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# Impact of Prior Robotic Experience on the Adaptation Curve for Robotic Rectal Cancer Surgery Using the hinotori Surgical Robot System: A Two-Surgeon CUSUM Analysis

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**Research Article**

**Keywords:** hinotori, rectal cancer, robotic surgery, adaptation curve, learning curve, CUSUM

**Posted Date:** May 4th, 2026

**DOI:** https://doi.org/10.21203/rs.3.rs-9489968/v1

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**Additional Declarations:** No competing interests reported.

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**Version of Record:** A version of this preprint was published at Journal of Robotic Surgery on June 1st, 2026. See the published version at https://doi.org/10.1007/s11701-026-03538-8.

## Abstract

# Background

The adaptation process for robotic rectal cancer surgery following the introduction of the hinotori Surgical Robot System is poorly defined, particularly among surgeons with varying levels of prior robotic experience.

# Methods

We retrospectively analyzed 55 consecutive hinotori-assisted rectal cancer operations performed by two surgeons at a single institution. Before hinotori introduction, Surgeon A had performed 262 da Vinci rectal cases and Surgeon B had performed 90. Total operative time, cockpit time, and setup time were evaluated chronologically using cumulative sum (CUSUM) analysis.

# Results

Twenty-six patients underwent surgery by Surgeon A and 29 by Surgeon B. For Surgeon A, setup time showed a turning point at case 11, decreasing from 29.5 min in cases 1–11 to 17.6 min in cases 12–26. In contrast, total operative time and cockpit time showed multiphasic patterns, with an early minimum at case 11 followed by secondary peaks at cases 19 and 21, respectively. For Surgeon B, setup time, cockpit time, and total operative time showed sequential turning points at cases 10, 13, and 22, respectively, each followed by a decreasing trend. Surgeon A's cohort also had shorter operative metrics.

# Conclusions

Adaptation after hinotori introduction differed according to prior robotic experience. In the more experienced surgeon, adaptation was most evident in setup efficiency. In contrast, in the less experienced surgeon, it progressed sequentially from setup to cockpit performance and then to overall operative time. Prior robotic experience should be considered when interpreting early outcomes after transition to a new platform.

## Introduction

With advances in medical technology, robotic surgery has become an important treatment option in colorectal surgery. In particular, rectal cancer surgery is well-suited to the technical advantages of robotic platforms because it requires precise manipulation within the confined pelvic cavity [1, 2]. The da Vinci™ surgical system was approved for clinical use by the U.S. Food and Drug Administration (FDA) in 2000 and has long dominated the field of robotic-assisted surgery [3]. Previous studies have demonstrated that robotic-assisted colorectal cancer surgery is safe and feasible, with oncological

outcomes comparable to or, in some settings, superior to those of conventional laparoscopic surgery [1, 2, 4].

Most studies on learning curves in robotic rectal surgery, however, have focused on the da Vinci platform and have shown that turning points and phase structures vary according to surgeon background, case selection, and the metrics analyzed [5–12]. Various methods, including cumulative sum (CUSUM) analysis, have been used to assess these learning curves, and operative performance has been shown to improve with accumulated experience. At the same time, prior studies have indicated that learning curves may be multiphasic and that outcome-based endpoints do not necessarily coincide with inflection points based on operative time [7–11, 13–14].

In recent years, the introduction of new robotic platforms, including the hinotori™ Surgical Robot System (hinotori), has changed the landscape of robotic surgery. Early operative performance after the introduction of a novel platform does not necessarily represent de novo acquisition of robotic skills; rather, it may reflect a mixture of platform transition, pre-existing robotic proficiency, team familiarity, and case selection. At our institution, two surgeons introduced hinotori for rectal cancer surgery after accumulating different levels of prior da Vinci experience. Surgeon A had performed more than 260 da Vinci robotic procedures, whereas Surgeon B had performed 90. This setting provides a useful opportunity to examine how prior robotic experience may modify the observable adaptation process after transition to a new platform.

In this study, we evaluated temporal changes in total operative time, cockpit time, and setup time in hinotori-assisted rectal cancer surgery using CUSUM analysis and compared adaptation patterns between two surgeons with different levels of prior da Vinci experience.

## Methods

# Study Design

A retrospective observational study was conducted at a single institution to evaluate learning curves for total operative time and cockpit time in procedures performed using the hinotori Surgical Robot System. The primary console surgeons were the two lead surgeons (Surgeon A and Surgeon B), both of whom had performed more than 100 robot-assisted colon and rectal procedures using the da Vinci system and had been certified through the Endoscopic Surgical Skill Qualification System of the Japanese Society of Endoscopic Surgery. Both surgeons participated in this study as primary operators. Before introduction of the hinotori system, their experience in da Vinci-assisted rectal cancer surgery was 262 cases for Surgeon A and 90 cases for Surgeon B.

In addition, to assess the maturity of the surgical team, setup time was measured as the interval from the start of the operation to cockpit activation. In cases requiring adhesiolysis due to a history of prior abdominal surgery, the time spent performing adhesiolysis was subtracted from the setup time.

The study period extended from January 2023 to March 2026. Of 94 consecutive patients diagnosed with rectal cancer during this period, 80 who underwent anterior resection with double-stapling technique (DST) anastomosis were eligible for inclusion. Of these, 55 consecutive cases performed by Surgeon A or Surgeon B were included in the analysis. Data for the analysis were extracted from a prospectively maintained colorectal database at our institution, which contains comprehensive clinical information on patient characteristics, preoperative assessments, surgical outcomes, and pathological findings. The present study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Fujita Health University (approval no. HM24-029).

## Patient demographics

The eligibility criteria for the use of the hinotori system in rectal cancer surgery included patients with clinical stage I–IV disease. However, because this study was conducted during the introductory phase of this novel robotic platform, patients with tumors that invaded adjacent organs extensively were excluded. In addition, to minimize procedural bias in the assessment of total operative time and cockpit time, patients undergoing intersphincteric resection, abdominoperineal resection with permanent stoma creation, or lateral lymph node dissection were excluded. Baseline patient characteristics, including age, sex, body mass index (BMI), and clinical stage, were collected to provide context for the analysis.

## hinotori Surgical Robot System

The hinotori, similar to the da Vinci system, consists of an “Operation Unit” with four robotic arms, a “Surgeon Cockpit,” and a “Monitor Cart.” In contrast to the da Vinci system, the hinotori has several distinctive features. First, it incorporates a docking-free system that allows adjustment of the instrument pivot position without requiring the port to be connected to the robotic arm, thereby ensuring adequate working space around the ports and minimizing tissue injury from excessive traction. At the same time, because of this docking-free architecture, a unique procedural step, referred to as pivot setting, is required. Second, the robotic arms have eight axes, offering enhanced flexibility and reducing interference both among the arms and between the arms and the patient’s body. In addition, the system is equipped with a monitoring function that provides an alert when potential interference is detected. Third, as of July 2024, the hinotori lacks certain advanced energy devices, including vessel sealing systems, ultrasonic coagulating shears, and a linear stapler for rectal transection.

## Operative technique

After roll-in of the Operation Unit, both groups underwent a single-docking robotic procedure using five ports for rectal mobilization, dissection, and rectal transection, followed by laparoscopic anastomosis. To compensate for the absence of advanced energy devices, the Double Bipolar Method (DBM) [15] was adopted for hinotori-assisted surgery. During the medial-to-lateral approach, Monopolar Curved Scissors were used for mobilization, enabling a wide surgical range of motion during dissection. For D3 lymph

node dissection at the root of the IMA, Maryland Bipolar Forceps (MBF) were used for dissection around vessels and nerves. When TSME was required, MBF was also used to circumferentially expose the rectal serosa in preparation for rectal transection with a linear stapler. At the end of the robotic procedure, the assistant introduced a linear stapler through the port for Arm 4 to divide the rectum. The remaining steps, including anastomosis, were completed using a conventional laparoscopic approach.

# Statistical analysis

All statistical analyses were performed using EZR version 1.68 (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria), with supplementary analyses conducted in Python. Continuous variables were expressed as medians (interquartile ranges) and compared using the Mann-Whitney U test. Categorical variables are expressed as numbers (percentages) and were compared using Fisher's exact test or the chi-square test, as appropriate. Learning curves were evaluated using the cumulative sum (CUSUM) method to assess temporal changes in surgical performance. For each surgeon and each time metric, CUSUM values were calculated as $CUSUMn = \Sigma(i = 1 \text{ to } n)(Xi - \bar{X})$, where Xi denotes the observed value for case i and $\bar{X}$ denotes the surgeon-specific mean for the corresponding metric. Separate CUSUM plots were generated for each surgeon. For patterns showing progressive improvement, a turning point was defined as an extremum followed by a sustained downward trend. When the CUSUM curve showed a non-monotonic or multiphasic pattern, local extrema and subsequent transitions were described descriptively rather than interpreted as a single definitive turning point. This analysis was used to characterize phases of adaptation for both the surgical team and the individual surgeons. Our time-based CUSUM approach aligned with previous studies of learning curves in robotic rectal surgery, while acknowledging that more complex, multidimensional, and risk-adjusted models have also been proposed [6,8–10,16].

## Results

A total of 55 consecutive patients were analyzed, including 26 cases performed by Surgeon A and 29 by Surgeon B.

Baseline characteristics are summarized in Table 1. Median BMI was significantly lower in Surgeon A's cohort than in Surgeon B's cohort (20.6 [IQR, 18.6–23.4] vs. 22.8 [IQR, 20.8–24.6] kg/m², p = 0.039), whereas other baseline variables were broadly comparable between groups.

Operative outcomes are shown in Table 2. Median total operative time was shorter in Surgeon A's cohort than in Surgeon B's cohort (214.5 [IQR, 188.5-234.5] vs. 249.0 [IQR, 214.0-317.0] min, p = 0.006), as was median cockpit time (121.5 [IQR, 109.2-140.5] vs. 153.0 [IQR, 117.0-180.0] min, p = 0.011). Median blood loss was also lower in Surgeon A's cases (10.5 [IQR, 7.2–17.5] vs. 18.0 [IQR, 10.0–30.0] mL, p = 0.029). Conversion, readmission, and reoperation were not observed in either cohort.

CUSUM findings are summarized in Table 3 and Figs. 1 and 2. For Surgeon A, setup time showed a clear turning point at case 11, with a decrease from 29.5 minutes in cases 1–11 to 17.6 minutes in cases 12–26. In contrast, total operative time and cockpit time did not show a single turning point associated with sustained improvement. Instead, both curves reached an early minimum at case 11. Subsequently, they rose again, with secondary peaks at case 19 for total operative time and case 21 for cockpit time, consistent with a multiphasic transition pattern.

For Surgeon B, setup time showed a turning point at case 10, cockpit time at case 13, and total operative time at case 22. These changes were followed by a decreasing trend, indicating staged improvement from operating-room setup to console efficiency and then to overall procedural duration.

## Discussion

The main finding of this study is that the adaptation pattern after the introduction of the hinotori differed according to prior robotic experience. In Surgeon A, who had performed more than 260 da Vinci rectal cases, the clearest change was a reduction in setup time, whereas total operative time and cockpit time did not decrease in a simple stepwise manner. This pattern is consistent with previous reports showing that highly experienced robotic surgeons do not always demonstrate an early, monotonic reduction in operative duration after adopting a new platform [5, 7, 11].

This distinction is important when interpreting early results after the introduction of a new robotic system. In a surgeon with substantial prior robotic experience, the observed changes may reflect a platform transition and workflow adjustments rather than the initial acquisition of robotic technique. Prior studies of robotic rectal surgery have likewise described multiphasic curves, plateau phases, and secondary increases associated with broader case selection or increasing procedural complexity [7–11].

The standardized use of the double bipolar method may also have influenced the present time-based adaptation curves. As described by Katsuno et al., this approach was developed as a hinotori-specific rectal dissection strategy using two bipolar instruments for coordinated traction, dissection, and hemostasis [15]. In our setting, the early reduction in setup time seen in both surgeons may therefore reflect not only increasing familiarity with the platform itself, but also gradual standardization of instrument arrangement, port use, and team workflow. For that reason, our results are best understood as an adaptation to a hinotori-based operative system rather than as pure acquisition of robotic rectal dissection skills.

For Surgeon B, the sequence of turning points suggested a more stepwise adaptation process. Setup efficiency improved first, probably reflecting increasing familiarity with docking and operating-room workflow, followed by reductions in cockpit time and, subsequently, in total operative time. This staged pattern resembles prior CUSUM-based reports in robotic colorectal and rectal surgery, in which technical familiarization precedes broader procedural efficiency [6, 10, 12, 17–19].

Differences in baseline case mix should also be taken into account. Surgeon B's cohort had a higher BMI, which may have contributed to longer operative metrics. This point underscores the need to interpret time-based curves in the context of patient selection and procedural difficulty, as emphasized in both robotic and laparoscopic learning-curve studies [11–12, 14, 16].

This study has several limitations. It was a retrospective, single-center study based on a limited number of cases. In addition, the CUSUM analysis relied on time-based metrics and was not risk-adjusted for case complexity or linked to a composite technical failure measure. Previous multidimensional and RA-CUSUM studies have shown that proficiency, as defined by operative time, may be achieved earlier than that defined by complications, oncologic quality, or composite performance indicators [8–9, 13, 16, 20].

Further studies incorporating risk-adjusted analyses, composite endpoints, and multicenter validation will be needed to determine whether the patterns observed here are reproducible in broader implementation settings, including technically demanding procedures such as intersphincteric resection and robotic lateral pelvic lymph node dissection [17–18].

# Conclusions

The adaptation pattern for hinotori-assisted rectal cancer surgery differed according to prior robotic experience. In the more experienced surgeon, adaptation was most clearly reflected by improved setup efficiency. In contrast, in the less experienced surgeon, it progressed sequentially through setup time, cockpit time, and total operative time. These findings indicate that prior robotic experience should be taken into account when interpreting early performance after transition to a new robotic platform.

# Declarations

**Previous presentation:** None

**Funding:** The authors received no specific funding for this work.

**Conflicts of interest:** Koji Morohara, Hidetoshi Katsuno, Tomoyoshi Endo, Susumu Shibasaki, Kenichi Nakamura, Kazuhiro Matsuo, Kazuki Tsujimura, Tetsuya Koide, Takashi Imanaka, Tsunekazu Hanai, and Zenichi Morise have no conflicts of interest or financial ties to disclose.

**Ethical approval:** This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Fujita Health University (approval no. HM24-029).

**Informed consent:** The requirement for written informed consent was waived owing to the retrospective nature of the study.

**Data availability:** The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Author contributions**

Koji Morohara: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing - original draft.

Hidetoshi Katsuno: Conceptualization, Methodology, Supervision, Writing - review & editing.

Tomoyoshi Endo: Data curation, Investigation, Writing - review & editing.

Susumu Shibasaki: Data curation, Investigation, Writing - review & editing.

Kenichi Nakamura: Data curation, Investigation, Writing - review & editing.

Kazuhiro Matsuo: Data curation, Investigation, Writing - review & editing.

Kazuki Tsujimura: Data curation, Investigation, Writing - review & editing.

Tetsuya Koide: Data curation, Investigation, Writing - review & editing.

Takashi Imanaka: Data curation, Investigation, Writing - review & editing.

Tsunekazu Hanai: Supervision, Writing - review & editing.

Zenichi Morise: Supervision, Project administration, Writing - review & editing.

**Disclosure**

Koji Morohara, Hidetoshi Katsuno, Tomoyoshi Endo, Susumu Shibasaki, Kenichi Nakamura, Kazuhiro Matsuo, Kazuki Tsujimura, Tetsuya Koide, Takashi Imanaka, Tsunekazu Hanai, and Zenichi Morise have no conflicts of interest or financial ties to disclose.

# References


1. Park EJ, Baik SH (2016) Robotic surgery for colon and rectal cancer. Curr Oncol Rep 18(1):5. 10.1007/s11912-015-0491-8
2. Kwak JM, Kim SH (2016) Robotic surgery for rectal cancer: an update in 2015. Cancer Res Treat 48(2):427–435. 10.4143/crt.2015.478Epub 2016 Feb 3
3. U.S. Food and Drug Administration. K050369–510(k) Premarket Notification: Intuitive Surgical da Vinci Surgical System, Model IS2000. (2005)
4. Kim CW, Baik SH (2014) Outcomes of robotic-assisted colorectal surgery compared with laparoscopic and open surgery: a systematic review. J Gastrointest Surg 18(4):816–830. 10.1007/s11605-014-2469-5Epub 2014 Feb 5
5. Akmal Y, Baek J-H, McKenzie S, Garcia-Aguilar J, Pigazzi A (2012) Robot-assisted total mesorectal excision: is there a learning curve? Surg Endosc 26(9):2471–2476. 10.1007/s00464-012-2216-5

6. Bokhari MB, Patel CB, Ramos-Valadez DI, Ragupathi M, Haas EM (2011) Learning curve for robotic-assisted laparoscopic colorectal surgery. Surg Endosc 25(3):855–860. 10.1007/s00464-010-1281-x
7. Sng KK, Hara M, Shin J-W, Yoo B-E, Yang K-S, Kim S-H (2013) The multiphasic learning curve for robot-assisted rectal surgery. Surg Endosc 27(9):3297–3307. 10.1007/s00464-013-2909-4
8. Park EJ, Kim CW, Cho MS, Baik SH, Kim DW, Min BS et al (2014) Multidimensional analyses of the learning curve of robotic low anterior resection for rectal cancer: 3-phase learning process comparison. Surg Endosc 28(10):2821–2831. 10.1007/s00464-014-3569-8
9. Kim HJ, Choi GS, Park JS, Park SY (2014) Multidimensional analysis of the learning curve for robotic total mesorectal excision for rectal cancer: lessons from a single surgeon's experience. Dis Colon Rectum 57(9):1066–1074. 10.1097/DCR.0000000000000174
10. Yamaguchi T, Kinugasa Y, Shiomi A, Sato S, Yamakawa Y, Kagawa H et al (2015) Learning curve for robotic-assisted surgery for rectal cancer: use of the cumulative sum method. Surg Endosc 29(7):1679–1685. 10.1007/s00464-014-3855-5
11. Noh GT, Han M, Hur H, Baik SH, Lee KY, Kim NK et al (2021) Impact of laparoscopic surgical experience on the learning curve of robotic rectal cancer surgery. Surg Endosc 35(10):5583–5592. 10.1007/s00464-020-08059-5
12. Coleman K, Fellner AN, Guend H (2023) Learning curve for robotic rectal cancer resection at a community-based teaching institution. J Robot Surg 17(6):3005–3012. 10.1007/s11701-023-01671-2
13. Tang B, Li T, Gao G, Shi J, Li T (2022) Learning curve of robotic-assisted total mesorectal excision for rectal cancer. Front Oncol 12:931426. 10.3389/fonc.2022.931426
14. Huang Y-M, Huang YJ, Wei P-L (2017) Outcomes of robotic versus laparoscopic surgery for mid and low rectal cancer after neoadjuvant chemoradiation therapy and the effect of learning curve. Med (Baltim) 96(40):e8171. 10.1097/MD.0000000000008171
15. Katsuno H, Morohara K, Endo T, Chikaishi Y, Kikuchi K, Nakamura K et al (2024) A new era in surgical oncology: preliminary insights into the hinotori Surgical Robot System's role in rectal surgery using the double bipolar method. World J Surg Oncol 22(1):215. 10.1186/s12957-024-03499-y
16. Tekkis PP, Senagore AJ, Delaney CP, Fazio VW (2005) Evaluation of the learning curve in laparoscopic colorectal surgery: comparison of right-sided and left-sided resections. Ann Surg 242(1):83–91. 10.1097/01.sla.0000167857.14690.68
17. Gao Y, Pan H, Ye J, Ruan H, Jiang W, Chi P et al (2024) Robotic intersphincteric resection for low rectal cancer: a cumulative sum analysis for the learning curve. Surg Today 54(11):1329–1336. 10.1007/s00595-024-02841-x
18. Zhang L, Hu C, Qin Q, Li R, Zhao J, Zhang Z et al (2024) Learning process analysis of robotic lateral pelvic lymph node dissection for local advanced rectal cancer: the CUSUM curve of 78 consecutive patients. Surg Today 54(3):220–230. 10.1007/s00595-023-02725-6
19. Aghayeva A, Baca B (2020) Robotic sphincter-saving rectal cancer surgery: a learning curve analysis. Int J Med Robot 16(4):e2112. 10.1002/rcs.2112

20. Liu H, Hao Q, Wang X, Cheng M, Qiu F, Zhou B (2025) Clinical efficacy and learning curve analysis of 101 robotic-assisted Warshaw procedures: a retrospective study. Surg Endosc 39(7):4177–4185. 10.1007/s00464-025-11790-6

# Tables

Table 1
Baseline characteristics by surgeon

| Variable | Surgeon A (n = 26) | Surgeon B (n = 29) | P value |
|---|---|---|---|
| Age, years | 66.5 (58.0-72.8) | 67.0 (62.0–74.0) | 0.473 |
| Male sex | 9 (34.6%) | 16 (55.2%) | 0.209 |
| BMI, kg/m² | 20.6 (18.6–23.4) | 22.8 (20.8–24.6) | 0.039 |
| Previous abdominal surgery | 10 (38.5%) | 13 (44.8%) | 0.838 |
| Tumor location, Rb | 4 (15.4%) | 7 (24.1%) | 0.510 |
| Multiple primary cancers | 2 (7.7%) | 1 (3.4%) | 0.598 |
| cT3/4 | 17 (65.4%) | 20 (69.0%) | 1.000 |
| cN positive | 15 (57.7%) | 17 (58.6%) | 1.000 |
| cM1 | 2 (7.7%) | 3 (10.3%) | 1.000 |
| Clinical stage III/IV | 15 (57.7%) | 17 (58.6%) | 1.000 |
| Preoperative EMR | 3 (11.5%) | 1 (3.4%) | 0.335 |
| Preoperative chemotherapy | 1 (3.8%) | 1 (3.4%) | 1.000 |
| Ileus | 1 (3.8%) | 3 (10.3%) | 0.613 |
| ASA III/IV | 0 (0.0%) | 1 (3.4%) | 1.000 |
| Procedure, LAR | 19 (73.1%) | 21 (72.4%) | 1.000 |
| D3 lymph node dissection | 26 (100.0%) | 28 (96.6%) | 1.000 |
| Covering stoma | 3 (11.5%) | 8 (27.6%) | 0.185 |

Table 2
Operative and postoperative outcomes by surgeon

| Variable | Surgeon A (n = 26) | Surgeon B (n = 29) | P value |
|---|---|---|---|
| Total operative time, min | 214.5 (188.5-234.5) | 249.0 (214.0-317.0) | 0.006 |
| Setup time, min | 20.0 (16.0-28.8) | 20.0 (16.0–22.0) | 0.287 |
| Cockpit time, min | 121.5 (109.2-140.5) | 153.0 (117.0-180.0) | 0.011 |
| Blood loss, mL | 10.5 (7.2–17.5) | 18.0 (10.0–30.0) | 0.029 |
| Mesorectal lymph node yield | 21.0 (13.8–28.8) | 21.0 (15.0–22.0) | 0.577 |
| Postoperative hospital stay, days | 11.0 (9.2–12.0) | 10.0 (8.0–13.0) | 0.160 |
| Conversion to open surgery | 0 (0.0%) | 0 (0.0%) | 1.000 |
| 30-day readmission | 0 (0.0%) | 0 (0.0%) | 1.000 |
| 30-day reoperation | 0 (0.0%) | 0 (0.0%) | 1.000 |
| 30-day complications | 1 (3.8%) | 1 (3.4%) | 1.000 |
| Anastomotic leakage | 1 (3.8%) | 0 (0.0%) | 0.473 |
| Surgical site infection | 1 (3.8%) | 1 (3.4%) | 1.000 |
| CD grade ≥ 2 complication | 1 (3.8%) | 1 (3.4%) | 1.000 |
| CD grade ≥ 3 complication | 1 (3.8%) | 0 (0.0%) | 0.473 |

Table 3
Key transition points in the CUSUM plots

| Surgeon | Metric | Key transition point(s) | Pattern/interpretation |
|---|---|---|---|
| **Surgeon A** | Total operative time | Case 11 (early minimum)<br><br>Secondary peak: case 19 | Multiphasic pattern;<br><br>no sustained monotonic improvement |
| | Cockpit time | Case 11 (early minimum)<br><br>Secondary peak: case 21 | Multiphasic pattern;<br><br>no sustained monotonic improvement |
| | Setup time | Case 11 | Clear improvement after case 11 |
| **Surgeon B** | Total operative time | Case 22 | Improvement after case 22 |
| | Cockpit time | Case 13 | Improvement after case 13 |
| | Setup time | Case 10 | Improvement after case 10 |

# Figures

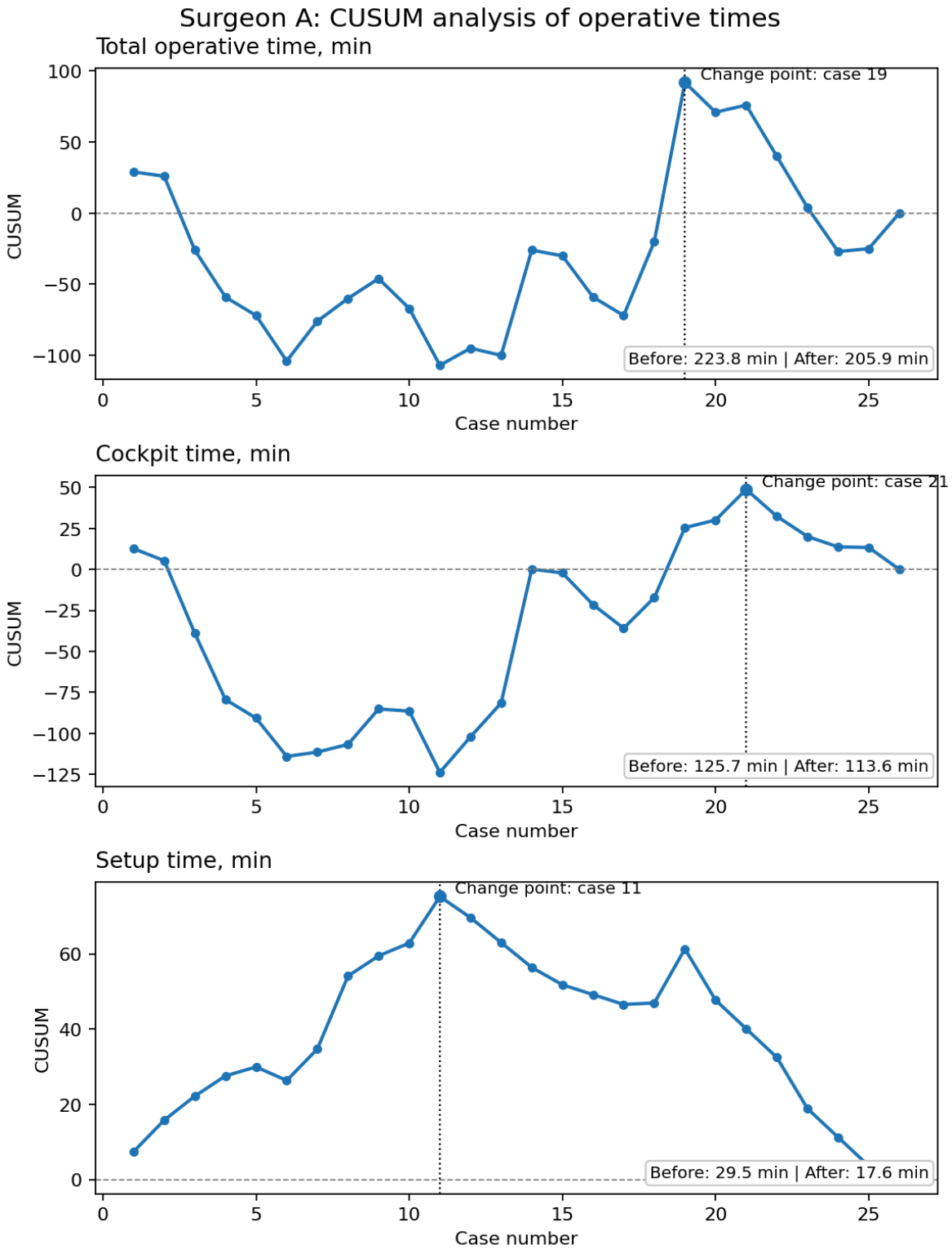



**Figure 1**

**CUSUM plots for Surgeon A.**

CUSUM plots of total operative time, cockpit time, and setup time in chronological order. The setup time showed a clear turning point at case 11. In contrast, total operative time and cockpit time did not show a

single turning point associated with sustained improvement. Instead, they exhibited multiphasic patterns, with an early minimum in case 11 and secondary peaks in cases 19 and 21, respectively.

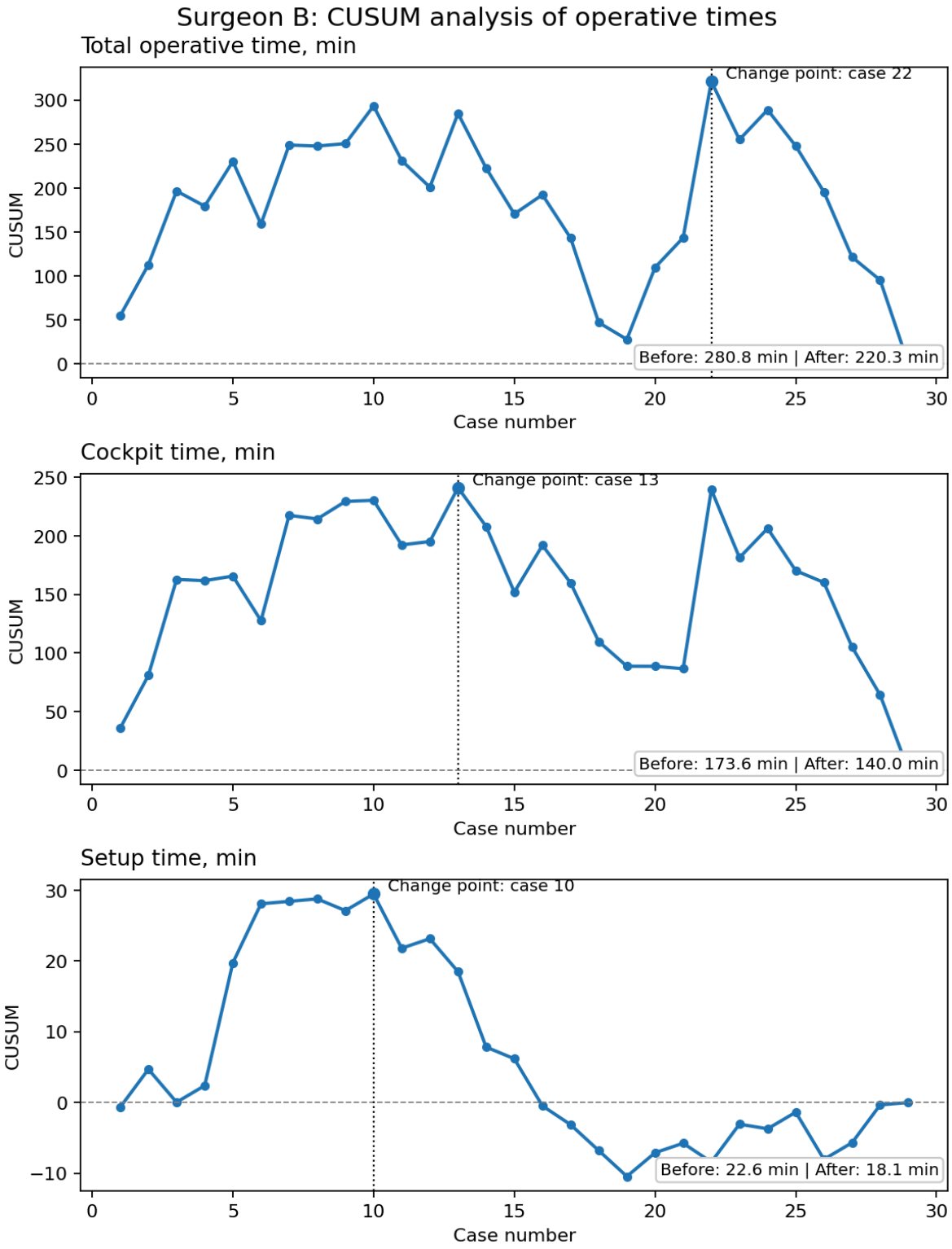



**Figure 2**

**CUSUM plots for Surgeon B.**

CUSUM plots of total operative time, cockpit time, and setup time in chronological order. Turning points were observed at case 10 for setup time, case 13 for cockpit time, and case 22 for total operative time, followed by a decreasing trend.