

Adoption of Single-Port Robot-Assisted Radical Prostatectomy Following Multiport Xi Experience: Lessons from a Learning Curve Analysis

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Research Article

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Abstract

Purpose

To evaluate whether surgical proficiency acquired with the multiport Xi robotic platform facilitates the early adoption of single-port (SP) robot-assisted radical prostatectomy (RARP).

Methods

We retrospectively analyzed the first 100 consecutive Xi RARP procedures and the first 100 consecutive SP RARP procedures performed by a single surgeon between March 2020 and July 2026. The SP platform was introduced after completion of the initial 100 Xi RARP procedures. Learning curves were evaluated using cumulative sum (CUSUM) analysis of console time, with a five-case moving average used to identify exploratory change points. Temporal trends in console and operative times were also assessed. Perioperative and pathologic outcomes were compared between the two cohorts.

Results

The exploratory CUSUM change point occurred at case 23 for Xi RARP and case 57 for SP RARP. Despite the later SP change point, console and operative times were relatively short and stable from the early phase of SP adoption. Median console time (67.0 vs. 97.5 min), operative time (95.0 vs. 145.0 min), and non-console time (28.0 vs. 44.0 min) were significantly shorter in the SP cohort (all $P < 0.001$). Pelvic lymph node dissection was performed less frequently with SP (1.0% vs. 29.0%, $P < 0.001$), reflecting differences in surgical strategy. Thirty-day emergency department visits and readmissions did not differ significantly between groups. The overall positive surgical margin rate was lower in the SP cohort (13.0% vs. 27.0%, $P = 0.021$); however, stage-stratified analyses showed no significant differences between platforms for pT2, pT3a, or pT3b disease.

Conclusions

Prior multiport Xi experience facilitated efficient adoption of SP RARP, with relatively short operative times observed from the beginning of SP use despite a later CUSUM change point. These findings suggest that robotic surgical proficiency may be transferable across platforms and support a complementary role for Xi and SP systems, with platform selection tailored to anticipated surgical extent.

Introduction

The single-port (SP) robotic platform was developed to further reduce the invasiveness of robotic surgery by enabling complex procedures through a single access site. Since its introduction, the SP

system has been rapidly incorporated into clinical practice across multiple surgical specialties. [1] In urology, robot-assisted radical prostatectomy (RARP) is among the most commonly performed robotic procedures, and the SP platform has been used with several approaches, including transperitoneal, extraperitoneal, transvesical, and Retzius-sparing techniques. These approaches have broadened the clinical applications of the SP system and provided surgeons with greater flexibility in selecting an access route according to patient and procedural characteristics. [2–5]

Despite its potential advantages, urologic surgeons may be hesitant to adopt SP RARP because the multiport Xi system is well established, technically familiar, and associated with excellent perioperative and oncologic outcomes. Although the technical feasibility of SP RARP has been demonstrated, previous studies have primarily focused on characterizing its learning curve, including the number of cases required to achieve procedural proficiency. [6, 7] Although these analyses are valuable for describing skill acquisition on the SP platform, they do not fully address whether proficiency previously acquired with the multiport Xi system is transferable to SP RARP. To our knowledge, no study has specifically examined this clinical platform transition through a comparison of first consecutive Xi RARP cases performed before SP adoption and first consecutive SP RARP cases performed thereafter. Therefore, whether extensive experience with Xi RARP facilitates the transition to SP RARP has not been established.

For surgeons who have already achieved proficiency in Xi RARP, the decision to adopt a new robotic platform may depend on whether comparable safety and operative efficiency can be maintained during the early transition period. Moreover, the SP platform differs from the Xi system in several technical aspects, including instrument configuration, triangulation, camera control, surgical-field exposure, and assistant access. [8] These differences may require surgeons to modify established operative techniques, raising concerns about a renewed and potentially prolonged learning curve. Clarifying the transferability of surgical proficiency between the two platforms therefore has practical clinical implications. Evidence of a safe and efficient transition could reduce barriers to SP adoption, whereas evidence of a substantial platform-specific learning curve could support the need for structured training, mentorship, and careful case selection during the initial adoption period.

Accordingly, rather than simply re-evaluating the number of SP RARP cases required to achieve procedural proficiency, this study aimed to determine whether prior experience with Xi RARP facilitates the early adoption of the SP platform. We compared the surgeon's first 100 consecutive Xi RARP procedures with the first 100 consecutive SP RARP procedures and analyzed learning-curve patterns, perioperative outcomes and pathologic outcomes. Through this analysis, we sought to determine whether established experience with Xi RARP enables a safe and efficient transition to SP RARP.

Materials and Methods

1. Patients and Data Collection

The Institutional Review Board of Inha University Hospital approved this retrospective analysis (approval no. 2026-08-001). We reviewed a consecutive series of RARP procedures performed by one surgeon at our institution from March 2020 through July 2026. The da Vinci SP Surgical System became available at our institution in December 2022, and the surgeon began performing SP RARP in July 2023 after completing the initial 100 Xi RARP procedures. The study therefore comprised procedures performed with the da Vinci Xi or SP platform (Intuitive Surgical, Sunnyvale, CA, USA). RARP was predominantly performed using an extraperitoneal approach; all SP procedures were performed using an extraperitoneal approach, whereas the Xi cohort included both extraperitoneal and transperitoneal procedures. Patients with incomplete follow-up data or unavailable final pathologic results were excluded. The final analysis included 200 RARP procedures, comprising the surgeon's first 100 consecutive Xi RARP procedures and first 100 consecutive SP RARP procedures. Preoperative variables included age, body mass index, serum prostate-specific antigen level, prostate volume, and biopsy International Society of Urological Pathology (ISUP) grade group. Perioperative variables and pathologic outcomes included total operative time, console time, non-console time (defined as total operative time minus console time), pelvic lymph node dissection, pathologic tumor stage, final pathologic ISUP grade group, positive surgical margin status, emergency department visits, and readmissions within 30 days after surgery.

2. Learning Curve Analysis (dup: abstract ?)

To evaluate the learning curve, cumulative sum (CUSUM) analysis of console time was performed separately for each platform. [9] For each platform, the CUSUM sequence was generated by successively adding the difference between each case-specific console time and the mean console time of that platform. Short-term variation in the resulting curve was reduced using a five-case moving average. The case at which the smoothed curve reached its maximum was designated as an exploratory change point. The change point was exploratory and was not derived using formal segmented regression or a statistical change-point model. In addition, five-case moving averages of console time and total operative time were plotted to visualize temporal changes in operative performance across consecutive cases.

3. Statistical Analysis

Continuous data were summarized using medians and interquartile ranges and between-group comparisons were performed with the Mann–Whitney U test. Categorical data were summarized as counts and proportions, with group differences evaluated using either the chi-square test or Fisher's exact test, depending on the data distribution. Statistical significance was defined as a two-sided P value < 0.05. All analyses were conducted in R version 4.6.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

1. Baseline Characteristics

Baseline characteristics were generally comparable between the two groups, although preoperative PSA was significantly higher in the Xi cohort (8.6 [6.1–16.4] vs. 7.4 [5.5–10.0] ng/mL, $P = 0.005$). Surgical approach also differed significantly between the groups ($P = 0.029$); all SP RARP procedures were performed using an extraperitoneal approach, whereas the Xi cohort included six transperitoneal procedures.

2. Learning Curve Analysis

CUSUM analysis of console time demonstrated distinct learning-curve patterns between the Xi and SP platforms (Fig. 1). The exploratory change point of the smoothed CUSUM curve was identified at case 23 for Xi RARP and case 57 for SP RARP. In the Xi cohort, the CUSUM curve increased steeply during the initial cases before reaching its maximum at case 23, followed by a gradual decline. In contrast, the SP cohort showed a more gradual increase, reaching its maximum at case 57 before subsequently declining.

Temporal trends in console and operative times across consecutive cases are shown in Fig. 2. Console time was substantially longer during the initial Xi cases and progressively decreased with increasing experience, whereas SP RARP began with relatively shorter console times and showed a more gradual reduction over consecutive cases (Fig. 2A). A similar pattern was observed for total operative time, with a pronounced early decline in the Xi cohort and relatively stable operative times throughout the SP cohort (Fig. 2B). Overall, the Xi cohort showed a greater reduction in operative times during the early cases, whereas the SP cohort demonstrated shorter and relatively stable operative times from the beginning of adoption.

3. Perioperative and Pathologic Outcomes

Perioperative and pathologic outcomes are summarized in Table 2. The SP group demonstrated significantly shorter operative time (95.0 [80.0–110.0] vs. 145.0 [125.0–175.0] min, $P < 0.001$), console time (67.0 [55.8–78.3] vs. 97.5 [79.0–128.3] min, $P < 0.001$), and non-console time (28.0 [23.0–34.0] vs. 44.0 [36.0–54.0] min, $P < 0.001$) compared with the Xi group. Pelvic lymph node dissection was performed less frequently in the SP group than in the Xi group (1.0% vs. 29.0%, $P < 0.001$). There were no significant differences in 30-day emergency department visits or readmissions between the groups.

Pathologic T-stage distribution did not differ significantly between the groups ($P = 0.162$), whereas final ISUP grade group distribution differed significantly ($P = 0.040$). The overall positive surgical margin rate was significantly lower in the SP group than in the Xi group (13.0% vs. 27.0%, $P = 0.021$). However, when stratified by pathologic stage, no significant differences in positive surgical margin rates were observed between the SP and Xi groups for pT2 (1.4% vs. 6.7%, $P = 0.176$), pT3a (29.4% vs. 38.1%, $P = 0.734$), or pT3b disease (63.6% vs. 78.9%, $P = 0.417$).

Discussion

The principal finding of the present study is that prior experience with Xi RARP facilitated the adoption of SP RARP, with relatively short console and operative times observed from the beginning of the SP experience. Although the two platforms demonstrated different CUSUM patterns, the SP cohort began at a substantially higher level of operative efficiency than the initial Xi cohort. These findings suggest that technical proficiency acquired through multiport robotic surgery may be transferable to the SP platform, allowing experienced robotic surgeons to adopt SP RARP without repeating the same early learning process encountered during their initial experience with robotic prostatectomy.

Although the CUSUM change point appeared later in the SP cohort than in the Xi cohort, this should not be interpreted as indicating a longer learning curve for the SP platform. The Xi cohort represented the surgeon's initial experience with RARP, whereas SP RARP was initiated after completion of 100 Xi RARP procedures. Consequently, console time was already considerably shorter from the beginning of the SP experience, with subsequent cases showing a more gradual improvement. The later CUSUM change point in the SP cohort therefore likely represents further refinement of an already established robotic technique rather than prolonged adaptation to the SP platform itself. This interpretation is also supported by the temporal trends in actual console and operative times, which demonstrated greater early improvement during the Xi experience and relatively stable operative performance from the early phase of SP adoption.

The SP cohort demonstrated significantly shorter console and operative times than the Xi cohort. However, these differences should be interpreted in the context of the surgical strategy used in the present study. The marked difference in the frequency of pelvic lymph node dissection between the two cohorts primarily reflects the evolution of our institutional practice rather than differences in platform capability. During the period when only the Xi system was available, all patients underwent Xi RARP regardless of the anticipated need for pelvic lymph node dissection. Following the introduction of the SP platform, our surgical strategy evolved. Although pelvic lymph node dissection is feasible during extraperitoneal SP RARP, creating a comparable operative field generally requires additional robotic dissection after docking, which would likely increase console time. Rather than extending the extraperitoneal dissection during SP RARP, we preferentially adopted a transperitoneal approach for patients requiring pelvic lymph node dissection because it provides more straightforward access to the pelvic lymphatic template. Thus, the shorter console time observed in the SP cohort should not be interpreted solely as an inherent advantage of the SP platform. In contrast, the shorter non-console time may partly reflect the simplified docking configuration of the SP system and the more limited extraperitoneal dissection required to establish the operative field. [10, 11]

The overall positive surgical margin rate was significantly lower in the SP cohort than in the Xi cohort. However, this finding should not be interpreted as evidence of an oncologic advantage of the SP platform. When stratified according to pathologic stage, positive surgical margin rates did not differ significantly between the platforms for pT2, pT3a, or pT3b disease, although numerically lower rates

were consistently observed in the SP cohort across all stages. Given the sequential nature of the study, this pattern may partly reflect the cumulative surgical experience acquired during the preceding Xi experience, which may have carried over after transition to the SP platform. In addition, the distribution of final ISUP grade groups differed between the cohorts, with higher-grade disease being more frequent in the Xi cohort. Thus, the lower overall positive surgical margin rate observed in the SP cohort may reflect a combination of accumulated surgical experience and differences in case mix rather than an inherent oncologic advantage of the SP platform. These findings are consistent with previous comparative studies reporting broadly similar oncologic outcomes between SP and multiport RARP. [12–15]

Taken together, these findings support a complementary rather than competitive role for the Xi and SP platforms. For surgeons already familiar with Xi RARP, adaptation to SP RARP may be relatively straightforward because many of the fundamental surgical steps and robotic skills are transferable between platforms. In our current practice, extraperitoneal SP RARP is preferentially performed in patients who do not require pelvic lymph node dissection, whereas patients requiring pelvic lymph node dissection are generally managed using a transperitoneal approach. Platform and approach selection can therefore be tailored to the anticipated surgical extent, allowing the technical and workflow characteristics of each platform to be used according to the clinical situation.

Several limitations should be considered when interpreting our findings. The retrospective design and experience from a single institution and surgeon may restrict their broader applicability; conversely, evaluating one surgeon provided greater consistency in operative technique. Second, because the SP cohort was treated after completion of the Xi cohort, differences between the platforms may have been influenced by cumulative surgical experience as well as temporal changes in patient selection and surgical strategy, particularly regarding pelvic lymph node dissection. Third, long-term functional outcomes were not evaluated because of the relatively short follow-up in the SP cohort. Nevertheless, this study provides practical insights into the transition from multiport Xi to single-port RARP and may serve as a useful reference for surgeons adopting the SP platform after prior Xi experience.

Conclusion

Prior experience with multiport Xi RARP facilitated the efficient adoption of SP RARP, with relatively short console and operative times observed from the early phase of SP use. Although the CUSUM change point occurred later with SP, this likely reflected further refinement from an already proficient baseline rather than a prolonged platform-specific learning curve. Xi and SP may therefore be considered complementary platforms, with platform and approach selection tailored to the anticipated surgical extent and need for pelvic lymph node dissection.

Table 1
Baseline characteristics of patients undergoing multiport Xi and single-port robot-assisted radical prostatectomy

Variable	Xi (n = 100)	SP (n = 100)	P value
Age, years	69 [64–73]	67 [62–71]	0.060
BMI, kg/m ²	24.9 [23.0–26.7]	24.7 [23.0–26.7]	0.976
Preoperative PSA, ng/mL	8.6 [6.1–16.4]	7.4 [5.5–10.0]	0.005
Prostate volume, mL	36.6 [29.4–48.9]	39.1 [31.9–48.0]	0.699
Biopsy ISUP grade group, n (%)			0.104
Grade Group 1	20 (20.0)	17 (17.0)	
Grade Group 2	21 (21.0)	36 (36.0)	
Grade Group 3	23 (23.0)	25 (25.0)	
Grade Group 4	22 (22.0)	14 (14.0)	
Grade Group 5	14 (14.0)	8 (8.0)	
Surgical approach, n (%)			0.029
Extraperitoneal	94 (94.0)	100 (100.0)	
Transperitoneal	6 (6.0)	0 (0.0)	

Table 2
Perioperative and pathologic outcomes according to surgical platform

Variable	Xi (n = 100)	SP (n = 100)	P value
Operative outcomes			
Operative time, min	145.0 [125.0–175.0]	95.0 [80.0–110.0]	< 0.001
Console time, min	97.5 [79.0–128.3]	67.0 [55.8–78.3]	< 0.001
Non-console time, min	44.0 [36.0–54.0]	28.0 [23.0–34.0]	< 0.001
Pelvic lymph node dissection, n (%)	29 (29.0)	1 (1.0)	< 0.001
30-day emergency department visit, n (%)	8 (8.0)	10 (10.0)	0.805
30-day readmission, n (%)	4 (4.0)	6 (6.0)	0.748
Pathologic outcomes			
Pathologic T stage, n (%)			0.162
T2	60 (60.0)	72 (72.0)	
T3a	21 (21.0)	17 (17.0)	
T3b	19 (19.0)	11 (11.0)	
Pathologic N stage, n (%)			< 0.001
Nx	76 (76.0)	99 (99.0)	
N0	21 (21.0)	0 (0.0)	
N1	3 (3.0)	1 (1.0)	
Final ISUP grade group, n (%)			0.040
Grade Group 1	5 (5.0)	2 (2.0)	
Grade Group 2	34 (34.0)	43 (43.0)	
Grade Group 3	36 (36.0)	45 (45.0)	
Grade Group 4	10 (10.0)	3 (3.0)	
Grade Group 5	15 (15.0)	7 (7.0)	
Positive surgical margin, n (%)	27 (27.0)	13 (13.0)	0.021
pT2	4/60 (6.7)	1/72 (1.4)	0.176
pT3a	8/21 (38.1)	5/17 (29.4)	0.734

Variable	Xi (n = 100)	SP (n = 100)	P value
Operative outcomes			
pT3b	15/19 (78.9)	7/11 (63.6)	0.417

Declarations

Ethics approval

Institutional Review Board of Inha University Hospital (approval no. 2026-08-001)

Conflicts of Interest

The authors have nothing to disclose.

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Data availability

The data generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Author Contribution

Conceptualization: DYC; Data curation: YMS, JWA, DHK; Formal analysis: YMS, DHK, DYC; Methodology: YMS, JWA; Project administration: DYC; Visualization: JWA, DYC; Writing - original draft: YMS, DYC; Writing - review & editing: DYC.

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References

1. Kaouk J, Garisto J, Bertolo R (2019) Robotic Urologic Surgical Interventions Performed with the Single Port Dedicated Platform: First Clinical Investigation. *Eur Urol* 75(4):684–691
2. Balasubramanian S et al (2022) Comparison of Three Approaches to Single-Port Robot-Assisted Radical Prostatectomy: Our Institution's Initial Experience. *J Endourol* 36(12):1551–1558
3. Jeong SH, Kwak C (2026) The evolving landscape of robot-assisted radical prostatectomy: A comprehensive review of surgical techniques. *Investig Clin Urol* 67(4):311–317
4. Koukourikis P et al (2022) Pure single-port retzius-sparing robot-assisted radical prostatectomy with the da Vinci SP: Initial experience and technique description. *BJUI Compass* 3(3):251–256
5. Soputro NA et al (2026) Single Port Robotic Radical Prostatectomy: A Propensity-matched Comparison of Transvesical Versus Extraperitoneal Approaches from the Single Port Advanced Research Consortium. *Eur Urol Oncol*
6. Hershenhouse JS et al (2026) The learning curve of single-port extraperitoneal robotic radical prostatectomy: Initial experience and outcomes from a newly graduated fellowship-trained robotic surgeon. *BJUI Compass* 7(3):e70184
7. Santarelli V et al (2025) Learning Curve of Single-Port Robotic-Assisted Extraperitoneal Radical Prostatectomy: A CUSUM-Based Analysis. *J Laparoendosc Adv Surg Tech A* 35(7):542–549
8. Eskandar K (2025) Single-port robotic-assisted radical prostatectomy: evaluating the Da Vinci SP system in minimally invasive urologic oncology. *World J Urol* 43(1):711
9. Woodall WH, Rakovich G, Steiner SH (2021) An overview and critique of the use of cumulative sum methods with surgical learning curve data. *Stat Med* 40(6):1400–1413
10. Cubisino A, Chazal M, Panaro F (2025) Application of the Da Vinci Single-Port (SP) Robot in General Surgery: A First Systematic Review. *Int J Med Robot* 21(6):e70123
11. Katsimperis S et al (2025) Single-Port vs. Multi-Port Robotic Surgery in Urologic Oncology: A Comparative Analysis of Current Evidence and Future Directions. *Cancers (Basel)*, 17(17)
12. Fahmy O et al (2021) Single-Port versus Multiple-Port Robot-Assisted Radical Prostatectomy: A Systematic Review and Meta-Analysis. *J Clin Med*, 10(24)
13. Ficarra V et al (2025) Comparison of Single- and Multiport Robot-assisted Approaches in Prostate and Renal Surgery: A Systematic Review and Meta-analysis. *Eur Urol* 88(6):589–613
14. Mirza W et al (2026) *da Vinci((R)) single-port versus da Vinci((R)) Xi multiport robot-assisted radical prostatectomy for localized prostate cancer: a GRADE-assessed systematic review and meta-analysis.* *BMC Surg*
15. Nguyen TT et al (2023) Single-port and multiport robot-assisted radical prostatectomy: A meta-analysis. *Prostate Int* 11(4):187–194

Figures

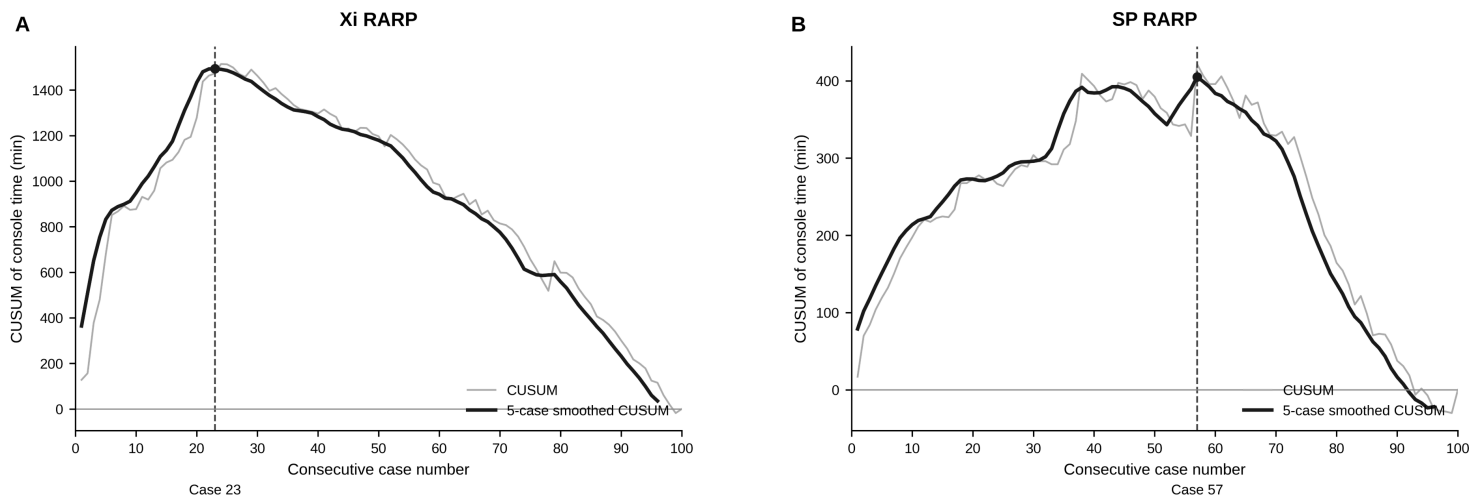


Figure 1

Cumulative sum learning curves for console time during robot-assisted radical prostatectomy. (A) Xi platform. (B) SP platform.

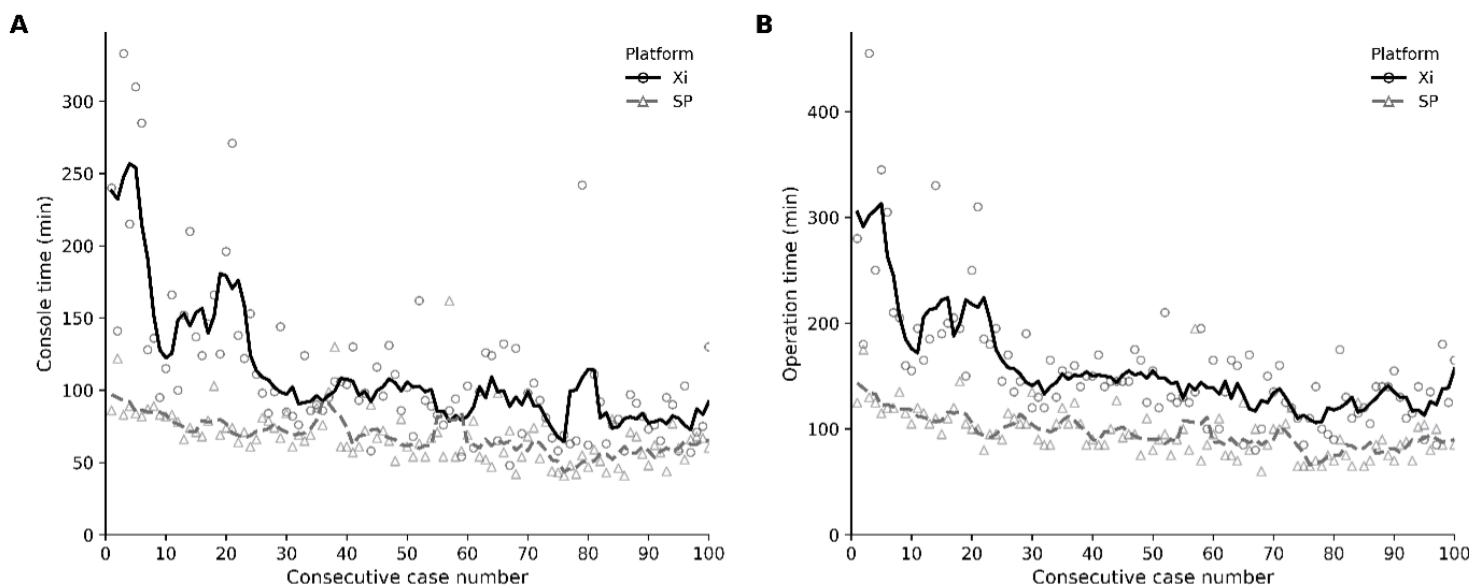


Figure 2

Comparison of learning curves during robot-assisted radical prostatectomy. (A) Console time. (B) Operative time. Xi is represented by open circles with a solid line, and SP by open triangles with a dashed line.