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Surgical margins and biochemical recurrence after the introduction of robot-assisted prostatectomy

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Introduction The DaVinci System is increasingly introduced in many centers worldwide, creating a need for data on surgical outcomes during the early phase of adoption. This study analyzes positive surgical margins (PSMs) and compares outcomes between open, laparoscopic, and robot-assisted radical prostatectomy.

Material and methods We retrospectively analyzed histopathologic and clinical data from 153, 126, and 721 patients who underwent open, laparoscopic, and robot-assisted radical prostatectomy, respectively. Patients with T2–T3 disease, no lymph node or distant metastases, and no history of neoadjuvant or adjuvant therapy were included. Additionally, surgeon-specific learning curves based on PSM rates were evaluated following the introduction of robot-assisted radical prostatectomy at our institution.

Results PSM were identified in 254 of 721 (35.2%) robot-assisted procedures, predominantly as focal margins, most often located at the apex. PSM rates were comparable between robot-assisted and laparoscopic surgery and higher after open prostatectomy ($p = 0.002$). PSM distribution was similar between robot-assisted and open approaches, while apical margins were most frequent following laparoscopic prostatectomy. PSMs were associated with a higher risk of early biochemical recurrence in the entire cohort ($p = 0.003$). Seminal vesicle invasion was consistently associated with early biochemical recurrence across all surgical approaches. Robot-assisted and laparoscopic surgery were associated with a lower risk of early biochemical recurrence than open prostatectomy. Surgeon-specific analysis demonstrated heterogeneous learning curves, with a reduction in PSM rates after the initial 50–100 cases and stabilization with increasing experience.

Conclusions Robot-assisted radical prostatectomy achieved PSM rates comparable to laparoscopic and lower than open prostatectomy during the early phase following its introduction. Despite more adverse pathology, robot-assisted surgery was not associated with an increased early biochemical recurrence, supporting its oncologic safety during adoption. These findings reflect the real-world learning curve associated with the implementation of robotic surgery.

Key Words: prostatectomy ‹› DaVinci ‹› RARP ‹› laparoscopy ‹› surgical margins ‹› prostate cancer

INTRODUCTION

Prostate cancer (PCa) is the second most commonly diagnosed cancer worldwide and the most prevalent malignancy in Western countries [1]. Radical prostatectomy (RP) remains a cornerstone treatment for patients with localized or locally advanced disease, providing favorable oncologic outcomes and potential for cure [2, 3]. Among various parameters used to assess surgical performance, the positive surgical margin rate (PSM) has emerged as a key indicator of RP quality [4]. PSMs are associated with an increased risk of biochemical recurrence (BCR), with the risk increasing proportionally to the length of the involved margin [5, 6]. The prevalence of PSMs depends not only on tumor stage and disease biology but also on the surgical approach and technical proficiency of the surgeon [7, 8]. Because PSMs are frequently considered an indication for adjuvant therapy, their presence may contribute to overtreatment in selected patients [9]. Consequently, optimizing surgical technique and selecting the most appropriate operative approach are essential to minimizing PSM rates.

Since the introduction of robot-assisted radical prostatectomy (RARP) in 2000, many cancer centers have incorporated robotic surgery into routine clinical practice, gradually replacing open and laparoscopic approaches [10]. Compared with open surgery, RARP has been associated with reduced blood loss, shorter hospital stay, and lower perioperative complication rates, as well as improved visualization and surgical precision. However, most comparative studies report little or no difference in PSM rates between RARP and laparoscopic radical prostatectomy (LRP) [8, 11]. Owing to differences in surgical technique and anatomical exposure, the distribution of PSM varies between approaches, and not all margin locations appear to confer the same risk of biochemical recurrence [12]. Furthermore, the steep learning curve associated with laparoscopy has been a limiting factor for its widespread adoption, whereas robotic surgery allows for more rapid acquisition of technical proficiency [13].

Although more than 85% of prostate cancer patients in the United States undergo robot-assisted procedures, the DaVinci Surgical System is still being implemented in several European oncology centers, largely due to high acquisition costs and limited availability [14]. The present study evaluates oncologic outcomes following the introduction of RARP at our institution in October 2022 and compares them with those of open and laparoscopic prostatectomy. Specifically, we assessed the prevalence and anatomical distribution of PSMs, examined the association between PSMs and early biochemical recurrence, and analyzed clinicopathologic features influencing these outcomes. In addition, we evaluated the institutional learning curve to provide real-world data that may facilitate the adoption of robotic prostatectomy in other centers.

MATERIAL AND METHODS

Study cohorts

The study group consisted of 1000 prostate cancer patients who underwent radical prostatectomy between October 2020 and October 2024. Among them, 721 patients underwent robot-assisted prostatectomy, 126 laparoscopic prostatectomy, and 153 open radical prostatectomy (ORP). All robotic radical prostatectomies were performed at the Department of Urology of the Oncology Center in Bydgoszcz. Data were collected retrospectively from medical records, with all personal identifiers anonymized to ensure patient confidentiality. Collected variables included patient demographics (age), clinicopathological tumor characteristics (stage, grade, lymph node involvement, resection margins, cancer invasion), and prostate-specific antigen (PSA) levels measured preoperatively and during postoperative follow-up at 6 weeks, 3 months, 6 months, 9 months, and 12 months.

All robot-assisted radical prostatectomies were performed consecutively from the introduction of the robotic program at our institution, representing the initial implementation phase. No robot-assisted procedures had been performed prior to the study period. Three surgeons were involved in the robotic program and were introduced sequentially. Surgeon 1 had prior laparoscopic experience and underwent structured training during program implementation but had no prior independent experience in robotic surgery. Subsequent surgeons initially assisted in robot-assisted procedures performed by Surgeon 1 and later transitioned to performing surgeries independently following dedicated training.

Cohort definition and inclusion criteria

For descriptive analyses of surgical margin status and its anatomical distribution, the entire RARP cohort (n = 721) was analyzed.

For comparative analyses between surgical approaches, a predefined comparative cohort was established. Patients were included if they met

the following criteria: pathological stage pT2 or pT3, absence of lymph node involvement, no evidence of distant metastases confirmed by surgery or imaging, and no history of neoadjuvant or adjuvant therapy. This comparative cohort consisted of 243 RARP, 126 LRP, and 153 ORP patients.

Early biochemical recurrence (BCR) was defined as at least one PSA value ≥0.2 ng/mL within 12 months after surgery. Patients who were initially qualified for immediate adjuvant therapy were excluded from the analysis of early BCR. If a patient was initially managed without adjuvant therapy but subsequently required additional treatment due to rising PSA levels that did not meet the predefined BCR threshold, the case was classified as prostate cancer recurrence. Median follow-up time was calculated for the comparative cohort based on the interval between surgery and the last available PSA measurement. Follow-up was limited to approximately 12 months, consistent with the definition of early biochemical recurrence.

Pathology analysis

All prostatectomy specimens were processed according to the Stanford protocol and evaluated using the Gleason grading system. Specimens were step-sectioned to allow comprehensive assessment of tumor grade, volume, and surgical margins. PSM was defined as the presence of malignant tumor cells at the inked surface of the resection specimen. Margin locations were categorized as right or left lobe, apex (right, left, or bilateral), and base. Seminal vesicle invasion was also recorded. The assessment of the surgical margins followed the diagnostic protocol of the College of American Pathologists [15]. PSMs were classified as focal if the length of margin involvement was ≤1 mm and extensive if >1 mm. The presence of two or more focal PSMs was classified as multifocal margin involvement (Figure 1). In a subset of cases, margin extent was not specified in the pathology reports.

Statistical analysis

Frequencies and proportions were used to summarize categorical variables, while continuous variables were reported as medians with interquartile ranges (IQR). The distribution of continuous variables was assessed for normality using the Shapiro–Wilk test. Because most variables were not normally distributed, the Kruskal-Wallis H test and Mann-Whitney U test were used for comparisons of continuous variables, and the chi-square test was applied for categorical variables. Correlations were assessed using Spearman's rank correlation coefficient.

To account for differences in clinicopathological characteristics between surgical approaches, multivariate logistic regression analyses were performed. Separate models were constructed to evaluate factors associated with positive surgical margins and early biochemical recurrence. Variables included in the multivariate analysis were selected a priori based on clinical relevance. Odds ratios (ORs) with corresponding 95% confidence intervals (CIs) were reported. All analyses were performed using Statistica v13.0 (StatSoft). All tests were two-sided, and p-values <0.05 were considered statistically significant.

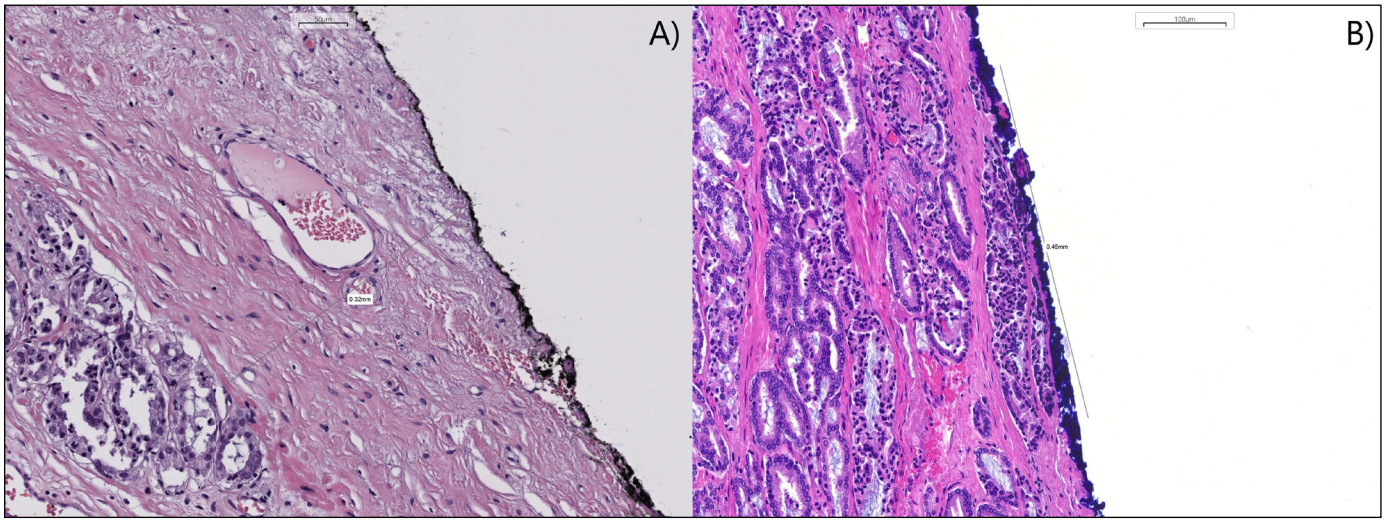

Figure 1. *Cross-sectional images of prostate resection specimens with* **A)** *negative surgical margin and* **B)** *positive surgical margin.*

Bioethical standards

The study was conducted following the Declaration of Helsinki, and the protocol was approved by the Bioethics Committee of the Nicolaus Copernicus University (KB881/2019).

RESULTS

The prevalence and location of PSM after robot-assisted prostatectomy

Between October 2022 and October 2024, a total of 721 patients underwent robot-assisted radical prostatectomy. The cohort was characterized by a substantial proportion of intermediate- and high-risk cases, with 483 (67%) classified as pT2 and 238 (33%) as pT3. 71.3% (514/721) of all cases were assigned to grade group 2 or 3. Adverse prognostic features were frequently observed, including angioinvasion in 195 (27%) cases and perineural invasion in 645 (89.6%) cases. Prostate cancer most frequently invaded the apex of the prostate (69.3%), followed by the base (24.4%), and the seminal vesicles (14.1%). Among patients with PSMs (35.2%, 254/721), focal (≤1 mm) margins were the most common (56.9%), whereas multifocal (≥2 foci), and extensive (>1 mm) margins were less frequent; detailed classification is presented in Table 1.

The location of positive surgical margins was available for 202 out of 254 cases. The most frequently involved sites were the lateral aspects of the prostate, with comparable involvement of the right and left lobes (48.0% and 44.1%, respectively), followed by the apex (34.2%). Basal margins were least commonly affected (17.3%). Because multiple margin locations could be present in a single patient, percentages exceed 100% (Figure 2).

Comparison of positive surgical margins between surgical approaches

Median follow-up time differed slightly between groups: 9.0 months (IQR 6–12) for RARP, 10.5 months (IQR 9–12) for LRP, and 9.0 months (IQR 6–9) for ORP ($p = 0.002$). Baseline clinicopathological characteristics were generally comparable between surgical approaches (Table 2). Median age and preoperative PSA levels were similar across patients undergoing robot-assisted, laparoscopic, and open prostatectomy. Likewise, no significant differences were observed in pathological stage distribution, grade group, or the prevalence of extracapsular extension, angioinvasion, perineural invasion, or tumor involvement of the apex and base of the prostate. In contrast, seminal vesicle invasion differed

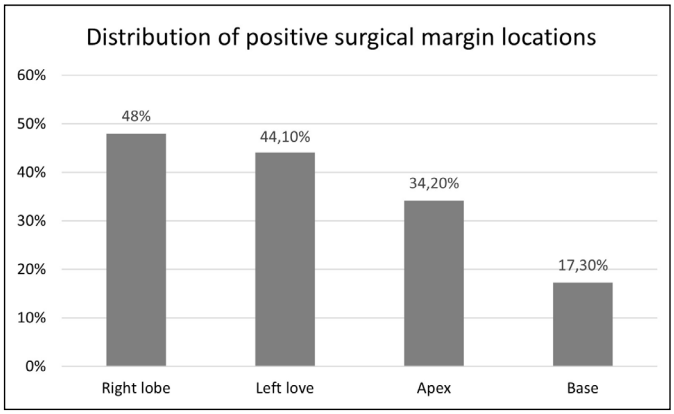

Figure 2. *Location and prevalence of positive surgical margins in patients undergoing robot-assisted radical prostatectomy.*

Table 1. *Clinicopathological characteristics of prostate cancer patients who underwent robot-assisted prostatectomy*

Variable	Robot-assisted radical prostatectomy (n = 721)
Age (median, IQR)	66 (62–71)
PSA before surgery (median, IQR)	7.65 (5.3–11.9)
Stage	
pT2	483 (67%)
pT3	238 (33%)
Grade group	
1	98 (13.6%)
2	300 (41.6%)
3	214 (29.7%)
4	61 (8.5%)
5	48 (6.7%)
Transcapsular invasion	
Absent	503 (69.8%)
Present	218 (30.2%)
Angioinvasion	
Absent	526 (73%)
Present	195 (27%)
Neuroinvasion	
Absent	75 (10.4%)
Present	645 (89.6%)
Apex invasion	
Absent	221 (30.7%)
Present	500 (69.3%)
Base invasion	
Absent	543 (75.3%)
Present	176 (24.4%)
Seminal vesicle invasion	
Absent	619 (85.9%)
Present	101 (14.1%)
Resection margins	
Negative	467 (64.8%)
Positive	254 (35.2%)
Positive surgical margin	
Focal	142 (55.9%)
Multifocal	24 (9.4%)
Extensive	19 (7.5%)
Not specified	69 (27.2%)

IQR – interquartile range

significantly between groups, with a higher prevalence observed in patients undergoing open surgery (p = 0.009). Additionally, the rate of PSMs varied significantly according to surgical approach, with the highest proportion observed in the open radical prostatectomy group (p = 0.002).

Anatomical distribution and extent of positive surgical margins by surgical approach

Analysis of distribution of surgical margins by anatomic location revealed differences between surgical approaches (Table 3). Right-sided positive surgical margins were more frequently observed after robot-assisted and open prostatectomy compared with laparoscopic procedures (p = 0.02). In contrast, no significant differences were observed for left-sided margins between groups. Apex involvement differed significantly according to surgical approach, with the highest prevalence observed after laparoscopic prostatectomy, whereas basal margin involvement did not differ significantly between techniques (p = 0.0001). No significant differences were observed in the extent of PSMs between robot-assisted, laparoscopic, and open procedures (Figure 3).

Analysis of early biochemical recurrence by surgical approach

Early biochemical recurrence was analyzed in relation to clinicopathologic features or prostate cancer and surgical approaches (Table 4). In univariable analyses stratified by surgical technique, invasion of the apex or base of the prostate was not associated with the risk of early biochemical recurrence. In contrast, seminal vesicle invasion was consistently associated with a higher risk of early biochemical recurrence across all surgical approaches (p <0.05).

Table 2. *Clinicopathological characteristics of prostate cancer patients by type of surgical approach*

Variable	RARP (n = 243)	LRP (n = 126)	ORP (n = 153)	Intergroup difference (p-value)
Age (median)	65 (45-80)	64 (45–75)	65 (49–78)	N/A
Follow-up time (median, IQR)	9 months (6–12)	10.5 months (9–12)	9 months (6–9)	0.002
PSA before surgery	10.54 (0.41–57)	10.03 (0.20–70)	12.67 (0.55–61.35)	
Stage				
pT2	164 (67.49%)	92 (73.02%)	91 (59.48%)	0.0525
pT3	79 (32.51%)	34 (26.98%)	62 (40.52%)	
Grade group				
1	39 (16.05%)	25 (19.84%)	27 (17.65%)	0.48
2	95 (39.09%)	55 (43.65%)	64 (41.83%)	
3	88 (36.21%)	34 (26.98%)	45 (29.41%)	
4	14 (5.76%)	10 (7.94%)	9 (5.88%)	
5	7 (2.88%)	2 (1.59%)	8 (5.23%)	
Transcapsular invasion				
No	17 (7.00%)	14 (11.11%)	12 (7.84%)	0.39
Yes	226 (93.00%)	112 (88.89%)	140 (91.50%)	
Angioinvasion				
No	155 (63.79%)	94 (74.60%)	99 (64.71%)	0.09
Yes	88 (36.21%)	32 (25.40%)	54 (35.29%)	
Neuroinvasion				
No	21 (8.64%)	17 (13.49%)	16 (10.46%)	0.14
Yes	222 (91.36%)	91 (72.22%)	137 (89.54%)	
Apex invasion				
No	79 (32.51%)	33 (26.19%)	43 (28.10%)	0.4
Yes	164 (67.49%)	93 (73.81%)	110 (71.90%)	
Base invasion				
No	170 (69.96%)	94 (74.60%)	100 (65.36%)	0.25
Yes	73 (30.04%)	32 (25.40%)	53 (34.64%)	
Seminal vesicle invasion				
No	20 (86.01%)	115 (91.27%)	121 (79.08%)	**0.009**
Yes	34 (13.99%)	10 (7.94%)	32 (20.92%)	
Resection margins				
No	156 (64.20%)	85 (67.46%)	75 (49.02%)	**0.002**
Yes	87 (35.80%)	41 (32.54%)	78 (50.98%)	

RARP – robot-assisted radical prostatectomy; LRP – laparoscopic radical prostatectomy; ORP – open radical prostatectomy

Positive surgical margins were not significantly associated with early biochemical recurrence when analyzed separately within each surgical group. However, in a pooled 2 × 2 analysis of the entire comparative cohort, positive surgical margins were associated with an increased risk of early biochemical recurrence (OR = 3.22, 95% CI: 1.51–6.85; Fisher's exact test, p = 0.032). The rates of early BCR were low and comparable in patients undergoing RARP and LRP (4.8% and 4.3%, respectively). In contrast, patients treated with ORP had a substantially higher rate of early BCR (24%) compared with both minimally invasive approaches (p = 0.002).

Table 3. *Anatomical distribution and prevalence of positive surgical margins by surgical approach*

Location	Prevalence of positive surgical margins			
	RARP (n = 243)	LRP (n = 126)	ORP (n = 153)	Intergroup difference (p-value)
Right margin	52 (21.4%)	14 (11.1%)	42 (27.5%)	0.02
Left margin	40 (16.5%)	16 (12.7%)	36 (23.5%)	0.61
Apex	21 (8.6%)	26 (20.6%)	30 (19.6%)	**0.0001**
Base	17 (7%)	5 (4%)	10 (6.5%)	0.51

*Statistically significant results are in bold.
RARP – robot-assisted radical prostatectomy; LRP – laparoscopic radical prostatectomy; ORP – open radical prostatectomy.

Table 4. *Association between histopathological features and the risk of early biochemical recurrence*

Histopathological variable	Risk ratio of early biochemical recurrence			
	RARP (n = 243)	LRP (n = 126)	ORP (n = 153)	Entire cohort
Apex invasion (Yes vs No)	5.3 [0.7–40.7] p = 0.1	2.3 [0.13–43] p = 0.57	0.9 [0.4–2.1] p = 0.78	2.02 [0.8–5.1] p = 0.16
Base invasion (Yes vs No)	1.4 [0.4.–4.7] p = 0.54	7.3 [0.7–75] p = 0.09	1.3 [0.6–3.1] p = 0.47	1.91 [0.9–4] p = 0.1
Seminal vesicle invasion (Yes vs No)	3.75 [1.1–12.8] **p = 0.035**	6.4 [0.7–59] **p = 0.01**	2.9 [1.4–6.1] **p = 0.005**	5.43 [2.3–12.84] **p = 0.0004**
Positive surgical margins (Yes vs No)	2.48 [0.79–7.8] p = 0.12	13.7 [0.74–254.7] p = 0.08	1.53 [0.6–3.52] p = 0.32	3.22 [1.51–6.85] **p = 0.032**

Statistically significant results are in bold.
RARP – robot-assisted radical prostatectomy; LRP – laparoscopic radical prostatectomy; ORP – open radical prostatectomy

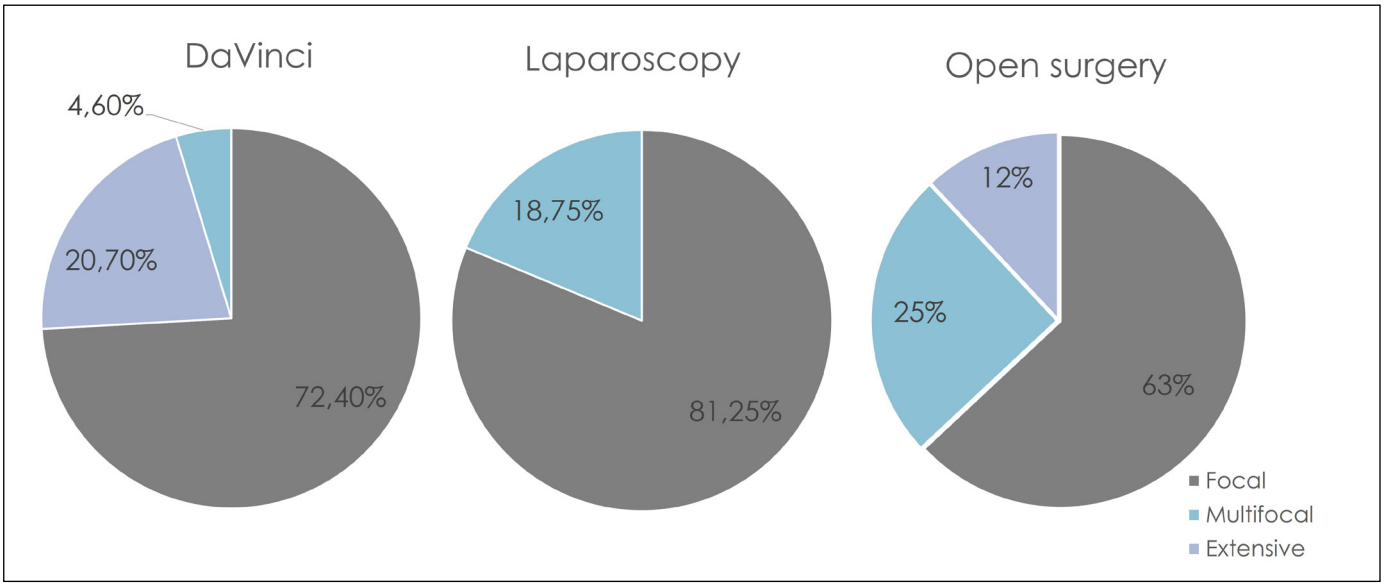

Figure 3. *Differences in the extent of positive surgical margins between surgical approaches.*

Distribution of negative and positive surgical margins following robot-assisted radical prostatectomy

Finally, temporal trends in surgical margin status were evaluated in 719 cases with available surgeon identification over the initial period following the introduction of robot-assisted radical prostatectomy at our institution (Figure 4). Importantly, no robotic-assisted procedures had been performed at our center prior to the study period, and the analyzed cases represent the earliest implementation phase of the robotic program.

The proportion of negative surgical margins (R0) demonstrated variability during the early phase, followed by a gradual improvement over time (Table 5). Conversely, the rate of positive surgical margins (R1) decreased with increasing surgical experience. Notably, a transient increase in R1 rates was observed following the introduction of additional surgeons, reflecting the staged implementation of the robotic program. Surgeon 1 had prior laparoscopic experience and underwent structured training during the implementation phase; however, he had not previously performed robotic surgery on a regular basis. Subsequent surgeons were initially involved as assistants during robot-assisted procedures performed by Surgeon 1 and later transitioned to performing surgeries independently.

In subsequent periods, the margin status appeared to stabilize, consistent with progression along the surgical learning curve. These findings highlight the multi-surgeon, real-world nature of the institutional learning process and are in line with the heterogeneity observed in surgeon-specific learning curves.

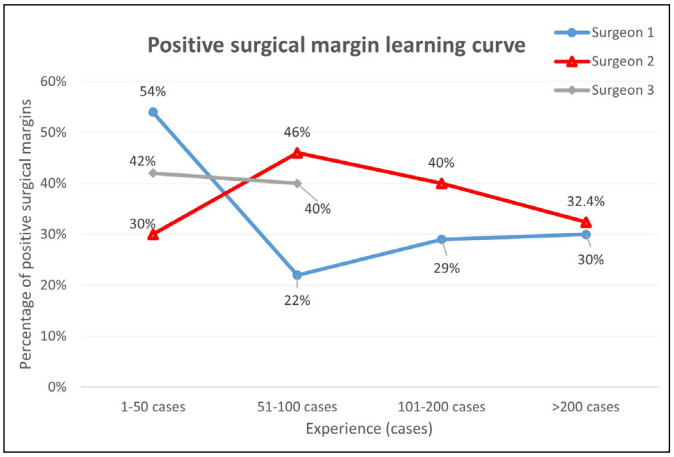

Figure 4. *Positive surgical margin (R1) rates across learning phases by surgeon. A reduction in R1 rates is observed with increasing experience, with substantial inter-surgeon variability. Data for Surgeon 3 are limited to early phases.*

DISCUSSION

In this study, we assessed the rate, anatomical distribution, and clinical relevance of PSM after robot-assisted, laparoscopic, and open radical prostatectomy in a high-volume center during the introduction of robotic surgery. PSMs were identified in 254 of 721 (35.2%) RARP specimens, the majority of which were focal and most commonly located in the right lobe. Despite a higher prevalence of seminal vesicle invasion, the overall PSM rate after RARP was comparable to laparoscopic and lower than open radical prostatectomy. The anatomical distribution of PSMs was similar between RARP and ORP, whereas the apex represented the most frequent margin location in the laparoscopic group. No statistically significant differences in the extent of PSMs were observed between the surgical approaches. Neither apical nor basal margin involvement correlated with an increased risk of early BCR across all analyzed groups. In contrast, seminal vesicle invasion was consistently

Table 5. *Positive surgical margin rates across learning phases by surgeon*

Surgeon	Learning phase	All cases	R1 cases	R1 (%)
Surgeon 1	Learning (1–50)	50	27	54%
	Intermediate I (51–100)	50	11	22%
	Intermediate II (101-200)	100	29	29%
	Experienced (>200)	80	24	30%
Surgeon 2	Learning (1–50)	50	15	30%
	Intermediate I (51–100)	50	23	46%
	Intermediate II (101–200)	100	40	40%
	Experienced (>200)	136	44	32.4%
Surgeon 3	Learning (1–50)	50	21	42%
	Intermediate I (51–100)	50	20	40%

The Intermediate II phase (101–200 cases) was not analyzed for Surgeon 3 due to extremely low sample size (n = 3). R1 denotes positive surgical margins

associated with a higher risk of early biochemical recurrence across all analyzed groups. Although the surgical margin status itself was not associated with BCR in our cohort, patients undergoing RARP or LRP demonstrated lower risk of early BCR compared with those treated with open prostatectomy. These findings should be interpreted in the context of the introduction of robotic surgery at our institution and potential variability related to surgeons' learning curve.

While the DaVinci System has been widely adopted in the United States and Western Europe, its implementation in Central and Eastern Europe is still in progress [14]. Consequently, data describing outcomes from the early phase of robotic program implementation in these regions are still limited, although initial single-center experiences using different robotic platforms have demonstrated feasibility and acceptable perioperative and early oncological outcomes [16]. In this context, the PSM rates observed at our institution appear appropriate for the clinical stage distribution of the treated cohort and are consistent with previously published series [17–19]. The extent of PSMs has been linked to reduced progression-free survival and is currently recommended for routine reporting by the American College of Pathologists [20, 21]. However, in our analysis, we found no differences in the prevalence of focal, multifocal, and extensive surgical margins between the surgical approaches (Figure 3). Although previous studies have reported smaller median margin length after RARP compared with laparoscopic prostatectomy, direct comparison is limited by the lack of uniform classification of PSM extent in the available literature [22]. Finally, consistent with prior reports, the most common locations of PSMs in our cohort were the posterolateral region and the prostatic apex [12, 23].

Despite radical treatment with prostatectomy or radiation, up to 50% of patients experience BCR within 10 years [24]. According to guideline-based criteria, post-radical prostatectomy BCR is defined as at least two PSA values ≥0.2 ng/ml in the absence of radiologic evidence of the disease [25]. While BCR is associated with worse oncologic outcomes and an higher risk of metastatic progression, not all patients with BCR benefit from adjuvant therapy, particularly those with high-risk features such as short PSA doubling time or higher Gleason score [26, 27]. Risk stratification after surgery is influenced by multiple confounding factors, including surgical margin status, PSA kinetics, and pathological tumor characteristics [28].

However, when the entire cohort was analyzed, the presence of PSMs was associated with an increased risk of early BCR (Table 4). This finding suggests that the prognostic impact of PSMs may become evident only when sufficient statistical power is achieved, and it supports the interpretation of PSMs as a relevant, albeit non-independent, risk factor for early recurrence. Importantly, the RADICALS-RT trials did not demonstrate a clinical benefit of routine adjuvant radiotherapy following radical prostatectomy [29]. Accordingly, the initiation of additional treatment should be guided by a combination of risk factor for BCR or adverse outcomes, including greater PSM length, multifocal margin involvement, or higher Gleason score [30–32] – notably, despite a higher prevalence of multifocal PSMs and a higher incidence of early BCR in patients undergoing ORP. Similarly, we did not observe a statistically significant association between the extent of PSMs and early BCR.

The DaVinci System has become a widely adopted, minimally invasive surgical modality, offering several advantages over traditional approaches. Although associated with substantial initial and maintenance costs, these may be offset by reduction in perioperative morbidity, shorter hospital stays, fewer BCRs, and improved postoperative recovery [33, 34]. The implementation of structured training protocols has also shortened operative time and improved cost-effectiveness [35]. This is particularly important given the relatively short learning curve of RAPR, with approximately 80 procedures required to achieve stable operative times and fewer procedures needed to stabilize blood loss [36]. Importantly, unlike LRP and ORP, surgeons performing RARP appear to achieve adequate disease control early in their learning curve, without an initial increase in BCR rates [37]. This observation is consistent with our institutional experience, where a progressive improvement in PSM rates was observed over time, reflecting the impact of the learning curve during the early implementation phase (Figure 4), with a transient increase following the introduction of additional surgical teams and a subsequent stabilization over time, indicating that early oncological outcomes should be interpreted in the context of surgical experience, particularly in multi-surgeon settings, and that the transition to robot-assisted prostatectomy can be rapid, safe, and feasible.

The study has several limitations. First, as the DaVinci System was introduced in our center in October 2022, the follow-up time is relatively short and does not allow the estimation of long-term biochemical recurrence after specific surgical approaches. Consequently, a modified definition of BCR based on guideline-based criteria was applied to enable early outcome evaluation [25].

Patients are still being followed, and the cohorts will be analyzed in the future. Follow-up duration differed between groups, which may reflect differences in the timing of surgical approaches and the introduction of robotic surgery. However, because the analysis focused on early biochemical recurrence within a 12-month period, the clinical impact of these differences is likely limited.

Despite efforts to construct relatively homogeneous cohorts, differences in seminal vesicle invasion were observed, which may have influenced the results. In addition, the analysis includes archival data for LRP and ORP from before October 2022, for which not all surgical indications were consistently reported. Therefore, selection bias related to surgeon preference and expertise cannot be excluded. Since October 2022, all patients in our center have been routinely qualified for robot-assisted prostatectomy.

Furthermore, the limited number of laparoscopic procedures performed at the Cancer Center required inclusion of cases from a second institution. Although identical surgical protocols and standards of care were applied, this may have affected the results. The association between PSMs and early biochemical recurrence was evaluated using univariable analyses, and residual confounding by other pathological risk factors cannot be excluded.

Finally, the retrospective design of the study represents an inherent limitation. The introduction of robot-assisted surgery during the study period resulted in a learning curve effect, which may have influenced surgical outcomes, particularly in the early phase. Additionally, unequal group sizes between surgical approaches may still introduce bias despite cohort restriction. Differences in follow-up duration between groups, especially for robot-assisted procedures with shorter observation time, may also affect the assessment of oncological outcomes.

CONCLUSIONS

RARP demonstrated PSM rates comparable to laparoscopic and lower than open radical prostatectomy, with no significant differences in margin extent between the analyzed surgical approaches. The anatomical distribution of PSMs was similar between RARP and ORP, whereas apical margins were most frequently observed following laparoscopic prostatectomy. Although ORP was associated with higher rates of early biochemical recurrence, these findings should be interpreted cautiously due to the relatively short follow-up period, and they warrant confirmation in larger prospective studies. PSM rates appear to decrease after the initial learning phase and stabilize with increasing surgical experience. Although early oncological outcomes should be interpreted with caution, these findings suggest that the transition to robot-assisted prostatectomy can be rapid and feasible.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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ETHICS APPROVAL STATEMENT

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