VILNIUS UNIVERSITY
MEDICAL FACULTY

The Final thesis

Advantages of Robot-Assisted Radical Prostatectomy. Literature Review

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2023

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Summary:

The objective of the study is to provide a systematic analysis of the advantages of robotic-assisted radical prostatectomy (RARP) versus laparoscopic radical prostatectomy (LRP) versus open radical prostatectomy (ORP). An independent systematic review of the literature was performed up to April 2023, using the PubMed database. Search strategies, selection criteria, and evidence reports were created in accordance with the recommendations of the Preferred Reporting Items for Systematic Review (PRISMA). Surgical, pathological, and functional outcomes, were reviewed. In the 14 studies, a total of 29472 patients were included in the review, 15067 (51%), 1713 (6%), and 12692 (43%) were RARP, LRP, and ORP, respectively. Across all studies, the RARP approach demonstrated significant advantages in the majority of outcomes. Robotic-assisted radical prostatectomy demonstrated advantages in surgical outcomes, including significantly lower estimated blood loss and reduced hospital stay compared to LRP and ORP. Functional outcomes favoured RARP, with higher rates of urinary continence and erectile function reported. Additionally, RARP showed favourable oncological outcomes, such as lower positive surgical margin rates and reduced risk of biochemical recurrence compared to other approaches. Recent evidence and technological advancements, such as fluorescence-guided surgery and 3D printing indicate, that RARP is an advantageous surgical option for the treatment of localized prostate cancer and is likely to continue to increase in popularity worldwide in the coming years. However, there is a need for further evaluation of long-term outcomes, and the higher cost associated with robotic surgery remains a notable concern in the context of prostate cancer treatment.

Keywords:

Radical Prostatectomy, Robot-assisted, Laparoscopic, Open

Introduction:

Prostate cancer is a highly prevalent malignancy in men, with an estimated 1.4 million cases diagnosed and 375 thousand deaths worldwide in 2020 alone. (1) The incidence of prostate cancer varies widely across the world and continues to rise globally, with the highest rates observed in North America, Europe, and Australia, and lower rates in Asia, Africa, and Latin America. (2)

While significant advances have been made in the diagnosis and treatment of prostate cancer in recent years, its exact causes and underlying mechanisms remain largely unknown. Several risk factors have been identified, including age, family history of prostate cancer, ethnicity, and certain genetic mutations: “Family history and ethnic background are associated with an increased prostate cancer incidence suggesting a genetic predisposition. Men of African descent have less favourable outcomes in the Western world due to a combination of biological, environmental, social, and health-care factors.”(2).

The disease is typically asymptomatic in its early stages, and symptoms may only appear when the cancer has grown and spread beyond the prostate gland. Consequently, there is an increasing emphasis on early detection and curative interventions for prostate cancer. The optimal therapeutic strategy for prostate cancer is determined by various factors, including the Gleason Grade Group, prostate-specific antigen (PSA) levels, and cancer stage. (3) Screening tests, including the PSA blood test and digital rectal examination (DRE), can help detect prostate cancer in its early stages. (2)

Treatment options for prostate cancer include surgery, radiation therapy, hormone therapy, and chemotherapy, and the choice of treatment depends on various factors such as the stage and aggressiveness of cancer, the patient's overall health, and their preferences. The primary objective of radical prostatectomy (RP), regardless of the approach used, is to remove cancer completely while attempting to preserve pelvic organ function whenever possible. The procedure involves removing the entire prostate gland, including the capsule and seminal vesicles, followed by the creation of a vesicourethral anastomosis. Over time, RP surgical techniques have progressed from traditional perineal and retropubic open procedures to minimally invasive laparoscopic and robotic-assisted methods. The anastomoses have also advanced from Vest approximation sutures to continuous suture waterproof anastomoses performed under direct visualization. Furthermore, precise mapping of the dorsal venous complex (DVC) and cavernous nerves has enabled superior visualization and the potential for the preservation of erectile function. (2)

The introduction of robot-assisted surgery and History of robot-assisted surgery:

In 1983, the world's first surgical robot, 'Arthrobot', was developed to assist with orthopaedic procedures. Two years later, in 1985, the PUMA 560 from Unimate in New Jersey was used for precise needle placement during computed tomography-guided brain biopsies. In 1988, the ROBODOC from Integrated Surgical Systems in Delaware was introduced for total hip arthroplasty, providing accurate preoperative planning and femur fitting for hip replacements. The PROBOT was used for transurethral surgery during clinical trials at Imperial College in London in the same year. In 1993, Computer Motion, Inc. released AESOP, a robotic arm used for laparoscopic camera holding and positioning. The CyberKnife was introduced in 1994 for stereotactic radiosurgery in neurosurgery. (4,5)

A significant milestone occurred in 1998 when two prominent robotic surgical systems were introduced: the ZEUS Robotic Surgical System developed by Computer Motion, Inc., and the da Vinci Surgical System created by Intuitive Surgical, Inc. headquartered in Sunnyvale, California. These systems featured a surgical control centre and robotic arms. In the same year, the first robot-assisted surgical procedure, specifically a heart bypass, using the da Vinci system, took place in Germany. (6) In 2000, the da Vinci robot was approved by the US Food and Drug Administration (FDA) for use in laparoscopic procedures. The first reported robot-assisted radical prostatectomy (RARP) was conducted in Paris, France, in the same year. (7) Intuitive Surgical, Inc. acquired Computer Motion, Inc. in 2003 and is now the leading company in the marketing of robotic surgical devices. Olympus and Samsung are also developing new robotic surgical systems, intending to create lower-cost and more compact machines.

"The introduction of robot-assisted surgery, especially the da Vinci Surgical System, is described as one of the biggest achievements in surgery since the introduction of anaesthesia and represents one of the most significant developments in minimally invasive surgery this decade."(2) Although initially utilized in orthopaedics, neurosurgery, and cardiac surgery, the system gained widespread popularity due to its successful use in urology, particularly in prostate surgery. Consequently, robotic-assisted surgery has become increasingly prevalent across various surgical disciplines, including general surgery, gynaecology, and head and neck surgery. (5)

The surgical approach for RARP involves several key steps. First, a pneumoperitoneum is created by introducing carbon dioxide gas into the abdominal cavity, providing a better working space in the abdominal cavity, and allowing the surgeon to access the prostate gland with greater precision. Then, several small incisions (approximately 8-12mm) are made in the abdomen to allow for the placement of the robotic arms and surgical instruments. Subsequently, the robotic system is placed over the patient's abdomen. The surgeon, who sits non-sterile at the console, which is connected to the robotic instruments, then meticulously separates the prostate gland from the adjacent tissues such as the bladder, urethra, and seminal vesicles. This precise dissection is facilitated by the use of high-definition cameras and advanced imaging technologies. Once the prostate gland is fully dissected, it is removed through one of the small incisions in the abdomen. The specimen is then sent to a pathologist for examination to confirm the presence of cancer and the extent of the disease. The final step in the RARP procedure, the reconstruction of the urinary tract, is critical in the procedure, as it ensures that the patient can resume normal urinary function following surgery. The surgeon reconnects the bladder and urethra using sutures, staples, or a combination of both. A small catheter is then inserted to drain urine from the bladder.

A literature review of current research on prostate cancer can provide valuable insights into the latest findings on its risk factors, diagnosis, treatment, and prognosis. This review aims to synthesize the most recent literature on the treatment method of robotic-assisted radical prostatectomy (RARP) and to provide a comprehensive overview of the current state of knowledge and advantages. By examining the latest research findings and identifying gaps in current knowledge, this review can contribute to a better understanding of the best treatment option for prostate cancer and inform future research directions in this important area of study.

LITERATURE SELECTION STRATEGY:

An independent systematic review of the literature was performed up to April 2023 using PubMed. Patient-related and intervention search terms were combined to build the following search string: "Robot-assisted-, Open, Laparoscopic Radical Prostatectomy" to find suitable studies, that were published between 2018 and 2023. The results were assessed and filtered. Preferred reporting items for systematic review, (PRISMA) recommendations were followed to design search strategies, selection criteria, and evidence reports. After a first screening based on title and abstract, full texts of potentially eligible studies were evaluated, and those meeting inclusion criteria were selected. The study eligibility was defined using PICOS (patient, intervention, comparator, outcome, study type) approach (Fig. 1). Inclusion criteria were the following: (P) studies focused on adults (> 18 years old) with a diagnosis of prostatic cancer; (I) undergoing robot-assisted radical prostatectomy; (C) in which laparoscopic radical prostatectomy or open radical prostatectomy was performed as a comparator; (O) evaluating one or more of the following outcomes: perioperative, oncological and functional outcomes; (S) in retrospective or prospective comparative studies.

Fig.1 PICOS (patient, intervention, comparator, outcome, study type)

Question Components	Components in your review
P – Patient or Population Describe the most important characteristics of the patient. (e.g., age, disease/condition, gender)	Prostatic Cancer
I – Intervention; Prognostic Factor; Exposure Describe the main intervention. (e.g., drug or other treatment, diagnostic/screening test)	Robot-assisted radical prostatectomy
C – Comparison (if appropriate) Describe the main alternative being considered. (e.g., placebo, standard therapy, no treatment, the gold standard)	1. Laparoscopic radical prostatectomy 2. Open radical prostatectomy
O – Outcomes Describe what you're trying to accomplish, measure, improve, affect. (e.g., reduced mortality or morbidity, improved memory, accurate and timely diagnosis)	Find advantages of robot-assisted radical prostatectomy
Your Research Question: **Robot-assisted,- Open-, Laparoscopic Radical Prostatectomy**	

Non-comparative studies, conference abstracts, editorials, reviews, case reports, letters to the editor, notes, book chapters, and non-English language articles were excluded. Possible missing articles were retrieved by the assessment of the reference of the article included and the previous review. When two studies used the same national database for overlapping periods, to avoid the danger of repeating data, only the most current or largest study published by the same authors or institutions was included. However, the smaller one could be used to analyse outcomes not reported by the former.

Description of included studies and quality assessment The PRISMA flow chart is shown in Supplementary Fig. 2. Our initial research identified 118 studies. Overall, after initial screening and full-text review, 14 studies were identified (Table 1). The study size reaches from a total of 231 (8) to 10.790 (9) patients and in the 14 studies reviewed, four different continents and 9 different countries are represented: Europe (Germany, Sweden, Norway), North America (USA), Asia (South-Korea, Japan, China) and Oceania with Australia.

Fig.2 PRISMA flow chart

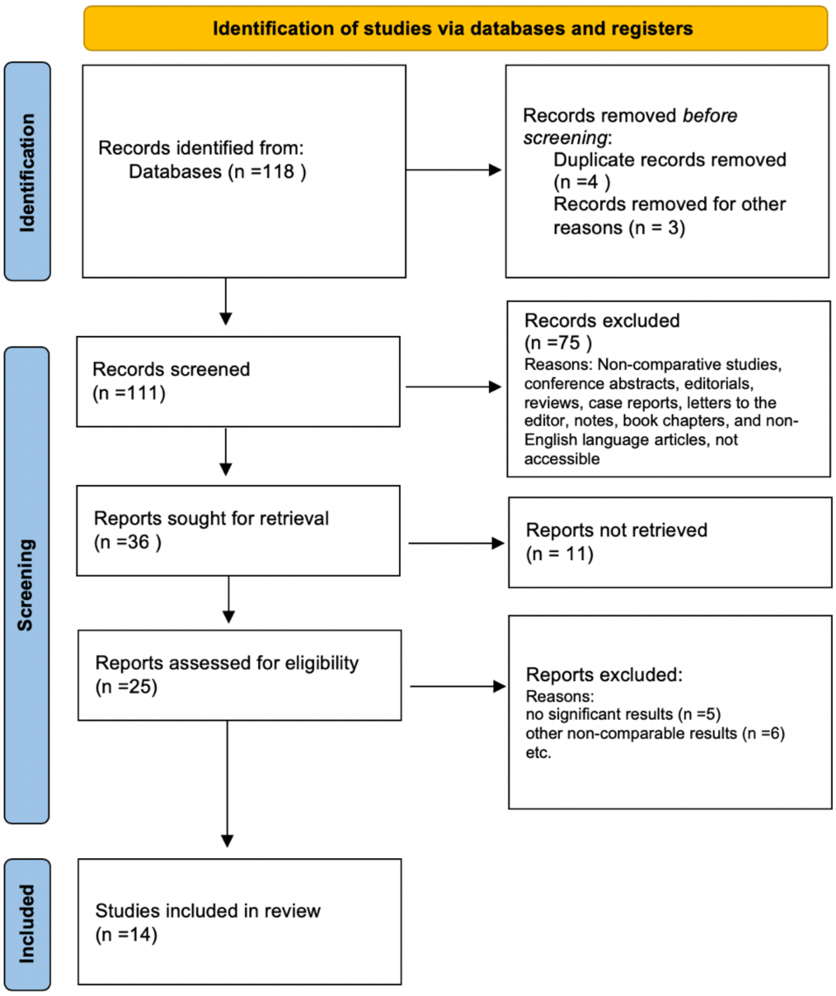

Table 1 lists the 14 studies, and the provided general information offers a comprehensive overview of each investigation. This table includes the reference and year published, the type of study, the number of patients with subcategories for each treatment method, the origin, the setting as well as the years the data was collected for each study.

Various aspects of RP surgery, including demographic and clinical characteristics of patients, surgical outcomes, pathological and oncological outcomes, and functional outcomes were investigated and compared in the selected studies. It is essential to evaluate these different aspects in the studies as they offer significant insights into the safety and effectiveness of the various RP surgical approaches.

Table 1 Overview of studies

REFERENCE, YEAR	TYPE OF STUDY	N CASES			STUDY ORIGIN	STUDY SETTING	YEARS DATA COLLECTED
		RARP	LRP	ORP			
Coughlin, 2018 (10)	randomised control study	163	N/A	163	Australia	Single-Center	23.08.2010-25.11.2014
Chang P, 2022 (11)	two prospective, longitudinal, multi-center cohorts	549	N/A	545	USA	Multicenter	2003-2006
Pompe RS, 2018 (12)	restrospective analysis	2159	N/A	2814	Germany	Single-Center	2013-2015
Sirisopana K, 2019 (13)	restrospective cohort	295	241	128	Thailand	Single-center	01.2008-07.2017
Huang W, 2019 (14)	restrospective analysis	179	71	97	China	Single-Center	01.2014-12.2016
Koizumi A, 2018 (15)	restrospective matched paired	187	136	127	Japan	Single-Center	04.2004-05.2016
Deng W, 2021 (8)		126	105	N/A	China	Single-Center	03.2015-03.2019
Lantz A, 2021 (16)	prospective controlled trial, 8year follow up	2699	N/A	885	Sweden	Multicenter	09.2008-11.2011
Nyberg M, 2018 (17)	prospective controlled trial	2251	0	791	Sweden	Multicenter	09.2008-2017
Yun JE, 2019 (18)	restrospective cohort	559	170	135	Korea	Multicenter	01.2010-12.2011
Haese A, 2019 (9)	comparative study	3783	N/A	7007	Germany	Single-Center	2008–2016
Stolzenburg, 2021 (19)	randomised, patient blinded control study	586	196	N/A	Germany	Multicenter	11.2014-04.2019
Okegawa, 2019 (20)	prospective non-randomized	450	250	N/A	Japan	Single-Center	01.04.2007-31.03.2018
Johnson, 2018 (21)	prospective non-randomized	1081	544	N/A	Norway	Single-Center	01.2003-12.2012

RARP robotic-assisted radical prostatectomy, LRP laparoscopic radical prostatectomy, ORP open radical prostatectomy

In **Table 2** the demographic and clinical characteristics of patients undergoing RP have been investigated. Most studies reported the overall mean age, body mass index (BMI), preoperative adenoma volume, TNM staging, preoperative PSA levels, and clinical Gleason score. In studies where the mean value for a specific outcome was not provided or was only given for each treatment group separately, a calculation was performed to determine the mean value. This calculation involved combining the mean values for each treatment group and dividing the result by the number of groups. The outcome of this calculation was then rounded to the appropriate number of decimal places, as specified by the study. This approach ensured that an accurate mean value was obtained for the outcome of interest, which could then be used to guide clinical decision-making and further research. Furthermore, some surgical outcomes, such as the duration of surgery (operative time), the volume of blood loss during surgery (estimated blood loss) and the length of hospital stay were evaluated across the different surgical approaches to RP and added to Table 2.

Table 2 Patients and tumor preoperative characteristics, Surgical Outcomes

REFERENCE, YEAR	AGE	BMI	PSA	PV (ml)	GLEASON (%)	cTNM (%)	Blood Loss (ml)			Operation Time (min)			Length of hospital stay (days)		
							RARP	*LRP*	*ORP*	*RARP*	*LRP*	*ORP*	*RARP*	*LRP*	*ORP*
Coughlin, 2018	35-70	N/A	N/A	N/A	N/A	N/A	N/A			N/A			N/A		
Chang P, 2022	63	<35 (94%)	4-10 - 716 (65%)	<30 - 266 (29%) 30-53 - 474 (52%) >53 - 164 (18%)	GS 6 - 533 (49) GS 7 - 486 (44) GS 8-10 - 75 (7)	T1 - 850 (78) T2 - 242 (22)	192	N/A	805	N/A			1,6	N/A	2,1
Pompe RS, 2018	64,7	26,2	7,7	37	GS 3+3 - 445 (9) GS = 3+4 - 2870 (58) GS = 4+3 - 1090 (22) GS = 8-10 - 546 (11)	T2 - 3041 (61) T3 - 1881 (38) T4 - 30 (1)	250	N/A	700	195	N/A	175	6	N/A	6
Sirisopana K, 2019	68	24,3	11,2	N/A	GS ≤6 - 241 (36) GS = 3+4 - 155 (23) GS = 4+3 - 112 (23) GS = 8 - 80 (12) GS = 9, 10 - 61 (9)	T1 - 565 (85) T3 - 78 (13) T4 - 1 (0,1)	300	500	1600	200	210	160	6	6	9
Huang W, 2019	63,8	23,8	19	32,5	GS ≤6 - 101 (30) GS 7 - 166 (48) GS ≥8 - 79 (23)	T1 - 41 (14) T2 - 298 (86)	76,4	122,7	273,3	181,6	187,9	166,7	N/A		
Koizumi A, 2018	67		6,9	N/A	*GS ≤6 - 146 (32)* *GS 7 - 223 (50)* *GS ≥7 - 81 (18)*	T1 - 316 (70) T2 - 125 (28) ≥T3 - 9 (2)	N/A			N/A			N/A		
Deng W, 2021	65,9	22,7	19,05	N/A	median 6-7	T1 - 117 (51) T2 - 114 (49)	124,2	157,3	N/A	139,4	159	N/A	14	15	N/A
Lantz A, 2021	64,00	24,00	N/A	N/A	ISUP 1 - 1815 (47) ISUP 2 - 1190 (30) ISUP 3 - 344 (9) ISUP ≥4 203 (5)	T1 - 2117 (59) T2 - 1256 (35) T3 - 106 (3)	N/A			N/A			N/A		
Nyberg M, 2018	63,10		Median (Q1;Q3) - 6,1 (4,5; 9,0)	N/A	GS ≤7 2742 (94) GS ≥7 176 (6)	T2 - 2125 (73) T3 - 759 (26) T4 - 13 (0.4)	N/A			N/A			N/A		
Yun JE, 2019	70,00	24,30	6,2	32,3	GS 6 - 414 (34) GS 7 - 290 (24) GS 8-9 - 160 (13)	Tx 34 (3) T1 - 266 (22) T2 - 426 (35) T3 - 138 (11)	250	300	700	199,5	242,5	120	7	6,5	6
Haese A, 2019	64	26	9,1 (5.1-10-1) quartile	N/A	GS 6 - 1468 (14) GS 3+4 - 7148 (66) GS 4+3 - 1722 (16) GS ≥8 - 433 (4)	T2 - 7842 (72) T3 - 2105 (20) T3b/T4 - 832 (8)	279	N/A	789	181	N/A	200	N/A		
Stolzenburg, 2021	65	27,1	7,8 (5.6, 11.55) quartile	N/A	GS 6 - 343 (46) GS 7 - 341 (46) GS 8 - 84 (11) GS 9 - 44 (6) GS 10 - 5 (0,7)	N/A	250	210	N/A	176	169	N/A	N/A		
Okegawa, 2019	67	24,1	7,9 (4-47,5) hig and low	N/A	GS 6 - 252 (36) GS 7 - 347 (50) GS 8-10 - 102 (14)	N/A	N/A			N/A			N/A		
Johnson, 2018	63	26	7,8 (0,6-67)	32	GS 6 - 746 (46) GS 7 - 705 (43) GS 8 - 137 (8) GS 9 - 21 (<)	T2 - 1022 (63) T3 - 570 (35) T4 - 3	N/A			135	213	N/A	2,9	3,2	N/A

RARP robotic-assisted radical prostatectomy, LRP laparoscopic radical prostatectomy, ORP open radical prostatectomy, BMI Body-Mass-Index, PSA prostatic specific antigen, PV prostate volume, GS Gleason score

The green values exhibit a statistically significant p-value (p<0.05), indicating a preference for them over the red values.

Tables 3.1 and 3.2 present a comprehensive comparison of functional outcomes observed in the studies reviewed, including urinary continence and recovery of erectile function (the ability to achieve an erection). The urinary continence (Table 3.1) was evaluated using one or more of the following measures: the patient's ability to control urine, the duration of catheterization, and the need for pads to manage urinary incontinence. The studies included in Table 3.2 reported outcomes related to erectile function using measures such as the International Index of Erectile Function (IIEF), sexual bother, or sexual function.

Table 3.1 Urinary Function

REFERENCE, YEAR	Urinary Function		
	RARP	***LRP***	***ORP***
Coughlin, 2018	Pad for incontinence (6/12/24 months) None 121 (84), 131 (90), 126 (91) One pad per day 18 (13), 14 (10), 9 (7) Two pads per day 3 (2), 0 (0), 3 (2) Three or more pads per day 1 (1), 1 (1), 0 (0)	N/A	Pad for incontinence (6/12/24 months) None 114 (85), 123 (91), 131 (90) One pad per day 17 (13), 10 (7), 7 (5) Two pads per day 3 (2), 1 (1), 0 (0) Three or more pads per day 0 (0), 0 (0), 0 (0)
Huang W, 2019	none - 43 (24.0) no pad usage after 1 week - 62 (34.6) no pad usage after 1 month - 107 (60.0) no pad usage after 3 months - 140 (78.2) no pad usage after 6 months - 163 (91.1) no pad usage after 1 year - 171 (95.5) 12-month urinary bother, n no bother - 47 (26.3) Very small bother - 45 (25.1) small bother - 59 (32.9) Moderate bother - 25 (14.0) severe bother - 3 (1.7)	none - 10 (14.1) no pad usage after 1 week - 16 (22.5) no pad usage after 1 month - 37 (52.1) no pad usage after 3 months - 53 (74.6) no pad usage after 6 months - 62 (87.3) no pad usage after 1 year - 66 (93.0) 12-month urinary bother, n no bother - 19 (26.8) Very small bother - 8 (11.3) small bother - 33 (46.5) Moderate bother - 7 (9.8) severe bother - 4 (5.6)	none - 24 (24.7) no pad usage after 1 week - 29 (29.9) no pad usage after 1 month - 44 (45.4) no pad usage after 3 months - 74 (76.3) no pad usage after 6 months - 89 (91.8) no pad usage after 1 year - 94 (96.9) 12-month urinary bother, n no bother - 25 (25.8) Very small bother - 20 (20.6) small bother - 36 (37.1) Moderate bother - 10 (10.3) severe bother - 6 (6.2)
Deng W, 2021	Continent on removal of catheter, n 61 (48.4) Continent at postoperative 3 months, n 82 (65.1) Continent at postoperative 12 months, n 114 (90.5) Continent at postoperative 24 months, n 114 (90.5)	Continent on removal of catheter, n 35 (33.3) Continent at postoperative 3 months, n 53 (50.5) Continent at postoperative 12 months, n 85 (81.0) Continent at postoperative 24 months, n 85 (81.0)	
Lantz A, 2021	Incontinence , n/N 577/2113 (27)	N/A	Incontinence , n/N 193/677 (29)
Yun JE, 2019	3months continence - 89,4% 6 months continence - 90,9% 12 months continence - 92,1% 24 months continence - 93,0% 36 months continence - 95%	3months continence - 80,6% 6 months continence - 84,1% 12 months continence - 86,5% 24 months continence - 87,6% 36 months continence - 89,2%	3months continence - 81,5% 6 months continence - 83% 12 months continence - 84,4% 24 months continence - 85,8% 36 months continence - 89,8%
Haese A, 2019	1week no pad- 21,8% one pad - 30,9% 3months continence - 78,4% 12 months continence - 88,8%	N/A	1week no pad- 25,8% one pad - 33,9% 3months continence - 77% 12months continence - 90,3%
Stolzenburg, 2021	**Pad for incontinence (3 months)** 0: 158 (54) Safety pad: 112 (21) 1: 99 (19) ≥2: 159 (30) **1. How often do you leak urine** Never 130 (25) About once per week or less often 88 (17) 2 or 3 times a week 55 (10) About once daily 47 (8-9) Several times a day 192 (36) All the time 15 (2.8) **2. How much urine do you leak** None 133 (25) Little 341 (65) Moderate 41 (7.8) Large 8 (1.5) **continence aid** (preop/3m) - 28 (5.3), 288 (52.7) continent after nerve spearing proc. - 66% continence after 3 months - 56%	**Pad for incontinence (3 months)** 0: 29 (46) Safety pad: 33 (20) 1: 42 (25) ≥2: 63 (38) **1. How often do you leak urine** Never 27 (16) About once per week or less often 23 (149) 2 or 3 times a week 22 (13) About once daily 15 (9,1) Several times a day 72 (44) All the time 6 (3.6) **2. How much urine do you leak** None 30 (18) Little 111 (67) Moderate 18 (118) Large 7 (4.2) **continence aid (preop/3m)** - 2 (1.2), 104 (60.8) continent after nerve spearing proc. - 50% continence after 3 months - 45%	N/A
Okegawa, 2019	12months - 90.3% continence	N/A	12months - 88% continence
Johnson, 2018	0: 158 (30) Safety pad: 112 (21) 1: 99 (19) ≥2: 159 (30)	0: 29 (17) Safety pad: 33 (20) 1: 42 (25) ≥2: 63 (38)	N/A

RARP robotic-assisted radical prostatectomy, LRP laparoscopic radical prostatectomy, ORP open radical prostatectomy

The green values exhibit a statistically significant p-value ($p<0.05$), indicating a preference for them over the red values.

Table 3.2 Erectile Function

REFERENCE, YEAR	Erectile Function		
	RALP	*LRP*	*ORP*
Coughlin, 2018	IIEF-6monts - 29,78 IIEF-12monts - 33,5 IIEF-24monts - 33,89 Erections firm enough for intercourse* (6/12/24months) No sexual activity or almost never 85 (59), 69 (47), 63 (46) Less than half the time or about half the time 24 (17), 23 (16), 18 (13) More than half the time or almost always 32 (22), 51 (35), 53 (38)	N/A	IIEF-6monts - 29,75 IIEF-12monts - 33,1 IIEF-24monts - 33,95 Erections firm enough for intercourse* (6/12/24months) No sexual activity or almost never 76 (57), 69 (51), 58 (44) Less than half the time or about half the time 28 (21), 25 (19), 25 (19) More than half the time or almost always 29 (22), 40 (30), 47 (36)
Huang W, 2019	12-month sexual bother, n no bother - 15 (8.4) Very small bother - 16 (8.9) small bother - 24 (13.4) Moderate bother - 37 (20.7) severe bother - 87 (48.6) no spontaneous morning erection, n 126 (70.4)	12-month sexual bother, n no bother - 12 (16.9) Very small bother - 6 (8.5) small bother - 6 (8.5) Moderate bother - 18 (25.4) severe bother - 29 (40.7) no spontaneous morning erection, n 52 (73.2)	12-month sexual bother, n no bother - 19 (19.6) Very small bother - 6 (6.2) small bother - 8 (8.2) Moderate bother - 21 (21.6) severe bother - 43 (44.4) no spontaneous morning erection, n 74 (76.3)
Deng W, 2021	IIEF-5 postop. 6 mths., median (IQR) 15 (10–18) IIEF-5 postop. 12 mths., median (IQR) 16 (10–190) IIEF-5 postop. 24 mths., median (IQR) 15 (9–18) Full potency recovery postop. 24 mths, n (%) 53 (42.1%)	IIEF-5 postop. 6 mths., median (IQR) 15 (9–17) IIEF-5 postop. 12 mths., median (IQR) 14 (9–18) IIEF-5 postop. 24 mths., median (IQR) 13 (9–16) Full potency recovery postop. 24 mths, n (%) 30 (28.6%)	
Lantz A, 2021	Erectile dysfunction , n/N 1195/1811 (66)	N/A	Erectile dysfunction , n/N 397/569 (70)
Nyberg M, 2018	Erectile dysfunction - 68%	N/A	Erectile dysfunction - 74%
Haese A, 2019	IIEF-5score -12months -53,4% Erection sufficient for intercourse - 83,6%	N/A	IIEF-5score -12months - 48,5% Erection sufficient for intercourse - 83%
Stolzenburg, 2021	Sexual activity (preop/3m) - 49 (46.7–51.4), 65.0 (62.6–67.4) Sexual function (preop/3m) - 66 (64.4–67.7), 49.1 (47.1–51.1) potency revovery - 18% IIEF sum (preop/3m) - 14.4 (13.8–15.0), 4.7 (4.1–5.3) Residual erectile function (preop/3m) - 3.4 (3.3–3.4), 2 (1.9–2.1)	Sexual activity (preop/3m) - 48.8 (44.6–53.1) 64.8 (60.6–69.1) Sexual function (preop/3m) - 67 (64–69.9), 46.9 (43.2–50.7) potency revovery - 6,7% IEF sum (preop/3m) -15.0 (14.0–16.0), 3.8 (2.8–4.9) Residual erectile function (preop/3m) - 3.5 (3.3–3.6), 1.8 (1.6–2.0)	N/A

RARP robotic-assisted radical prostatectomy, LRP laparoscopic radical prostatectomy, ORP open radical prostatectomy, IIEF International Index of Erectile Function

The green values exhibit a statistically significant p-value ($p<0.05$), indicating a preference for them over the red values.

Table 4 provides a comparative analysis of the Pathological and oncological outcomes observed in the different studies reviewed. These outcomes include the presence of cancer cells at the edge of the tissue removed during surgery (Positive surgical margin or PSM), the rate of biochemical recurrence (BCR), which is an increase in PSA levels indicating

possible cancer recurrence and overall mortality. The outcomes for Cancer-Specific Survival were not assessed, as no data was found in the chosen studies.

By examining these various aspects, clinicians and researchers can gain a more comprehensive understanding of the functional outcomes associated with each surgical approach to RP. The reporting of these outcomes in a structured table format provides a useful overview for clinicians and researchers to compare the effectiveness and safety of the different RP surgical approaches. In the following stage, the results will be analysed and compared to gain a better understanding of the impact of the different surgical approaches on patient outcomes in prostate cancer surgery. By examining these factors across multiple studies, trends and patterns can be identified that can inform treatment decisions and improve patient care. Overall, a comprehensive evaluation of these factors is crucial in understanding the long-term effectiveness of the different surgical approaches in managing prostate cancer.

Due to the abundance of previously published reviews on the topic, a comprehensive comparison of complications using the Clavien-Dindo score was not conducted in this study.

Table 4 Oncological Outcomes

REFERENCE, YEAR	PSM (%)			BCR (%)			Overall Mortality (%)		
	RARP	*LRP*	*ORP*	*RARP*	*LRP*	*ORP*	*RARP*	*LRP*	*ORP*
Coughlin, 2018	N/A			4 (3)	N/A	13 (9)	N/A		
Chang P, 2022	Overall - 109 (20) pT2 - 53 (13) pT3 - 56 (43)	N/A	Overall - 83 (16) pT2 - 47 (11) pT3 - 36 (36)	N/A			N/A		
Pompe RS, 2018	RX - 4029 (81) R0 - 869 (17 ,5) R1 - 72 (1 ,4)			N/A			N/A		
Sirisopana K, 2019	Overall - 110 (37) pT2 - 36 pT3 - 74 pT4 - 0	Overall - 91 (37) pT2 - 34 pT3 - 56 pT4 - 1	Overall - 38 (29) pT2 - 17 pT3 - 21 pT4 - 0	N/A			N/A		
Huang W, 2019	Overall - 54 (30,2)	Overall - 23 (32 ,4)	Overall - 25 (25 ,8)	N/A			N/A		
Koizumi A, 2018	Overall - 13,4	Overall - 18,4	Overall - 27 ,6	N/A			N/A		
Deng W, 2021	Overall - 18 (14 ,3) pT2 - 10 (10 ,8) pT3 - 8 (24 ,2)	Overall - 21 (20 ,0) pT2 - 15 (17 ,6) pT3 - 6 (30 ,0)	N/A	N/A			N/A		
Lantz A, 2021	564 (21)	N/A	181 (21)	452/1706 (27) High risk group- 51%	N/A	169/558 (30) High risk group- 69%	Overall 155/2699 (5.7) Low Risk 36/783 (4.6) Intermediate Risk 93/1669 (5.5) High Risk 26/220 (12)	N/A	Overall 73/885 (8.2) Low Risk 15/254 (5.9) Intermediate Risk 39/525 (7.5) High Risk 16/77 (21)
Nyberg M, 2018	N/A			218/1538 (14)		98/631 (16)	N/A		
Yun JE, 2019	Overall - 160 (29) pT2 - 73 (13 ,1) pT3 - 87 (15 ,6)	Overall - 35 (20) pT2 - 17 pT3 - 18	Overall - 47 (35) pT2 - 24 pT3 - 23	12mths - 90 (16 ,1) 24mths - 107 (19 ,1) 36mths - 117 (20 ,9)	12mths - 31 (18 ,2) 24mths - 34 (20) 36mths - 34 (20)	12mths - 29 (21 ,5) 24mths - 30 (22 ,2) 36mths - 31 (23 ,0)	<90 days - 0 <12 months - 1 <24 months - 3	<90 days - 0 <12 months - 0 <24 months - 0	<90 days - 0 <12 months - 0 <24 months - 0
Haese A, 2019	Total 451 (11 ,9) pT2 - 215 (7 ,8) pT3 - 124 (17 ,0) pT4 - 112 (39 ,3)	N/A	Total 825 (12) pT2 - 366 (7 ,2) pT3 - 252 (18 ,3) pT4 - 206 (37 ,3)	24mths - 53 (1,4) 48mths - 97 (2,6) 72mths - 112 (3) 96mths - 115 (3)	N/A	24mths - 163 (2,3) 48mths - 252 (3,6) 72mths - 283 (4) 96mths - 286 (4)	N/A		
Stolzenburg, 2021	RX - 2 (0,4) R0 - 426 (80) R1 - 101 (19)	RX - 0 R0 - 162 (86) R1 - 26 (14)	N/A	N/A			N/A		
Okegawa, 2019	Total 93 (20 ,7) pT2 - 36 pT3 - 74 pT4 - 0	Total 78 (31 ,2) pT2 - 39 pT3 - 53 pT4 - 1	N/A	46 (10,2)	53 (21,2)	N/A	N/A		
Johnson, 2018	Overall - 243 (22,4) pT2 - 65 (10 ,7) pT3 - 178 (40 ,3)	Overall - 150 (28) pT2 - 84 (20,3) pT3 - 66 (51,6)	N/A	N/A			N/A		

RARP robotic-assisted radical prostatectomy, LRP laparoscopic radical prostatectomy, ORP open radical prostatectomy

The green values exhibit a statistically significant p-value (p<0.05), indicating a preference for them over the red values.

RESULTS:

Demographics and clinical characteristics

Among the 29472 patients included in the meta-analysis, 15067 (51%), 1713 (6%) and 12692 (43%) were RARP, LRP and ORP, respectively. The participants had a mean age ranging from 63 to 70 years, with an average BMI of 22.7 reported in the study by Deng et al. (8) and an average BMI of 27 reported in the study by Stolzenburg et al. (19). The average PSA levels ranged from 6.2ng/ml Yun et. al (18) to 19 ng/ml in the study by Huang et. al. (14). The cT stage, Gleason score, and prostate volume for each study can be found in Table 2.

Surgical outcomes

The main intraoperative outcomes are illustrated in Table 2.

Estimated blood loss (EBL) was different across the three groups with a total average of 215,2 ml, 258 ml and 812,2 ml for RARP, LRP and ORP. Significantly lower EBL was observed in patients who underwent RARP compared to ORP and LRP groups. The EBL values in the study by Sirisipona et al. (13) were reported as 1,600 ml, 500 ml, and 300 ml for ORPs, LRPs, and RARPs, respectively. The statistical analysis showed a significant difference, with a p-value of less than 0.001 for RARPs compared to LRPs and a p-value of less than 0.001 for LRPs compared to ORPs. In line with the aforementioned findings, the study carried out by Deng et al. (8) demonstrated a statistically significant difference in estimated blood loss between the RARP and LRP groups. Specifically, the results indicated that the RARP group had a substantially lower estimated blood loss compared to the LRP group, with values of 124.2 ml and 157.3 ml, respectively (p = 0.003). In addition, Yun et al. (18) showed significantly less blood loss for RARP too, with a median of 250 ml vs. 300 ml or 700 ml for the LRP and RRP groups and a P value of under 0.0001. The lowest amount of blood loss was observed in the RARP approach, as reported by Huang et al. (14) with a value of 76.4 ml. Overall, most studies, with the exception of the Stolzenburg et al. study, found that RARP had the lowest blood loss values, followed by LRP, while ORP had more than three times higher blood loss values.

Statistical differences in terms of **operative time (OT)** were found in eight studies favouring ORP over RARP and RARP over LRP. The study by Yun et. Al. yielded a significantly reduced mean operative time for ORP compared to the RARP and LRP groups, with values of 120 min versus 199,5 min versus 242,5 min (p = 0.0001). LRP had the highest average time with 196,9 min followed by RARP with 175,9 min and the lowest average time was seen in ORP with 164,3 min. Again, the highest value for RARP was found in the study conducted by Sirisopana et al. with 200 min and or LRP in the study by Yun et al. with 242,5 min.

Regarding the **length of hospital stay** post-surgery, no significant difference was found in the postoperative length of hospital stay. On average the time of hospital stay was 4,7 days for RARP and 5,2, 5,7 for LRP and ORP. The shortest hospital stay was reported in the US study conducted by Chang et al. (11), which was 1.6 days for the RARP group. The results of the study by Deng et al. regarding the length of hospital stay were excluded, as they differed a lot from all other studies.

Cheng et al. also found a significance in terms of patient satisfaction regarding the appearance of the surgical incision (95% for RARP vs 89% for ORP; p <0.001).

Functional outcomes

The RARP group reported better functional outcomes (urinary continence and erectile function compared) to LRP and ORP as seen in Table 4.

Huang et al. (14) reported that one year after surgery, 15.9% of men experienced moderate to severe urinary incontinence, with similar rates observed across the ORP, LRP, and RARP groups (16.5%, 15.4%, and 15.7% respectively). Notably, only 4.6% of men reported the use of pads. Furthermore, the results of Deng et al. (8) showed that RARP had higher continence rates following catheter removal (48.4% vs. 33.3%, p = 0.021), as well as at 3 months (65.1%

vs. 50.5%, p = 0.025), and 24 months (90.5% vs. 81.0%, p = 0.037). The study by Haese et al. (9) also noted modestly higher continence rates in the RARP group at 12 months (90.3% vs. 88.8%, P = 0.01), however, the 1-week continence rates were higher in the ORP group (25.8% vs 21.8%, p < 0.001).

In terms of **erectile function**, Huang et al. revealed that 67.7% of men reported moderate to severe erectile dysfunction one year after surgery, with similar rates observed among the ORP, LRP, and RARP groups (66%, 66.1%, and 69.3% respectively). Interestingly, 16.1% of men with a grade 3-4 erection hardness score were hesitant to engage in sexual activity postoperatively. Moreover, Deng et al. showed significantly higher median erectile function scores at 6 and 24 months post-operation in the RARP group compared to the LRP group (15 vs. 15, p = 0.042, and 15 vs. 13, p = 0.026, respectively). Additionally, Nyberg et al. (17) demonstrated a significant difference favouring robot-assisted laparoscopic prostatectomy at 24 months, with lower rates of erectile dysfunction compared to other approaches (68% vs. 74%; AOR 0.72, 95% confidence interval [CI] 0.57–0.91; p= 0.006). Similarly, the study by Lantz et al. (16) showed significantly lower rates of erectile dysfunction in the RARP group compared to other approaches (66% vs. 70%; aRR 0.93, 95% CI 0.87–0.99).

Oncological outcomes

The **positive surgical margin** rates among the different surgical approaches were compared by calculating the total overall average. The results showed that the lowest PSM rate was observed in patients who underwent RARP, with a rate of 21.7%, followed by ORP at 23.8% and LRP at 25.1%. The study conducted by Haese et al. (9) reported the lowest PSM rates for RARP and ORP, with values of 11.9% and 12%, respectively, and Koizumi et al. (15) was the lowest for LRP with 18.4%. On the other hand, the highest PSM rates were reported in the studies conducted by Sirisipona et al. (13), with rates of 37% for both RARP and LRP and in the study conducted by Yun et al. (18), with a rate of 35% for the open approach. Koizumi et al. (15) found that the PSM rates for open radical prostatectomy, laparoscopic radical prostatectomy, and robot-assisted radical prostatectomy were 27.6%, 18.4%, and 13.4%, respectively. The propensity score-matched analysis showed that the PSM rate for robot-assisted radical prostatectomy was significantly lower than that for open radical prostatectomy, but there was no significant difference between robot-assisted radical prostatectomy and laparoscopic radical prostatectomy. The authors also revealed that in the groups undergoing open radical prostatectomy and laparoscopic radical prostatectomy, positive surgical margins were most frequently found at the apex, whereas in the group undergoing robot-assisted radical prostatectomy, the bladder neck was most frequently found. (15)

According to the Johnson et al. (21) study, the positive surgical margin rate for pT2 tumours was significantly higher in patients who underwent LRP compared to those who underwent RARP, with rates of 20.3% and 10.6%, respectively ($p < .001$). In Okegawa et al. (20), the PSM rate was significantly lower for RARP in men with pT2c, pT3a, or pT3b disease ($p = 0.006$, $p = 0.009$, and $p = 0.027$, respectively).

Regarding the **biochemical recurrence**, most studies did not show a significant difference, however, in the study conducted by Coughlin et al. (10), a superiority test showed that the two proportions regarding Biochemical Recurrence (3% in RARP vs 9% in ORP) were significantly different (p=0,0199) and the study by Lantz et al. (16) showed a significantly lower BCR (51% vs 69%; adjusted RR 0.80, 95% CI 0.62–1.03) in the D'Amico high-risk group for RARP vs ORP. Furthermore, in the study by Okegawa et al. (20), the multivariate analysis demonstrated that RARP was associated with a reduced risk of biochemical recurrence compared to other surgical approaches. The hazard ratio was 0.8, indicating a lower risk of BCR, and the statistical significance was determined to be $p = 0.014$.

Additionally, the study by Lantz et al. reported that, Prostate cancer–specific mortality (PCSM) was significantly lower in the RARP group at 8 yr. after surgery (40/2699 vs 25/885; aRR 0.56, 95% CI 0.34–0.93) (16).

DISCUSSION:

As Radical Prostatectomy can nowadays be performed by an open-, laparoscopic- and robotic-assisted approach, it is important to point out the advantages of RARP.

Starting with the incision size, the open approach requires a large incision in the lower abdomen or perineum (45-90mm), while the laparoscopic and robotic approaches require smaller incisions. RARP requires the smallest incisions, typically 8-12 mm in size. Smaller wounds have better wound healing and are not so prone to be infected. Therefore the patients who underwent the RARP and LRP have shorter hospital stays in comparison to the patients who were operated on following the open approach. (2,22)

Regarding **Visualization**, the open approach provides direct visualization of the surgical field, while the laparoscopic and robotic approaches use a camera and high-definition monitor for visualization. RARP provides a 3D view of the surgical field for the surgeon operating at the console, which enhances visualization and spatial awareness for the surgeon. In addition, robotic systems like da Vinci offer an enhanced depth perception due to the stereoscopic view, which may be more difficult to achieve with laparoscopy alone. However, the use of 3D visualization technology in laparoscopic surgeries has been shown to improve depth perception and spatial awareness, potentially providing similar benefits to RARP. (22)

In terms of **instrument dexterity**, the open approach uses handheld surgical instruments, while the laparoscopic and robotic approaches use long, thin instruments that are inserted through the incision sites. RARP allows for enhanced dexterity and precision of instrument movements due to the ability of the robotic system to rotate a full 360 degrees using seven degrees of freedom. This allows the surgeon to complete more challenging and technically demanding techniques during the procedure. (25,26) This enables surgeons to perform more complex manoeuvres and operate in previously inaccessible areas of the body with greater accuracy and precision, resulting in better outcomes for patients. The instruments connected to the robotic arm can be left in one position without a single movement, eliminating physiological tremors, and allowing them to hold onto a certain tissue for a longer period.

Another benefit is the diminished extent of **estimated blood loss.** In general, the majority of studies, excluding Stolzenburg et al., indicated that RARP exhibited the lowest blood loss values, followed by LRP, while ORP displayed blood loss values over three times higher. As previously mentioned, RARP has been demonstrated to have the lowest amount of blood loss among the three approaches, with an average of 210.2 ml. Conversely, the open approach tends to involve the highest volume of blood loss, averaging 833.5 ml. These findings can be attributed to the surgeon's ability to use the robot to control bleeding more effectively and the procedure's minimally invasive nature

Concerning the duration of the surgery, the open approach exhibited the shortest average **operative time** of 167.2 minutes, which was approximately 4 minutes shorter than the robot-assisted approach. Notably, RARP has demonstrated the **shortest hospital stay**, with an average of 4.7 days (1 day longer than ORP) compared to the other two approaches. The open approach generally entails a lengthier recovery period, due to the more invasive nature of the technique, whereas the laparoscopic and robotic approaches typically facilitate faster recovery times.

In general, the results indicate that RARP provides better surgical outcomes in terms of estimated blood loss (EBL), hospital stay, and operation time compared to LRP and ORP. The reduced EBL in the RARP group suggests improved control over bleeding during the procedure, leading to potentially faster recovery and reduced complications. Moreover, the shorter hospital stay associated with RARP reflects efficient postoperative management and a smoother recovery process. Additionally, the shorter operation time of RARP demonstrates the enhanced surgical precision and efficiency offered by the robotic system.

Urinary continence is a crucial aspect of postoperative quality of life for patients undergoing prostatectomy. Huang's study revealed that one year after surgery, moderate to severe urinary incontinence was reported by 15.9% of men, with similar rates observed across the ORP, LRP, and RARP groups. However, it is important to note that the overall incidence of incontinence was relatively low, with only 4.6% of men reporting the use of pads. Th study by Deng et al. (8) demonstrated that RARP outperformed LRP in terms of continence rates. The RARP group exhibited higher proportions of continence upon catheter removal, as well as at 3 and 24 months post-operation. Similarly, Haese et al. (9) reported modestly higher continence rates in the RARP group at 12 months compared to other approaches. However, the initial 1-week continence rates favoured the ORP group. These findings suggest that RARP has a positive impact on urinary continence recovery, with better outcomes observed in the long term.

Erectile function is another important aspect of post-prostatectomy outcomes. Huang et al. (14) indicated that a significant proportion of men experienced moderate to severe erectile dysfunction one year after surgery, with similar rates observed across the ORP, LRP, and RARP groups. Notably, a considerable number of men with a grade 3-4 erection hardness score were hesitant to engage in sexual activity postoperatively. Deng's et al. study provided evidence of superior erectile function outcomes in the RARP group compared to the LRP group. The RARP group demonstrated significantly higher median erectile function scores at 6 and 24 months post-operation. The studies by Nyberg et al. and Lantz et al. also supported the advantages of RARP, showing lower rates of erectile dysfunction in the RARP group compared to other approaches.

Overall, the findings suggest that RARP offers favourable outcomes in terms of urinary continence and erectile function compared to LRP and ORP. The improved continence rates observed in the RARP group indicate better control over postoperative urinary incontinence, contributing to enhanced quality of life. Similarly, the superior erectile function outcomes associated with RARP highlight its potential in preserving sexual function following prostatectomy. These advantages can be attributed to the enhanced surgical precision and dexterity afforded by the robotic system.

Oncological outcomes play a crucial role in evaluating the effectiveness of different surgical approaches for prostate cancer treatment. The analysis of **positive surgical margin** rates across the studies reviewed indicates that RARP offers advantages over ORP and LRP. Overall, RARP consistently demonstrated the lowest PSM rates, with an average overall PSM value of 21,7% vs 23,8% and 25,1% in ORP and LRP. This suggests that RARP allows for better preservation of the surgical margins, which is important in reducing the risk of disease recurrence. The propensity score-matched analysis of the study conducted by Koizumi further supports the advantage of RARP over ORP in terms of PSM rates. The values across the robot-assisted approach varied from 11,9% in Haese et al. to 37% in the study by Sirisipona et al. (9,13). These findings highlight the importance of surgical technique and surgeon expertise in achieving optimal oncological outcomes. Additionally, Koizumi et al. (15) indicated different locations of positive surgical margins among the approaches, with the apex being more common in ORP and LRP, while the bladder neck was predominant in RARP. These findings suggest that RARP allows for precise dissection and improved visualization of critical anatomical structures, leading to better margin control.

When considering **biochemical recurrence**, most studies did not show a significant difference among the approaches. However, the studies by Coughlin et al. and Lantz et al. indicated favourable outcomes for RARP. Coughlin et al. found significantly lower BCR rates in the RARP group compared to ORP, and Lantz reported lower BCR rates for RARP in the D'Amico high-risk group. These findings suggest that RARP may have a potential advantage in reducing the risk of disease recurrence. (10,16)

In terms of **prostate cancer-specific mortality** (PCSM), the study by Lantz et al. showed a significant reduction in PCSM in the RARP group compared to other approaches. This indicates that RARP may offer improved long-term survival outcomes for prostate cancer patients. The absence of PCSM values in the other studies limits the scope of the literature review and hinders a comprehensive comparative analysis. Without PCSM data, it is challenging to draw meaningful conclusions or make informed assessments regarding the impact of prostate cancer on mortality rates. Including PCSM values in future research would enable a more thorough understanding of the relationship between prostate cancer and mortality outcomes.

Overall, the results of these studies support the advantages of RARP over ORP and LRP in terms of oncological outcomes. RARP consistently demonstrated lower PSM rates, potentially leading to reduced disease recurrence. Additionally, RARP showed promising results in terms of BCR and PCSM rates. Another study by Bravi et al. (24) reported the impact of experience on the risk of PSM and BCR. The authors found, that more experienced surgeons have a lower risk of positive margins, while the probability of recurrence after robotic prostatectomy is not affected by experience. (24)

Although the results reviewed did not cover the overall and major **complication rate**, the study by Johnson et al. (21) examined the outcomes of 1081 patients who underwent RARP and 544 patients who underwent LRP and presented valuable data in this regard. The study revealed comparable overall postoperative complications between the two approaches, but significantly higher rates of major complications in patients who underwent LRP. The authors noted that while both laparoscopic and robotic approaches are minimally invasive, the robotic platform provides certain technical advantages that can potentially enhance safety by reducing invasiveness and minimizing the risk of organ injuries. (24) Additionally, Wu et al. (25) showed, that undergoing RARP was associated with fewer acute and chronic postoperative complications than undergoing ORP or LRP. The open approach has been associated with higher complication rates, such as wound infections and blood clots, while the laparoscopic and robotic approaches have lower complication rates.

Even though the literature did not include a comprehensive comparison of the overall hospitalization cost among the three surgical techniques, additional information can show the advantages or disadvantages of RARP. However, when considering the cost aspect, it is crucial to acknowledge the inherent limitations and heterogeneity of the available data on cost-reporting systems. A study by Bolenz et al. (26) conducted in 2009 in a US centre examined the direct and component costs associated with RARP, LRP, and open RP. According to their research, the median direct cost for RALP was higher ($6752 vs. $5687 vs. $4437, respectively) than it was for laparoscopic and open RP. Specifically, supply and operating room costs were identified as the most expensive components in robotic surgery. (26) More recently, the study by Deng et al. compared the hospitalization cost, where RARP again showed a higher average cost of $6,950 compared to $4,533 in LRP and a p-value of under 0.001. (8) Yun et al. compared the total costs in Korean centres and showed that RARP is associated with higher operative and total hospital charges, which include not only the surgical procedure itself but also the expenses related to purchasing and maintaining the robotic system. These findings indicate that the utilization of robotic technology in RARP contributes to increased costs compared to other surgical techniques. (18) In addition to that, once surgeons have overcome the learning curve and achieved improved functional and oncological outcomes, the robotic operative charges for RARP have shown a significant decrease. This suggests that the initial higher costs associated with the robotic system can be offset by the long-term benefits in terms of surgical outcomes. (26)

The integration of image-guided surgery and robotics has opened up new possibilities for intraoperative imaging technologies, including augmented reality, fluorescence imaging, optical coherence tomography, confocal laser endomicroscopy, and 3D printing. (27) **Fluorescence-guided surgery** (FGS) is one notable advancement in robot-assisted radical prostatectomy (RARP) that has improved the visualization of the prostate gland during surgery. FGS involves the use of a fluorescent dye that selectively accumulates in the prostate tissue, allowing the surgeon to identify the prostate gland and visualize its boundaries more clearly These technologies hold promise in enhancing surgical precision and visualization. However, despite their potential, there are still challenges that need to be addressed, such as managing tissue deformation and accurately tracking prostate movements. Furthermore, the widespread adoption of these advanced technologies is hindered by the limited scientific evidence available in the literature.

Another technological advancement in RARP is the utilization of **three-dimensional (3D) printing** to create patient-specific models of the prostate gland. These models can be used for surgical planning and simulation of the procedure.

Another benefit is, that the incorporation of robotic technology in RARP has enabled the development of new surgical techniques that were not feasible with traditional open surgery. Nerve-sparing surgery is one such technique that aims to preserve the nerves responsible for erectile function and urinary continence. Future research will also focus on the use of advanced imaging techniques, such as multiparametric magnetic resonance imaging (MpMRI), to better identify patients who are suitable candidates for nerve-sparing surgery. MpMRI can provide detailed images of the prostate gland and surrounding structures, allowing surgeons to more precisely determine the location of cancer as well as the proximity of nerves responsible for erectile function and urinary continence. (2)

As the use of RARP continues to increase, several areas of future research could further improve the technique and its outcomes. One such area is the use of artificial intelligence (AI) to aid in surgical planning and decision-making. AI algorithms could analyse patient-specific imaging and clinical data to predict the optimal surgical approach and improve the accuracy of surgical planning. To further validate the efficacy and benefits of these advanced technologies, it is crucial for urologic surgeons to actively improve and evaluate them in clinical settings, preferably through well-designed comparative and randomized trials.

In summary, RARP offers several advantages over open and laparoscopic approaches, including smaller incisions, enhanced visualization, improved instrument dexterity, less blood loss, shorter hospital stay, faster recovery time, and lower complication rates. These advantages are due to the use of the robotic system, which provides greater precision, control, and visualization for the surgeon during the procedure. It is worth noting that advances in technology and techniques have made laparoscopic procedures more comparable to robotic procedures in terms of outcomes and patient benefits. However, it's important to consider that individual patient characteristics and surgeon expertise also play a significant role in determining outcomes. Further research and long-term follow-up studies are warranted to gain a comprehensive understanding of the advantages and limitations of RARP compared to other approaches in the management of prostate cancer.

CONCLUSIONS AND SUGGESTIONS:

This review of the literature highlighted several advantages of robot-assisted over the laparoscopic and open approach. First, RARP allows the surgeon to perform the procedure with greater precision, as the robot provides a 3D view of the operative field, as well as enhanced dexterity and control. This leads to a lower risk of nerve damage and better preservation of sexual function. Additionally, RARP is associated with reduced blood loss compared to open surgery, which can be attributed to the surgeon’s ability to use the robot to control bleeding more effectively and the procedure's minimally invasive nature. Due to the smaller incision size and the less invasive approach, patients undergoing RARP can also benefit from less pain and faster recovery time and therefore have a shorter hospital stay and quicker return to normal activities, including work and exercise, compared to those who undergo open surgery. Also, overall happiness has increased following the RARP procedure, as the smaller incisions result in improved cosmetic outcomes. RARP is also associated with improved cancer control compared to open surgery, as the robotic-assisted precise removal of the entire prostate gland and any involved lymph nodes leads to better oncologic outcomes. Finally, RARP is associated with a lower risk of infection due to the procedure's minimally invasive nature. Altogether, RARP has evolved into a globally used technique, but it has not yet reached the true "robotic surgery" stage where machines have the intelligence to perform operations independently. The implementation of human-operated telesurgery has not been possible due to minimal delays in long-distance transmission. Multiple studies suggest that RARP is associated with higher costs compared to ORP and LRP and therefore RARP is not yet a common treatment in countries with lower economic health systems. However, the potential long-term benefits and improved patient outcomes should be considered when evaluating the overall cost-effectiveness of RARP in prostate cancer treatment.

In conclusion, the numerous advantages of robot-assisted radical prostatectomy establish it as a highly promising and arguably the most favourable treatment option available for patients with prostate cancer.

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