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Predictors of positive surgical margins after robot-assisted radical prostatectomy

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Introduction Positive surgical margins (PSMs) after robot-assisted laparoscopic radical prostatectomy (RALRP) are linked to increased biochemical recurrence risk, but predictors remain inconsistent. This study aimed to identify predictors of PSM through a prospective cohort analysis and a systematic review with meta-analysis.

Material and methods We analyzed 100 consecutive patients undergoing RALRP at a tertiary centre (2016–2018). Logistic regression assessed associations between clinical, pathological, and surgical variables and PSM. Cox regression evaluated the impact of PSM on biochemical recurrence. In parallel, a meta-analysis of studies reporting regression-based predictors of PSM after RALRP was conducted. Random-effects models pooled adjusted and unadjusted odds ratios.

Results In the cohort, 22% of patients had PSM, most frequently at the apex. Independent predictors were capsular invasion (OR = 2.63; 95% CI: 0.95–7.32) and lower prostate weight (OR = 0.964 per gram; 95% CI: 0.95–0.98). PSM independently predicted biochemical recurrence (HR = 5.29; 95% CI: 1.38–20.19). The meta-analysis of 13 studies confirmed significant associations between PSM and higher pathological T stage (aOR = 5.58; 95% CI: 1.95–9.20), higher prostate-specific antigen level (aOR = 1.05 per ng/ml; 95% CI: 1.01–1.09), and higher pathological Gleason score. Larger prostate weight and volume were protective. Associations with biopsy Gleason score, body mass index, nerve-sparing status, and age were inconsistent.

Conclusions Tumour aggressiveness, reflected by pathological stage, capsular invasion, and Gleason score, is the strongest determinant of PSM after RALRP, while larger prostate weight is protective. Integrating cohort and meta-analytic findings provides a comprehensive synthesis of factors associated with surgical margin status that may inform future risk stratification and surgical planning.

Key Words: robot-assisted laparoscopic radical prostatectomy ‹› positive surgical margin ‹› prostate cancer ‹› predictors ‹› meta-analysis

INTRODUCTION

Prostate cancer is the second most common malignancy among men and a leading cause of cancer-related mortality worldwide [1]. Radical prostatectomy, performed through open, laparoscopic, or robot-assisted approaches, remains a cornerstone of curative treatment for localized disease. The oncologic efficacy of surgery is largely determined by the absence of tumour cells at the inked resection margin, known as a positive surgical margin (PSM) [2]. PSMs are associated with an increased risk of biochemical recurrence (BCR), the need for secondary treatments, and potentially reduced cancer-specific survival [3].

Robot-assisted laparoscopic radical prostatectomy (RALRP) has gained widespread adoption due to its potential advantages, including improved visualization, greater dexterity, and shorter convalescence compared with conventional techniques. Nevertheless, reported PSM rates after RALRP vary widely, ranging from less than 10% to over 30% [4–6], reflecting differences in surgical expertise, pathological definitions, patient selection, and tumour biology. Moreover, the location of the margin – such as apical, posterolateral, or base – may influence recurrence risk and guide intraoperative decision-making [7, 8].

Identifying predictors of PSM is clinically relevant for preoperative counselling, surgical planning, and benchmarking outcomes across institutions. Previous research has explored factors including preoperative prostate-specific antigen (PSA) level, biopsy and pathological Gleason score, pathological T stage, tumour volume, prostate size, and nerve-sparing status. However, most studies have been single-centre and retrospective [3, 9–11], and findings have often been inconsistent. Several meta-analyses have investigated predictors of PSM in radical prostatectomy in general, but few have specifically focused on RALRP, where surgical ergonomics and dissection techniques differ [4, 12].

To address these gaps, we conducted a prospective cohort study of consecutive patients undergoing RALRP at a tertiary referral centre to identify predictors of PSM and assess their association with biochemical recurrence. To enhance external validity and overcome limitations of single-centre data, we also performed a systematic review and meta-analysis focused exclusively on RALRP. Unlike prior studies, our analysis provides a comprehensive synthesis of all reported predictors of PSM in the robotic setting and distinguishes between adjusted and unadjusted associations to better define independent risk factors. By integrating prospective clinical data with a structured quantitative synthesis, we aimed to provide a more complete and methodologically consistent evaluation of determinants of surgical margin status in contemporary robotic prostatectomy.

MATERIAL AND METHODS

Study design and patient population

We conducted a prospective cohort study including all consecutive patients undergoing RALRP for clinically localized prostate cancer at a tertiary referral centre between January 2016 and December 2018. All cases were performed by experienced robotic surgeons using a standardised surgical approach. Patients with prior prostate surgery, salvage prostatectomy, or incomplete records were excluded. The study was approved by the institutional review board, and all patients provided written informed consent.

Data collection and definitions

Preoperative variables included age, body mass index (BMI), PSA level, clinical T stage, biopsy Gleason score, and prostate volume (measured by transrectal ultrasound). Operative variables included nerve-sparing status, console time, estimated blood loss, and prostate weight. Surgeon experience was represented by a binary "learning curve" variable, defined as the first 50 versus last 50 consecutive RALRP cases performed during the study period (2016–2018), to evaluate the potential effect of procedural experience on margin outcomes. Pathological variables comprised pathological T stage, pathological Gleason score, tumour volume percentage, and presence of extracapsular extension, seminal vesicle invasion, lymphovascular invasion, and capsular invasion. PSM was defined as tumour cells in contact with the inked specimen surface.

Follow-up and outcome measures

Patients were reviewed postoperatively at 6 weeks, 3 months, 6 months, and every 6 months thereafter. BCR was defined as a postoperative PSA level ≥0.2 ng/ml on two consecutive measurements. This definition was selected because it was widely accepted and routinely applied in clinical practice during the study period (2016–2018).

Surgical technique

All procedures were performed using the da Vinci® Xi robotic platform via a six-port transperitoneal anterior approach. Dissection was primarily anterograde, beginning with bladder neck division followed by seminal vesicle isolation and posterior Denonvilliers' fascia dissection. The neurovascular bundles were identified using a combination of intrafascial or interfascial nerve-sparing techniques, depending on the preoperative risk of extracapsular extension as judged by MRI and biopsy findings. Bilateral nerve-sparing was attempted in patients with favourable oncologic features and was omitted when high tumour burden was suspected on one or both sides. Apical dissection was performed under direct 30° downward endoscopic visualization with preservation of maximal urethral length, while posterolateral dissection followed the prostatic capsule to minimise tension on the neurovascular bundles. Bladder neck preservation and meticulous hemostasis were maintained throughout to standardise margin control across surgeons.

Systematic review and meta-analysis

The systematic review was conducted in accordance with PRISMA guidelines. We searched PubMed, Scopus, and Web of Science from inception to March 2025 using terms related to "robot-assisted laparoscopic radical prostatectomy" and "positive surgical margin" (suppl. Table S1). We included studies reporting regression-based predictors of PSM after RALRP in multivariable or univariable analysis. Non-English articles, conference abstracts, reviews, editorials, and studies combining RALRP with other surgical approaches without separate data were excluded. Both adjusted and unadjusted effect estimates were analysed separately to distinguish independent predictors from potentially confounded associations.

Two reviewers independently screened titles/abstracts and assessed full texts for eligibility, with disagreements resolved by consensus. Data extracted included study design, population characteristics, surgical technique, and predictors assessed. Risk of bias was evaluated using the Newcastle–Ottawa Scale for observational studies.

Statistical analysis

For the cohort study, univariable logistic regression assessed associations between patient, tumour, and surgical variables and PSM. Variables demonstrating a p-value <0.10 in univariable analysis or deemed clinically relevant based on prior literature were subsequently entered into a multivariable model using a backward stepwise elimination approach. Cox regression was used to evaluate the impact of PSM on BCR, adjusting for relevant confounders.

For the meta-analysis, odds ratios (ORs) with 95% confidence intervals (CIs) were extracted for each predictor. Adjusted ORs from multivariable models were preferred; if unavailable, unadjusted ORs were used. Pooled estimates were calculated using a random-effects model (DerSimonian–Laird method). Heterogeneity was assessed with the I^2 statistic and Cochran's Q test. Subgroup analyses explored sources of heterogeneity, and publication bias was evaluated using funnel plots and Egger's test. Statistical significance was set at $p < 0.05$. Analyses were performed in STATA (version XX; StataCorp, College Station, TX, USA).

Bioethical standards

This research was based on 2 study designs. The cohort study utilized anonymized data in the hospital registry, while the systematic review study was based on the analysis of published data; hence, institutional review board (IRB) approval was not required in both cases. The retrieval of informed consent was not applicable to this research.

RESULTS

Cohort study

Among 100 consecutive RALRP patients, the overall PSM rate was 22% (n = 22; Figure 1). Margin location was most often apical (10/22, 45.5%), followed by circumferential (7/22, 31.8%) and basal (5/22, 22.7%) (Figure 2).

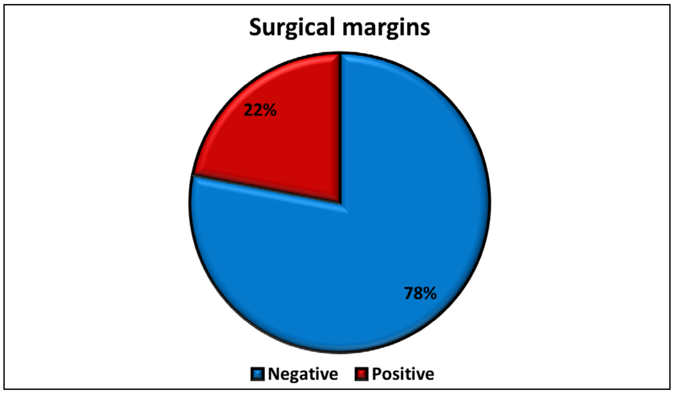

Figure 1. *Incidence of positive surgical margins in the studied patients.*

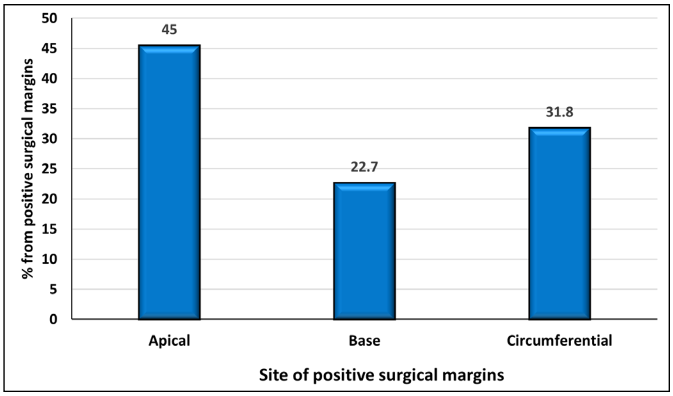

Figure 2. *Site of positive surgical margins in the studied patients.*

Mean age was 65.8 ±5.2 years (range: 50–73.8). Median/mean PSA at presentation was 8.1 ±3.2 ng/ml (range: 2.7–17.7). Sixty-four percent had biopsy Gleason 7; MRI stages were T2 in 68% and T3 in 15%. Nerve-sparing was performed in 55% (25 unilateral, 30 bilateral). Between groups, age, PSA, Gleason score, MRI stage, and nerve-sparing did not differ significantly (Table 1), although PSA tended to be higher with PSM (8.8 ±3.9 vs 7.9 ±2.9 ng/ml).

Mean prostate weight was 52.6 ±20.5 g (range: 16–120). Pathology was most often pT2c (37%) and pT3a (34%); postoperative Gleason 7 occurred in 70%. Capsular invasion was present in 45%, perineural invasion in 75%, and seminal vesicle invasion in 7% (Table 2).

On stratified analyses, larger prostate weight associated with negative margins (54.8 ±21.8 g vs 44.7 ±12.5 g; p = 0.007). Higher pathological stage increased PSM risk (pT3 31.7%, pT4 100% vs pT2 13.8%; p = 0.015). PSM counts fell numerically across the learning curve (first 50: 15; second 50: 7) without statistical significance overall or within stage strata. Capsular invasion was more frequent with PSM (31.1% vs 14.5%; p = 0.025); perineural and seminal vesicle invasion were not significant (both p > 0.05). Nearly all with postoperative Gleason >7 (3/4) had PSM. BCR occurred more often with PSM (p = 0.011), and PSA at 3, 6, and 12 months remained higher in the PSM group (Table 3).

In multivariable analysis (Table 4), independent predictors of PSM were capsular invasion (OR 2.63) and lower prostate weight (OR per gram 0.964; p <0.001). In Cox regression (Table 5), PSM independently predicted BCR with HR ≈ 5.0 after adjustment for learning curve, pathological stage, and presenting PSA.

Meta-analysis of predictors of positive surgical margin

A total of 1,128 records were identified, of which 630 were duplicates. Following screening and full-text

Table 1. *Preoperative clinicodemographic characteristics of patients undergoing RALRP*

	All patients		Negative margins (n = 78)		Positive margins (n = 22)		Test statistic	p
Age (years)								
Min–Max	50.0–73.8		50.0–73.8		50.1–71.8		0.101	0.920
Mean ±SD	65.8 ±5.2		65.7 ±5.3		65.9 ±4.8			
Presenting PSA								
Min–Max	2.7–17.7		3.5–17.7		2.7–16.8		0.946	0.353
Mean ±SD	8.1 ±3.2		7.9 ±2.9		8.8 ±3.9			
Preoperative Gleason score								
6	28	100.0	21	75.0	7	25.0	2.843	0.385
7	64	100.0	51	79.7	13	20.3		
8	4	100.0	2	50.0	2	50.0		
9	4	100.0	4	100.0	0	0.0		
Radiological T stage (MRI)								
NAD	17	100.0	14	82.4	3	17.6	3.568	0.174
T2	68	100.0	53	77.9	15	22.1		
T3	15	100.0	11	73.4	4	26.6		
D'Amico risk stratification								
Low	13	100.0	10	76.9%	3	23.1%	1.492	0.526
Intermediate	38	100.0	32	84.2%	6	15.8%		
High	49	100.0	36	73.5%	13	26.5%		
Nerve sparing								
None	45	100.0	38	84.4%	7	15.6%	2.28	
Unilateral	25	100.0	20	80.0%	5	20.0%		
Bilateral	30	100.0	21	70.0%	9	30.0%		

MRI – magnetic resonance imaging; RALRP – robot-assisted laparoscopic radical prostatectomy; SD – standard deviation

Table 2. *Operative and postoperative characteristics of the studied patients*

	All patients		Negative margins (n = 78)		Positive margins (n = 22)		Test statistic	p
Prostate volume								
Min–Max	16.0–120.0		16.0–120.0		24.0–72.0		–2.775	0.007*
Mean ±SD	52.6 ±20.5		54.8 ±21.8		44.7 ±12.5			
Pathological Stage								
pT2	58	100.0%	50	86.2%	8	13.8%	11.6	0.015*
pT3	41	100.0%	28	68.3%	13	31.7%		
pT4	1	100.0%	0	0.0%	1	100%		
Learning curve case load								
All cases								
First 50	50	100.0	35	70.0%	15	30.0%	3.730	0.053
Second 50	50	100.0	43	86.0%	7	14%		
T2								
First 50	29	100.0	21	79.3%	8	20.7%	2.805	0.094
Second 50	29	100.0	26	89.7%	3	10.3%		
T3								
First 50	21	100.0	14	66.7%	7	33.3%	1.109	0.292
Second 50	21	100.0	17	42.9%	4	57.1%		
Postoperative Gleason score								
6	26	100.0	19	73.1%	7	26.9%	7.486	0.041*
7	70	100.0	58	82.9%	12	17.1%		
8	1	100.0	0	0.0%	1	100.0		
9	3	100.0	1	33.3%	2	66.7%		
Tumor invasion								
Capsular invasion	Yes = 45	100.0	31	68.9	14	31.1	6.371	0.025*
	No = 55	100.0	47	85.5	8	14.5		
Perineural invasion	Yes = 75	100.0	59	78.7	16	21.3	2.968	0.289
	No = 25	100.0	19	76.0	6	24.0		
Seminal vesicles invasion	Yes = 7	100.0	4	57.1	3	42.9	1.908	0.167
	No = 93	100.0	74	79.6	4	57.1		
Biochemical recurrence	9	100.0	4	5.1%	5	22.7%	6.490	0.011*

SD – standard deviation

Table 3. *PSA level at 3-, 6-, and 12-months follow-up of the studied patients*

	Negative margins			Positive margins			Test statistic	p
	n	mean	SD	n	mean	SD		
PSA 3 months	79	0.0313	0.03804	21	0.3786	1.15833	2.698	0.008*
PSA 6 months	78	0.0376	0.09706	20	0.4350	1.25802	2.800	0.006*
PSA 12 months	77	0.0435	0.13383	18	0.3361	0.60042	3.938	<0.001*

*Significant at p <0.05
PSA – prostate-specific antigen; SD – standard deviation.

assessment, 13 studies met the inclusion criteria (Figure 3) [3, 11, 13–22]. All were observational studies of RALRP evaluating predictors of PSM, with most providing multivariable regression models. Methodological quality was generally high (suppl. Tables S2–S3).

Preoperative characteristics

Six adjusted studies demonstrated that higher preoperative PSA was significantly associated with increased PSM risk (pooled aOR = 1.05; 95% CI: 1.01–1.09; I^2 = 63.65%) [13, 16, 17, 18, 20, 21]. Two unadjusted studies yielded a similar, though non-significant, trend (pooled OR = 1.04; 95% CI: 0.93–1.14; I^2 = 66.32%) [14, 18]. Age and BMI were not consistently predictive; pooled analyses of adjusted data showed no significant association for age (aOR = 1.01; 95% CI: 0.98–1.03; I^2 = 35.13%) [13, 18, 20] and only a marginal effect for BMI (aOR = 1.02; 95% CI: 1.00–1.03; I^2 = 0.01%) [16–20].

Tumour-related variables

Biopsy Gleason score yielded mixed results. A score >7 vs ≤6 was non-significant in one study (aOR = 2.13; 95% CI: 0.76–5.99) [3], while pooled comparisons of score 7 vs ≤6 across two studies showed no effect (aOR = 0.86; 95% CI: 0.35–1.38; I^2 = 10.78%) [3, 17]. Continuous analyses in two studies demonstrated a modest protective association (aOR = 0.66; 95% CI: 0.36–0.97; I^2 = 8.60%) [20, 21]. In contrast, pathological Gleason score ≥7 was associated with increased PSM risk in both categorical (aOR = 1.88; 95% CI: 1.29–2.74) [18] and continuous (aOR = 1.92; 95% CI: 1.15–3.22) [20] analyses.
Pathological stage was one of the strongest predictors. Pooled data from three studies indicated that pT3 vs pT2 disease was associated with more than a five-fold increase in PSM risk (aOR = 5.58; 95% CI: 1.95–9.20; I^2 = 38.44%) [11, 18, 22]. Single studies reported even higher risk for pT4 vs pT2 (aOR = 27.9; 95% CI: 2.8–277.8) [11] and lower risk for pT2 vs pT3b (aOR = 0.16; 95% CI: 0.05–0.46) [17].
Clinical T stage was less consistent. Pooled estimates for cT3 vs cT1 (aOR = 1.27; 95% CI: 0.64–1.91; I^2 = 0%) [11, 13] and cT2 vs cT1 (aOR = 1.19; 95% CI: 0.12–3.69; I^2 = 80.09%) [11, 13] were non-significant. Tumour percentage in the prostate was also not predictive (aOR = 1.02; 95% CI: 0.99–1.04; I^2 = 0%) [11, 13, 16].

Surgical and anatomical factors

Prostate weight demonstrated a negative association in the cohort study but was inconsistent across meta-analysis studies; pooled adjusted data from three studies did not reach significance (aOR = 0.69; 95% CI: 0.11–1.26; I^2 = 99.93%) [18, 20, 22]. Nerve-sparing showed heterogeneity in effect direction, with one study suggesting a protective effect (aOR = 0.13; 95% CI: 0.02–0.73) [20] and another reporting a non-significant trend (aOR = 0.69; 95% CI: 0.45–1.06) [20].
Capsular, perineural, and lymphatic invasion, as well as extracapsular extension, were evaluated in single studies, none showing significant associations [3, 15]. Bilateral disease (aOR = 0.64; 95% CI: 0.32–1.27) [17] and operative time (aOR range: 1.001–1.008 per unit) [22] were also not significant.

Surgeon volume

A single study found no evidence of association between annual surgeon case volume and PSM risk

Table 4. *Backward stepwise binary logistic regression for variables associated with PSMs*

		p	Odds ratio	95% CI	
				Lower	Upper
Model (1)	Learning curve	0.276	0.546	0.183	1.624
	Postoperative Gleason score	0.979	0.996	0.746	1.330
	Capsular invasion	0.279	2.295	0.511	10.313
	Weight of gland (g)	0.072	0.967	0.933	1.003
	Pathological stage (pT3)	0.559	1.537	0.363	6.509
Model (2)	Capsular invasion	0.064	2.630	0.945	7.318
	Weight of gland (g)	<0.001*	0.964	0.949	0.980

*Significant at p <0.05.
CI – confidence interval
The "learning curve" variable was defined as the first 50 versus last 50 consecutive RALRP cases performed during the study period

Table 5. *Cox-regression for variables associated with biochemical recurrence*

	p	Hazard ratio	95% CI	
			Lower	Upper
Learning curve	0.492	0.614	0.152	2.473
PSMs	0.015*	5.285	1.383	20.19
Pathological stage (pT3)	0.905	0.922	0.24	3.537
Presenting PSA	0.451	0.921	0.743	1.141

*Significant at p <0.05.
CI – confidence interval; PSA – prostate-specific antigen; PSM – positive surgical margin

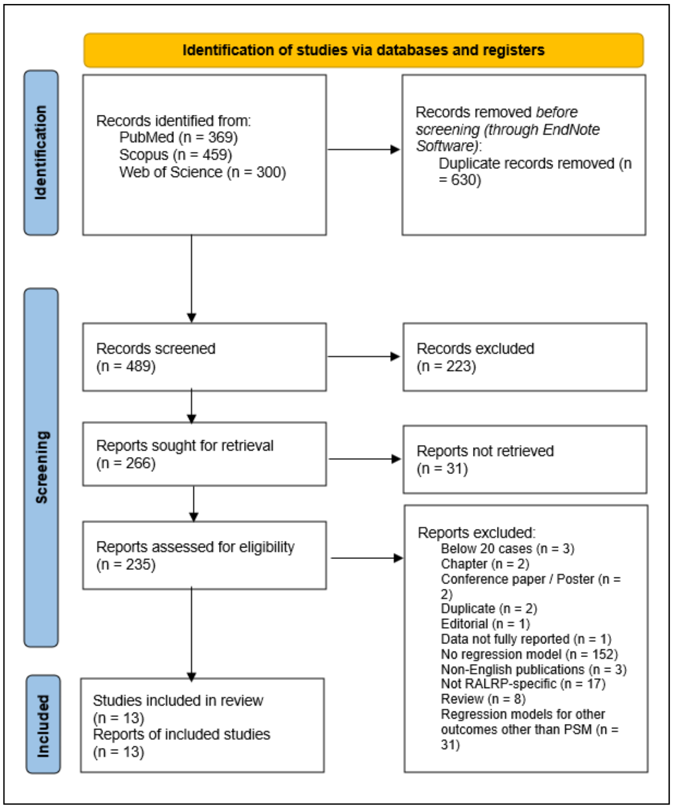

Figure 3. *A PRISMA flow diagram showing the results of the literature search.*

(aOR = 1.00; 95% CI: 0.99–1.00), indicating that higher procedural experience did not independently influence margin status [18]. Full pooled estimates for all evaluated predictors are summarised in Table 6. The most significant predictors of PSM are listed in Table 7.

DISCUSSION

In this combined prospective cohort study and systematic review with meta-analysis, we sought to define predictors of PSMs in patients undergoing RALRP. The integration of original clinical data with quantitative synthesis of published evidence provides a more comprehensive understanding of the key oncological and surgical factors contributing to PSMs. This approach enhances the robustness of our conclusions and provides a comprehensive synthesis of all reported predictors of PSM specifically in the RALRP setting, while distinguishing independent predictors based on adjusted analyses. Rather than identifying entirely novel predictors, our study clarifies the relative importance and consistency of previously reported factors using a standardized analytic framework.

The overall PSM rate in our institutional cohort was 22%, consistent with several prior reports ranging between 19.2% and 22.5% [23, 24], though variability across the literature remains wide, potentially reaching as high as 40% [3, 25]. These differences reflect variability in surgical expertise, pathological definitions, patient selection, and tumour biology. Moreover, variability in pathological definitions of PSM, including criteria related to margin length or focal involvement, may substantially influence reported prevalence and complicate comparisons across studies (suppl. Table S3). The apex was the most common site of PSMs in our cohort (45.5%), aligning with previous studies [11, 26–28]. Apical margins are technically challenging due to poor anatomical delineation between the prostate and external urinary sphincter, absence of a distinct prostatic capsule, and the surgeon's attempt to preserve maximal urethral length [29]. These observations suggest that patients with higher preoperative risk features may benefit from careful intraoperative margin control at anatomically vulnerable sites, particularly during apical and posterolateral dissection, while balancing functional preservation. Additionally, the lack of tactile feedback in robotic platforms, although partially mitigated by visual cues [30, 31], may also contribute to apical or iatrogenic PSMs. Moreover, posterolateral PSMs have been linked to robotic arm-induced tension during dissection, especially in nerve-sparing procedures [12]. Importantly, our analysis was not intended to define specific clinical thresholds or develop new prediction tools but rather to clarify the consistency and relative importance of reported predictors across studies. These findings may inform future risk modelling and standardization of reporting.

In our prospective cohort, multivariate regression identified capsular invasion and prostate weight as independent predictors of PSM. Capsular invasion increased the odds of PSM by approximately 2.5 times, while each additional gram of prostate weight conferred a modest protective effect.

Table 6. *A list of the reported predictors of PSM in RALRP in the literature along with the meta-analytic effect estimate summary*

Predictor	Model	Measure/ category	Studies	OR/aOR	95% CI	Heterogeneity (I^2)	References	Adjusted confounders
PSA	Unadjusted	Continuous	2	1.04	0.93–1.14	66.32%	He (2018); Marchetti (2011)	None
	Adjusted	Continuous	6	1.05	1.01–1.09	63.65%	Hao (2022); Kang (2016); Kowalcyzky (2011); Marchetti (2011); Tsivian (2012); Yao (2014)	Age, BMI, PSA, cT stage, pT stage, % of tumor, Positive biopsy needles, ISUP score, Tumor diameter, PI-RADS score, Tumor location, Prostate volume, Tumor size, Bilateral, Biopsy GS, Pathologic GS, NSS, Surgeon experience, Prostate weight, Race, Cumulative experience, Stage
Biopsy Gleason score	Unadjusted	Continuous	1	0.97	0.83–1.13	N/A	He (2018)	None
	Adjusted	7 vs ≤6	2	0.86	0.35–1.38	10.78%	Ficarra (2009); Kowalczyk (2011)	Prostate volume, cT stage, Biopsy GS, pT stage, Pathologic GS, PNI, LI, Tumor size, Bilateral, Preoperative PSA, NSS
		8 vs ≤6	1	0.83	0.22–3.19	N/A	Kowalczyk (2011)	BMI, prostate volume, tumor size, bilateral, biopsy GS, pT stage, preoperative PSA, NSS
		9 vs ≤6	1	0.35	0.07–1.88	N/A	Kowalczyk (2011)	BMI, prostate volume, tumor size, bilateral, biopsy GS, pT stage, preoperative PSA, NSS
		>7 vs ≤6	1	2.13	0.76–5.99	N/A	Ficarra (2009)	Clinical model (prostate volume on TRUS, cT stage, and biopsy GS); pathological model (prostate volume in specimen, pT stage, PNI, LI, and pathological GS)
		Continuous	2	0.66	0.36–0.97	8.60%	Tsivian (2012); Yao (2014)	Age, Race, BMI, Cumulative experience, NSS, Prostate weight, Biopsy GS, Pathologic GS, Stage, cT stage, PSA
Pathological Gleason score	Unadjusted	Continuous	1	1.2	0.78–1.84	N/A	He (2018)	None
		≥7 vs ≤6	1	2.13	1.4–3.3	N/A	Marchetti (2011)	None
	Adjusted	7 vs ≤6	1	0.91	0.45–1.86	N/A	Ficarra (2009)	Clinical model (prostate volume on TRUS, cT stage, and biopsy GS); pathological model (prostate volume in specimen, pT stage, PNI, LI, and pathological GS)
		>7 vs ≤6	1	0.65	0.22–1.89	N/A	Ficarra (2009)	Clinical model (prostate volume on TRUS, cT stage, and biopsy GS); pathological model (prostate volume in specimen, pT stage, PNI, LI, and pathological GS)
		Continuous	1	1.92	1.15–3.22	N/A	Tsivian (2012)	Age, race, BMI, cumulative experience, NSS, prostate weight, biopsy GS, pathologic GS, and stage
		≥7 vs ≤6	1	1.88	1.29–2.74	N/A	Marchetti (2011)	Age, BMI, PSA, surgeon experience, prostate weight, pathological GS, and pT stage

Table 6. *Continued*

Predictor	Model	Measure/ category	Studies	OR/aOR	95% CI	Heterogeneity (I^2)	References	Adjusted confounders
	Unadjusted	pN1 vs pN0	1	2.81	0.75–3.76	N/A	He (2018)	None
		pT3 vs pT2	1	9.78	5.40– 17.70	N/A	Marchetti (2011)	None
		pT3-4 vs pT2	1	3.63	1.05– 12.58	N/A	He (2018)	None
Pathological T Staging	Adjusted	pT2 vs pT3a	1	1.63	0.64–4.12	N/A	Kang (2016)	BMI, PSA, cT stage, pT stage, % of tumor
		pT2 vs pT3b/T4	1	5.14	1.96– 13.78	N/A	Kang (2016)	BMI, PSA, cT stage, pT stage, % of tumor
		pT2 vs pT3-4	1	11.9	6.16– 22.76	N/A	Ficarra (2009)	Clinical model (prostate volume on TRUS, cT stage, and biopsy GS); pathological model (prostate volume in specimen, pT stage, PNI, LI, and pathological GS)
		pT2 vs pT3b	1	0.16	0.05–0.46	N/A	Kowalczyk (2011)	BMI, prostate volume, tumor size, bilateral, biopsy GS, pT stage, preoperative PSA, NSS
		pT3 vs pT2	3	5.58	1.95–9.20	38.44%	Coelho (2010); Marchetti (2011); Yip (2012)	Age, BMI, PSA, cT stage, Number of positive cores, % of positive cores, Biopsy GS, AUA-SS, NSS, Presence of median lobe, % of tumor, Gland size, Histopathologic characteristics, pT stage, Pathologic GS, Surgeon experience, Prostate weight, T stage, Operative time
		pT3-4 vs pT2	1	5.03	1.10–22.99	N/A	He (2018)	Age, BMI, PSA, prostate volume, biopsy GS, pathologic GS, biopsy cores, and pT stage
		pT3a vs pT3b	1	1.16	0.38–3.5	N/A	Kowalczyk (2011)	BMI, prostate volume, tumor size, bilateral, biopsy GS, pT stage, preoperative PSA, NSS
		pT4 vs pT2	1	27.9	2.8–277.8	N/A	Coelho (2010)	Age, BMI, PSA, cT stage, number of positive cores, % of positive cores, biopsy GS, AUA-SS, NSS, presence of median lobe, % of tumor, gland size, histopathologic characteristics, pT stage, and pathologic GS
Clinical T Staging	Adjusted	cT1 vs cT2	1	2.22	1.23–3.99	N/A	Ficarra (2009)	Clinical model (prostate volume on TRUS, cT stage, and biopsy GS); pathological model (prostate volume in specimen, pT stage, PNI, LI, and pathological GS)
		cT1c vs cT2	1	1.5	0.82–2.77	N/A	Kang (2016)	BMI, PSA, cT stage, pT stage, % of tumor
		cT1c vs cT3	1	4.43	1.55– 12.71	N/A	Kang (2016)	BMI, PSA, cT stage, pT stage, % of tumor
		cT2 vs cT1	2	1.19	0.12–3.69	80.09%	Coelho (2010); Hao (2022)	Age, BMI, PSA, cT stage, Number of positive cores, % of positive cores, Biopsy GS, AUA-SS, NSS, Presence of median lobe, % of tumor, Gland size, Histopathologic characteristics, pT stage, Pathologic GS, Positive biopsy needles, ISUP score, Tumor diameter, PI-RADS score, Tumor location
		cT3 vs cT1	2	1.27	0.64–1.91	0%	Coelho (2010); Hao (2022)	Age, BMI, PSA, cT stage, Number of positive cores, % of positive cores, Biopsy GS, AUA-SS, NSS, Presence of median lobe, % of tumor, Gland size, Histopathologic characteristics, pT stage, Pathologic GS, Positive biopsy needles, ISUP score, Tumor diameter, PI-RADS score, Tumor location
Percentage of tumor (%)	Adjusted	Continuous	3	1.02	0.99–1.04	0%	Coelho (2010); Hao (2022); Kang (2016)	Age, BMI, PSA, cT stage, Number of positive cores, % of positive cores, Biopsy GS, AUA-SS, NSS, Presence of median lobe, % of tumor, Gland size, Histopathologic characteristics, pT stage, Pathologic GS, Positive biopsy needles, ISUP score, Tumor diameter, PI-RADS score, Tumor location

Table 6. *Continued*

Predictor	Model	Measure/ category	Studies	OR/aOR	95% CI	Heterogeneity (I^2)	References	Adjusted confounders
Prostate volume	Unadjusted	Continuous	1	1	0.98–1.01	N/A	He (2018)	None
	Adjusted	Continuous	2	0.71	0.17–1.26	94.90%	Ficarra (2009); Kowalczyk (2011)	Prostate volume, cT stage, Biopsy GS, pT stage, Pathologic GS, PNI, LI, Tumor size, Bilateral, Preoperative PSA, NSS
Age	Unadjusted	Continuous	2	0.97	0.95–1.00	0.03%	He (2018); Marchetti (2011)	None
	Adjusted	Continuous	3	1.01	0.98–1.03	35.13%	Hao (2022); Marchetti (2011); Tsivian (2012)	Age, BMI, PSA, Positive biopsy needles, ISUP score, % of tumor, Tumor diameter, PI-RADS score, Tumor location, Surgeon experience, Prostate weight, Pathologic GS, pT stage, Race, Cumulative experience, NSS, Biopsy GS, Stage
BMI	Unadjusted	Continuous	2	1.02	0.98–1.07	0.01%	He (2018); Marchetti (2011)	None
	Adjusted	Continuous	5	1.02	1.00–1.03	0.01%	Kang (2016); Kowalczyk (2011); Marchetti (2011); Nik-Ahd (2020); Tsivian (2012)	BMI, PSA, cT stage, pT stage, % of tumor, Prostate volume, Tumor size, Bilateral, Biopsy GS, Preoperative PSA, NSS, Surgeon experience, Prostate weight, Pathologic GS, Age, Race, Year of surgery, Grade group, Extracapsular extension, Seminal vesicle invasion, Surgical volume, Cumulative experience, Stage
Nerve-sparing surgery	Adjusted	Yes vs no	1	0.69	0.45–1.06	N/A	Tsivian (2012)	Age, race, BMI, cumulative experience, NSS, prostate weight, biopsy GS, pathologic GS, and stage
		No vs yes	1	0.13	0.02–0.73	N/A	Yao (2014)	Biopsy GS, cT stage, NSS, and PSA
Prostate weight	Unadjusted	Continuous		0.97	0.96–0.99	N/A	Marchetti (2011)	None
	Adjusted	Continuous	3	0.69	0.11–1.26	99.93%	Marchetti (2011); Tsivian (2012); Yip (2012)	Age, BMI, PSA, Surgeon experience, Prostate weight, Pathologic GS, pT stage, Race, Cumulative experience, NSS, Biopsy GS, Stage, T stage, Operative time
Surgeon volume	Unadjusted	Continuous	1	0.99	0.99–1.00	N/A	Marchetti (2011)	None
	Adjusted	Continuous	1	1	0.99–1.00	N/A	Marchetti (2011)	Age, BMI, PSA, surgeon experience, prostate weight, pathological GS, and pT stage
Perineuronal invasion	Adjusted	No vs yes	1	1.37	0.59–3.18	N/A	Ficarra (2009)	Clinical model (prostate volume on TRUS, cT stage, and biopsy GS); pathological model (prostate volume in specimen, pT stage, PNI, LI, and pathological GS)
Lymphatic invasion	Adjusted	No vs yes	1	1.02	0.42–2.52	N/A	Ficarra (2009)	Clinical model (prostate volume on TRUS, cT stage, and biopsy GS); pathological model (prostate volume in specimen, pT stage, PNI, LI, and pathological GS)
Tumor diameter	Adjusted	Continuous	1	1.08	0.75–1.56	N/A	Hao (2022)	Age, positivie biopsy needles, ISUP score, % of tumor, tumor diameter, PI-RADS score, PSA, cT stage, and tumor location
Number of biopsy cores	Unadjusted	Continuous	1	1.07	0.89–1.29	N/A	He (2018)	None
	Unadjusted	≥12 vs <12	1	2.37	0.93–6.08	N/A	He (2018)	None
	Adjusted	≥12 vs <12	1	2.87	1.04–7.89	N/A	He (2018)	Age, BMI, PSA, prostate volume, biopsy GS, pathologic GS, biopsy cores, and pT stage
Extracapsular invasion	Adjusted	Yes vs no	1	1.64	0.62–4.34	N/A	Islamoglu (2018)	Not specified
Tumor size	Adjusted	Continuous	1	1.88	1.17–3.03	N/A	Kowalczyk (2011)	BMI, prostate volume, tumor size, bilateral, biopsy GS, pT stage, preoperative PSA, NSS
Bilateral disease	Adjusted	Bilateral vs unilateral	1	0.64	0.32–1.27	N/A	Kowalczyk (2011)	BMI, prostate volume, tumor size, bilateral, biopsy GS, pT stage, preoperative PSA, NSS

Table 6. *Continued*

Predictor	Model	Measure/ category	Studies	OR/aOR	95% CI	Heterogeneity (I^2)	References	Adjusted confounders
Operative time	Adjusted	Continuous	1	1	1.001–1.008	N/A	Yip (2012)	T stage, operative time and prostate weight

aOR – adjusted odds ratio; BMI – body mass index; CI – confidence interval; GS – Gleason score; LI – lymphatic invasion; NSS – nerve-sparing surgery; N/A – not appliable; OR – crude odds ratio; PNI – perineuronal invasion; PSA – prostate-specific antigen; TRUS – transrectal ultrasound

Table 7. *Summary of key pooled predictors of positive surgical margins after RALRP (adjusted analyses only)*

Characteristic	Studies	aOR	2.5% CI	97.5% CI	I^2 (%)
PSA	6 studies	1.05	1.01	1.09	63.65%
Biopsy Gleason score (per point)	2 studies	0.66	0.36	0.97	8.60%
pT3 vs pT2	3 studies	5.58	1.95	9.2	38.44%
BMI (per point)	5 studies	1.02	1.001	1.03	0.01%

aOR – adjusted odds ratio; BMI – body mass index; CI – confidence interval; I^2 – heterogeneity index; PSA – prostate-specific antigen; RALRP – robot-assisted laparoscopic radical prostatectomy

These findings reinforce the importance of tumour aggressiveness and anatomical factors in influencing surgical margins. Importantly, we also confirmed that PSM was a significant independent predictor of biochemical recurrence (BCR), corroborating earlier findings [18, 25, 32, 33].

The systematic review and meta-analysis provided novel and broader insight into the predictors of PSM across 13 eligible studies. Several key findings emerged. First, pathological T stage (pT3 vs pT2) was consistently associated with significantly higher PSM risk (aOR 5.58; 95% CI: 1.95–9.20), with only moderate heterogeneity. This was supported by additional single-study estimates comparing pT3–4 or pT4 with pT2, both of which yielded strong associations. These findings emphasize the dominant influence of tumour extension on surgical clearance.

Second, PSA level showed a modest but statistically borderline association with PSM (aOR 1.05; 95% CI: 1.01–1.09) across 6 adjusted models. While prior studies have offered conflicting interpretations of PSA's predictive value [10, 32–36], our pooled analysis consolidates evidence in support of its inclusion in preoperative risk stratification tools.

Third, pathological Gleason score – particularly when assessed as a continuous variable or dichotomized as ≥7 vs ≤6 – emerged as a clinically important predictor, with strong associations reported in individual studies [18, 20]. Conversely, biopsy Gleason score showed less consistent predictive value, likely reflecting sampling limitations and interobserver variability.

Fourth, prostate volume and weight were inversely associated with PSM risk in both our cohort and the pooled analysis, echoing previous findings [3, 10, 11, 16]. This may reflect earlier detection and favorable tumour-to-gland ratio in larger prostates, though high heterogeneity in the pooled estimates (e.g., I^2 = 99.9% for weight) suggests variability in measurement and reporting.

Interestingly, clinical T stage, age, and BMI did not demonstrate robust associations with PSM in pooled analyses. Although some variables reached statistical significance in individual studies, their clinical relevance appears limited due to small effect sizes or inconsistent findings across studies. This distinction between statistical and practical significance is important when interpreting predictors for clinical decision-making.

The role of nerve-sparing surgery remains complex and controversial. While our cohort revealed a higher raw rate of PSM among patients undergoing nerve-sparing procedures (50% vs 15.6%), this difference was not statistically significant, and multivariate analysis did not identify it as an independent risk factor. This is consistent with our SR/MA findings, which revealed divergent results across studies (e.g., Yao et al. [21] showing aOR 0.13; Tsivian et al. [20] showing aOR 0.69). These differences may reflect variation in surgical technique, patient selection, and tumour laterality, and highlight the importance of individualized planning and surgeon expertise.

Notably, surgeon experience, reported in the meta-analysis, emerged as a protective factor (aOR 0.57; 95% CI: 0.42–0.78), reinforcing prior evidence that increased case volume is associated with lower PSM rates [8, 34–36]. While our sample size limited a formal learning curve analysis, prior research by Ahlering et al. [37], Atug et al. [38], Patel et al. [39], Jaffe et al. [35], and Gondo et al. [40] supports a learning-curve-associated decline in PSM rates, indicating that while key operative metrics typically improve within the first 100–200 cases, achieving a plateau of oncologic excellence – particularly with respect to margin control – may require 300–400 procedures, as also highlighted in previous systematic reviews [12, 41, 42]. These findings underscore the value of surgical mentorship, procedural standardization, and high-volume practice settings.

Our SR/MA also revealed substantial heterogeneity in the measurement, reporting, and adjustment of certain predictors (e.g., biopsy GS, prostate volume), pointing to an urgent need for standardized reporting guidelines in robotic prostatectomy outcomes research. Moreover, certain clinically plausible predictors – such as tumour location, multifocality, and nerve-sparing laterality – were either inconsistently reported or not amenable to meta-analysis due to limited data, representing fertile ground for future hypothesis-driven investigation.

An important contribution of the present study is the comprehensive evaluation of all reported predictors of PSM after RALRP within a single understanding framework. While many individual predictors have been previously described, prior studies have been heterogeneous in design, analytical adjustment, and reporting. By systematically synthesizing both adjusted and unadjusted evidence and integrating these findings with prospective clinical data, our study provides a clearer hierarchy of risk factors and a more consistent evidence base for preoperative risk stratification and surgical planning.

From a clinical perspective, it is important to distinguish between predictors reflecting tumour biology and those with potential implications for surgical decision-making. Factors such as pathological stage, capsular invasion, and Gleason score primarily reflect disease aggressiveness and are not directly modifiable intraoperatively; however, their identification may support preoperative risk stratification and patient counselling regarding the likelihood of margin positivity. In contrast, anatomical and procedural considerations, including prostate size and nerve-sparing approach, may influence surgical planning and intraoperative strategy, although their effects were less consistent across studies. These distinctions highlight that the clinical value of identified predictors lies primarily in risk assessment and operative planning rather than direct modification of oncologic risk.

Collectively, the findings support a structured approach to risk assessment in patients undergoing RALRP, whereby tumour-related characteristics inform preoperative counselling regarding oncologic risk, while anatomical and procedural considerations may guide surgical planning. Although the study does not introduce new operative techniques or thresholds, it provides a consolidated evidence base to support individualized decision-making and future development of predictive models.

This study has several limitations. The prospective cohort was modest in size; however, it was designed to complement rather than replace the broader evidence synthesis and to provide internally consistent clinical data for integration with pooled estimates. The cohort was drawn from a single institution, and the modest sample size precluded subgroup analyses based on tumour stage, PSM site, or nerve-sparing laterality. Although all operations were performed following standardized robotic protocols, potential inter-surgeon variability in technique, experience, and case selection may have influenced the observed margin rates and oncologic outcomes. This variability could not be fully accounted for in the present analysis but represents an important consideration for future multicenter or surgeon-stratified studies. In addition, BCR was defined using a PSA threshold of ≥0.2 ng/ml consistent with clinical practice during the study period; however, contemporary definitions increasingly consider PSA kinetics

and lower PSA values, which may influence recurrence detection.
In the SR/MA, the limited number of studies reporting consistent multivariate models for certain predictors restricted the scope of some pooled analyses. Furthermore, we intentionally did not perform a meta-analysis of the incidence rate of PSM after RALRP due to the large volume of eligible studies (>150), which warrants a separate dedicated analysis. Furthermore, heterogeneity in PSM definitions across included studies may have influenced pooled estimates and limits direct comparison of reported margin rates. Future research focusing on incidence and site-specific predictors is necessary to further refine surgical strategies.

CONCLUSIONS

By combining prospective clinical data with the first meta-analysis dedicated to predictors of PSM in RALRP, our study provides a comprehensive synthesis of currently reported determinants of oncological margin status in robotic prostatectomy. Tumour aggressiveness – reflected by pathological stage, capsular invasion, and Gleason score – emerges as the strongest determinant of PSM, while modifiable factors such as prostate weight and surgeon experience also play pivotal roles. These findings provide a consolidated evidence base that may support future risk stratification strategies and multicentre studies.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

ETHICS APPROVAL STATEMENT

The ethical approval was not required.

SUPPLEMENTARY MATERIALS

Suppl. Table S1. *The search strategy employed in the database search to retrieve studies reporting PSM predictors in patients undergoing RALRP*

Database	No.	Search query	Results
PubMed	#1	"positive surgical margin"[tiab] OR "positive surgical margins"[tiab] OR PSM[tiab]	16,357
	#2	Prostatectom*[tiab] OR RALP[tiab]	38,980
	#3	Robot*[tiab]	89,155
	#4	Laparoscopic*[tiab]	146,195
	#5	Radical[tiab]	278,835
	#6	#1 AND #2 AND #3 AND #4 AND #5	369
Scopus	#1	TITLE-ABS-KEY ("positive surgical margin") OR TITLE-ABS-KEY ("positive surgical margins") OR TITLE-ABS-KEY (PSM)	28,164
	#2	TITLE-ABS-KEY (Prostatectom*) OR TITLE-ABS-KEY (RALP)	67,500
	#3	TITLE-ABS-KEY (Robot*)	745,153
	#4	TITLE-ABS-KEY (Laparoscopic*)	203,115
	#5	TITLE-ABS-KEY (Radical)	858,885
	#6	#1 AND #2 AND #3 AND #4 AND #5	459
Web of Science	#1	AB="positive surgical margin" OR AB="positive surgical margins" OR AB=PSM	22,418
	#2	AB=Prostatectom* OR AB=RALP	29,969
	#3	AB=Robot*	377,206
	#4	AB=Laparoscopic*	119,073
	#5	AB=Radical	544,120
	#6	#1 AND #2 AND #3 AND #4 AND #5	300

Suppl. Table S2. *A complete list of excluded articles during the full-text screening phase*

ID	Authors	YOP	Title	Decision
325	Park, Jeong, Jeon, Lee, Choi, Seo	2013	Comparison of oncological and functional outcomes of pure versus robotic-assisted laparoscopic radical prostatectomy performed by a single surgeon	≥1 pad use/day
110	Fan, Wang, Xiong, et al.	2022	Robot-Assisted Radical Prostatectomy Using the KangDuo Surgical Robot-01 System: A Prospective, Single-Center, Single-Arm Clinical Study	16 cases
65	Chang, Choi, Chung, Rha	2018	Retzius-sparing robot-assisted radical prostatectomy using the Revo-i robotic surgical system: surgical technique and results of the first human trial	17 cases
105	Eandi, Nelson, Josephson, Lau, Kawachi, Wilson,	2010	Robotic assisted laparoscopic salvage prostatectomy for radiation resistant prostate cancer	18 cases
3	Abdollah, Sood, Sammon, et al.	2016	When Should a Positive Surgical Margin Ring a Bell? An Analysis of a Multi-Institutional Robot-Assisted Laparoscopic Radical Prostatectomy Database	Biochemical and clinical recurrence
86	Connolly, Gilmore, Kerger, et al.	2012	Robotic radical prostatectomy as the initial step in multimodal therapy for men with high-risk localised prostate cancer: initial experience of 160 men	Biochemical failure, downgrading
135	Ginzburg, Staff, Tortora, et al.	2012	Prostate cancer biochemical recurrence rates after robotic-assisted laparoscopic radical prostatectomy	Biochemical recurrence
138	Gong, Lu, Nagata, et al.	2025	Prostate-Specific Antigen Decline Rate in the First Month Is a Timely Predictive Factor for Biochemical Recurrence After Robot-Assisted Radical Prostatectomy	Biochemical recurrence
168	Hu, Ou	2017	Assessments of Neoadjuvant Hormone Therapy Followed by Robotic-Assisted Radical Prostatectomy for Intermediate- and High-Risk Prostate Cancer	Biochemical recurrence
190	Jung, Arkoncel, Cho, et al.	2011	Significance of perineural invasion, lymphovascular invasion, and high-grade prostatic intraepithelial neoplasia in robot-assisted laparoscopic radical prostatectomy	Biochemical recurrence
264	Marcq, Hannink, Rizk, et al.	2018	Risk of biochemical recurrence based on extent and location of positive surgical margins after robot-assisted laparoscopic radical prostatectomy	Biochemical recurrence
279	Mitsunari, Kurata, Harada, et al.	2024	Predictive Factors for Early Biochemical Recurrence Following Robot-assisted Radical Prostatectomy	Biochemical recurrence
337	Porpiglia, Bertolo, Manfredi, et al.	2018	Five-year Outcomes for a Prospective Randomised Controlled Trial Comparing Laparoscopic and Robot-assisted Radical Prostatectomy	Biochemical recurrence
340	Preisser, Pompe, Heinze, Haese, Graefen, Tilki	2020	Effect of bladder neck sparing at robot-assisted laparoscopic prostatectomy on postoperative continence rates and biochemical recurrence	Biochemical recurrence
358	Ritch, May, Herrell, et al.	2014	Biochemical recurrence-free survival after robotic-assisted laparoscopic vs open radical prostatectomy for intermediate- and high-risk prostate cancer	Biochemical recurrence
417	Suzuki, Kubota, Sumiyoshi, et al.	2025	Impact of aspirin on biochemical recurrence of prostate cancer after robot assisted radical prostatectomy in a multicenter retrospective cohort study	Biochemical recurrence
184	Jindal, Dalela, Menon	2018	Functional and oncological outcomes of robotic radical prostatectomy	Chapter
333	Piechaud	2008	Bladder neck dissection during robotic-assisted laparoscopic radical prostatectomy	Chapter
280	Mohareri, Lobo, Savdie, Black, Salcudean	2015	A system for MR-ultrasound guidance during robot-assisted laparoscopic radical prostatectomy	Conference paper
215	Kowalczyk, Hevelone, Lipsitz, Yu, Lynch, Hu	2013	Effect of minimizing tension during robotic-assisted laparoscopic radical prostatectomy on urinary function recovery	Continence
236	Lee, Graves, Su, et al.	2014	Functional and oncologic outcomes of graded bladder neck preservation during robot-assisted radical prostatectomy	Continence
247	Liu, Wang, Shao, et al.	2025	The impact of prostate volume on Retzius-sparing robot-assisted laparoscopic radical prostatectomy with retrograde release of the neurovascular bundle	Continence
410	Srivastava, Pham, Sooriakumaran, et al.	2013	Effect of a risk-stratified grade of nerve-sparing technique on early return of continence after robot-assisted laparoscopic radical prostatectomy	Continence
423	Tewari, Metgud, Theckumparampil, et al.	2013	Functional outcomes following robotic prostatectomy using athermal, traction free risk-stratified grades of nerve sparing	Continence
47	Busch, Leva, Ferrari, et al.	2015	Matched comparison of robot?assisted, laparoscopic and open radical prostatectomy regarding pathologic and oncologic outcomes in obese patients	Duplicate
67	Chang, Wu	2021	There are no differences in positive surgical margin rates or biochemical failure–free survival among patients receiving open, laparoscopic, or robotic radical prostatectomy: A nationwide cohort study from the national cancer database	Duplicate

Suppl. Table S2. *Continued*

ID	Authors	YOP	Title	Decision
422	Tatenuma, Kawase, Sasaki, et al.	2023	Association of hospital volume with perioperative and oncological outcomes of robot-assisted laparoscopic radical prostatectomy: a retrospective multicenter cohort study	EBL, console time, biochemical recurrence
434	Touijer	2011	Positive surgical margin rate, location, and size following laparoscopic versus robotic-assisted laparoscopic radical prostatectomy	Editorial
14	Allaparthi, Dhanani, Tuerk	2010	Significance of prostate weight on peri and postoperative outcomes of robot assisted laparoscopic extraperitoneal radical prostatectomy	N/A
15	Al-Mamari, Mentine, Burté, Rouyer, Jacob, Amiel	2015	[RALP: comparison of the oncological and functional outcomes of the intrafascial and the interfascial approaches]	N/A
16	Altaylouni, Elezkurtaj, Rossner, et al.	2023	Robot-Assisted Laparoscopic Prostatectomy Experience and Pathological Quality: Are They Always Linked?	N/A
29	Atug	2007	Transperitoneal versus extraperitoneal robotic-assisted radical prostatectomy: which one?	N/A
30	Bajpai, Sanchez-Gonzalez, Reddy, Razdan	2022	Robot-Assisted Radical Prostatectomy After Prior Transurethral Resection of Prostate: An Analysis of Perioperative, Functional, Pathologic, and Oncologic Outcomes	N/A
72	Chen, Xu, Wu, Liu, et al.	2020	Efficacy evaluation of anterior partial Retzius-sparing robot-assisted laparoscopic radical prostatectomy	N/A
85	Collette, Van Den Ouden, Engel, Klaver	2013	Peroperative, oncological, functional learning curves of robot assisted laparoscopic radical prostatectomy (RALP) in a high volume hospital	N/A
94	Diamand, Mjaess, Benijts, Assenmacher, Assenmacher	2025	Retzius-sparing versus standard robot-assisted laparoscopic prostatectomy: A two-year patient-reported and oncological assessment	N/A
122	Fujii, Hara, Morinaka, et al.	2020	Introduction of robot-assisted laparoscopic radical prostatectomy in kawasaki medical school hospital treatment results of initial 100 patients	N/A
130	Gatti, Gritti, Finamanti, Peroni, Simeone	2013	[Short and medium term oncological results after robot-assisted prostatectomy: a comparative prospective non randomized study]	N/A
136	Gkeka, Peteinaris, Katsakiori, et al.	2024	Robot-assisted radical prostatectomy using the avatera system™: a prospective pilot study	N/A
142	Gorelova, Berkut, Mamizhev, Semeiko, Nosov	2024	Comparative analysis of the outcomes of laparoscopic radical prostatectomy and initial experience with robot-assisted radical prostatectomy	N/A
211	Kongchareonsombat	2019	Perioperative outcomes and the learning curve for robotic-assisted laparoscopic radical prostatectomy in Thailand by a single surgeon: Six years' experience in Ramathibodi hospital	N/A
291	Msezane, Lin, Shalhav, Zagaja, Zorn,	2007	Prostate weight: an independent predictor for positive surgical margins during robotic-assisted laparoscopic radical prostatectomy	N/A
294	Nagai, Shimizu, Gonda, et al.	2024	Learning curve of multiple surgeons for robot-assisted radical prostatectomy using the cumulative sum method: a retrospective single-institution study	N/A
302	Noël, Lodia, Karim, et al.	2022	Neurovascular structure-adjacent frozen-section examination robotic-assisted radical prostatectomy: outcomes from 500 consecutive cases in the UK	N/A
348	Pushkar, Kolontarev	2010	Robot-assisted radical prostatectomy: analysis of the first 80 cases	N/A
349	Qu, Tao, Zhu, Liu, Yu, Zhang	2021	Analysis of the correlation between preoperative factors and positive surgical margin after robot-assisted laparoscopic radical prostatectomy	N/A
352	Rambaran, Kliffen, De Lange, Klaver	2011	Robot assisted laparoscopic radical prostatectomy in a peripheral hospital: Peri-operative details and shortterm oncological and functional outcome in first 400 consecutive cases	N/A
355	Razdan, Razdan	2024	Robotic radical prostatectomy (RALP) with pre-existing inflatable penile prosthesis (IPP): technical innovations to improve safety and outcomes	N/A
388	Siripalangkanont	2020	Comparison of Treatment Outcomes between Laparoscopic and Robot-Assisted Laparoscopic Radical Prostatectomy in Clinically Localized Prostate Cancer, A Single-Surgeon Experience	N/A
401	Sooriakumaran, Wiklund, Lee, Nilsson, Tewari	2011	Learning curve for robotic assisted laparoscopic prostatectomy: a multi-institutional study of 3794 patients	N/A
418	Svetocheva, Tsarichenko, Suhanov, Bezrukov, Rapoport	2021	Reconstruction of the ligamentous apparatus of the lower pelvis in robot-assisted radical prostatectomy as a stage of the learning curve	N/A
425	Thaidumrong, Duangkae	2024	Surgical Experience and Results of Retzius Sparing Robotic Assisted Laparoscopic Radical Prostatectomy: First Report in Thailand	N/A

Suppl. Table S2. *Continued*

ID	Authors	YOP	Title	Decision
426	Thakker, Geldmaker, Ball, Pak, Lyon, Pathak	2024	Creation of a Novel, Race-Adjusted, and Risk-Adapted Scoring System to Predict Positive Surgical Margins and Prolonged Operative Time During Robotic Radical Prostatectomy	N/A
440	Tsujioka, Nirazuka, Hasegawa, Izumi, Nakayama, Saito	2024	Comparison of Robot-Assisted Laparoscopic Prostatectomy Using the Made-in-Japan Robotic System Hinotori Versus Da Vinci: A Propensity Score-Matched Analysis	N/A
471	Xu, An, Zhu, Hu, Ni, Li	2024	Application of perineal single-port robot-assisted radical prostatectomy	N/A
484	Yokoyama, Ebara, Tatenuma, et al.	2025	Efficacy and safety of neoadjuvant chemohormonal therapy for high-risk prostate cancer treated with robot-assisted laparoscopic radical prostatectomy: a propensity score-matched analysis (the MSUG94 group)	N/A
487	Youssef, Raghunand, Pow-Sang, Johnstone	2022	Analysis of MRI radiomic pelvimetry and correlation with margin status after robotic prostatectomy	N/A
150	Guo, Wang, Xu, Li, et al.	2025	Robot-assisted partial nephrectomy and robot-assisted radical prostatectomy using the Chinese surgical systems KangDuo-SR-2000 and EDGE MP1000 versus the Da Vinci Xi system: a prospective, single-center, non-randomized clinical trial	N/A
343	Prilepskaya, Kolontarev, Govorov, et al.	2015	Comparison of oncological results and functional outcomes of radical prostatectomy techniques retropubic, laparoscopic and robot-assisted	N/A
239	Leitsmann, Bremmer, Mohr, Trojan, Leitsmann, Reichert	2023	Impact of multiparametric magnetic resonance imaging targeted biopsy on functional outcomes in patients following robot-assisted laparoscopic radical prostatectomy	No 95% CI reported
4	Adili, Kolesar, Wong, Hoogenes, Dason, Shayegan	2017	Positive surgical margin rates during the robot-assisted laparoscopic radical prostatectomy learning curve of an experienced laparoscopic surgeon	No regression
5	Akand, Avci, Duman, Erdogru	2015	Open, laparoscopic and robot-assisted laparoscopic radical prostatectomy: comparative analysis of operative and pathologic outcomes for three techniques with a single surgeon's experience	No regression
6	Akand, Avci, Ates	2015	Transperitoneal versus extraperitoneal robot-assisted laparoscopic radical prostatectomy: A prospective single surgeon randomized comparative study	No regression
8	Albadine, Chaux, Jeong, et al.	2012	Characteristics of positive surgical margins in robotic-assisted radical prostatectomy, open retropubic radical prostatectomy, and laparoscopic radical prostatectomy: a comparative histopathologic study from a single academic center	No regression
13	Alip, Han, Rha, Na	2022	Comparing Revo-i and da Vinci in Retzius-Sparing Robot-Assisted Radical Prostatectomy: A Preliminary Propensity Score Analysis of Outcomes	No regression
22	Antonelli, Mattei, Fankhauser	2023	Anterior Sphincter-sparing Suturing of the Vesicourethral Anastomosis During Robotic-assisted Laparoscopic Radical Prostatectomy	No regression
23	Artibani, Cavalleri, Iafrate, et al.	2008	Learning curve and preliminary experience with da Vinci-assisted laparoscopic radical prostatectomy	No regression
24	Asimakopoulos, D'Orazio, Pereira, et al.	2010	Complete periprostatic anatomy preservation during robot-assisted laparoscopic radical prostatectomy (RALP): the new pubovesical complex-sparing technique	No regression
27	Atug, Srivastav, Burgess, Thomas, Davis	2006	Positive Surgical Margins in Robotic-Assisted Radical Prostatectomy: Impact of Learning Curve on Oncologic Outcomes	No regression
28	Atug, Woods, Srivastav, Thomas, Davis	2006	Transperitoneal versus extraperitoneal robotic-assisted radical prostatectomy: Is one better than the other?	No regression
31	Ban, Kang, Park, Cheon	2009	Learning curve with robotic-assisted laparoscopic radical prostatectomy: A prospective study	No regression
32	Barocas, Kordan, Herrell, et al.	2010	Robotic assisted laparoscopic prostatectomy versus radical retropubic prostatectomy for clinically localized prostate cancer: comparison of short-term biochemical recurrence-free survival	No regression
37	Bock, Lantz, Carlsson, Sjoberg, et al.	2022	Learning curve for robot-assisted laparoscopic radical prostatectomy in a large prospective multicentre study	No regression
39	Bouchier-Hayes, Canavan, O'Malley,	2012	Initial consecutive 125 cases of robotic assisted laparoscopic radical prostatectomy performed in Ireland's first robotic radical prostatectomy centre	No regression
40	Bove, Celestino, De Carlo, Vespasiani, Finazzi Agrò	2015	3D vs 2D laparoscopic radical prostatectomy in organ-confined prostate cancer: comparison of operative data and pentafecta rates: a single cohort study	No regression
55	Canda, Akbulut, Asil, Kiliç, Igören, Balbay	2012	Results of robotic radical prostatectomy in the hands of surgeons without previous laparoscopic radical prostatectomy experience	No regression
61	Cetin, Karaca, Ozbilen, et al.	2022	Laparoscopic surgery experience does not influence oncological and functional results of robotic-assisted laparoscopic prostatectomy	No regression

Suppl. Table S2. *Continued*

ID	Authors	YOP	Title	Decision
64	Chan, Chen, Hsu, Yang, Lin	2017	A comparative study of laparoscopic and robotic assisted radical prostatectomy performed by a single surgeon	No regression
68	Chang, Wang, Yang, et al.	2016	Robotic-assisted Laparoscopic Radical Prostatectomy From a Single Chinese Center: A Learning Curve Analysis	No regression
70	Chen, Dong, Wang, et al.	2020	Experience of one single surgeon with the first 500 robot-assisted laparoscopic prostatectomy cases in mainland China	No regression
74	Cheng, YChau, Lam, So	2017	Comparative study of laparoscopic radical prostatectomy and robot-assisted radical prostatectomy on perioperative, oncological and functional outcomes	No regression
77	Choo, Cho, Ku, Kim, Kwak	2013	Impact of prostate volume on oncological and functional outcomes after radical prostatectomy: robot-assisted laparoscopic versus open retropubic	No regression
80	Cimen, Gul, Uysal, Balbay	2019	Serving as a bedside surgeon before performing robotic radical prostatectomy improves surgical outcomes	No regression
81	Cimen, Altinova, Adsan, Balbay	2019	Does the experience of the bedside assistant effect the results of robotic surgeons in the learning curve of robot assisted radical prostatectomy?	No regression
83	Coelho, Guglielmetti, Orvieto, et al.	2012	Does the presence of median lobe affect outcomes of robot-assisted laparoscopic radical prostatectomy?	No regression
87	de Carvalho, Jaba Guglielmetti, Cordeiro, Rocco, Nahas, Patel, Coelho	2020	Retrograde Release of the Neurovascular Bundle with Preservation of Dorsal Venous Complex During Robot-assisted Radical Prostatectomy: Optimizing Functional Outcomes	No regression
90	Deng, Zhu, Cheng, Xiong, et al.	2021	Functional Preservation and Oncologic Control following Robot-Assisted versus Laparoscopic Radical Prostatectomy for Intermediate- and High-Risk Localized Prostate Cancer: A Propensity Score Matched Analysis	No regression
91	Deng, Liu, Zhang, et al.	2021	Functional and Oncological Outcomes Following Robot-Assisted and Laparoscopic Radical Prostatectomy for Localized Prostate Cancer With a Large Prostate Volume: A Retrospective Analysis With Minimum 2-Year Follow-Ups	No regression
92	Dev, Patel, Parashar, et al.	2015	Surgical margin length and location affect recurrence rates after robotic prostatectomy	No regression
93	Di Pierro, Stucki, Beatrice, Danuser, Mattei	2011	A prospective trial comparing consecutive series of open retropubic and robot-assisted laparoscopic radical prostatectomy in a centre with a limited caseload	No regression
97	Dogra, Singh, Bora, Nayak	2014	Extraperitoneal robot-assisted laparoscopic radical prostatectomy: Initial experience	No regression
98	Dong, Cui, Liu, et al.	2024	Feasibility, safety and effectiveness of robot-assisted radical prostatectomy with a new robotic surgical system: a prospective, controlled, randomized clinical trial	No regression
99	Doumerc, Savdie, Rahman, et al.	2010	Should experienced open prostatic surgeons convert to robotic surgery? The real learning curve for one surgeon over 3 years	No regression
100	Doumerc, Savdie, Rahman, Pe Benito, Stricker	2010	Robot-assisted laparoscopic prostatectomy: analysis of an experienced open surgeon's learning curve after 300 procedures	No regression
108	Fan, Zhou, Lv, Wang, Ren, Tian	2024	Comparison of perioperative and functional outcomes of single-incision versus standard multi-incision robot-assisted laparoscopic radical prostatectomy: a prospective, controlled, nonrandomized trial	No regression
109	Fan, Chen, Wang, et al.	2023	Robot-Assisted Laparoscopic Radical Prostatectomy Using the KangDuo Surgical Robot System vs the da Vinci Si Robotic System	No regression
115	Ficarra, Fracalanza, D'Elia, et al.	2009	A prospective, non-randomized trial comparing robot-assisted laparoscopic and retropubic radical prostatectomy in one European institution	No regression
116	Fode, Jakobsen	2014	Radical prostatectomy: initial experience with robot-assisted laparoscopic procedures at a large university hospital	No regression
117	Fonseca, Rebola, Lúcio, et al.	2023	Retzius-sparing robot-assisted radical prostatectomy in a medium size oncological center holds adequate oncological and functional outcomes	No regression
125	Galfano, Sozzi, Strada, et al.	2013	Beyond the learning curve of the Retzius-sparing approach for robot-assisted laparoscopic radical prostatectomy: oncologic and functional results of the first 200 patients with ? 1 year of follow-up	No regression
127	Gárate, Valero, Matheus, León, Dávila	2015	Pentafecta outcomes after robot-assisted laparoscopic radical prostatectomy: first 100 cases in Latinoamerican Hospital	No regression
128	García Cortés, Gutiérrez Castañé, Chiva San Román, et al.	2022	Comparison of surgical approaches to radical prostatectomy in our series beyond oncological and functional outcomes	No regression

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ID	Authors	YOP	Title	Decision
134	Ginzburg, Staff, Tortora, et al.	2010	Does prior abdominal surgery influence outcomes or complications of robotic-assisted laparoscopic radical prostatectomy?	No regression
141	Good, Laird, Stolzenburg, Cahill, McNeill	2015	A Critical Analysis of the Learning Curve and Postlearning Curve Outcomes of Two Experience- and Volume-Matched Surgeons for Laparoscopic and Robot-Assisted Radical Prostatectomy	No regression
147	Gu, Wong	2014	Does elevated body mass index (BMI) affect the clinical outcomes of robot-assisted laparoscopic prostatectomy (RALP): a prospective cohort study	No regression
152	Haapiainen, Koskimäki, Riikonen, et al.	2023	Robot-assisted versus three-dimensional laparoscopic radical prostatectomy: 12-month outcomes of a randomised controlled trial	No regression
155	Hampton, Satterthwaite, Wilson, Crocitto	2008	Patients with prior TURP undergoing robot-assisted laparoscopic radical prostatectomy have higher positive surgical margin rates	No regression
163	Herrera-Muñoz, Preciado-Estrella, Trujillo-Ortiz, Sedano-Basilio, et al.	2017	First Mexican study comparing open radical prostatectomy and robotic-assisted laparoscopic radical prostatectomy	No regression
164	Hill, Coomer, Bryant, et al.	2023	Same-day discharge robot-assisted laparoscopic prostatectomy: feasibility, safety and patient experience	No regression
165	Hirasawa, Nakashima, Shimodaira, et al.	2016	Impact of a preoperatively estimated prostate volume using transrectal ultrasonography on surgical and oncological outcomes in a single surgeon's experience with robot-assisted radical prostatectomy	No regression
166	Hong, Taylor, Wu, Reeves	2012	Effects of robotic-assisted laparoscopic prostatectomy on surgical pathology specimens	No regression
167	Hong, Linder, Engel	2010	Learning curve may not be enough: assessing the oncological experience curve for robotic radical prostatectomy	No regression
173	Hye, Seong	2009	Comparison of initial surgical outcomes between laparoscopic radical prostatectomy and robot-assisted laparoscopic radical prostatectomy performed by a single surgeon	No regression
174	İnkaya, Tahra, Sobay, Kumcu, Küçük, Boylu	2019	Comparison of surgical, oncological, and functional outcomes of robot-assisted and laparoscopic radical prostatectomy in patients with prostate cancer	No regression
175	Inoue, Hayashi, Teishima, Matsubara	2022	Longitudinal analysis of trifecta outcome in Japanese patients with prostate cancer following robot-assisted laparoscopic radical prostatectomy	No regression
177	Jackson, Siegrist, Haddock, Staff, Laudone, Wagner	2016	Experienced Open vs Early Robotic-assisted Laparoscopic Radical Prostatectomy: A 10-year Prospective and Retrospective Comparison	No regression
178	Jae, Gyung	2009	Laparoscopic radical prostatectomy versus robot-assisted laparoscopic radical prostatectomy: A single surgeon's experience	No regression
180	Jeong, Park, Lee, Kumon, Hong, Rha	2010	Robot-assisted laparoscopic radical prostatectomy in the Asian population: modified port configuration and ultradissection	No regression
192	Kakiuchi, Gordetsky, Izumi, et al.	2013	Role of frozen section analysis of surgical margins during robot-assisted laparoscopic radical prostatectomy: a 2608-case experience	No regression
194	Kanehira, Takata, Ishii, et al.	2019	Predictive factors for short-term biochemical recurrence-free survival after robot-assisted laparoscopic radical prostatectomy in high-risk prostate cancer patients	No regression
196	Kapoor, Kumar	2023	A Randomized Controlled Study of Robot-Assisted versus 3D Laparoscopic Radical Prostatectomy in Patients with Carcinoma Prostate	No regression
199	Kenney, Mustafa, Wen, et al.	2016	Robotic-assisted laparoscopic versus open salvage radical prostatectomy following radiotherapy	No regression
202	Kim, Kaswick, Derboghossians, Jung, et al.	2013	Achieving proficiency with robot-assisted radical prostatectomy: Laparoscopic-trained versus robotics-trained surgeons	No regression
205	Kim, Jeong, Oh, Yu, Rha	2010	Robot-assisted laparoscopic radical prostatectomy after previous cancer surgery	No regression
207	Kishimoto, Yamamichi, Okusa, et al.	2016	Impact of prior abdominal surgery on the outcomes after robotic- assisted laparoscopic radical prostatectomy: single center experience	No regression
208	Ko, Kang, Park, et al.	2009	Does robot-assisted laparoscopic radical prostatectomy enable to obtain adequate oncological and functional outcomes during the learning curve? From the Korean experience	No regression
210	Koizumi, Nara, Takayama, et al.	2018	Incidence and location of positive surgical margin among open, laparoscopic and robot-assisted radical prostatectomy in prostate cancer patients: a single institutional analysis	No regression

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ID	Authors	YOP	Title	Decision
212	Koo, Yoon, Chung, Hong, Yang, Rha	2014	Robot-assisted radical prostatectomy in the Korean population: a 5-year propensity-score matched comparative analysis versus open radical prostatectomy	No regression
218	Ku, Ha	2015	Learning curve of robot-assisted laparoscopic radical prostatectomy for a single experienced surgeon: comparison with simultaneous laparoscopic radical prostatectomy	No regression
221	Kurokawa, Mizuno, Okada, et al.	2017	New steps of robot-assisted radical prostatectomy using the extraperitoneal approach: a propensity-score matched comparison between extraperitoneal and transperitoneal approach in Japanese patients	No regression
222	Kuroki, Kimura, Tsuda, et al.	2022	Division of dorsal vascular complex using soft coagulation without suture ligation during robot-assisted laparoscopic radical prostatectomy: a propensity score-matched study in a single-center experience	No regression
223	Labanaris, Zugor	2012	Robotic-assisted radical prostatectomy in men ?75 years of age. Surgical, oncological and functional outcomes	No regression
226	Labanaris, Witt	2013	Robot-assisted radical prostatectomy in patients with a pathologic prostate specimen weight ?100 grams versus ?50 grams: Surgical, oncologic and short-term functional outcomes	No regression
228	Lantz, Akre, Angenete, et al.	2021	Functional and Oncological Outcomes After Open Versus Robot-assisted Laparoscopic Radical Prostatectomy for Localised Prostate Cancer: 8-Year Follow-up	No regression
230	Laurila, Jarrard	2009	Robotic-assisted laparoscopic and radical retropubic prostatectomy generate similar positive margin rates in low and intermediate risk patients	No regression
234	Lee, Jeong, Park, Loreazo, Oh, Rha	2010	Learning curve for robot-assisted laparoscopic radical prostatectomy for pathologic t2 disease	No regression
245	Lim, Kim, Shin, et al.	2014	Retzius-sparing robot-assisted laparoscopic radical prostatectomy: combining the best of retropubic and perineal approaches	No regression
251	Lott, Favorito	2015	Is previous experience in laparoscopic necessary to perform robotic radical prostatectomy? A comparative study with robotic and the classic open procedure in patients with prostate cancer	No regression
260	Mahamongkol, Aussavavirojekul, Hansomwong, Srinualnad	2023	The Impact of Retro-apical Urethral Dissection Approach Technique on Positive Surgical Margins in Robotic-assisted Laparoscopic Radical Prostatectomy: A Study in Thailand	No regression
267	Martínez, Lim, Nott, Al-Bareeq, Wignall, Stitt, Pautler	2010	Effect of prostate gland size on the learning curve for robot-assisted laparoscopic radical prostatectomy: does size matter initially?	No regression
268	Martinschek, Ritter, Heinrich, Trojan	2012	Radical prostatectomy after previous transurethral resection of the prostate: robot-assisted laparoscopic versus open radical prostatectomy in a matched-pair analysis	No regression
272	Mazzone, Gandi, Bassi, Sacco	2020	Robotic surgery for prostate cancer: functional and oncological outcomes in a last generation referral center	No regression
275	Mikhail, Billatos, Zorn, et al.	2006	Robotic-assisted laparoscopic prostatectomy: first 100 patients with one year of follow-up	No regression
276	Mirmilstein, Gbolahan, Srirangam, et al.	2018	The neurovascular structure-adjacent frozen-section examination (NeuroSAFE) approach to nerve sparing in robot-assisted laparoscopic radical prostatectomy in a British setting- a prospective observational comparative study	No regression
278	Mirza, Wineland, Tawfik, Thrasher	2011	A comparison of radical perineal, radical retropubic, and robot-assisted laparoscopic prostatectomies in a single surgeon series	No regression
286	Mortezavi, Hefermehl, Spahn, et al.	2013	Continuous low-dose aspirin therapy in robotic-assisted laparoscopic radical prostatectomy does not increase risk of surgical hemorrhage	No regression
287	Moskovic, Rehman, Nabizada-Pace, Brajtbord, Samadi,	2010	High body mass index does not affect outcomes following robotic assisted laparoscopic prostatectomy	No regression
288	Mottrie, Novara, Ficarra	2011	Robotic radical prostatectomy: a critical analysis of the impact on cancer control	No regression
289	Mottrie, De Naeyer, Schatteman, Carpentier, Fonteyne	2007	Robot-assisted laparoscopic radical prostatectomy: oncologic and functional results of 184 cases	No regression
293	Murphy, Crowe, Peters, Costello	2009	Operative details and oncological and functional outcome of robotic-assisted laparoscopic radical prostatectomy: 400 cases with a minimum of 12 months follow-up	No regression
295	Nesterov, Tevlin, Strat	2011	Robot-assisted laparoscopic prostatectomy: our experience	No regression

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ID	Authors	YOP	Title	Decision
304	Nyarangi-Dix, Gradinarov, Hofer, et al.	2019	Retzius-sparing robot-assisted laparoscopic radical prostatectomy: functional and early oncologic results in aggressive and locally advanced prostate cancer	No regression
309	Ou, Chang, Mei, Yang, Hung, Wang, Tung	2016	Prophylactic Robotic-assisted Laparoscopic Radical Prostatectomy for Preoperative Suspicion of Prostate Cancer: Experience with 55 Cases	No regression
310	Ou, Wang, Cheng, Patel	2008	Robotic-assisted radical prostatectomy by a single surgeon in Taiwan: experience with the initial 30 cases	No regression
311	Ou, Wang, Cheng, Patel	2009	Comparison of robotic-assisted versus retropubic radical prostatectomy performed by a single surgeon	No regression
312	Ou, Wang, Cheng, Patel	2010	Robotic-assisted laparoscopic radical prostatectomy: learning curve of first 100 cases	No regression
313	Ou, Wang, Yang, Cheng, Patel, Tewari	2011	The learning curve for reducing complications of robotic-assisted laparoscopic radical prostatectomy by a single surgeon	No regression
314	Ou, Wang, Hung, Cheng, Tewari, Patel	2013	The trifecta outcome in 300 consecutive cases of robotic-assisted laparoscopic radical prostatectomy according to D'Amico risk criteria	No regression
316	Ou, Chang, Wang, et al.	2014	The surgical learning curve for robotic-assisted laparoscopic radical prostatectomy: experience of a single surgeon with 500 cases in Taiwan, China	No regression
321	Papachristos, Te Marvelde, Moon	2015	Laparoscopic versus robotic-assisted radical prostatectomy: an Australian single-surgeon series	No regression
322	Parekattil, Vieweg	2009	Hemostatic Hydrodissection of the Neurovascular Bundles during Robotic Assisted Laparoscopic Radical Prostatectomy- Safety & efficacy trial	No regression
326	Park, Choi, Rha	2008	Robot-assisted laparoscopic radical prostatectomy: Clinical experience of 200 cases	No regression
331	Philippou, Rowe	2012	Robot-assisted laparoscopic prostatectomy versus open: comparison of the learning curve of a single surgeon	No regression
334	Ploussard, Salomon, Vordos, et al.	2010	Robot-assisted extraperitoneal laparoscopic radical prostatectomy: experience in a high-volume laparoscopy reference centre	No regression
338	Porres, Labanaris, Zugor, Witt, Heidenreich	2012	Robot-assisted radical prostatectomy in elderly patients: Surgical, oncological and functional outcomes	No regression
339	Potdevin, Jeong, Kim	2009	Functional and oncologic outcomes comparing interfascial and intrafascial nerve sparing in robot-assisted laparoscopic radical prostatectomies	No regression
357	Rhee, Heathcote	2013	Robot-assisted laparoscopic radical prostatectomy using modular training programme in a private hospital	No regression
363	Rochat, Dubernard, Hebert, Kreaden	2011	Mid-term biochemical recurrence-free outcomes following robotic versus laparoscopic radical prostatectomy	No regression
365	Roy, Watson, Singh	2023	Comparison of robotic-assisted laparoscopic radical prostatectomy: SP versus XI, a single surgeon experience	No regression
372	Sayyid, Lu, Terris, Klaassen, Madi	2017	Retzius-Sparing Robotic-Assisted Laparoscopic Radical Prostatectomy: A Safe Surgical Technique with Superior Continence Outcomes	No regression
377	Seetharam Bhat, Moschovas, et al.	2020	Trends in clinical and oncological outcomes of robot-assisted radical prostatectomy before and after the 2012 US Preventive Services Task Force recommendation against PSA screening: a decade of experience	No regression
379	Shah, Zhao, Pins, Bhalani, Dalton	2008	Pathologic outcomes during the learning curve for robotic-assisted laparoscopic radical prostatectomy	No regression
381	Shikanov, Al-Ahmadie, Katz, Zagaja, Shalhav, Zorn	2009	Extrafascial versus interfascial nerve-sparing technique for robotic-assisted laparoscopic prostatectomy: comparison of functional outcomes and positive surgical margins characteristics	No regression
392	Slusarenco, Prostomolotov, Sukhanov, Bezrukov	2020	Analysis of Learning Curve in Robot-Assisted Radical Prostatectomy Performed by a Surgeon	No regression
393	Smith, Chan, Chang, et al.	2007	A comparison of the incidence and location of positive surgical margins in robotic assisted laparoscopic radical prostatectomy and open retropubic radical prostatectomy	No regression
403	Sooriakumaran, Srivastava, Shariat, et al.	2014	A multinational, multi-institutional study comparing positive surgical margin rates among 22393 open, laparoscopic, and robot-assisted radical prostatectomy patients	No regression
413	Sumitomo, Kato, Yoshizawa, Watanabe, Zennami, Nakamura	2015	Comparative investigation on clinical outcomes of robot-assisted radical prostatectomy between experienced open prostatic surgeons and novice open surgeons in a laparoscopically naïve center with a limited caseload	No regression

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ID	Authors	YOP	Title	Decision
427	Thiel, Heckman, Winfield	2008	Prospective evaluation of factors affecting operating time in a residency/fellowship training program incorporating robot-assisted laparoscopic prostatectomy	No regression
430	Tobias-Machado, Rubinstein, Costa, Hidaka	2016	Robotic-assisted radical prostatectomy learning curve for experienced laparoscopic surgeons: does it really exist?	No regression
435	Tozawa, Umemoto, Mizuno, Okada, Kawai, Takahashi, Kohri	2014	Pitfalls of robot-assisted radical prostatectomy: a comparison of positive surgical margins between robotic and laparoscopic surgery	No regression
441	Tugcu, Evren, Seker, et al.	2017	Single plus one port robotic radical prostatectomy (SPORP); Initial experience	No regression
442	Uberoi, Patel, Sawczuk, Munver	2010	Robot-assisted laparoscopic radical prostatectomy in patients with prostate cancer with high-risk features: predictors of favorable pathologic outcome	No regression
443	Ucar, Gülkesen, Caylan, Kutlu, Güntekin	2019	Does The Learning Curve Affect the Surgical, Functional, and Oncologic Outcomes in Bilateral Nerve-Sparing Robot Assisted Laparoscopic Prostatectomy?	No regression
446	Vasdev, Kass-Iliyya, Hamid, et al.	2013	Developing a robotic prostatectomy service and a robotic fellowship programme – defining the learning curve	No regression
447	Vasudeo, Khanna, Rawal, et al.	2023	Surgical and oncological outcomes of robot-assisted versus laparoscopic radical nephroureterectomy for upper-tract urothelial carcinoma: A single-center comparative analysis	No regression
450	Villamil, Martinez, Giudice, et al.	2013	Incidence and location of positive surgical margins following open, pure laparoscopic, and robotic-assisted radical prostatectomy and its relation with neurovascular preservation: a single-institution experience	No regression
452	Vora, Marchalik, Kowalczyk, et al.	2013	Robotic-assisted prostatectomy and open radical retropubic prostatectomy for locally-advanced prostate cancer: multi-institution comparison of oncologic outcomes	No regression
454	Wagenhoffer, Schymik, Schachtner, et al.	2015	Switching from Endoscopic Extraperitoneal Radical Prostatectomy to Robot-Assisted Laparoscopic Prostatectomy: Comparing Outcomes and Complications	No regression
466	Wolanski, Jones, Mullavey, Walsh, Gianduzzo	2012	Preliminary results of robot-assisted laparoscopic radical prostatectomy (RALP) after fellowship training and experience in laparoscopic radical prostatectomy (LRP)	No regression
467	Wu, Cashy, Perry, Nadler	2010	Suture versus staple ligation of the dorsal venous complex during robot-assisted laparoscopic radical prostatectomy	No regression
468	Xiao, Lan, Miao, Cao, Wang	2025	Comparison of robot-assisted laparoscopic radical prostatectomy via modified extraperitoneal approach and transvesical approach	No regression
474	Xylinas, Ploussard, Salomon, et al.	2010	Intrafascial nerve-sparing radical prostatectomy with a laparoscopic robot-assisted extraperitoneal approach: early oncological and functional results	No regression
476	Yang, Monn, Kaimakliotis, Cary, Cheng, Koch	2015	Oncologic and quality-of-life outcomes with wide resection in robot-assisted laparoscopic radical prostatectomy	No regression
478	Yasui, Kurokawa, Okada, et al.	2014	Impact of prostate weight on perioperative outcomes of robot-assisted laparoscopic prostatectomy with a posterior approach to the seminal vesicle	No regression
479	Yaxley, Chambers, Occhipinti, et al.	2016	Robot-assisted laparoscopic prostatectomy versus open radical retropubic prostatectomy: early outcomes from a randomised controlled phase 3 study	No regression
480	Yılmaz, Ayrancı, Erdi, et al.	2022	Robotic-assisted laparoscopic radical prostatectomy: Initial outcomes of 500 cases	No regression
481	Yılmaz, Özsoy, Ölçücü, Aksaray, Okuducu, Ateş	2021	Is Retzius-sparing robot-assisted laparoscopic radical prostatectomy effective in early continence? A single-center experience of the first 50 patients	No regression
486	You, Sung	2012	Effect of Bladder Neck Preservation and Posterior Urethral Reconstruction during Robot-Assisted Laparoscopic Radical Prostatectomy for Urinary Continence	No regression
491	Zilberman, Yong, Ferrandino, Albala	2012	Does body mass index have an impact on the rate and location of positive surgical margins following robot assisted radical prostatectomy?	No regression
492	Zorn, Gofrit, Shikanov, et al.	2008	Long-term functional and oncological outcomes of patients undergoing sural nerve interposition grafting during robot-assisted laparoscopic radical prostatectomy	No regression
493	Zorn, Orvieto, Mikhail, Zagaja, Shalhav	2007	Robotic-assisted laparoscopic prostatectomy: functional and pathologic outcomes with interfascial nerve preservation	No regression
494	Zorn, Steinberg, Taxy, Zagaja, Shalhav	2008	Planned nerve preservation to reduce positive surgical margins during robot-assisted laparoscopic radical prostatectomy	No regression
495	Zorn, Mikhail, Gofrit, et al.	2007	Effect of prostate weight on operative and postoperative outcomes of robotic-assisted laparoscopic prostatectomy	No regression
496	Zugor, Porres, Witt	2012	Surgical, oncologic, and short-term functional outcomes in patients undergoing robot-assisted prostatectomy after previous transurethral resection of the prostate	No regression

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ID	Authors	YOP	Title	Decision
497	Zugor, Bauer, Witt	2012	Surgical and oncological outcomes in patients with a preoperative PSA value <4 ng/ml undergoing robot-assisted radical prostatectomy	No regression
498	Zugor, Heidenreich, Porres, Labanaris	2012	Surgical and oncological outcomes in patients with preoperative PSA >20 ng/ml undergoing robot-assisted radical prostatectomy	No regression
131	Gianduzzo	2025	Retzius-sparing radical prosatectomy: First 200 Australian cases	No regression
159	Harty, Canes, Sorcini, Moinzadeh,	2013	Comparison of positive surgical margin rates in high risk prostate cancer: open versus minimally invasive radical prostatectomy	No regression
367	Ryabov	2022	Comparative assessment of the learning curve of retropubic, laparoscopic, perineal, and robot-assisted radical prostatectomy	No regression
373	Schlomm, Huxhold, Steuber, et al.	2012	Neurovascular structure-adjacent frozen-section examination (NeuroSAFE) increases nerve-sparing frequency and reduces positive surgical margins in open and robot-assisted laparoscopic radical prostatectomy: experience after 11,069 consecutive patients	No regression
412	Suh, Song, Lee, et al.	2014	Location of positive surgical margin and its association with biochemical recurrence rate do not differ significantly in four different types of radical prostatectomy	No regression
463	White, Stephens, Maatman, Maatman	2009	Comparative analysis of surgical margins between radical retropubic prostatectomy and RALP: are patients sacrificed during initiation of robotics program?	No regression
103	Du, Yang, Chang, et al.	2020	Single-port robot-assisted laparoscopic radical prostatectomy through different approaches: initial experience and outcomes	Non-English
356	Ren, Feng, Ou, et al.	2021	Comparison of clinical efficacy of transperitoneal robot assisted laparoscopic radical prostatectomy versus extraperitoneal single port robot assisted laparoscopic radical prostatectomy	Non-English
458	Wang, Liu, Zhang, Mao, Zhang	2019	Curative effects of anatomic reconstruction of periurethral structure in robotic assisted laparoscopic radical prostatectomy	Non-English
18	Amornratananont, Worawichawong, Chalermsanyakorn, et al.	2020	Perioperative outcomes of robot-assisted laparoscopic radical prostatectomy (RALRP) and LRP in patients with prostate cancer based on risk groups	Not RALRP-specific
45	Busch, Leva, Ferrari, et al.	2015	Matched comparison of robot-assisted, laparoscopic and open radical prostatectomy regarding pathologic and oncologic outcomes in obese patients	Not RALRP-specific
48	Busch, Leva, Ferrari, et al.	2015	Matched comparison of robotaEuroassisted, laparoscopic and open radical prostatectomy regarding pathologic and oncologic outcomes in obese patients	Not RALRP-specific
66	Chang, Wu	2020	There Are No Differences in Positive Surgical Margin Rates or Biochemical Failure-Free Survival among Patients Receiving Open, Laparoscopic, or Robotic Radical Prostatectomy: A Nationwide Cohort Study from the National Cancer Database	Not RALRP-specific
75	Chino, Sun, Lee, Albala, Moul, Koontz	2009	Robot-assisted laparoscopic prostatectomy is not associated with early postoperative radiation therapy	Not RALRP-specific
153	Haglind, Stranne, Wallerstedt, et al.	2015	Urinary Incontinence and Erectile Dysfunction After Robotic Versus Open Radical Prostatectomy: A Prospective, Controlled, Nonrandomised Trial	Not RALRP-specific
198	Kasraeian, Chan, Sanchez-Salas, Validire, et al.	2011	Comparison of the rate, location and size of positive surgical margins after laparoscopic and robot-assisted laparoscopic radical prostatectomy	Not RALRP-specific
213	Koutlidis, Champigneulle, Mangin, Cormier	2012	Robot-assisted or pure laparoscopic nerve-sparing radical prostatectomy: what is the optimal procedure for the surgical margins? A single center experience	Not RALRP-specific
244	Liao, Tai, Chen, Pu, Huang	2018	Oncological outcomes of high-risk prostate cancer patients between robot-assisted laparoscopic radical prostatectomy and laparoscopic radical prostatectomy in Taiwan	Not RALRP-specific
330	Pearce, Karrison, Patel, Eggener,	2016	Comparison of Perioperative and Early Oncologic Outcomes between Open and Robotic Assisted Laparoscopic Prostatectomy in a Contemporary Population Based Cohort	Not RALRP-specific
362	Rocco, Melegari, Ospina, et al.	2009	Robotic vs open prostatectomy in a laparoscopically naive centre: a matched-pair analysis	Not RALRP-specific
415	Sun, Jiang, Ma, Chen, Liu	2022	Clinical Analysis of Perioperative Outcomes on Neoadjuvant Hormone Therapy before Laparoscopic and Robot-Assisted Surgery for Localized High-Risk Prostate Cancer in a Chinese Cohort	Not RALRP-specific
464	Williams, D'Amico, Weinberg, et al.	2010	Radical retropubic prostatectomy and robotic-assisted laparoscopic prostatectomy: likelihood of positive surgical margin(s)	Not RALRP-specific

Suppl. Table S2. *Continued*

ID	Authors	YOP	Title	Decision
154	Hagman, Carlsson, Höijer,et al.	2021	Urinary continence recovery and oncological outcomes after surgery for prostate cancer analysed by risk category: results from the LAParoscopic prostatectomy robot and open trial	Not RALRP-specific
259	Magheli, Su, Guzzo, et al.	2011	Impact of surgical technique (open vs laparoscopic vs robotic-assisted) on pathological and biochemical outcomes following radical prostatectomy: an analysis using propensity score matching	Not RALRP-specific
368	Sachdeva, Voysey, Kelly, Johnson, Aning, Soomro	2017	Positive surgical margins and biochemical recurrence following minimally-invasive radical prostatectomy- An analysis of outcomes from a UK tertiary referral centre	Not RALRP-specific
461	Weerakoon, Sethi, Ischia, Webb	2012	Predictors of positive surgical margins at open and robot-assisted laparoscopic radical prostatectomy: a single surgeon series	Not RALRP-specific
402	Sooriakumaran, Nyberg, Derogar, et al.	2018	Erectile Function and Oncologic Outcomes Following Open Retropubic and Robot-assisted Radical Prostatectomy: Results from the LAParoscopic Prostatectomy Robot Open Trial	Oncologic outcome
237	Lei, Williams, Hevelone, et al.	2011	Athermal division and selective suture ligation of the dorsal vein complex during robot-assisted laparoscopic radical prostatectomy: description of technique and outcomes	Optime, continence, and urinary function
170	Huang, Wainger, Su, et al.	2021	Comparison of Perioperative and Pathologic Outcomes Between Single-port and Standard Robot-assisted Radical Prostatectomy: An Analysis of a High-volume Center and the Pooled World Experience	Poster
187	Johnson, Diep, Berg, et al.	2018	Switching from laparoscopic radical prostatectomy to robot assisted laparoscopic prostatectomy: comparing oncological outcomes and complications	Postoperative complications
43	Brennhovd, Fosså, Giercksky, Vlatkovic, Dahl	2013	Robot-assisted radical prostatectomy of clinical high-risk patients with prostate cancer: a controlled study of operative and short-term postoperative events	Postoperative events
305	Okegawa, Samejima, Ninomiya, et al.	2020	Laparoscopic radical prostatectomy versus robot-assisted radical prostatectomy: comparison of oncological outcomes at a single center	PSA relapse
375	Schroeck, Freedland, Albala, Mouraviev, Polascik, Moul	2008	Comparison of prostate-specific antigen recurrence-free survival in a contemporary cohort of patients undergoing either radical retropubic or robot-assisted laparoscopic radical prostatectomy	PSAR
380	Shikanov, Gofrit, Zagaja, Steinberg, Shalhav, Zorn	2008	Robotic laparoscopic radical prostatectomy for biopsy Gleason 8 to 10: prediction of favorable pathologic outcome with preoperative parameters	PT2N0 disease
2	Abdollah, Sood, Sammon, et al.	2016	Intermediate-term cancer control outcomes in prostate cancer patients treated with robotic-assisted laparoscopic radical prostatectomy: a multi-institutional analysis	Recurrence
71	Chen, Lian, Wang, et al.	2020	Short-term therapeutic outcomes of robotic-assisted laparoscopic radical prostatectomy for oligometastatic prostate cancer: a propensity score matching study	Recurrence
42	Bravi, Vertosick, Mazzone, et al.	2019	The Impact of Experience on the Risk of Surgical Margins and Biochemical Recurrence after Robot-Assisted Radical Prostatectomy: A Learning Curve Study	Regression done, no raw data
12	Alchin, Lawrentschuk	2017	Predicting the risk of positive surgical margins following robotic-assisted radical prostatectomy	Review
33	Basiri, Tabatabaei, Woo, Laguna, Shemshaki	2018	Comparison of retropubic, laparoscopic and robotic radical prostatectomy: who is the winner?	Review
57	Cao, Qi, Chen	2019	Robot-assisted and laparoscopic vs open radical prostatectomy in clinically localized prostate cancer: perioperative, functional, and oncological outcomes: A Systematic review and meta-analysis	Review
84	Coelho, Patel, Orvieto, et al.	2010	Retropubic, laparoscopic, and robot-assisted radical prostatectomy: a critical review of outcomes reported by high-volume centers	Review
96	Djavan, Finkelstein, Sadri, Farr, Apolikhin, Lepor	2010	Oncologic, Functional, and Cost Analysis of Open, Laparoscopic, and Robotic Radical Prostatectomy	Review
161	Hegarty	2006	Radical prostatectomy: a comparison of open, laparoscopic and robot-assisted laparoscopic techniques	Review
319	Pansadoro	2019	Extrafascial robot-assisted laparoscopic radical prostatectomy in locally advanced prostate cancer	Review
327	Parsons	2008	Outcomes of retropubic, laparoscopic, and robotic-assisted prostatectomy	Review
285	Mortezavi, Seifert, Wild, Schmid, Sulser, Eberli	2012	Intrafascial dissection significantly increases positive surgical margin and biochemical recurrence rates after robotic-assisted radical prostatectomy	RFS

Suppl. Table S2. *Continued*

ID	Authors	YOP	Title	Decision
169	Huang, Hevelone, Lipsitz, Yu, et al.	2011	The impact of prostate size, median lobe, and prior benign prostatic hyperplasia intervention on robot-assisted laparoscopic prostatectomy: Technique and outcomes	Urinary function recovery, EBL, operative time, function recovery

EBL – estimated blood loss; N/A – not available (not accessible); RALRP – robot-assisted laparoscopic radical prostatectomy; YOP – year of publication

Suppl. Table 3. *The baseline characteristics and methodological quality of included studies in the meta-analysis*

Author	Year	Country	Sample size	Surgery type	Age	PSM	Definition	NOS Score
Yao et al.	2014	Japan	84	RALP	64.0 ±6.95	18 (21.4%)	The presence of tumor cells at the surgical margin	8 (good)
Yip et al.	2012	Hong Kong	235	RALP	66.4 ±5.9	47 (20.7%)	–	9 (good)
Hao et al.	2022	China	903	RALP	70 [IQR 66–75]	151 (16.7%)	–	9 (good)
Kowalczyk et al.	2011	USA	610	RALP	59.6 ±6.5 / 57.9 ±6.6	86 (14.10%)	–	9 (good)
Islamoglu et al.	2018	Turkey	111	RALP	64 (range 44–75)	29 (26.13%)	–	9 (good)
Ficarra et al.	2009	Italy	322	RALRP	61.4 ±6.6	95 (29.5%)	The presence of tumor at the inked margin	9 (good)
Nik-Ahd et al.	2020	USA	4766	RALP and RRP	≈62–63 (IQR 58–66)	1458 (30.59%)	–	9 (good)
Marchetti et al.	2011	USA	690	RALRP	58 (IQR 54–63)	105 (15.2%)	–	9 (good)
Kang et al.	2016	South Korea / USA	271	RALRP	62.9 (range 40–80)	68 (25.1%)	The presence of tumor on the inked margin of the specimen. PSM was categorized into four groups based on site: apical, posterolateral (PL), bladder neck (BN), and multifocal (MF)	9 (good)
Coelho et al.	2010	USA	876	RALRP	61 (IQR 56–66)	101 (11.5%)	The presence of tumor tissue on the inked surface of the specimen and were categorized into four groups based on their locations: apex, bladder neck (BN), posterolateral (PL), and multifocal (MF)	9 (good)
Asimakopoulos et al.	2021	France	1679	RALP	61.5 ±6.4	375 (22.6%)	Focal PSM: single PSM (sPSM) ≤3 mm; – Extensive PSM: sPSM with linear length >3 mm or several margins regardless of the length	9 (good)
He et al.	2018	China	181	RALP	68.13 ±5.88	38 (21%)	–	9 (good)
Tsivian et al.	2012	USA	560	RALP	60.1 (IQR 55.1–64.7)	130 (23.2%)	The presence of PCa cells at the inked margin of the prostatectomy specimen	9 (good)

IQR – interquartile range; NOS – Newcastle Ottawa Scale; RALP – robot-assisted laparoscopic prostatectomy; RALRP – robot-assisted laparoscopic radical prostatectomy; RRP – retropubic radical prostatectomy; USA – United States of America

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