six weeks and six months postoperatively. Exclusion criteria were simultaneous bilateral THA, revision THA, and complex primary THA (including but not limited to prior osteotomy, retained hardware, or severe dysplasia). Staged bilateral procedures were eligible and were included as independent hips. Consecutive RA-THA and M-THA patients treated over the study period were included. Patients undergoing elective THA using approaches other than the DAA were also excluded. Missing data were handled by pairwise deletion.

Variables

Baseline demographic variables included age, sex, and body mass index (BMI). Operative variables included procedure time (defined as the interval from procedure start to procedure completion) and operative side. Radiographic variables comprised acetabular component inclination, acetabular component anteversion, and leg-length discrepancy (LLD), each measured pre- and post-operatively as described below.

Radiographic Assessment

All radiographic measurements were performed independently by two assessors (XX and XX) on post-operative radiographs, and the mean of the two measurements was used for analysis. Acetabular inclination and LLD were measured on the anteroposterior pelvic radiograph. Acetabular anteversion was measured on the cross-table lateral radiograph using the method described by Woo and Morrey [16]. Inter-rater reliability was assessed using the intraclass correlation coefficient (ICC), with two-way random-effects, absolute-agreement, single-measure specification. For robotic cases, planned (target) component position and LLD were derived from the pre-operative computed tomography (CT)-based surgical plan.

Outcome Measures

The primary outcome was the learning curve for RA-THA using the DAA. This was assessed in two ways: operative time and radiographic accuracy across sequential cases. Cases were ordered by robotic case number, which corresponded to chronological sequence. A cumulative summation (CUSUM) analysis was used to identify whether operative time stabilised across the case series, indicating transition from the learning phase to proficiency. Radiographic accuracy was assessed by the deviation of achieved from planned component position across sequential cases.

Secondary outcomes were radiographic component positioning and planned-versus-achieved component position (RA-THA only). Acetabular component position was assessed against the Lewinnek safe zone [4], defined as inclination 40° ± 5° and anteversion 15° ± 5. Planned-versus-achieved accuracy was expressed as the mean signed deviation (achieved − planned) and the mean absolute deviation between the achieved and planned values.

Statistical Methods

Continuous variables are presented as means with standard deviations (SD) or medians with interquartile range (IQR) for normally and non-normally distributed data, respectively. Categorical variables are presented as proportions. Distributional normality was assessed using the Shapiro-Wilk test. Differences in normally distributed continuous variables were assessed using the two-sample t-test, and non-normally distributed variables using the Mann-Whitney U test. Equality of variance was assessed using the Levene test. Categorical variables were compared using the Fisher exact test. Inter-rater reliability was categorized a priori as poor (< 0.50), moderate (0.50–0.75), good (0.75–0.90), or excellent (> 0.90) [17]. All analyses were performed using Python v3.12.3 (Python Software Foundation, Beaverton, Oregon, United States). A value of $P < .05$ was considered statistically significant.

RESULTS

Descriptive Data

A total of 85 primary THA procedures were included for final analysis, comprising 45 RA-THA and 40 M-THA. The mean age across all patients was 63.1 ± 13.1 years, 53 patients (62.4%) were women, and the mean BMI was 28.4 ± 5.8. Age and sex did not significantly differ between groups, whereas BMI was significantly higher in the M-THA group (30.1 ± 6.2 vs 26.9 ± 5.1, $P = .013$, Table 1). Operative time was significantly longer following RA-THA (median 60 minutes [IQR 52 to 69] vs 40 minutes [IQR 34 to 50], $P < .001$). Inter-rater reliability was excellent across all radiographic measures, with intraclass correlation coefficients of 0.94 for inclination, 0.97 for anteversion, and 0.94 for post-operative LLD.

Learning Curve

Operative time did not demonstrate a learning curve across the RA-THA case series. Mean operative time was 61.5 ± 13.6 minutes and remained stable from the first case. Cumulative summation analysis demonstrated no sustained change-point (Figure 1), and operative time did not significantly differ between the first and second halves of the series (61.3 vs 61.8 minutes, $P = .90$).

Radiographic accuracy similarly did not improve across the case series. The absolute deviation between achieved and planned values did not significantly change across sequential cases for inclination, anteversion, or LLD (all $P > .05$).

Component Positioning and Leg Length Discrepancy

Mean acetabular inclination did not significantly differ between groups ($P = .535$), whereas the variance in inclination was significantly lower following RA-THA ($P = .007$, Table 2). A greater proportion of RA-THA cups fell within the Lewinnek inclination safe zone (73.3%

vs 50.0%, $P = .043$). Mean anteversion did not significantly differ between groups ($P = .490$), nor did anteversion safe-zone attainment ($P = 1.000$) or attainment of both parameters within the safe zone ($P = .717$). Achieved leg-length discrepancy did not differ between groups ($P = .383$).

Planned Versus Achieved Component Position

Among the 44 RA-THA cases with available pre-operative plan data, the mean absolute deviation between achieved and planned values was 3.4° for inclination and 5.1 mm for LLD, with signed deviations of +1.4° and +2.3 mm, respectively (Table 3). The mean absolute deviation for anteversion was 9.8°, with a signed deviation of +8.8° (achieved 28.2 ± 9.3° vs planned 19.4 ± 3.1°).

DISCUSSION

This study evaluated the early adoption of robotic-assisted THA using the direct anterior approach at a single institution, assessed through the learning curve and the accuracy of acetabular component positioning. No learning curve was identified for operative time, and radiographic accuracy did not improve across the case series. Acetabular inclination did not differ in mean value between the robotic-assisted and manual groups, although the variance in inclination was significantly lower following RA-THA. This finding was not observed for anteversion. Achieved cup position closely reproduced the pre-operative plan for inclination, with a small and unbiased deviation in leg-length discrepancy, whereas achieved anteversion was systematically greater than planned. The absence of a learning curve warrants interpretation in the context of the existing literature.

Prior work has consistently shown that the accuracy of robotic cup positioning is preserved from the earliest cases, even where a learning curve for operative time is present. Kayani et al. identified a 12-case learning curve for operative time and team confidence during RA-THA, without a corresponding learning curve for the accuracy of cup inclination, anteversion, or leg-length correction [11]. A comparable pattern has been reported in robotic total knee arthroplasty, in which workflow integration was achieved within seven cases while implant-positioning accuracy was preserved throughout [12]. Our findings extend this pattern to both operative time and radiographic accuracy. This contrasts with earlier adoption series describing a decrease in operative time and acetabular outliers with accumulating experience [9], and with more recent work describing a short operative-time curve of approximately 12 cases [10]. Our result therefore sits at the shorter end of the reported spectrum. A potential explanation is the experience of the operating surgeon. A high-volume, fellowship-trained arthroplasty

surgeon may transfer existing manual expertise directly to the robotic workflow. This possibility is supported by the robotic knee literature, in which an experienced team was noted to blunt the apparent learning curve [12]. The direct anterior approach may also contribute to this phenomenon. This interpretation must be tempered, as the approach carries an independent learning curve of more than 50 cases before revision risk stabilises [18], and its contribution cannot be isolated within the present design.

With respect to component positioning, mean acetabular inclination did not differ between groups, whereas the variance in inclination was significantly reduced following RA-THA. The principal benefit of robotic assistance lies in reducing the dispersion of cup positioning and the frequency of outliers, rather than in shifting the average position. This is consistent with comparative studies demonstrating superior safe-zone attainment and fewer outliers with robotic assistance than with manual technique [6, 19], and with a systematic review reporting equivalent mean inclination and anteversion but higher rates of safe-zone positioning with robotic THA [20]. The clinical relevance of reduced variance is supported by registry data identifying cup malposition, rather than mean orientation, as the driver of dislocation risk [3, 21]. This precision advantage did not extend to anteversion, for which neither the mean nor the variance differed between groups. A similar dissociation was observed in a matched-pair analysis in which robotic assistance improved inclination accuracy and reproducibility without a corresponding benefit for version [22], suggesting that anteversion remains more difficult to control and measure reliably even with robotic guidance.

The comparison of achieved with planned component position further characterises positioning accuracy during early adoption. Inclination was reproduced accurately relative to the plan, consistent with cadaveric work demonstrating close robotic reproduction of planned cup

orientation and leg length [23]. The mean absolute deviation in leg-length discrepancy was 5.1 mm, but the near-zero signed deviation indicates scatter rather than systematic error, which is the more clinically meaningful consideration given the effect of limb-length inequality on function and satisfaction [24]. Achieved anteversion, by contrast, was systematically greater than planned by approximately 9°. This offset may reflect measurement and reference-frame factors rather than true malpositioning. Acetabular orientation can be defined operatively, radiographically, or anatomically, and these definitions differ systematically [25]. The pre-operative plan is derived from a computed tomography reference frame, whereas achieved anteversion was measured radiographically, and radiographic anteversion is considerably more sensitive than inclination to measurement method and can diverge substantially from computed tomography [26]. A contributory surgical mechanism cannot be entirely excluded, although no direct evidence supports one, and the robotic platform is designed to maintain the planned orientation during impaction [22]. As the pre-operative plan is CT-based, a post-operative CT would provide the most accurate measure of achieved version and allow a direct comparison within the same reference frame. The observed offset in acetabular anteversion may therefore be correctable through measurement standardisation, and this warrants further evaluation.

This study has several limitations. Its retrospective design and single-surgeon, single-institution cohort limit generalisability and introduce the potential for selection bias, and the groups were not matched, with a significant difference in body mass index between them. The findings reflect the practice of an experienced arthroplasty surgeon, and the absence of a learning curve may not be reproducible among surgeons earlier in their training or with lower operative volumes, a factor known to influence cup malposition risk [3]. The sample size is modest, and the study was not powered to detect differences in infrequent outcomes. More specifically,

Complications following robotic-assisted THA are relatively low and have not been shown to differ between robotic and manual techniques [27], and the present cohort was not adequately powered to assess these outcomes. Achieved anteversion was measured radiographically rather than against the intraoperative robotic value, and plain radiographs are inherently less reliable than computed tomography for version measurement, which is the parameter that behaved atypically in this study [26] . Finally, the analysis was confined to radiographic and operative outcomes during early adoption and did not include patient-reported or longer-term clinical outcomes, which will be necessary to determine whether the observed accuracy translates into clinical benefit. Taken together, these limitations underscore that the present findings are hypothesis-generating. A prospective, multi-surgeon randomised controlled trial, incorporating patient-reported and longer-term outcomes, is ultimately warranted to define the true value of robotic-assisted THA during early adoption and to establish whether improved radiographic precision confers meaningful clinical benefit.

CONCLUSION

Robotic-assisted THA using the direct anterior approach demonstrated no learning curve in operative time or radiographic accuracy across the early adoption period. Acetabular inclination was placed with significantly lower variance than manual THA, reflecting improved precision, whereas anteversion did not differ between groups. These findings, limited by the retrospective single-surgeon design, warrant a prospective multi-surgeon randomised controlled trial to determine whether this improved precision confers meaningful clinical benefit.

FIGURE AND TABLE LEGENDS

Table 1 Patient demographics and baseline characteristics

Table 2 Acetabular component positioning and leg length discrepancy

Table 3 Planned versus achieved component position following RA-THA (n = 44)

Fig. 1 Operative time across the robotic-assisted THA case series with cumulative summation (CUSUM) analysis

REFERENCES

1. Korber S, Antonios JK, Sivasundaram L, et al (2021) Utilization of technology-assisted total hip arthroplasty in the United States from 2005 to 2018. Arthroplast Today 12:36–44. https://doi.org/10.1016/j.artd.2021.08.020

2. Kanawade V, Dorr LD, Banks SA, et al (2015) Precision of robotic guided instrumentation for acetabular component positioning. J Arthroplasty 30:392–397. https://doi.org/10.1016/j.arth.2014.10.021

3. Callanan MC, Jarrett B, Bragdon CR, et al (2011) The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. Clin Orthop Relat Res 469:319–329. https://doi.org/10.1007/s11999-010-1487-1

4. Lewinnek GE, Lewis JL, Tarr R, et al (1978) Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am 60:217–220

5. Domb BG, Redmond JM, Louis SS, et al (2015) Accuracy of Component Positioning in 1980 Total Hip Arthroplasties: A Comparative Analysis by Surgical Technique and Mode of Guidance. J Arthroplasty 30:2208–2218. https://doi.org/10.1016/j.arth.2015.06.059

6. Domb BG, El Bitar YF, Sadik AY, et al (2014) Comparison of robotic-assisted and conventional acetabular cup placement in THA: a matched-pair controlled study. Clin Orthop Relat Res 472:329–336. https://doi.org/10.1007/s11999-013-3253-7

7. Ng N, Gaston P, Simpson PM, et al (2021) Robotic arm-assisted versus manual total hip arthroplasty : a systematic review and meta-analysis. Bone Joint J 103-B:1009–1020. https://doi.org/10.1302/0301-620X.103B6.BJJ-2020-1856.R1

8. Bensa A, Pagliazzi G, Miele A, et al (2025) Robotic-Assisted Total Hip Arthroplasty Provides Greater Implant Placement Accuracy and Lower Complication Rates, but Not Superior Clinical Results Compared to the Conventional Manual Approach: A Systematic Review and Meta-Analysis. J Arthroplasty 40:1921–1931. https://doi.org/10.1016/j.arth.2024.12.014

9. Redmond JM, Gupta A, Hammarstedt JE, et al (2015) The learning curve associated with robotic-assisted total hip arthroplasty. J Arthroplasty 30:50–54. https://doi.org/10.1016/j.arth.2014.08.003

10. Buchan GBJ, Hecht CJ, Lawrie CM, et al (2023) The learning curve for a novel, fluoroscopy-based robotic-assisted total hip arthroplasty system. Int J Med Robot 19:e2518. https://doi.org/10.1002/rcs.2518

11. Kayani B, Konan S, Huq SS, et al (2021) The learning curve of robotic-arm assisted acetabular cup positioning during total hip arthroplasty. Hip Int 31:311–319. https://doi.org/10.1177/1120700019889334

12. Kayani B, Konan S, Huq SS, et al (2019) Robotic-arm assisted total knee arthroplasty has a learning curve of seven cases for integration into the surgical workflow but no learning curve effect for accuracy of implant positioning. Knee Surg Sports Traumatol Arthrosc 27:1132–1141. https://doi.org/10.1007/s00167-018-5138-5

13. Wang Z, Hou J-Z, Wu C-H, et al (2018) A systematic review and meta-analysis of direct anterior approach versus posterior approach in total hip arthroplasty. J Orthop Surg Res 13:229. https://doi.org/10.1186/s13018-018-0929-4

14. Ang JJM, Onggo JR, Stokes CM, Ambikaipalan A (2023) Comparing direct anterior approach versus posterior approach or lateral approach in total hip arthroplasty: a systematic review and meta-analysis. Eur J Orthop Surg Traumatol 33:2773–2792. https://doi.org/10.1007/s00590-023-03528-8

15. von Elm E, Altman DG, Egger M, et al (2007) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Epidemiology 18:800–804. https://doi.org/10.1097/EDE.0b013e3181577654

16. Woo RY, Morrey BF (1982) Dislocations after total hip arthroplasty. J Bone Joint Surg Am 64:1295–1306

17. Koo TK, Li MY (2016) A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med 15:155–163. https://doi.org/10.1016/j.jcm.2016.02.012

18. de Steiger RN, Lorimer M, Solomon M (2015) What is the learning curve for the anterior approach for total hip arthroplasty? Clin Orthop Relat Res 473:3860–3866. https://doi.org/10.1007/s11999-015-4565-6

19. Clement ND, Gaston P, Bell A, et al (2021) Robotic arm-assisted versus manual total hip arthroplasty. Bone Joint Res 10:22–30. https://doi.org/10.1302/2046-3758.101.BJR-2020-0161.R1

20. Emara AK, Samuel LT, Acuña AJ, et al (2021) Robotic-arm assisted versus manual total hip arthroplasty: Systematic review and meta-analysis of radiographic accuracy. Int J Med Robot 17:e2332. https://doi.org/10.1002/rcs.2332

21. Biedermann R, Tonin A, Krismer M, et al (2005) Reducing the risk of dislocation after total hip arthroplasty: the effect of orientation of the acetabular component. J Bone Joint Surg Br 87:762–769. https://doi.org/10.1302/0301-620X.87B6.14745

22. Kamath AF, Durbhakula SM, Pickering T, et al (2022) Improved accuracy and fewer outliers with a novel CT-free robotic THA system in matched-pair analysis with manual THA. J Robot Surg 16:905–913. https://doi.org/10.1007/s11701-021-01315-3

23. Nawabi DH, Conditt MA, Ranawat AS, et al (2013) Haptically guided robotic technology in total hip arthroplasty: a cadaveric investigation. Proc Inst Mech Eng H 227:302–309. https://doi.org/10.1177/0954411912468540

24. Flecher X, Ollivier M, Argenson JN (2016) Lower limb length and offset in total hip arthroplasty. Orthop Traumatol Surg Res 102:S9-20. https://doi.org/10.1016/j.otsr.2015.11.001

25. Murray DW (1993) The definition and measurement of acetabular orientation. J Bone Joint Surg Br 75:228–232. https://doi.org/10.1302/0301-620X.75B2.8444942

26. Westacott DJ, McArthur J, King RJ, Foguet P (2013) Assessment of cup orientation in hip resurfacing: a comparison of TraumaCad and computed tomography. J Orthop Surg Res 8:8. https://doi.org/10.1186/1749-799X-8-8

27. Zhang Y, Li S, Liu X, et al (2026) Robot-Assisted Total Hip Arthroplasty Versus Conventional Surgery in Terms of Surgical Accuracy, Function, Trauma, and Complications: A Prospective, Multicenter, Parallel-Group, Open-Label Randomized Controlled Trial. J Arthroplasty 41:841-848.e1. https://doi.org/10.1016/j.arth.2025.07.029

346 **Table 1** Patient demographics and baseline characteristics

Characteristic	**RA-THA (n = 45)**	**M-THA (n = 40)**	**P**
Age, years (mean ± SD)	62.2 ± 12.4	64.0 ± 13.9	.540
Women, n (%)	32 (71.1)	21 (52.5)	.116
BMI (mean ± SD)	26.9 ± 5.1	30.1 ± 6.2	.013
Operative time, minutes (median [IQR])	60 [52–69]	40 [34–50]	<.001

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348 BMI, body mass index; IQR, interquartile range; SD, standard deviation; RA-THA, robotic-
349 assisted total hip arthroplasty; M-THA, manual total hip arthroplasty
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Table 2 Acetabular component positioning and leg length discrepancy

Parameter	**RA-THA (n = 45)**	**M-THA (n = 40)**	**P ***	**P †**
Acetabular Component Positioning				
Inclination, ° (mean ± SD)	42.1 ± 4.2	42.9 ± 7.4	.535	.007
Within Lewinnek zone (35-45°), n (%)	33 (73.3)	20 (50.0)	.043	—
Anteversion, ° (mean ± SD)	28.4 ± 9.3	27.0 ± 8.9	.490	.834
Within Lewinnek zone (10–20°), n (%)	10 (22.2)	8 (20.0)	1.000	—
Both parameters within zone, n (%)	5 (11.1)	3 (7.5)	.717	—
Leg Length Discrepancy, mm (mean ± SD)	2.9 ± 5.5	3.5 ± 4.7	0.383	0.209

SD, standard deviation; RA-THA, robotic-assisted total hip arthroplasty; M-THA, manual total hip arthroplasty

* Means were compared with the two-sample t-test, and proportions with the Fisher exact test.

† Equality of variance was compared with the Levene test.

Table 3 Planned versus achieved component position following RA-THA (n = 44)

Parameter	Planned, mean ± SD	Achieved, mean ± SD	Mean deviation	Mean absolute deviation
Post-operative LLD, mm	0.8 ± 4.1	3.2 ± 5.5	+2.3	5.1
Inclination, °	40.7 ± 1.3	42.1 ± 4.2	+1.4	3.4
Anteversion, ° ‡	19.4 ± 3.1	28.2 ± 9.3	+8.8	9.8

LLD, leg-length discrepancy; SD, standard deviation; RA-THA, robotic-assisted total hip arthroplasty

‡ Achieved anteversion was measured with the Woo and Morrey cross-table method.

Fig. 1 Operative time across the robotic-assisted THA case series with cumulative summation (CUSUM) analysis

