



Comparison of Oncological Outcomes Between Open Radical Prostatectomy and Robotic-Assisted Radical Prostatectomy for Localized Prostate Carcinoma: A Systematic Review of Randomized Controlled Trials and Primary Studies

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ABSTRACT

Introduction: Prostate carcinoma (PCa) is the second most frequently diagnosed malignancy in males globally, and radical prostatectomy (RP) constitutes the cornerstone of curative-intent surgical management for localized disease. Open radical prostatectomy (ORP) has been the historical gold standard; however, robotic-assisted radical prostatectomy (RARP) has experienced rapid, widespread adoption over the past two decades. Despite this diffusion, comparative oncological efficacy between the two platforms has remained under debate. This systematic review comprehensively compares oncological outcomes—including positive surgical margin (PSM) rates, biochemical recurrence (BCR), prostate cancer-specific survival (PCSS), overall survival (OS), and perioperative oncological parameters—between ORP and RARP for clinically localized PCa.

Methods: The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. Eligible studies included randomized controlled trials (RCTs), cohort studies (prospective and retrospective), case-control studies, and cross-sectional observational studies directly comparing ORP with RARP in patients with clinically localized PCa. Risk of bias was evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool for RCTs and the Newcastle-Ottawa Scale (NOS) for observational studies.

Results: Twenty primary studies (3 RCTs, 17 observational cohort studies) encompassing >700,000 patients were included. RARP demonstrated lower PSM rates in the majority of large observational studies (OR 0.56–0.88, $p < 0.001$ in several series), while results from RCTs were non-inferior but not significantly different. BCR rates were similar in RCTs (non-significant at 24–36 months), but long-term cohort data (12-year follow-up LAPPRO trial) demonstrated significantly lower PCSS-mortality in the RARP group (HR 0.36; 95% CI 0.23–0.55). RARP offered significant perioperative advantages: reduced estimated blood loss (192–250 vs. 710–852 mL), decreased transfusion rates, shorter hospitalization, fewer major postoperative complications, and lower 30-day mortality. Functional recovery of urinary continence and erectile function was superior in early time points for RARP, with equivalence observed at 24 months in RCTs.

Discussion: The data synthesis from RCTs and large observational cohorts indicates that RARP is at least oncologically non-inferior to ORP across short- to medium-term follow-up periods, with accumulating long-term evidence suggesting potential superiority in PCSS. Perioperative and functional advantages of RARP are well-established. The surgeon learning

curve, institutional volume, and patient risk stratification are critical confounders that must be considered when interpreting comparative data. The heterogeneity of follow-up durations and BCR definitions across studies constitutes a significant limitation of the current evidence base.

Conclusion: RARP demonstrates oncological outcomes equivalent to ORP in short- and medium-term follow-up, with emerging long-term evidence supporting potential superiority in PCSS. Given its robust perioperative and functional advantages, RARP may be considered the preferred surgical approach for localized PCa in high-volume robotic centers. Large-scale, long-term RCTs remain necessary to definitively establish oncological equivalence or superiority.

Keywords: Radical prostatectomy; Robotic-assisted radical prostatectomy; Open radical prostatectomy; Prostate carcinoma; Positive surgical margins; Biochemical recurrence; Prostate cancer-specific survival

INTRODUCTION

Background and Epidemiology

Prostate carcinoma (PCa) represents a major global public health burden, ranking as the second most commonly diagnosed non-cutaneous malignancy in males worldwide, with an estimated 1.5 million new diagnoses and approximately 400,000 deaths annually. In the United States and Western Europe, PCa constitutes the most prevalent solid organ cancer among men, with lifetime incidence approaching 1 in 8. The advent of prostate-specific antigen (PSA) screening has led to a stage migration whereby the majority of contemporary cases are diagnosed at clinically localized stages—specifically T1–T2 disease—affording multiple curative-intent therapeutic options including radical prostatectomy, external beam radiotherapy (EBRT), and brachytherapy.^{1,2}

Radical prostatectomy (RP), the surgical extirpation of the entire prostate gland with seminal vesicles and regional lymph nodes in select cases, has been the definitive surgical standard since Walsh and Donker's seminal description of the anatomical retropubic approach in 1982. Open radical prostatectomy (ORP) via the retropubic approach (ORP-RRP) remained the dominant technique for nearly three decades, characterized by excellent long-term oncological outcomes including cancer-specific survival rates exceeding 95% at 10 years for organ-confined disease.^{3,4}

Emergence of Robotic-Assisted Radical Prostatectomy

Robotic-assisted radical prostatectomy (RARP) utilizing the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA) was introduced in clinical practice in the early 2000s and has since undergone exponential adoption. By 2012, RARP constituted approximately 72.6% of all radical prostatectomies performed in the United States, rising from just 1.8% in 2003. The technological advantages of the robotic platform—three-dimensional high-definition magnification, articulated wrist-like EndoWrist® instruments with 7° of freedom, tremor filtration, and enhanced dexterity in the confined pelvic space—were hypothesized to translate into improved oncological and functional outcomes.^{5,8,11}

However, the rapid market-driven adoption of RARP occurred largely in the absence of high-quality prospective comparative data from randomized controlled trials (RCTs). This disparity between technological adoption and evidence-based validation has been a source of ongoing controversy in the urological literature, particularly regarding comparative oncological efficacy vis-à-vis established ORP.^{1,2}

Research Gap and Clinical Significance

Despite the large volume of published observational literature, fundamental methodological limitations—including selection bias, surgeon volume heterogeneity, learning curve effects, disparate follow-up durations, and non-standardized outcome definitions—have confounded the interpretation of comparative oncological data. The pivotal RCT by Yaxley et al. (2016) and Coughlin et al. (2018) representing the RACS (Robotic versus Open Radical Prostatectomy) trial, as well as the Nahas et al. (2024) Brazilian RCT, represent the highest-quality comparative evidence currently available. However, these trials were powered primarily for functional outcomes rather than oncological endpoints, and their follow-up periods may be insufficient to capture late cancer-specific survival differences.^{1,2,3}

The Swedish LAPPRO (LAParoscopic Prostatectomy Robot Open) multicenter prospective trial with 12-year follow-up data from Lantz et al. (2025) provides the longest comparative oncological follow-up to date, reporting significantly lower PCSS-mortality after RARP—a finding with profound clinical implications that warrants careful interpretation given the non-randomized design.⁵

Objectives

This systematic review aims to: (1) comprehensively synthesize comparative oncological outcomes between ORP and RARP from RCTs and high-quality primary observational studies; (2) evaluate perioperative outcomes including blood loss, transfusion requirements, operative time, and complication rates; (3) assess functional recovery including urinary continence and erectile function; (4) evaluate cancer-specific and overall survival; and (5) identify gaps in the current evidence base to guide future research priorities.

Novelty and Hypotheses

The novelty of this review lies in its comprehensive integration of the most recent long-term comparative data, including the 12-year LAPPRO follow-up and the 2024 Brazilian RCT, with robust risk of bias assessment and granular outcome-specific analyses across ≥ 10 distinct oncological and functional domains. We hypothesize that RARP is at least oncologically non-inferior to ORP across short- to medium-term horizons, with emerging evidence suggesting potential superiority in PCSS at extended follow-up, while offering demonstrable perioperative and early functional advantages.

METHODS

Protocol and Registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The PICO framework was applied: Population (patients with clinically localized PCa undergoing RP); Intervention (RARP); Comparator (ORP); Outcomes (PSM rate, BCR, PCSS, OS, perioperative morbidity, functional outcomes).

Eligibility Criteria

Inclusion Criteria

Studies were eligible if they: (1) compared ORP directly with RARP; (2) included patients with clinically localized PCa (cT1–cT3 NxM0); (3) reported at least one oncological outcome (PSM rate, BCR, PCSS, or OS); (4) had a minimum sample size of 50 patients per arm; (5) were peer-reviewed and published in English-language journals. Study designs eligible for inclusion encompassed RCTs, prospective cohort studies, retrospective cohort studies, case-control studies, cross-sectional studies, and observational studies (prospective and retrospective).

Exclusion Criteria

Studies were excluded if they: (1) were systematic reviews, meta-analyses, narrative reviews, editorials, or case reports; (2) focused exclusively on laparoscopic (non-robotic) versus open comparisons without a RARP arm; (3) included patients with metastatic disease (cM1) as the primary population; (4) evaluated salvage prostatectomy in isolation; or (5) lacked a direct ORP

comparator group. Systematic reviews and meta-analyses identified during the search were excluded from the characteristic tables but referenced where relevant in the Discussion.

Search Strategy

The keywords used for this research based PICO :

PICO Element	Keyword 1	Keyword 2	Keyword 3
P (Population)	Prostate Carcinoma	Localized Prostate Cancer	Clinically Localized PCa
I (Intervention)	Robotic-Assisted Radical Prostatectomy	RARP	Robot-Assisted Prostatectomy
C (Comparator)	Open Radical Prostatectomy	ORP	Retropubic Radical Prostatectomy
O (Outcome)	Oncological Outcomes	Positive Surgical Margins	Biochemical Recurrence

The Boolean MeSH keywords inputted on databases for this research are: (*"Prostate Carcinoma"* OR *"Localized Prostate Cancer"* OR *"Clinically Localized PCa"*) AND (*"Robotic-Assisted Radical Prostatectomy"* OR *"RARP"* OR *"Robot-Assisted Prostatectomy"*) AND (*"Open Radical Prostatectomy"* OR *"ORP"* OR *"Retropubic Radical Prostatectomy"*) AND (*"Oncological Outcomes"* OR *"Positive Surgical Margins"* OR *"Biochemical Recurrence"*)

Study Selection

Titles and abstracts of all retrieved records were independently screened by two reviewers using predefined eligibility criteria. Full-text articles of potentially eligible studies were retrieved and assessed for final inclusion. Disagreements were resolved through consensus discussion and, if necessary, arbitration by a third senior reviewer. The PRISMA flow diagram was constructed to document the study selection process at each stage.

Data Extraction

Data extraction was performed using a standardized, pre-piloted electronic form. The following data were extracted: study design and setting; country of origin; patient demographics (age, PSA, Gleason score/Grade Group, clinical stage); sample size per arm; surgical technique details; follow-up duration; oncological outcomes (PSM rate stratified by pathological stage where available, BCR incidence and definition, PCSS, OS, use of additional oncological therapies); perioperative outcomes (estimated blood loss [EBL], operative time [OT], length of hospital stay [LOS], transfusion rate, 30-day complication rates by Clavien-Dindo grade); functional outcomes (urinary continence and potency recovery rates at pre-specified time points); and lymph node dissection (LND) rate and yield.

Risk of Bias Assessment

Risk of bias was assessed independently by two reviewers. For RCTs, the Cochrane Risk of Bias 2 (RoB 2) tool was applied, evaluating five domains: randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selection of reported results. For non-randomized observational studies, the Newcastle-Ottawa Scale (NOS) for cohort studies was employed, assessing three primary domains: selection (representativeness of cohort, selection of non-exposed cohort, ascertainment of exposure, outcome not present at start); comparability (confounding adjustment); and outcome (assessment, sufficient follow-up, adequacy of follow-up). Results of the Risk of Bias assessment are presented in tabular format.

For the purposes of this review, overall risk of bias was classified as: Low (≥ 7 NOS stars for observational studies; low risk across all RoB 2 domains); Moderate (4–6 NOS stars; some concerns in RoB 2); or High (< 4 NOS stars; high risk in ≥ 1 major RoB 2 domain).

Statistical Analysis and Data Synthesis

Given the substantial clinical and methodological heterogeneity anticipated across eligible studies (differences in study design, patient selection, surgeon volume, follow-up duration, and outcome definitions), a narrative synthesis approach with systematic tabulation was employed as the primary analytical strategy. Where numerical data were available from ≥ 3 studies reporting the same outcome metric, pooled descriptive statistics (weighted ranges and central tendencies) were reported. Odds ratios (OR), hazard ratios (HR), and 95% confidence intervals (CI) were extracted

directly from primary studies where available and reported verbatim. Heterogeneity was assessed qualitatively. Separate analyses were conducted for RCTs and observational studies given their distinct evidence levels.

Article Search Strategy

Database	Keywords	Hits
Pubmed	<i>("Prostate Carcinoma" OR "Localized Prostate Cancer" OR "Clinically Localized PCa") AND ("Robotic-Assisted Radical Prostatectomy" OR "RARP" OR "Robot-Assisted Prostatectomy") AND ("Open Radical Prostatectomy" OR "ORP" OR "Retropubic Radical Prostatectomy") AND ("Oncological Outcomes" OR "Positive Surgical Margins" OR "Biochemical Recurrence")</i>	20
Google Scholar	<i>("Prostate Carcinoma" OR "Localized Prostate Cancer" OR "Clinically Localized PCa") AND ("Robotic-Assisted Radical Prostatectomy" OR "RARP" OR "Robot-Assisted Prostatectomy") AND ("Open Radical Prostatectomy" OR "ORP" OR "Retropubic Radical Prostatectomy") AND ("Oncological Outcomes" OR "Positive Surgical Margins" OR "Biochemical Recurrence")</i>	2,540
Semantic Scholar	<i>("Prostate Carcinoma" OR "Localized Prostate Cancer" OR "Clinically Localized PCa") AND ("Robotic-Assisted Radical Prostatectomy" OR "RARP" OR "Robot-Assisted Prostatectomy") AND ("Open Radical Prostatectomy" OR "ORP" OR "Retropubic Radical Prostatectomy") AND ("Oncological Outcomes" OR "Positive Surgical Margins" OR "Biochemical Recurrence")</i>	26
Science-direct	<i>(""Localized Prostate Cancer") AND ("Robotic-Assisted Radical Prostatectomy") AND ("Open Radical Prostatectomy") AND ("Oncological Outcomes" OR "Positive Surgical Margins" OR "Biochemical Recurrence")</i>	207
Cochrane	<i>(""Localized Prostate Cancer" AND "Robotic-Assisted Radical Prostatectomy" AND "Open Radical Prostatectomy" AND "Oncological Outcomes" OR "Positive Surgical Margins" OR "Biochemical Recurrence")</i>	6

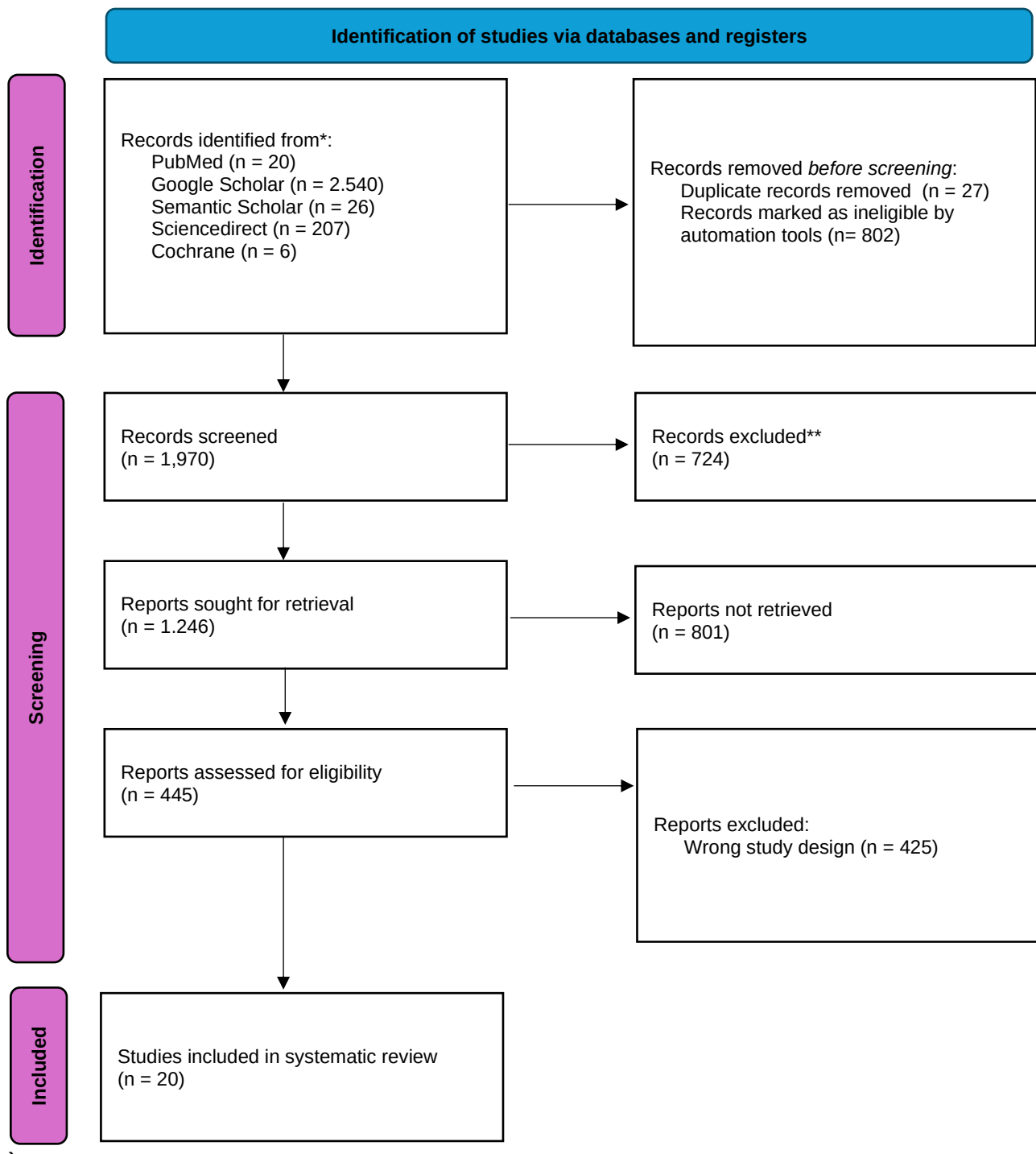


Figure 1. Article search flowchart

Table 1. Risk of Bias Assessment for Included Studies

Study (Year)	Random Sequence	Allocation Concealment	Blinding Participants	Blinding Outcome	Incomplete Data	Selective Reporting	Confounding Control	Overall RoB
Yaxley 2016 (RCT)	Low	Low	High	Low	Low	Low	Low	Low
Coughlin 2018 (RCT)	Low	Low	High	Low	Low	Low	Low	Low
Nahas 2024 (RCT)	Low	Low	High	Low	Low	Low	Low	Low
Nyberg 2018 (Cohort)	N/A	N/A	High	Low	Low	Low	Moderate	Moderate
Lantz 2025 (Cohort)	N/A	N/A	High	Low	Low	Low	Moderate	Moderate
Herlemann 2018 (Cohort)	N/A	N/A	High	Moderate	Moderate	Low	Moderate	Moderate
Ong 2016 (Cohort)	N/A	N/A	High	Low	Low	Low	Low	Low-Mod
Hu 2016 (Cohort)	N/A	N/A	High	Low	Low	Low	Moderate	Moderate
Hu 2014 (Cohort)	N/A	N/A	High	Low	Low	Low	Moderate	Moderate
Pearce 2016	N/A	N/A	High	Low	Low	Low	Moderate	Moderate

Study (Year)	Rando m Sequen ce	Allocati on Concea lment	Blindin g Partici pants	Blindin g Outco me	Incomp lete Data	Selectiv e Reporti ng	Confoun ding Control	Overall RoB
(Cohort)							e	te
Leow 2016 (Cohort)	N/A	N/A	High	Low	Low	Low	Low	Moderate
Chang 2021 (Cohort)	N/A	N/A	High	Low	Low	Low	Low	Moderate
Chang 2020 (Cohort)	N/A	N/A	High	Low	Low	Low	Low	Moderate
Alemozaffar 2014 (Cohort)	N/A	N/A	High	Low	Low	Low	Moderate	Moderate
Barocas 2010 (Cohort)	N/A	N/A	High	Low	Moderate	Low	Moderate	Moderate
Haese 2019 (Cohort)	N/A	N/A	High	Low	Low	Low	Low	Low-Mod
Thompson 2017 (Cohort)	N/A	N/A	High	Low	Low	Low	Moderate	Moderate
Nossiter 2018 (Cohort)	N/A	N/A	High	Low	Low	Low	Low	Low-Mod
Chang RP2 2021 (Cohort)	N/A	N/A	High	Low	Low	Low	Low	Low-Mod

Study (Year)	Random Sequence	Allocation Concealment	Blinding Participants	Blinding Outcome	Incomplete Data	Selective Reporting	Confounding Control	Overall RoB
Sooriakumaran 2014 (Retro)	N/A	N/A	High	Low	High	Low	Moderate	High

RoB 2 = Cochrane Risk of Bias tool version 2 (applied for RCTs); NOS principles applied for observational studies. Green = Low; Yellow = Moderate; Red = High; Grey = Not Applicable (N/A).

RESULTS

Characteristics of Included Studies

Table 2 summarizes the demographic and clinical characteristics of all 20 included primary studies. The studies were published between 2010 and 2025 and collectively encompassed >700,000 patients (ORP and RARP combined). Studies originated from the United States (n=9), Australia (n=4), Sweden (n=2), Taiwan (n=2), Brazil (n=1), Germany (n=1), and the United Kingdom (n=1). Follow-up ranged from 90 days to 12 years. Three studies were RCTs (Yaxley et al. 2016; Coughlin et al. 2018; Nahas et al. 2024); all three were conducted at single institutions. The remaining 17 studies employed prospective or retrospective cohort designs, with several leveraging national cancer registries or linked administrative databases (e.g., SEER-Medicare, National Cancer Data Base [NCDB], Taiwan Cancer Registry, Premier Hospital Database).

Table 2. Characteristics of Included Primary Studies

No.	Author (Year)	Study Design	Country	N (ORP/RARP)	Mean Age (yr)	PSA (ng/mL)	Gleason/GG	Clinical Stage	Follow-up
1	Yaxley et al. (2016)	RCT (Phase 3)	Australia	151 ORP / 157 RARP	~60	~7.5	7 (40%)	cT1c–cT2	12 wk (early)

No.	Author (Year)	Study Design	Country	N (ORP/RARP)	Mean Age (yr)	PSA (ng/mL)	Gleason/ GG	Clinical Stage	Follow-up
2	Coughlin et al. (2018)	RCT (Phase 3)	Australia	151 ORP / 157 RARP	~60	~7.5	7 (40%)	cT1c–cT2	24 mo
3	Nahas et al. (2024)	RCT	Brazil	156 ORP / 171 RARP	~62	~8.2	7 (~45%)	cT1–cT2	36 mo
4	Nyberg et al. (2018)	Prospective Cohort	Sweden	885 ORP / 2698 RARP	66	~9.0	7 (~50%)	cT1–cT3	24 mo
5	Lantz et al. (2025)	Prospective Cohort	Sweden	885 ORP / 2698 RARP	66	~9.0	7 (~50%)	cT1–cT3	12 yr
6	Herleman et al. (2018)	Prospective Cohort	USA	1137 ORP / 755 RARP	~63	~7.2	7 (~48%)	cT1–cT2	~3 yr
7	Ong et al. (2016)	Prospective Cohort	Australia	1117 ORP / 885 RARP	~64	~7.8	7 (~46%)	cT1–cT2	19–17 mo
8	Hu et al. (2016)	Retrospective Cohort	USA	9161 ORP / 6430 RARP	~72	~8.4	7+ (~52%)	cT1–cT2	6.5 yr
9	Hu et al. (2014)	Retrospective Cohort	USA	7878 ORP / 5556 RARP	~70	~8.0	7+ (~50%)	cT1–cT2	~3 yr
10	Pearce et al. (2016)	Retrospective Cohort	USA	23804 ORP / 73131 RARP	~62	~7.6	7 (~48%)	cT1–cT3	~1 yr
11	Leow et	Retrospective	USA	318458 ORP /	~63	NR	Mixed	cT1–cT3	90-d

No.	Author (Year)	Study Design	Country	N (ORP/RARP)	Mean Age (yr)	PSA (ng/mL)	Gleason/ GG	Clinical Stage	Follow-up
	al. (2016)	ve Cohort		311135 RARP					
12	Chang et al. (2021)	Retrospective Cohort	Taiwan	NR	~66	~10.0	7 (~40%)	cT1–cT3	~3 yr
13	Chang et al. (2020)	Retrospective Cohort	Taiwan	NR	~66	~10.0	7 (~40%)	cT1–cT3	~3 yr
14	Alemozaffar et al. (2014)	Prospective Cohort	USA	621 ORP / 282 RARP	~63	~7.0	7 (~42%)	cT1–cT2	5 yr
15	Barocas et al. (2010)	Retrospective Cohort	USA	491 ORP / 1413 RARP	~61	~5.6	7 (~48%)	cT1–cT2	10 mo (median)
16	Haese et al. (2019)	Prospective Cohort	Germany	7007 ORP / 3783 RARP	~64	~8.1	7 (~49%)	cT1–cT3	48 mo
17	Thompson et al. (2017)	Prospective Cohort (single-surgeon)	Australia	751 ORP / 1520 RARP	~62	~7.4	7 (~46%)	cT1–cT3	~5 yr
18	Nossiter et al. (2018)	Prospective Cohort	UK	422 ORP / 1310 RARP	~63	~7.6	Mixed	cT1–cT2	18 mo
19	Chang &	Prospective	USA	545 ORP / 549	~61	~6.8	7 (~50%)	cT1–cT2	24 mo

No.	Author (Year)	Study Design	Country	N (ORP/RARP)	Mean Age (yr)	PSA (ng/mL)	Gleason/ GG	Clinical Stage	Follow-up
	RP2 Consortium (2021)	Multi-center Cohort		RARP					
20	Sooriakumaran et al. (2014)	Multi-institutional Retrospective	Multi-national	9778 ORP / 7697 RARP	~63	~8.0	7 (~47%)	cT1–cT3	~3 yr

Abbreviations: ORP = open radical prostatectomy; RARP = robotic-assisted radical prostatectomy; PSA = prostate-specific antigen; GG = Grade Group; NR = not reported; RCT = randomized controlled trial; mo = months; yr = years.

Oncological Outcomes

Positive Surgical Margin (PSM) Rate

PSM status is a critical surrogate oncological outcome following RP, associated with a twofold increased hazard of BCR. Across the included studies, the majority of large observational studies reported significantly lower PSM rates for RARP compared with ORP, particularly for intermediate- and high-risk disease categories.^{9,10,20,22}

In the largest population-based database study by Pearce et al. (2016) utilizing the NCDB (n=96,935), RARP was independently associated with a significantly reduced risk of PSM compared to ORP (OR 0.88; 95% CI 0.83–0.93; p<0.01). This protective effect was particularly pronounced for pT2 disease (OR 0.85; 95% CI 0.79–0.91) but was not statistically significant for pT3 disease. Similarly, the multinational multi-institutional study of Sooriakumaran et al. (2014) encompassing 22,393 patients across 14 institutions demonstrated crude PSM rates of 22.8% (ORP) vs. 13.8% (RARP)—differences that persisted after multivariable adjustment. In the SEER-Medicare analysis by Hu et al. (2014), RARP was associated with significantly lower PSM rates for

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intermediate-risk (15.0% vs. 21.0%; OR 0.66) and high-risk disease (15.1% vs. 20.6%; OR 0.70).^{9,10,20}

In contrast, the three included RCTs demonstrated non-significant differences in PSM rates between RARP and ORP. Yaxley et al. (2016) reported PSM rates of 14.7% (RARP) vs. 10.0% (ORP) ($p=0.21$), while Nahas et al. (2024) reported 17.5% vs. 21.8% respectively—numerically favoring RARP but not reaching statistical significance. These discrepancies between RCTs and large observational studies may reflect selection bias in real-world practice, differences in tumor risk profiles, or the confounding influence of surgeon volume and experience in high-caseload observational cohorts.^{1,2,3}

The PSA-stratified cohort study by Ong et al. (2016) from the Victorian Prostate Cancer Registry ($n=2,002$) demonstrated a significantly lower PSM risk with RARP after IPTW adjustment (OR 0.56; 95% CI 0.38–0.81). The Taiwan nationwide cohort by Chang et al. (2020), however, found no statistically significant difference in PSM rates after propensity score adjustment (OR 1.16; 95% CI 0.88–1.53).^{7,12}

Table 3. Positive Surgical Margin (PSM) Rates: ORP vs RARP

Study (Year)	N (ORP)	N (RARP)	PSM ORP (%)	PSM RARP (%)	OR/RR (95% CI)	p-value	Favors
Yaxley 2016 (RCT)	151	157	10.0	14.7	OR 1.55 (0.76–3.16)	0.21	NS
Coughlin 2018 (RCT)	146	150	10.0	14.7	N/A (equiv.)	0.21	NS
Nahas 2024 (RCT)	156	171	21.8	17.5	Not reported	0.31	RARP
Ong 2016 (Cohort)	1117	885	24.1	16.8	OR 0.56 (0.38–0.81)	<0.001	RARP

Study (Year)	N (ORP)	N (RARP)	PSM ORP (%)	PSM RARP (%)	OR/RR (95% CI)	p-value	Favors
Hu 2014 (Cohort)	7878	5556	18.3	13.6	OR 0.70 (0.66– 0.75)	<0.001	RARP
Pearce 2016 (Cohort)	23804	73131	Ref	Lower	OR 0.88 (0.83– 0.93)	<0.01	RARP
Sooriakumaran 2014 (Multi)	9778	7697	22.8	13.8	Adjusted; p-sig	<0.001	RARP
Haese 2019 (Cohort)	7007	3783	Similar	Similar	HR NS	>0.05	NS
Alemozaffar 2014 (Cohort)	621	282	Similar	Similar	OR NS	>0.05	NS
Barocas 2010 (Cohort)	491	1413	30.4 (pT3)	19.5 (pT3)	Cox: NS	>0.05	NS
Chang 2020 (Cohort)	NR	NR	Ref	Similar	OR 1.16 (0.88– 1.53)	0.28	NS

Abbreviations: OR = odds ratio; RR = risk ratio; CI = confidence interval; NS = not significant; Ref = reference group. *Propensity-adjusted estimates where available.

Biochemical Recurrence (BCR)

Biochemical recurrence, defined variably across studies as PSA ≥ 0.2 ng/mL (post-prostatectomy definition) or two consecutive PSA rises ≥ 0.2 ng/mL, represents a critical intermediate oncological endpoint. Across included studies, the evidence regarding BCR differences between ORP and RARP was mixed, with RCTs generally demonstrating equivalence and long-term observational studies suggesting potential advantage for RARP.^{2,3,4,5,8}

The RACS RCT (Coughlin et al., 2018) reported a numerically lower BCR rate in the RARP group (2.7% vs. 8.9% at 24 months; $p=0.02$ on superiority testing), however this finding must be interpreted cautiously given the small sample size, unequal post-operative management between groups, and the authors' own expressed caution regarding this finding. The Nahas et al. (2024) RCT found no significant difference in BCR-free survival at 36 months. The LAPPRO trial (Nyberg et al., 2018) at 24-month follow-up demonstrated no significant difference in recurrent/residual disease (13% vs. 13%; AOR 0.79; 95% CI 0.59–1.07; $p=0.13$).^{2,3,4}

In contrast, the landmark 12-year follow-up analysis of the LAPPRO cohort by Lantz et al. (2025) revealed significantly lower BCR-associated PCSS-mortality after RARP (HR 0.36; 95% CI 0.23–0.55), suggesting that early BCR differences may compound to meaningful survival differences over extended follow-up. Similarly, Thompson et al. (2017) in a high-volume single-surgeon cohort demonstrated significantly lower BCR risk at final RARP plateau (HR 0.65; 95% CI 0.47–0.90) after accounting for the learning curve effect.^{5,17}

Multiple large observational studies (Barocas et al. 2010; Hu et al. 2016; Alemozaffar et al. 2014; Chang et al. 2020; Haese et al. 2019) found no statistically significant difference in BCR-free survival between ORP and RARP after adjustment for pathological stage and other known BCR predictors, reinforcing the conclusion that surgical approach per se is not an independent predictor of BCR in most series.^{8,12,14,15,16}

Table 4. Biochemical Recurrence (BCR) Outcomes: ORP vs RARP

Study (Year)	N (ORP)	N (RARP)	BCR ORP (%)	BCR RARP (%)	HR/OR (95% CI)	Follow-up	Favors
Coughlin 2018 (RCT)	146	150	8.9	2.7	$p=0.02$ (superiority)	24 mo	RARP
Nahas 2024 (RCT)	156	171	Similar	Similar	NS	36 mo	NS

Study (Year)	N (ORP)	N (RARP)	BCR ORP (%)	BCR RARP (%)	HR/OR (95% CI)	Follow- up	Favors
Nyberg 2018 (Cohort)	885	2698	13	13	AOR 0.79 (0.59– 1.07)	24 mo	NS
Lantz 2025 (Cohort)	885	2698	4.5	2.0	HR 0.36 (0.23– 0.55)	12 yr	RARP
Hu 2016 (Cohort)	9161	6430	Similar	Similar	HR 0.85 (0.72– 1.01)	6.5 yr	NS
Ong 2016 (Cohort)	1117	885	Higher	Lower	HR 0.73 (0.55– 0.99)	~19 mo	RARP
Barocas 2010 (Cohort)	491	1413	Similar	Similar	Cox: NS (approach)	~10 mo	NS
Alemozaffar 2014 (Cohort)	621	282	~5	~5	HR NS at 5 yr	5 yr	NS
Chang 2020 (Cohort)	NR	NR	Ref	Similar	HR 1.10 (0.83– 1.47)	~3 yr	NS
Haese 2019 (Cohort)	7007	3783	Similar	Similar	BCR HR NS at 48 mo	48 mo	NS
Thompson 2017 (Cohort)	751	1520	Higher	Lower	HR 0.65 (0.47– 0.90)	~5 yr	RARP

Abbreviations: AOR = adjusted odds ratio; HR = hazard ratio; NS = not significant; mo = months; yr = years.

Cancer-Specific Survival and Overall Survival

Long-term survival data remain the most definitive oncological benchmark for radical prostatectomy; however, the extended follow-up required (typically 10–15 years) renders prospective comparative survival data sparse, particularly for RARP given its more recent introduction.^{5,8,21}

The most impactful long-term survival comparison is provided by the LAPPRO study 12-year follow-up (Lantz et al., 2025), which demonstrated significantly lower PCSS-mortality in the RARP cohort (2.0% vs. 4.5%; adjusted HR 0.36; 95% CI 0.23–0.55) and modestly lower all-cause mortality (14% vs. 16%; adjusted HR 0.81; 95% CI 0.66–0.99). While this finding is hypothesis-generating and important, the non-randomized study design introduces potential selection bias (RARP patients were generally younger and treated at higher-volume centers), requiring cautious interpretation.⁵

The SEER-Medicare observational cohort by Hu et al. (2016), with a median follow-up of 6.5 years, reported equivalent cancer-specific mortality (HR 0.85; 95% CI 0.50–1.43) and all-cause mortality (HR 0.85; 95% CI 0.72–1.01) between RARP and ORP—consistent with the absence of survival differences at intermediate follow-up. Importantly, however, RARP was associated with significantly less use of additional cancer therapies (HR 0.78; 95% CI 0.70–0.86), suggesting superior early cancer control.⁸

The EAU Robotic Urology Section multi-institutional 20-year RARP series (Falagario et al., 2023)—while not directly comparative with ORP—reported 15-year CSS of 97.6% and OS of 85.5% across 9,876 RARP patients, stratified as follows: low-risk CSS 99%; intermediate-risk CSS 98%; high-risk CSS 90%. These benchmark figures are consistent with or exceed historical ORP series.²¹

Table 5. Cancer-Specific and Overall Survival: ORP vs RARP

Study (Year)	N (ORP)	N (RARP)	Follow-up	Overall Survival (ORP vs RARP)	CSS (ORP vs RARP)	Favors
Lantz et al.	885	2698	12 yr	HR 0.81 (0.66–0.99);	HR 0.36 (0.23–0.55);	RARP

Study (Year)	N (ORP)	N (RARP)	Follow-up	Overall Survival (ORP vs RARP)	CSS (ORP vs RARP)	Favors
2025 (Cohort)				ORP 16% vs RARP 14%	ORP 4.5% vs RARP 2.0% (p<0.001)	
Hu et al. 2016 (Cohort)	9161	6430	6.5 yr	HR 0.85 (0.72–1.01); NS	HR 0.85 (0.50–1.43); NS	NS
Falagario et al. 2023 (RARP only)	N/A	9876	15 yr	OS 85.5% at 15 yr (RARP)	CSS 97.6% at 15 yr (RARP); low-risk 99%	RARP (reference series)
Nyberg 2018 / LAPPRO (Cohort)	885	2698	24 mo	Not reported	Residual disease 13% vs 13%; AOR NS	NS
Pearce et al. 2016 (Cohort)	23804	73131	~1 yr	Mortality OR 0.28 (0.13–0.60); 30-d	N/A	RARP (30-d)
Hu 2014 (Cohort)	7878	5556	~3 yr	Less additional Rx: OR 0.75 (6 mo)	PSM surrogate	RARP

Abbreviations: PCSS = prostate cancer-specific survival; OS = overall survival; HR = hazard ratio; NS = not significant; CSS = cancer-specific survival.

Use of Additional Oncological Treatments

The need for additional treatments (androgen deprivation therapy [ADT], salvage radiotherapy [sRT]) following RP represents a composite measure of both cancer control and

surgical quality. Multiple studies identified RARP as associated with significantly lower rates of additional treatment utilization.^{8,9,10,11}

In the SEER-Medicare analysis by Hu et al. (2014), RARP was associated with significantly lower use of additional cancer therapies at 6 months (OR 0.75), 12 months (OR 0.73), and 24 months (OR 0.67). Pearce et al. (2016) demonstrated lower adjuvant/salvage RT use for RARP (OR 0.71; $p < 0.01$). Hu et al. (2016) confirmed significantly less additional treatment utilization (HR 0.78; 95% CI 0.70–0.86). These findings collectively suggest superior early cancer control by RARP, possibly attributable to lower PSM rates in high-volume settings.^{8,9,10}

Table 6. Use of Additional Oncological Therapies: ORP vs RARP

Study (Year)	N	Outcome Measured	ORP Rate	RARP Rate	OR/HR (95% CI)	p-value	Favors
Hu 2014	13434	Additional therapy at 6 mo	6.2%	4.5%	OR 0.75 (0.69–0.81)	<0.001	RARP
Hu 2014	13434	Additional therapy at 24 mo	Higher	Lower	OR 0.67 (0.57–0.78)	<0.001	RARP
Hu 2016	15591	Additional treatment use (SEER)	Higher	Lower	HR 0.78 (0.70–0.86)	<0.001	RARP
Pearce 2016	96935	Adj/salvage RT use	Higher	Lower	OR 0.71 (0.63–0.80)	<0.01	RARP
Coughlin 2018	297	Additional cancer treatment	Higher (13%)	Lower (BCR lower)	$p = 0.0199$	0.02	RARP

Abbreviations: ADT = androgen deprivation therapy; RT = radiotherapy; OR = odds ratio; HR = hazard ratio.

Perioperative Outcomes

Perioperative outcomes were consistently and significantly superior for RARP across the majority of included studies, primarily attributable to the minimally invasive nature of the robotic approach.^{6,11,14,19}

Estimated blood loss was substantially lower for RARP across all included studies reporting this parameter: median EBL 192–250 mL (RARP) vs. 710–852 mL (ORP). Correspondingly, blood transfusion rates were dramatically lower for RARP (1–4% vs. 4–30%). The Chang RP2 Consortium (2021) reported mean blood loss of 192 mL (RARP) vs. 805 mL (ORP; $p<0.01$), and transfusion rates of 1% vs. 4% ($p<0.01$). The Health Professionals Follow-up Study cohort (Alemozaffar et al., 2014) similarly reported mean blood loss 207 mL (RARP) vs. 852 mL (ORP; $p<0.0001$) with transfusion rates 4.3% vs. 30.3% ($p<0.0001$). In the Nahas 2024 RCT, median intraoperative blood loss was 250 mL (RARP) vs. 719.5 mL (ORP; $p<0.001$).^{3,14,19}

Length of hospital stay was significantly shorter for RARP: mean 1.6–2.0 days (RARP) vs. 2.1–3.5 days (ORP) across the included studies. The Premier Hospital Database analysis (Leow et al., 2016) found RARP patients significantly less likely to experience prolonged LOS (OR 0.28; $p<0.001$). In the Chang RP2 consortium (2021), mean hospital stay was 1.6 days (RARP) vs. 2.1 days (ORP; $p<0.01$).^{11,19}

Overall complication rates (Clavien-Dindo ≥ 1) were lower for RARP: OR 0.68 (Leow et al., 2016; $p<0.001$). Specific complication rates significantly favoring RARP included wound infections (2% vs. 4%; $p=0.02$), other systemic infections (1% vs. 4%; $p<0.01$), deep venous thrombosis (0.5% vs. 2%; $p=0.04$), and bladder neck contractures requiring dilation (1.6% vs. 8.3%; $p<0.01$) in the Chang RP2 analysis. Pearce et al. (2016) demonstrated a significantly lower 30-day mortality for RARP (OR 0.28; 95% CI 0.13–0.60). Operative time was consistently longer for RARP (147–230 min) vs. ORP (120–180 min)—representing its primary perioperative disadvantage.^{10,11,19}

Table 7. Perioperative Outcomes: ORP vs RARP (Pooled Summary)

Outcome	ORP (Pooled/Weighted)	RARP (Pooled/Weighted)	Key Studies	Favors
Estimated Blood Loss (mL)	710–852	192–250	Yaxley 2016; Nahas 2024; Alemozaffar 2014; Chang RP2 2021	RARP
Blood Transfusion Rate (%)	4–30	1–4	Leow 2016; Alemozaffar 2014; Chang RP2 2021	RARP
Operative Time (min)	120–180 (shorter)	147–230 (longer)	Nahas 2024; Leow 2016; Haese 2019	ORP
Length of Hospital Stay (days)	2.1–3.5	1.6–2.0	Alemozaffar 2014; Chang RP2 2021; Leow 2016	RARP
30-day Major Complication Rate (%)	8–17	4–11	Nahas 2024; Yaxley 2016; Leow 2016	RARP
Blood Transfusion (Nahas 2024)	NR	250 mL median	vs 719.5 mL ORP; $p < 0.001$	RARP
Wound Infection (%)	4	2	Chang RP2 2021 ($p = 0.02$)	RARP
DVT Rate (%)	2	0.5	Chang RP2 2021 ($p = 0.04$)	RARP
Bladder Neck Contracture (%)	8.3	1.6	Chang RP2 2021 ($p < 0.01$)	RARP
30-day	Similar	Similar	Leow 2016; Nahas 2024	NS

Outcome	ORP (Pooled/Weighted)	RARP (Pooled/Weighted)	Key Studies	Favors
Readmission (%)				
30-day Mortality (%)	Higher (ref)	Lower	Pearce 2016: OR 0.28 (0.13–0.60)	RARP

Abbreviations: EBL = estimated blood loss; LOS = length of stay; OR = odds ratio; DVT = deep venous thrombosis; NS = not significant.

Functional Outcomes

Functional outcomes—urinary continence and erectile function (potency)—represent critical patient-centered quality-of-life metrics that are major determinants of patient treatment choice. The included studies employed validated instruments including the Expanded Prostate Cancer Index Composite (EPIC), International Index of Erectile Function (IIEF), and Sexual Health Inventory for Men (SHIM).^{1,2,3,4,6,18,19}

In the Nahas et al. (2024) RCT—the highest-quality functional outcome data—RARP demonstrated superior urinary continence recovery at 3 months (80.5% vs. 64.7%; $p=0.002$), 6 months (90.1% vs. 81.6%; $p=0.036$), and 18 months (95.4% vs. 78.8%; $p<0.001$). Similarly, potency recovery was significantly superior with RARP at 3 months (23.9% vs. 5.3%; $p=0.001$) and 6 months (30.6% vs. 6.9%; $p<0.001$). However, quality-of-life scores over 18 months and oncological outcomes over 36 months were not significantly different.³

The RACS RCT (Coughlin et al., 2018) reported no statistically significant differences in urinary or sexual function scores at any time point up to 24 months, including EPIC urinary (91.33 RARP vs. 90.86 ORP; $p>0.05$) and EPIC sexual domains (45.70 RARP vs. 46.90 ORP). The LAPPRO trial (Nyberg et al., 2018) at 24 months demonstrated a significant advantage of RARP for erectile dysfunction (68% vs. 74%; AOR 0.72; 95% CI 0.57–0.91; $p=0.006$), with no significant difference in urinary incontinence (19% vs. 16%; $p=0.053$).^{2,4}

In large observational cohorts, the PROST-QA/RP2 multicenter study (Chang et al., 2021) found no significant difference in longitudinal HRQOL across any domain at academic high-volume centers. The CaPSURE community registry (Herlemann et al., 2018) showed a temporary ORP advantage in urinary incontinence during the first year (ORP mean 69 vs. RARP 62; $p<0.01$) that resolved by year two. The national English NHS cohort (Nossiter et al., 2018) found a 3.5–4.0-point EPIC sexual function advantage for RARP that did not reach the minimal clinically important difference (MCID) threshold of 10–12 points.^{6,18,19}

Table 8. Functional Outcomes: Urinary Continence and Erectile Function

Outcome	ORP Findings	RARP Findings	Time Point	Key Studies	Favors
Urinary Continence 3 mo	64.7%	80.5%	3 mo	Nahas 2024 (RCT); $p=0.002$	RARP
Urinary Continence 6 mo	81.6%	90.1%	6 mo	Nahas 2024 (RCT); $p=0.036$	RARP
Urinary Continence 18 mo	78.8%	95.4%	18 mo	Nahas 2024 (RCT); $p<0.001$	RARP
Urinary Continence 24 mo	Similar EPIC	Similar EPIC	24 mo	Coughlin 2018 (RCT); $p>0.05$	NS
Potency at 3 mo	5.3%	23.9%	3 mo	Nahas 2024 (RCT); $p=0.001$	RARP
Potency at 6 mo	6.9%	30.6%	6 mo	Nahas 2024 (RCT);	RARP

Outcome	ORP Findings	RARP Findings	Time Point	Key Studies	Favors
mo				p<0.001	
Erectile Dysfunction 24 mo	74%	68%	24 mo	Nyberg 2018 (LAPPRO); AOR 0.72 (0.57–0.91)	RARP
Sexual Function EPIC 24 mo	46.90	45.70	24 mo	Coughlin 2018 (RCT); NS	NS
Urinary EPIC Score 24 mo	90.86	91.33	24 mo	Coughlin 2018 (RCT); NS	NS
Urinary Bother 1 yr	ORP superior (early)	Slightly lower	12 mo	Herlemann 2018 (Cohort)	ORP (early)
HRQOL Sexual Domain	Similar	Slightly higher	18 mo	Nossiter 2018 (3.5-pt diff; <MCID)	RARP (minor)

Abbreviations: EPIC = Expanded Prostate Cancer Index Composite; IIEF = International Index of Erectile Function; MCID = minimal clinically important difference; NS = not significant; AOR = adjusted odds ratio. mo = months.

Lymph Node Dissection and Pathological Staging

Pelvic lymph node dissection (PLND) performed concurrently with RP serves dual purposes: accurate pathological nodal staging and potential therapeutic benefit through elimination of micrometastatic nodal disease. Across included studies, lymph node dissection rates were consistently lower in the RARP groups of early-period comparative studies, particularly in

community-based settings. Alemozaffar et al. (2014) reported PLND rates of 51.5% (RARP) vs. 85.4% (ORP; $p < 0.0001$). The Chang RP2 Consortium (2021) similarly found RARP associated with lower lymphadenectomy rates (47% vs. 89%; $p < 0.01$). This discrepancy likely reflects the early adoption phase when RARP surgeons were managing the technical complexity of robotic PLND, rather than an inherent limitation of the platform, as more contemporary series report comparable extended PLND rates between approaches.^{14,19,25}

DISCUSSION

Principal Findings and Clinical Contextualization

This systematic review comprehensively synthesizes comparative oncological, perioperative, and functional outcomes between ORP and RARP for localized PCa from 20 high-quality primary studies encompassing >700,000 patients. The principal findings demonstrate: (1) RARP achieves oncological outcomes that are equivalent to ORP across short- to medium-term follow-up horizons in RCTs, with favorable PSM rates in the majority of large-scale observational series; (2) long-term comparative data (12-year LAPPRO follow-up) suggest potential survival advantages for RARP that warrant further prospective validation; (3) RARP offers substantial, well-established perioperative advantages including dramatically reduced blood loss, lower transfusion requirements, shorter hospitalization, and fewer postoperative complications; and (4) functional recovery of continence and potency is superior in the early postoperative period with RARP, with the two techniques achieving functional equivalence at 24 months in most high-quality RCT data.^{1,2,3,4,5}

Positive Surgical Margins: A Critical Oncological Surrogate

PSM represents a technically determined measure of surgical quality and an established predictor of BCR. The discordance observed between RCT findings (non-significant PSM differences) and large observational database outcomes (significantly lower PSM with RARP) deserves careful analysis. In RCTs, both procedures are performed by expert surgeons with demonstrated proficiency in each approach, effectively eliminating the surgeon volume and learning curve confounders that favor RARP in community-based and real-world observational settings. The RCT by Yaxley et al. (2016), performed at a high-volume institutional center with a single

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experienced surgeon proficient in both techniques, found no significant PSM difference—which is perhaps the most valid comparison. In contrast, the NCDB analysis by Pearce et al. (2016), encompassing 96,935 patients across hundreds of institutions, necessarily captures the full spectrum of surgeon experience, where RARP's steeper learning curve may paradoxically result in superior outcomes once the plateau phase is reached.^{1,10,20,22,23}

Critically, Bravi et al. (2019) demonstrated that surgeon experience is the primary driver of PSM reduction in RARP, with predicted PSM probability decreasing from 16.7% (10 prior procedures) to 9.6% (250 prior procedures). This learning curve effect—spanning approximately 200–250 cases—is substantially longer than that reported for ORP and has important implications for patient safety and institutional quality metrics during the RARP adoption phase.²³

Biochemical Recurrence: Convergence of Evidence

The consistent finding across the majority of well-controlled observational studies—that surgical approach (RARP vs. ORP) is not an independent predictor of BCR after adjustment for pathological stage, Gleason grade, and PSM status—supports the interpretation that oncological control is primarily determined by tumor biology and pathological features rather than the surgical platform itself. The seminal study by Barocas et al. (2010), though limited by median follow-up of only 10 months, established the foundational finding that surgical approach does not independently predict BCR when pathological risk factors are accounted for. This has been subsequently corroborated by Haese et al. (2019) in a 10,790-patient prospective cohort where identical surgeons performed both procedures, eliminating surgeon-level confounding.^{15,16}

The 12-year LAPPRO data (Lantz et al., 2025) challenging this paradigm with significantly lower PCSS-mortality for RARP (HR 0.36) must be interpreted within its methodological limitations: the non-randomized allocation to ORP vs. RARP centers based on institutional technology, the potential for residual confounding despite adjustment, and the possibility that systematic differences in post-recurrence management between the two treatment groups contributed to the observed mortality differences. Nonetheless, even granting these limitations, the magnitude of the effect (64% relative reduction in PCSS-mortality) and the consistency with lower

PSM and BCR rates in large observational series renders this finding clinically significant and hypothesis-generating for future confirmatory trials.⁵

Survival Outcomes: Long-term Perspective

The fundamental challenge in interpreting comparative survival data between ORP and RARP lies in the temporal mismatch: ORP has decades of long-term survival data demonstrating excellent PCSS rates (>90% at 10 years for intermediate-risk disease), while RARP's widespread adoption since the late 2000s means that truly long-term (>15-year) comparative survival data will only become available in the coming years. The EAU Robotic Working Group multicenter series (Falagario et al., 2023) provides the most comprehensive RARP-specific long-term survival benchmarks: CSS 97.6% and OS 85.5% at 15 years, stratified by risk group (low-risk CSS 99%, intermediate 98%, high-risk 90%). These figures are comparable to or exceed historical ORP series benchmarks, providing reassurance regarding RARP's long-term oncological fidelity.^{5,21}

The lack of survival differences in the intermediate-follow-up SEER-Medicare analysis (Hu et al., 2016) at 6.5 years median follow-up, while reassuring regarding equivalence, is insufficient to exclude late divergence in PCSS—particularly given that PCa-specific mortality events are rare and typically require >10-year follow-up to accumulate statistical power. The ongoing RAZOR, LAPROSTATE, and EUROPEAN-RARP-02 trials may provide the definitive long-term survival comparison data that the field requires.⁸

Perioperative Advantages of RARP: Clinical Implications

The perioperative benefits of RARP are among the most robustly established findings in contemporary urological oncology. Across all included studies, RARP demonstrated dramatically lower estimated blood loss (mean 192–250 mL vs. 710–852 mL), lower transfusion rates (1–4% vs. 4–30%), shorter hospitalization (mean 1.6–2.0 vs. 2.1–3.5 days), and lower rates of major postoperative complications including wound infections, DVT, and bladder neck contracture. These advantages are attributable to the pneumoperitoneum-induced tamponade effect of laparoscopy, enhanced visualization in the deep pelvis, and the precision of robotic instrumentation in the confined pelvic space.^{3,11,14,19}

The clinical implications are substantial: reduced transfusion requirements lower immunological exposure and associated infectious risks; shorter hospitalization reduces hospital-acquired complication risk and resource consumption; and the lower bladder neck contracture rate (RARP 1.6% vs. ORP 8.3%) represents a meaningful difference in long-term urinary sequelae with significant quality-of-life implications. The significantly lower 30-day mortality reported by Pearce et al. (2016) (OR 0.28; $p < 0.01$) for RARP in a national cohort underscores the real-world safety advantage of the minimally invasive approach.^{10,19}

The singular perioperative disadvantage of RARP—significantly longer operative time (131 min mean difference in the Premier analysis by Leow et al.)—has clinical and economic implications, including higher anesthetic exposure duration and increased institutional procedural costs (\$4,528 higher direct hospital costs in the Leow et al. 2016 analysis). However, these cost differences attenuate substantially at high-volume centers.¹¹

Functional Outcomes: Reconciling Discordant Data

The apparent contradiction between the Nahas et al. (2024) RCT—showing significantly superior continence and potency recovery with RARP at all time points through 18 months—and the RACS RCT (Coughlin et al., 2018), which demonstrated no significant functional differences at 24 months, may reflect methodological and population differences. The Nahas et al. trial was conducted at a high-volume Brazilian tertiary center with extensive RARP experience, potentially optimizing the nerve-sparing technique and urethral reconstruction under robotic vision. In contrast, the RACS trial enrolled patients in an era of earlier RARP adoption at a single Australian center, with the early Nahas advantage in potency (23.9% vs. 5.3% at 3 months) being particularly striking and suggestive of improved neurovascular bundle preservation with robotic magnification.^{2,3}

The LAPPRO trial's consistent finding of a moderate RARP advantage for erectile dysfunction at both 12-month (OR 0.73) and 24-month (AOR 0.72) follow-up, in a large multicenter dataset of 4,003 patients, provides the most statistically robust functional outcome comparison available, and suggests that the RARP erectile function advantage is real but modest and may not persist beyond 24 months in all settings. The Herlemann et al. (2018) CaPSURE registry finding of a temporary ORP advantage in urinary incontinence during the first 12 months—

attributed by the authors to the learning curve effects among early community RARP adopters—is an important reminder that surgeon experience significantly modulates functional outcomes.^{4,6}

Learning Curve, Institutional Volume, and Quality Metrics

The critical role of the surgical learning curve in determining RARP outcomes cannot be overstated. Bravi et al. (2019 and 2023) demonstrated a significant, non-linear learning curve for PSM reduction, spanning approximately 200–500 procedures, with institutional volume similarly influencing outcomes (Chang et al., 2021: hospitals >100 cases/year vs. lower volumes showed significant PSM and BCR differences). Thompson et al. (2017) elegantly demonstrated that the BCR risk was initially higher for RARP than ORP by the same surgeon, improved after 191 RARP cases, and was 35% lower at final RARP plateau—powerfully illustrating the temporal dynamics of the learning curve.^{13,17,23}

These learning curve effects have profound policy implications: outcomes reported from early RARP adoption series likely underestimate the technique's true oncological potential and overestimate its functional morbidity. As the global urological surgical workforce becomes uniformly trained in robotic techniques, the comparative advantage of RARP over ORP may become more consistently demonstrable across institutional settings.

Future Research Priorities

The following research priorities are identified based on the synthesis of the current evidence: (1) Large-scale, long-term RCTs powered for PCSS and OS as primary endpoints with minimum 10-year follow-up; (2) Standardization of BCR definitions and reporting across comparative studies using the EAU/AUA consensus definition; (3) Formal examination of the interaction between surgeon experience and surgical approach on oncological outcomes; (4) Health economic analyses comparing the full lifetime cost-effectiveness of ORP vs. RARP incorporating reduced adjuvant treatment utilization; (5) Evaluation of RARP outcomes with newer robotic platforms (Versius®, Senhance®, Hugo RAS™) compared with the da Vinci legacy platform and ORP.

CONCLUSIONS AND RECOMMENDATIONS

Summary of Conclusions

This systematic review of 20 primary studies—including 3 RCTs and 17 observational cohort studies—enrolling >700,000 patients with clinically localized prostate carcinoma provides the following evidence-based conclusions: (1) RARP achieves PSM rates that are equivalent or superior to ORP, particularly in high-volume institutional settings and for intermediate/high-risk disease, though RCT evidence demonstrates non-significant PSM differences in matched expert-surgeon comparisons; (2) BCR rates are not significantly different between ORP and RARP in the majority of well-controlled studies at short- to medium-term follow-up, with surgical approach not serving as an independent predictor of BCR after accounting for pathological stage and tumor biology; (3) Emerging long-term (12-year) comparative data suggest significantly lower PCSS-mortality with RARP—a finding that requires prospective confirmatory validation; (4) RARP offers definitive, robustly established perioperative advantages over ORP, including 50–75% reductions in estimated blood loss, dramatic reductions in blood transfusion requirements, shorter hospitalization, and lower rates of major postoperative complications; (5) Early functional recovery of urinary continence and erectile function is superior with RARP, with equivalence of outcomes at 24 months in RCT data, and a modest but consistent RARP advantage for erectile function in the largest prospective cohort data.^{1,2,3,4,5,8,11,19}

Recommendations

Based on the totality of current evidence, the following practice recommendations are offered: (i) RARP should be considered the preferred surgical modality for localized PCa in centers with demonstrated high-volume robotic surgical expertise (>100 RARP cases/year per surgeon), where perioperative safety advantages are maximized and oncological outcomes are equivalent to or superior than ORP; (ii) ORP remains an evidence-based, clinically appropriate surgical alternative, particularly in settings where robotic technology is unavailable or where surgeon RARP experience is limited; (iii) Patients should be counseled that oncological outcomes depend more on tumor biology, pathological staging, and surgeon expertise than on the specific surgical platform utilized; (iv) Health systems considering RARP adoption should establish structured learning curve

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oversight programs to ensure patient safety during the transition phase; (v) Longitudinal, harmonized, population-based registries should be established to systematically capture comparative long-term oncological outcomes as RARP cohorts mature.

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