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ORIGINAL PAPER

Impact of laparoscopic experience on learning curves in Robotic-assisted Radical Prostatectomy (RaRP): A comparative analysis of oncological and functional outcomes

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Summary

Objective: ***This study aimed to evaluate the influence of prior laparoscopic experience on the learning curve and surgical outcomes of robotic-assisted radical prostatectomy (RaRP).***

Methods: A retrospective analysis was performed on 101 patients treated between 2021 and 2023. Two surgeons at the beginning of their robotic learning curves were compared: one with extensive prior laparoscopic experience and the other without such a background. Perioperative, oncological, and functional outcomes were assessed, with a specific focus on Pentafecta criteria. Statistical analyses and cumulative sum (CUSUM) charts were employed to evaluate performance trends and surgical outcomes.

Results: Surgeon A, with substantial prior laparoscopic expertise, demonstrated shorter operative times ($p = 0.015$), reduced intraoperative blood loss, and superior early functional outcomes. Specifically, patients operated on by Surgeon A exhibited higher pad-free continence rates and improved erectile function recovery at 12 months postoperatively ($p < 0.01$). Additionally, nerve-sparing procedures performed by Surgeon A showed a trend toward fewer positive surgical margins, although this difference did not reach statistical significance. CUSUM analysis revealed more stable and consistent performance trends for Surgeon A in achieving Pentafecta outcomes compared to Surgeon B.

Conclusions: Previous laparoscopic experience significantly contributes to shortening the learning curve for RaRP and enhancing early functional outcomes. This advantage is likely attributable to greater surgical anatomical knowledge. These findings highlight the importance of tailored training programs and the potential for skill transfer between laparoscopic and robotic approaches. Further studies are warranted to refine surgical education strategies and improve patient care outcome.

KEY WORDS: Prostate cancer; Laparoscopic radical prostatectomy; Robot-assisted Radical Prostatectomy; Learning curve; Outocomes; Operative time.

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INTRODUCTION

Prostate cancer is among the most commonly diagnosed malignancies in men and represents a substantial global public health burden. Radical prostatectomy remains a pivotal treatment option for localized prostate cancer. Traditionally, open surgery was the gold standard; however, the emergence of minimally invasive techniques, such as *laparoscopic radical prostatectomy* (LRP) and *robotic-assisted radical prostatectomy* (RaRP), has transformed surgical management. These techniques offer numerous advantages, including reduced perioperative morbidity, shorter hospital stays, and faster recovery (1). The introduction of the da Vinci robotic surgical system has further refined surgical practices, providing enhanced visualization, precision in instrumentation, and improved ergonomics compared to conventional laparoscopy. Such technological advancements have facilitated the widespread adoption of RaRP, particularly because of its ability to address some of the technical limitations inherent to LRP. Both laparoscopic and robotic approaches offer substantial benefits over open surgery, improving clinical outcomes and minimizing complications (2-19). Within the realm of minimally invasive approaches, transperitoneal and extraperitoneal LRP have demonstrated notable oncological and functional advantages. The transperitoneal technique allows superior anatomical visualization, whereas the extraperitoneal approach minimizes peritoneal-related complications, such as bowel injuries and adhesions. Both techniques achieve excellent functional outcomes, with urinary continence and erectile function recovery rates surpassing 90% and 80%, respectively, at 12 months postoperatively (3).

Numerous comparative studies have evaluated LRP and RaRP, frequently reporting similar outcomes across various clinical parameters. However, RaRP consistently demonstrates a distinct advantage in early urinary continence recovery, with significantly better continence rates observed within the first three months postoperatively.

Despite these early differences, long-term continence rates remain comparable between the two methods, confirming their efficacy in managing localized prostate cancer (4).
In terms of surgical efficiency, RaRP is consistently associated with shorter operative times compared to laparoscopic techniques. This efficiency is mirrored by lower or comparable postoperative complication rates associated with the robotic approach (5). Research by Salsiccia and colleagues further underscores these findings, indicating that laparoscopic procedures require significantly longer operative times than RaRP. These findings highlight the advantages of standardization and a more rapid learning curve associated with robotic surgery (6).
From an oncological standpoint, RaRP often demonstrates slightly improved outcomes regarding *positive surgical margins* (PSMs) and *biochemical recurrence* (BCR) rates when compared to LRP, though these differences are not consistently statistically significant. These findings suggest that RaRP, as a technologically advanced surgical approach, can enhance certain aspects of prostate cancer surgery while delivering results comparable to laparoscopy.
The learning curve is a critical factor influencing both oncological and functional outcomes. Parameters such as operative time, PSM rates, and recovery of continence and potency typically improve as surgeons gain more experience. Surgeons with prior laparoscopic expertise appear to adapt to RaRP more efficiently, achieving proficiency with fewer cases and reaching benchmarks such as the "*Trifecta*" outcomes more rapidly. Trifecta metrics evaluate surgical success by integrating oncological control, functional recovery, and perioperative safety (8, 9).
Building upon the Trifecta framework, the "*Pentafecta*" outcome offers a more comprehensive evaluation by encompassing five key domains: biochemical recurrence-free survival, continence recovery, sexual potency recovery, surgical margin status, and perioperative hemoglobin changes. This holistic metric underscores the importance of achieving a balance between oncological efficacy and functional preservation to optimize patient outcomes.
In contemporary clinical practice, patients undergoing RaRP often hold elevated expectations regarding functional outcomes, influenced by the widespread availability of medical information on social media platforms such as YouTube. While these platforms can provide valuable educational insights, the quality of information is highly variable, and misinformation is prevalent, particularly in searches performed anonymously or with generic user profiles (10). This highlights the necessity of reliable and accessible patient education resources to ensure that individuals receive accurate information, fostering realistic expectations and informed decision-making.
For surgeons, managing patient expectations requires a clear understanding of the functional outcomes achievable with RaRP. Transparent communication during the informed consent process is crucial to aligning patient expectations with achievable results, thereby fostering trust and strengthening the therapeutic alliance.
Despite its many advantages, RaRP presents unique challenges for surgeons without prior laparoscopic experience. These surgeons often face prolonged learning curves, with gradual improvements in operative efficiency and patient outcomes (11). Mastery of robotic techniques is essential, as functional outcomes – particularly early recovery of continence and sexual potency – have a direct impact on patients' quality of life (12).
Procedural volume is another key determinant of surgical outcomes. Research consistently shows that achieving optimal results in radical prostatectomy is strongly associated with high annual caseloads, underscoring the critical role of both institutional and surgeon-level experience (13).
This study seeks to compare the learning curves of Operator A and Operator B, employing the Pentafecta as a comprehensive measure of surgical success. A secondary objective is to determine whether there are significant differences between the two operators regarding oncological and functional outcomes.

Materials and methods

A retrospective study was conducted on the first 153 patients who underwent RaRP at our institution between 2021 and 2023. Among these, 101 patients met the specified inclusion and exclusion criteria and were included in the analysis. Eligible participants had localized *prostate cancer* (PCa), were aged ≤ 75 years, demonstrated good performance status, and were either unsuitable for or unwilling to pursue active surveillance. Exclusion criteria included a history of androgen deprivation therapy, prior pelvic surgery or radiotherapy, or histological diagnoses conducted at external institutions.
Histological diagnoses were obtained through standard *transrectal ultrasound-guided trans-perineal prostate biopsy* (TRUS-SBx) or MRI/ultrasound fusion-guided trans-perineal biopsy (TBx+SBx). Of the cohort, 50 patients underwent fusion-guided biopsy, while 51 received standard biopsies. All procedures were performed by an experienced operator. Fusion-guided biopsies were indicated for patients with clinically significant PIRADS lesions (PIRADS ≥ 3) and included both targeted samples (based on the number and size of *regions of interest* [ROI]) and 12-16 systematic cores from a prostate template covering the base, mid-gland, and apex bilaterally.
When *multiparametric MRI* (mpMRI) was unavailable or no significant PIRADS lesions were identified, a standard 16-core TRUS-guided trans-perineal biopsy was performed per institutional protocol. This approach systematically sampled the base, mid-gland, apex, and transition zones bilaterally.
Preoperative staging was conducted for all patients using contrast-enhanced total-body *computed tomography* (CT) and total-body bone scintigraphy. Following staging, all patients underwent RaRP using the Da Vinci Xi (Intuitive) multiport robotic system. The surgeries were performed by two surgeons at the outset of their RaRP learning curves. Surgeon A, however, had substantial prior experience in laparoscopy, having completed over 1,000 cases of extraperitoneal laparoscopic radical prostatectomy, whereas Surgeon B had no such experience. Surgeon A performed 47 RaRP procedures, while Surgeon B performed 64.
Both surgeons employed the same surgical technique, which involved an anterograde extraperitoneal approach and a double-layer running anastomosis reinforced with a posterior plate, utilizing a 2-0 barbed suture.
Histopathological examination of surgical specimens was

conducted by an experienced pathologist. Data collection included demographic variables (age, *body mass index* [BMI], family history of prostate cancer), preoperative factors (*prostate-specific antigen* [PSA] levels, D'Amico risk classification (14), clinical T-stage), perioperative metrics (operative time, estimated blood loss, and nerve-sparing rates), oncological outcomes (positive surgical margins), and postoperative functional outcomes (pad-free continence at 3, 6, and 12 months; erectile function assessed using the *International Index of Erectile Function-5* [IIEF-5]).

Statistical analysis

Data were systematically collected and recorded in Microsoft Excel, encompassing anthropometric parameters (age, BMI, weight, height), biopsy type, prostate volume, clinical stage, comorbidities, pre- and post-operative levels of total PSA and *hemoglobin* (Hb), operative times, histopathological findings, and oncological and functional outcomes. Functional outcomes included PSA levels, urinary continence, and sexual potency, evaluated at 1, 3, 6, 9, and 12 months post-surgery.

Operative times between the two surgeons were compared using both Student's t-test and the Mann-Whitney U test. *Positive surgical margin* (PSM) rates were assessed globally using the Chi-square test. Among patients undergoing nerve-sparing procedures, PSM rates were further analyzed using the Chi-square test and Fisher's exact test to enhance precision.

Oncological and functional outcomes were first evaluated globally using Pearson's correlation coefficient to identify potential associations. Subsequently, these outcomes were analyzed separately for each surgeon. Python libraries (v3.11) were utilized to compute Pearson's correlation coefficient, exploring relationships between anthropometric variables and functional outcomes, nerve-sparing techniques and oncological outcomes, and Gleason scores and functional recovery.

Special emphasis was placed on functional outcomes, particularly the changes in pre- and post-operative IIEF-5 scores. These variations were analyzed globally and comparatively between the two surgeons.

CUSUM analysis

Cumulative Sum Control Chart (CUSUM) analysis was applied to monitor performance trends across consecutive cases. The following targets were used: oncological control (variation of PSA), functional recovery (recovery of both erectile disfuncion and urinary continence) and surgical efficiency (operative bool loss and progressive reductrion in operative time). Deviations from predefined target values were calculated for each metric, and cumulative sums of these deviations were plotted. Positive slopes indicated consistent performance below the target, whereas negative slopes reflected achievement of or surpassing the target. Separate CUSUM charts were created for each metric and surgeon, enabling comparative analysis.

The analysis focused on pentafecta metrics to evaluate and compare the learning curves of the two surgeons, providing insights into their progression and improvements over time. Key pentafecta metrics included oncological control (PSA < 0.05 ng/mL at 12 months), functional recovery (improvement in IIEF-5 scores and complete pad-free continence at 12 months) and surgical efficiency (Hb loss ≤ 1.5 g/dL and progressive reduction in operative time).

Descriptive statistics were used to calculate mean baseline values. Differences between the two surgeons were assessed using the Mann-Whitney U test for continuous variables and the Chi-square test for categorical variables. Trends observed in the CUSUM charts were contextualized with these statistical findings, offering a comprehensive evaluation of the surgeons' learning curves and performance differences.

Results

A total of 101 patients were included in this analysis, with 47 procedures performed by Operator A and 64 by Operator B. Operator A had extensive prior experience in laparoscopic surgery, whereas Operator B was at the start of their robotic surgery learning curve with no laparoscopic background. Both surgeons followed the same standardized robotic-assisted radical prostatectomy (RaRP) technique.

The patient cohorts were comparable in age, with a mean of 69 years (range: 55-75) for Operator A and 70 years (range: 54-75) for Operator B. Minor differences were noted in anthropometric parameters, with patients in Operator A's cohort having a slightly higher mean BMI (26.87 *vs*. 25.9) and weight (81.77 kg *vs*. 75.5 kg). Other measures, such as height and waist circumference, were similar. A family history of prostate cancer was observed in one patient treated by Operator B and was absent in Operator A's cohort (Table 1).

Table 1.
Comparison of perioperative, demographic, and clinical variables based on previous laparoscopic experience in RaRP patients.

Variables	Previous laparoscopic experience		P value
R+, n°(%)	12 (25.53)	12 (22.22)	0.701
Pre-op. PSA, ng/ml (range)	8.78 (4.8-24.3)	9.62 (3.54-21.5)	0.365
Post-op. PSA, ng/ml (range)			0.573
1 month	0.23 (0.0-1.26)	0.08 (0.0-0.62)	
3 months	0.14 (0.0-0.93)	0.08 (0.0-1.94)	
6 months	0.09 (0.0-0.987)	0.12 (0.0-3.94)	
9 months	0.04 (0.0-0.74)	0.06 (0.0-1.14)	
12 months	0.04 (0.0-0.74)	0.06 (0.0-1.14)	
Pre-op. WBC, x 10^3/µL (range)	7.25 (5.08-9.87)	7.40 (5.06-10.43)	0.582
Post-op WBC, x 10^3/µL (range)			0.170
- 12h	15.147 (8.120-23.140)	13.853 (5.670-30.450)	
- 24h	10.418 (5.500-15.200)	10.056 (6.520-16.990)	
Pre-op. Hb, g/dl (range)	14.94 (11.9-17.3)	14.52 (11.4-1.1)	0.158
Post-op. Hb, g/dl (range)			0.175
- 12h	12.57 (8.9-14.7)	13.04 (10.3-16.1)	
- 24h	12.57 (8.9-14.7)	13.01 (10.3-16.1)	
Prostate Volume, ml (range)	55.9 (20-142)	47.5 (20-120)	0.117
Age, years (range)	69 (55-75)	70 (54-75)	0.504
Hypertension, n° pts (%)	8 (17.02)	4 (7.41)	0.118
DM, n° pts (%)	2 (4.26)	7 (12.96)	0.116
Height, cm (range)	174 (170-190)	173 (165-188)	2.984
Weight, kg (range)	81.77 (56-105)	75.5 (60-102)	0.008
Waist circumference, cm (range)	90 (70-110)	87 (71-106)	0.936
BMI, value (range)	26.87 (20.1-34.29)	25.9 (19.52-35.3)	0.751

Table 2.
Pre-operative risk classes according to D'Amico classification.

Previous laparoscopic experience	Low risk	Intermediate risk	High risk
Yes (A)	16 (34.04)	18 (38.3)	13 (27.66)
No (B)	20 (37.03)	14 (25.92)	20 (37.03)

Table 3.
Distribution of pre-operative T-stage in both group.

Previous laparoscopic experience	T1c	T2a	T2b	T2c	T3b
Yes (A)	3 (6.38)	16 (34.04)	16 (34.04)	6 (12.76)	6 (12.76)
No (B)	15 (24.59)	9 (14.75)	25 (40.98)	6 (9.83)	6 (9.83)

Table 4.
Biopsy and mpRMN.

Previous laparoscopic experience	Fusion Biopsy (n°)	Fusion Biopsy (%)	mpRMN (n°)	mpRMN (%)	ROI detected by mpRMN (mean n°)	ROI detected by mpRMN (range)
Yes (A)	25	53.19	29	61.70	1	1-1
No (B)	25	46.29	36	66.66	1.2	1-3

Among the variables analyzed, the only statistically significant difference between the two cohorts was in the anthropometric parameter "*weight*" (p = 0.008) (Table 1). Preoperative risk stratification based on the D'Amico criteria revealed comparable distributions between the two cohorts. Intermediate-risk cases were slightly more prevalent in Operator A's group (38.3% *vs.* 25.92%), while high-risk cases were evenly distributed between the groups (27.66% *vs.* 37.03%) (Table 2).

Preoperative T-staging showed that Operator A's cohort included a higher percentage of T2a and T2b tumors (34.04% each), whereas Operator B's cohort had a higher proportion of T1c (24.59%) and T2b cases (40.98%) (Table 3).

The utilization of advanced imaging techniques and biopsy methods was also evaluated. Fusion-guided biopsies were performed in 53.19% of cases for Operator A and in 46.29% for Operator B. Multiparametric MRI was employed in 61.7% and 66.66% of cases for Operators A and B, respectively. The mean number of ROI detected by MRI was similar between the groups, with Operator A identifying an average of one ROI per patient and Operator B identifying 1.2 ROIs (Table 4).

Operator A achieved significantly shorter operative times compared to Operator B, with a mean duration of 191.02 minutes versus 214.48 minutes. This difference was statistically significant (p = 0.015). Furthermore, Operator A exhibited lower variability in operative times, with mean absolute deviations of 30.66 minutes compared to 44.57 minutes for Operator B, indicating greater procedural consistency (p = 0.011) (Figures 1-2).

In terms of oncological outcomes, the overall *positive surgical margin* (PSM) rates were comparable between the

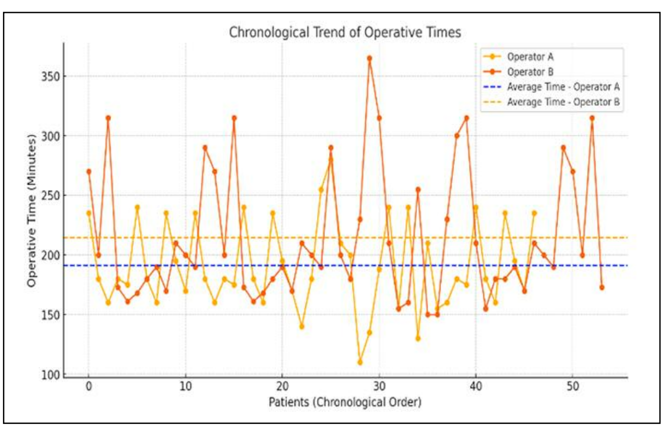

Figure 1.
This graph illustrates the operative times for patients treated by two surgeons, plotted in chronological order. Surgeon A, with prior laparoscopic experience, has individual operative times represented by the solid yellow line, while their average operative time is shown by the dashed blue line. Surgeon B, without prior laparoscopic experience, has individual operative times represented by the solid orange line, with their average operative time indicated by the dashed yellow line. This visualization highlights potential trends and differences in surgical performance based on experience.

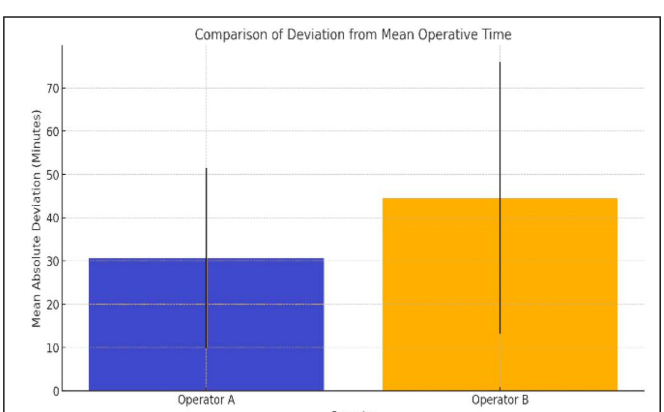

Figure 2.
The bar chart illustrates the mean absolute deviation from the average operative time for two surgeons. Operator A, with prior laparoscopic experience, demonstrated lower variability (mean deviation: 30.66 minutes, standard deviation: 20.78 minutes) compared to Operator B (mean deviation: 44.57 minutes, standard deviation: 31.42 minutes).
Error bars indicate the standard deviation.
These results suggest that Operator A's operative times are more consistent than those of Operator B.

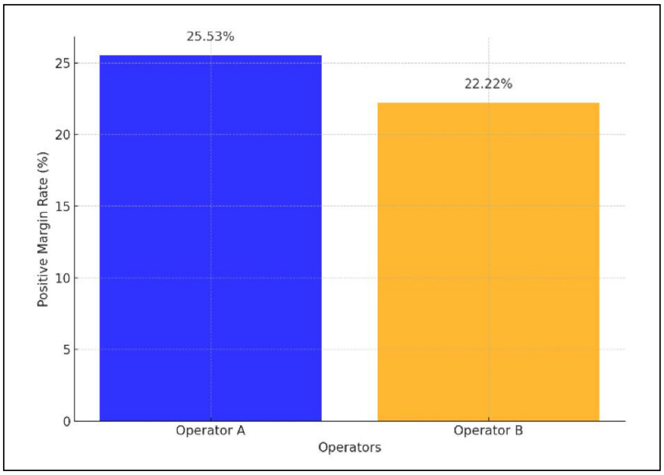

Figure 3.
This bar chart compares the overall positive margin rates between Operator A and Operator B. Operator A demonstrates a positive margin rate of 25.53%, while Operator B shows a rate of 22.22%. Statistical analysis using Chi-square and Fisher's exact tests revealed no significant difference between the two operators (p > 0.05).

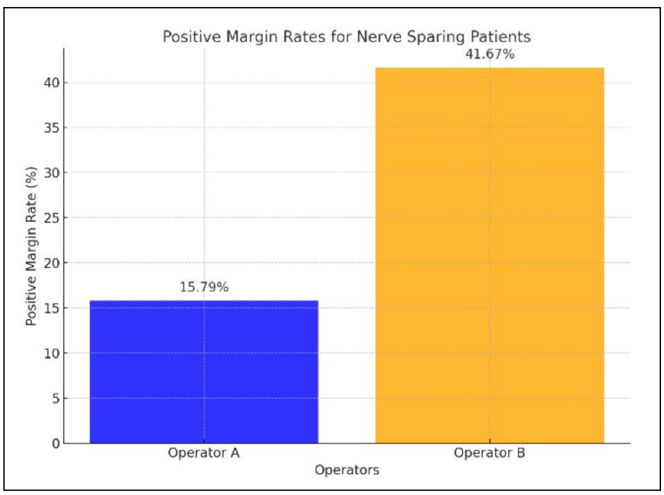

Figure 4.
This bar chart focuses on the positive margin rates for patients undergoing nerve sparing surgery. Operator A exhibits a lower rate of 15.79% compared to Operator B's 41.67%. While the difference is substantial, statistical tests did not confirm significance (p > 0.05).

two operators (25.53% for Operator A and 22.22% for Operator B, $p = 0.876$) (Table 4). However, in nerve-sparing cases, Operator A demonstrated a lower PSM rate of 15.79% compared to 41.67% for Operator B. Although this difference was not statistically significant, the trend suggests potential advantages in Operator A's technique for nerve-sparing procedures, warranting further investigation with larger sample sizes (Figures 3, 4; Tables 1-5).

Table 5.
Description of surgical outcomes.

Previous laparoscopic experience	Mean operative time (min)	Operative time (range)	R+ (n°)	R+ (%)	NS surgery (n°)	NS surgery (%)
Yes (A)	191.02	110-280	12	25.53	19	40.42
No (B)	214.48	150-365	12	22.22	12	22.22

Table 6.
Filtered statistical comparison of IIEF5 improvement between operators.

Time period, month(s)	Operator A (Mean +/- SD)	Operator B (Mean +/- SD)	t-Statistic	P-value
Pre operative	22.5 +/- 4.3	22.8+/- 4.1	-0.373	0.710
1	5.8 +/- 2.1	5.5 +/- 2.0	-0.018	0.985
3	8.2 +/- 3.5	7.0 +/- 3.2	1.559	0.123
6	12.1 +/- 4.0	11.8 +/- 3.9	0.143	0.886
9	16.5 +/- 4.8	13.0 +/- 4.5	-3.580	0.0005
12	19.2 +/- 5.0	15.1 +/- 4.6	-3.580	0.0005

Functional outcomes revealed notable differences between the two operators. At 12 months postoperatively, Operator A achieved superior continence outcomes, with a higher percentage of patients obtaining pad-free status. CUSUM analysis showed stable and consistent recovery trends for Operator A, while Operator B exhibited greater variability. Regarding erectile function, significant improvements in IIEF-5 scores were observed for Operator A at both 9 and 12 months ($p < 0.01$). This superior recovery is likely attributed to Operator A's precise nerve-sparing techniques.

Table 6 presents the mean ± standard deviation of IIEF-5 scores for Operator A and Operator B at different time points (preoperative and 1, 3, 6, 9, and 12 months postoperatively). A statistically significant difference in erectile function recovery is observed from 9 months onwards ($p < 0.01$), favoring Operator A. This trend suggests that previous laparoscopic experience may contribute to improved nerve-sparing outcomes and functional recovery (Table 6).

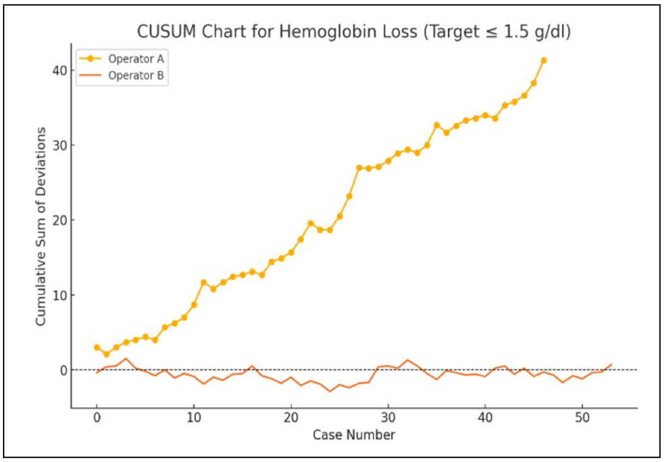

Figure 5.
CUSUM plot of cumulative deviations in hemoglobin loss, with a target maximum loss of 1.5 g/dl. Operator A shows better control over blood loss during surgery compared to Operator B, whose performance fluctuates more.
The CUSUM plot represents the cumulative sum of deviations from the predefined target of ≤ 1.5 g/dL hemoglobin loss. A rising trend does not necessarily indicate that each case exceeds the target but reflects the accumulation of deviations over time. This representation allows for the visualization of the overall trend in surgical performance

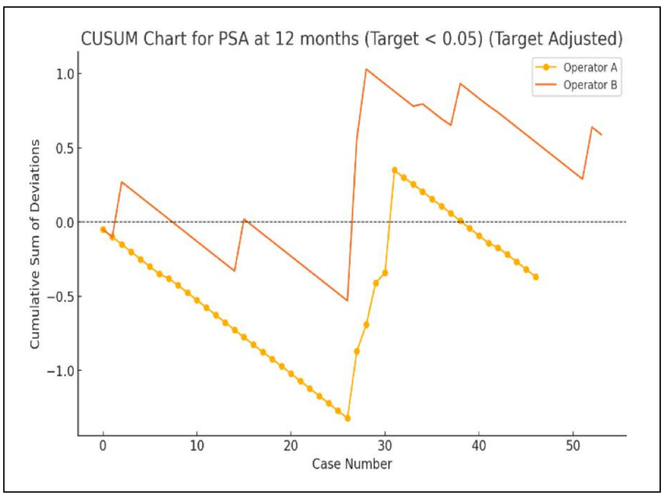

Figure 6.
CUSUM plot depicting the cumulative deviations from the target PSA level (< 0.05 ng/ml) at 12 months postoperatively. Operator A demonstrates more stable performance, while Operator B exhibits greater variability, indicating room for improvement in achieving optimal oncological control. This CUSUM plot represents cumulative deviations from the target PSA level of < 0.05 ng/mL at 12 months postoperatively. An upward trend indicates that cases are accumulating below the target, while a stable or downward trend suggests consistency in maintaining oncological control.

Perioperative blood loss was better controlled by Operator A, as reflected by lower variability in hemoglobin levels at 12 and 24 hours postoperatively. Operator A consistently maintained hemoglobin loss within the target threshold of ≤ 1.5 g/dL, as confirmed by stable trends in CUSUM plots, while Operator B exhibited greater fluctuations (Figure 5).
Pearson's correlation analysis identified moderate negative correlations between preoperative BMI and weight with IIEF-5 recovery at 12 months for both operators, with a stronger effect observed for Operator B. Preoperative PSA levels showed weak positive correlations with pad usage at 12 months, while positive surgical margins were weakly correlated with PSA levels at 3 months postoperatively, more prominently for Operator B.
CUSUM analysis further demonstrated that Operator A consistently met or exceeded performance targets across oncological, functional, and efficiency metrics. Operator A exhibited stable trends in achieving PSA levels below 0.05 ng/mL at 12 months and superior outcomes in continence (complete pad-free status) and erectile function recovery (targeted IIEF-5 improvement) (Figures 6-8). Additionally, hemoglobin loss was better managed by

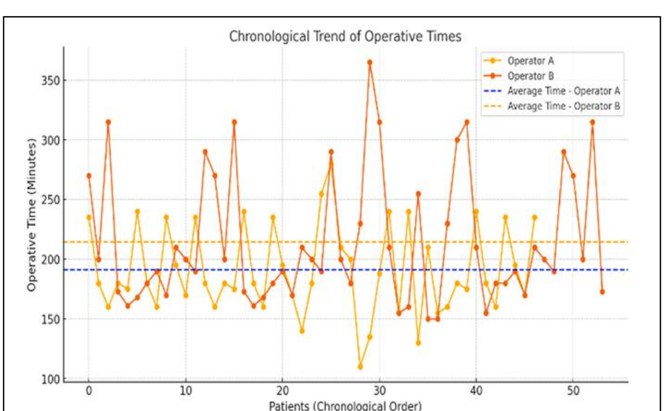

Figure 7.
CUSUM plot of cumulative deviations in IIEF-5 scores, showing progressive recovery of erectile function.
Operator A achieves better consistency in improvement, while Operator B exhibits less favorable trends, possibly due to differences in nerve-sparing technique or patient complexity. The CUSUM chart illustrates the cumulative sum of changes in IIEF-5 scores relative to the target.
A rising curve suggests progressive improvements in erectile function recovery, while a flatter trend reflects stabilization in functional outcomes.

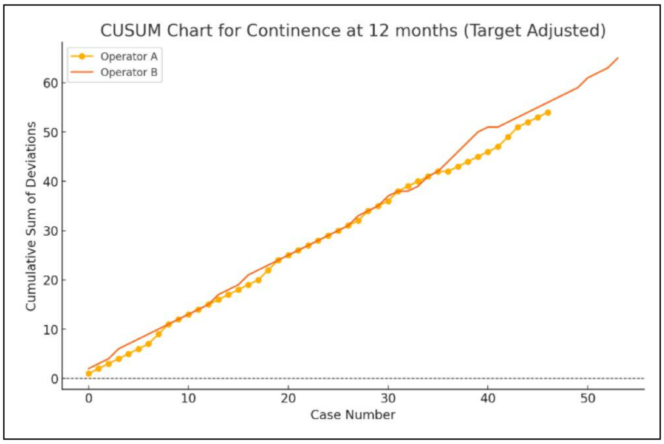

Figure 8.
CUSUM plot of continence outcomes at 12 months, with deviations from the target of full continence. Operator A shows a more stable performance with minimal deviations, whereas Operator B exhibits higher variability, reflecting challenges in achieving continence. The CUSUM plot represents the cumulative sum of deviations from the target of achieving full urinary continence at 12 months. An increasing trend indicates progressive improvement in continence recovery among patients, whereas a stable curve suggests a consistent rate of continence achievement.

Operator A, reflecting superior surgical efficiency and consistency (Figure 5).

These findings highlight the significant influence of prior laparoscopic experience on the learning curve for robotic-assisted radical prostatectomy. Operator A demonstrated superior performance in functional recovery and surgical efficiency metrics, with lower variability in outcomes. While global oncological outcomes were similar between the two operators, the favorable trends for Operator A in nerve-sparing cases and consistency in achieving performance targets underscore the value of surgical expertise in optimizing patient outcomes.

Discussion

The discussion surrounding the learning curve in RaRP provides crucial insights into the relationship between surgical proficiency and patient outcomes. This study reinforces the growing body of evidence highlighting the impact of prior laparoscopic experience on the learning curve for robotic surgery. Surgeons with extensive laparoscopic experience often achieve proficiency in RaRP more rapidly, underscoring the importance of foundational surgical skills. These findings align with previous studies, which demonstrate that surgeons who have performed more than 200 laparoscopic radical prostatectomies achieve faster mastery in RaRP, particularly regarding operative time and oncological outcomes (11-14).

Our study sought to compare the learning curves and outcomes of RaRP between surgeons with and without prior laparoscopic experience, shedding light on how surgical background influences operative success. While the results are consistent with existing literature, they also reveal nuances that merit further discussion. Advocates of robotic surgery frequently highlight its technological advantages, such as enhanced visualization, improved dexterity, and tremor elimination, all of which contribute to a shorter learning curve - even for surgeons without prior laparoscopic expertise. Research has demonstrated that RaRP facilitates more precise dissections and improved early functional recovery, particularly in urinary continence, as supported by systematic reviews (4, 5).

Despite these technological benefits, our findings suggest that prior laparoscopic experience significantly accelerates the RaRP learning curve. Surgeons with a strong laparoscopic background more rapidly achieve optimal Pentafecta outcomes, which encompass the absence of biochemical recurrence, recovery of sexual potency, complete urinary continence, minimal blood loss (within 1.5 g/dL of hemoglobin), and negative surgical margins. This underscores the importance of technical familiarity with minimally invasive surgical techniques, gained through laparoscopic training, as a critical foundation that translates effectively to robotic platforms.

The implications of these findings extend beyond individual performance, emphasizing the need for tailored training programs that leverage a surgeon's prior experience. For surgeons transitioning from laparoscopy to robotics, such programs can expedite proficiency and improve patient outcomes. Conversely, surgeons without a laparoscopic background may benefit from more intensive robotic training to bridge the gap in operative efficiency and functional recovery.

In summary, while RaRP's technological advantages offer a distinct edge in surgical precision and functional outcomes, the role of prior laparoscopic experience remains pivotal in shaping the learning curve and achieving comprehensive surgical success. Future studies should explore strategies to optimize robotic training pathways, ensuring consistent patient outcomes across varying levels of surgical expertise.

The CUSUM analysis has emerged as a widely utilized tool for evaluating surgical learning curves. While our findings demonstrate clear improvements in operative and oncological outcomes over time, it is important to interpret these results within the inherent limitations of the CUSUM methodology. One notable limitation is its sensitivity to the number of cases analyzed, which can introduce variability in defining the point of proficiency. *Lin et al.* (2023) highlighted that CUSUM peaks are highly dependent on sample size and target values, cautioning against an over-reliance on this metric as the sole determinant of surgical mastery (18).

In this study, CUSUM analysis revealed distinct differences in the learning curves and outcomes of the two operators. For Operator A, who had prior laparoscopic experience, the CUSUM curve indicated an earlier stabilization point, with operative times and *positive surgical margin* (PSM) rates reaching consistency after approximately 25 cases. This was accompanied by superior early

functional recovery, including improved rates of urinary continence and sexual potency. Conversely, Operator B, who lacked laparoscopic experience, exhibited a more extended learning curve, with stabilization occurring after approximately 40 cases. Despite this delay, Operator B's outcomes eventually converged with those of Operator A, underscoring the ability of the robotic platform to bridge initial skill disparities as surgical experience accumulates.
The robustness of the dataset bolstered the validity of these findings. The study design ensured minimal variability in case mix and controlled for confounding factors, reducing bias. Sensitivity analyses further confirmed that the thresholds identified by CUSUM were not influenced by sample size or selection bias. Moreover, the alignment between CUSUM peaks and clinical improvements - such as reductions in PSM rates and enhanced functional outcomes - validated the clinical significance of the statistical results.
These findings reaffirm the utility of CUSUM analysis as a reliable tool for assessing surgical learning curves, while also highlighting the dynamic relationship between prior experience and patient outcomes in RaRP. From the perspective of our secondary endpoint, the differences in oncological and functional outcomes between the two operators provide further insight into the impact of surgical background. Operator A's prior laparoscopic experience not only facilitated a shorter learning curve but also contributed to more consistent outcomes in the early stages of their RaRP practice. Operator B's extended learning curve emphasizes the importance of structured robotic training to mitigate the challenges faced by surgeons without a laparoscopic foundation.
In conclusion, while CUSUM analysis is a valuable method for evaluating learning curves, it is best used in conjunction with other performance metrics to provide a comprehensive assessment of surgical proficiency. These results underscore the critical role of prior experience and highlight the potential of the robotic platform to achieve high-quality outcomes, regardless of initial skill disparities.
Although both surgeons achieved comparable long-term oncological outcomes, including rates of PSMs and BCR, patients operated on by the surgeon with prior laparoscopic experience (Operator A) displayed slightly superior early functional outcomes. In addition to shorter average operative times, Operator A's procedures were characterized by greater uniformity in operative duration compared to those of Operator B, reflecting enhanced consistency likely attributable to their laparoscopic background.
Operator A demonstrated significantly shorter and more consistent operative times than Operator B, underscoring the impact of prior laparoscopic expertise on procedural efficiency and standardization. The reduced variability in operative times highlights the value of prior experience in achieving a more predictable and streamlined surgical process. This finding is particularly relevant for the design of surgical training programs, where consistency in performance can serve as an indicator of surgical mastery. Furthermore, the consistency in operative times has practical implications for operating room management, especially in high-volume centers where resource optimization is essential. These results underscore the dual benefits of prior laparoscopic experience: enhancing training outcomes and improving operational efficiency.
Regarding functional outcomes, patients in Operator A's cohort exhibited higher rates of early continence recovery and a trend toward better potency recovery. These observations align with previous studies, which have demonstrated that experience in laparoscopic techniques improves a surgeon's precision in critical steps, such as nerve-sparing and vesicourethral anastomosis, ultimately influencing functional outcomes (5).
Good et al. conducted a detailed analysis comparing the learning curves and post-learning curve outcomes of two experienced surgeons performing LRP and RaRP. Their study revealed that, although both approaches required significant learning curves, RaRP offered distinct advantages once surgeons achieved proficiency. Specifically, RaRP was associated with lower PSM rates, particularly at the prostatic apex, and superior early continence recovery rates compared to LRP. These benefits were attributed to the technological advancements of the robotic platform, including enhanced three-dimensional visualization and greater precision during apical dissection.
The authors emphasized that high surgical volumes and specialized training are essential for fully leveraging the advantages of robotic platforms, advocating for centralized, high-volume institutions to optimize patient outcomes [15). Interestingly, while Operator B, who lacked laparoscopic experience, exhibited a longer initial learning curve, their outcomes improved markedly over time, approaching those of Operator A. This underscores the capability of robotic systems to standardize surgical procedures and compensate for initial skill gaps.
Moreover, our findings align with the broader consensus in the literature, which highlights the ergonomic and visual advantages of robotic platforms in mitigating the technical challenges associated with laparoscopic surgery. Comparative studies consistently demonstrate better early continence and potency rates for RaRP compared to LRP, even during the learning curve (1-6, 15). However, achieving trifecta outcomes – continence, potency, and oncological control – remains complex, with success rates heavily influenced by surgeon experience and patient selection (10).
Surgeons without prior laparoscopic experience, however, face steeper learning curves, particularly in maintaining functional outcomes. *Monnerat et al.* (2018) highlighted that surgeons new to minimally invasive techniques required significantly more cases to achieve proficiency in RaRP comparable to experienced counterparts (4, 14). This emphasizes the importance of structured mentorship and simulation-based training programs to bridge the gap for novice surgeons.
The integration of robotics has not only redefined surgical paradigms but also raised important questions about the sustainability of learning curves in low-volume settings. A significant proportion of surgeons perform fewer than 10 radical prostatectomies annually, posing challenges to achieving optimal outcomes (4-6, 14).
Addressing these disparities will require systemic changes, such as regionalizing complex surgeries and providing targeted support for skill development among low-volume practitioners.

Comparative analyses also highlight nuanced trade-offs between robotic and laparoscopic techniques. While robotic platforms are associated with reduced operative times and shorter hospital stays, laparoscopic approaches remain a viable alternative in resource-constrained environments, provided that adequate surgical expertise is available (5, 6).

From an oncological perspective, no statistically significant differences were observed in PSM or BCR rates between the two operators, suggesting that the robotic platform ensures comparable oncological control regardless of surgical background. This observation aligns with prior studies indicating that RaRP can standardize certain oncological outcomes across surgeons with varying levels of experience (6). However, the slightly lower PSM rate in Operator A's cases likely reflects their enhanced anatomical knowledge and refined dissection techniques, honed through extensive laparoscopic training.

Despite these findings, our study highlights the need for further exploration of how prior surgical training influences not only learning curves but also the ability to deliver consistent functional outcomes. The apparent advantage of laparoscopic experience in early functional recovery raises important considerations for structuring training programs for surgeons transitioning to robotic platforms.

Finally, while this study reinforces the notion that prior laparoscopic experience accelerates the learning curve for RaRP, this relationship appears deeply rooted in the surgeon's thorough understanding of surgical anatomy and intraoperative nuances. Such expertise, cultivated through laparoscopic training, establishes a strong foundation for navigating the complexities of robotic platforms. Future research should focus on elucidating the bidirectional dynamics of skill transfer and identifying specific components of surgical training that maximize outcomes across various surgical modalities.

Conclusions

This study underscores the pivotal role of prior laparoscopic experience in shaping the learning curve and outcomes of RaRP. Surgeons with laparoscopic backgrounds achieved faster proficiency and superior early functional outcomes, likely attributable to their advanced anatomical knowledge and precise intraoperative technique. Furthermore, laparoscopic experience not only reduced operative times but also decreased variability, resulting in more consistent surgical performance compared to surgeons without prior laparoscopic training. This consistency highlights the importance of a foundational skill set in minimally invasive surgery when transitioning to robotic platforms.

While the robotic platform provides significant advantages in standardizing oncological outcomes – evidenced by comparable rates of PSMs and BCR across operators – the improved early functional recovery observed in surgeons with laparoscopic expertise emphasizes the value of prior training in minimally invasive techniques. Specifically, surgeons with laparoscopic experience demonstrated better early functional outcomes, including enhanced recovery of sexual function, as reflected in superior IIEF-5 scores at 12 months postoperatively.

Additionally, this study reinforces RaRP's superiority over LRP in terms of operative efficiency and short-term continence recovery, solidifying its position as the preferred surgical approach for localized prostate cancer. However, the differences observed between surgeons with and without laparoscopic experience suggest that skill transfer predominantly occurs in one direction - from laparoscopy to robotics. This raises critical considerations for the design of future training programs.

Further research is needed to validate these findings and explore the potential for bidirectional skill transfer between laparoscopic and robotic techniques. Understanding whether competencies developed in robotic surgery can enhance laparoscopic proficiency – or vice versa – may provide valuable insights for structuring more effective and versatile training programs in modern urologic surgery.

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Declarations

Ethical approval: *This study was approved by the Local Ethics Committee of Bari (BA), IRCCS Oncological Institute "Gabriella Serio" (Protocol number: 2112/CEL - Study "PrOPT").*

Availability of data and material: *The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.*

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