

Peri- and postoperative complications and outcome after radical prostatectomy with open, laparoscopic, and robotic-assisted approach

Perioperacijske i poslijeoperacijske komplikacije te ishod nakon radikalne prostatektomije otvorenim, laparoskopskim i robotski asistiranim pristupom

Romano Oguić^{1,2*}, Louisa Haupt³, Dražen Rahelić^{1,2}, Nino Rubinić^{1,2}, Klara Smolić^{1,2}, Josip Španjol^{1,2}

¹ Clinical Hospital Center Rijeka,
Department of Urology, Rijeka, Croatia

² University of Rijeka, Faculty of Medicine,
Department of Urology, Rijeka, Croatia

³ University of Rijeka, Faculty of Medicine,
Rijeka, Croatia

*Corresponding author:

Assoc. prof. Romano Oguić, MD
Clinical Hospital Center Rijeka, Department
of Urology
Toma Strižić Street 3, 51000 Rijeka, Croatia
E-mail: romano.oguc@gmail.com

<http://hrcak.srce.hr/medicina>

Abstract. Prostate cancer ranks among the most prevalent malignancies globally. This study evaluated perioperative and postoperative complications following radical prostatectomy, comparing three distinct surgical approaches: the conventional open technique and two minimally invasive procedures-laparoscopic surgery and robotic-assisted surgery using the da Vinci system. The focus was on common complications, including urinary dysfunction, erectile dysfunction, blood loss, transfusion requirements, postoperative pain, length of hospital stay, and operative duration. The analysis highlighted notable differences among the surgical techniques, particularly in urinary and erectile dysfunction, blood loss, and transfusion rates. The findings underscored that the da Vinci robotic system represents a technologically advanced method, outperforming the other approaches in these aspects. Laparoscopic surgery yielded better outcomes compared to the open approach. Differences in hospital stay were minimal across all techniques. The comparative analysis of surgical techniques for radical prostatectomy indicates that the robotic-assisted approach is associated with reduced urinary and erectile dysfunction, lower blood loss, decreased transfusion rates, and shorter hospital stays, showcasing its advantages over the other two techniques. Laparoscopy demonstrated superior results compared to the open approach. However, the open technique had a shorter operative time, followed by robotic-assisted surgery and laparoscopy. Differences in hospital stay across the techniques were minor.

Keywords: postoperative complications; prostatectomy; prostatic neoplasms; surgical procedures, operative

Sažetak. Rak prostate jedna je od najčešćih malignih bolesti na globalnoj razini. Ovo istraživanje procijenilo je perioperacijske i poslijeoperacijske komplikacije nakon radikalne prostatektomije, uspoređujući tri različita kirurška pristupa: konvencionalnu otvorenu tehniku i dvije minimalno invazivne metode – laparoskopsku kirurgiju i robotski potpomognutu kirurgiju pomoću sustava da Vinci. Fokus je bio na uobičajenim komplikacijama, uključujući urinarnu disfunkciju, erektilne disfunkcije, gubitak krvi, potrebu za transfuzijom, poslijeoperacijsku bol, duljinu boravka u bolnici i trajanje operacije. Analiza je ukazala na značajne razlike među kirurškim tehnikama, posebice u urinarnim i erektilnim disfunkcijama, gubitku krvi i stopama transfuzije. Rezultati su pokazali da sustav da Vinci predstavlja tehnološki naprednu metodu nadmašujući ostale pristupe u ovim aspektima. Laparoskopska kirurgija dala je bolje rezultate u usporedbi s otvorenim pristupom. Komparativna analiza kirurških tehnika za radikalnu prostatektomiju pokazuje da je robotski potpomognuta

metoda povezana sa smanjenim urinarnim i erektilnim disfunkcijama, manjim gubitkom krvi, smanjenim stopama transfuzije i kraćim boravkom u bolnici, što potvrđuje njezine prednosti u usporedbi s ostalim dvjema metodama. Laparoskopjska kirurgija pokazala je bolje rezultate u usporedbi s otvorenim pristupom. Međutim, otvorenu tehniku obilježava kraće trajanje operacije, nakon nje po trajanju slijede robotski potpomognuta kirurgija i laparoskopija. Razlike u duljini boravka u bolnici bile su minimalne među tehnikama.

Cljučne riječi: neoplazme prostate; operativni kirurški zahvati; poslijeoperacijske komplikacije; prostatektomija

INTRODUCTION

Epidemiology and Etiology of Prostate cancer

Prostate cancer (PC) is among the most prevalent malignancies affecting men globally. It ranks as the second most commonly diagnosed cancer in men and represents the fifth leading cause of cancer-related mortality. In its early stages, prostate cancer often remains asymptomatic, with active surveillance being a viable management strategy in certain cases¹. The risk of developing prostate cancer escalates with age, making men over the age of 65 the most vulnerable population. Additionally, African American men experience a higher incidence of prostate cancer and tend to develop more aggressive forms of the disease compared to their white counterparts².

The etiology of prostate cancer is multifactorial and remains incompletely understood, although numerous risk factors have been associated with its development. These risk factors include age, ethnicity, family history, genetic predispositions, obesity, diet, hormonal influences, smoking, alcohol consumption, and certain medications. While none of these factors have been definitively identified as direct causes, research has demonstrated their substantial role in the progression of prostate cancer. The incidence of prostate cancer increases notably with age, with men aged 60 to 79 being the most commonly affected demographic. Family history and genetic background significantly contribute to prostate cancer risk, particularly when multiple family members have been diagnosed with the disease. Ethnicity is also a critical risk factor, with men of Black African ancestry experiencing higher incidence rates, more

aggressive disease forms, and greater mortality compared to other ethnic groups. Lifestyle choices and dietary habits, including smoking, excessive alcohol intake, and obesity, can markedly influence the risk of developing prostate cancer². The risk of developing prostate cancer is known to increase with higher levels of cigarette smoking and alcohol consumption. Additionally, there is an established correlation between elevated insulin-like growth factor levels, sex hormones, and adipokines with a heightened risk of prostate cancer in individuals who are obese or have an elevated body mass index (BMI)³.

Robotic-assisted radical prostatectomy is associated with reduced risks of urinary and erectile dysfunction, lower blood loss, decreased transfusion rates, and shorter hospital stays compared to open and laparoscopic approaches.

Clinical features of prostate cancer

Prostate cancer generally remains asymptomatic in its early stages, often being diagnosed incidentally through routine screening procedures. However, when symptoms do arise, they predominantly present as lower urinary tract symptoms. In more advanced stages of the disease, patients may experience systemic manifestations such as fatigue, weight loss, and anorexia. Additionally, if the cancer has metastasized to distant sites, bone pain and lymphedema may develop².

Diagnostic and therapy

The Gleason grading system is the standard method for assessing the stage of prostate cancer in patients. It is used in conjunction with the TNM classification system to evaluate the risk of the disease and inform treatment decisions. Histological analysis relies on the largest available tissue samples to identify specific patterns. A numerical scale, ranging from 1 to 5, is applied to indicate the level of tumor aggressiveness, with the sum of the two most prevalent patterns determining the Gleason score, which ranges from 2 to 10. The TNM classification system, meanwhile, designates T for the primary tumor, N for the lymph nodes, and M for metastases. The T

category assesses the extent of local invasion and tumor progression, while N indicates the involvement of regional lymph nodes, and M evaluates both regional and distant metastases. The integration of these grading systems allows for the formulation of personalized treatment strategies and provides an estimate of the patient's prognosis. Thus, clinical staging plays a critical role in the management of prostate cancer⁴.

There is no single definitive test for diagnosing prostate cancer. The diagnostic process relies on a combination of digital rectal examination (DRE) and the measurement of prostate-specific antigen (PSA) levels in the serum². While PSA is an organ-specific marker for the prostate, it is not cancer-specific. Elevated PSA levels are associated with an increased risk of prostate cancer and can be detected during routine screening or when prostate cancer is suspected due to the presence of symptoms. However, it is important to note that factors such as prostate inflammation, recent manipulations of the prostate, and benign prostate conditions can lead to false-positive PSA results⁴.

One of the preferred methods for further evaluating suspected prostate cancer is transrectal ultrasonography combined with biopsy. Another effective technique is multiparametric MRI, which provides high-quality, three-dimensional imaging. This type of MRI is particularly valuable for guiding prostate biopsies, offering additional insights in cases where there is clinical suspicion of prostate cancer despite a negative transrectal ultrasound, with or without a biopsy, and assisting in the staging of confirmed prostate cancer. Established imaging modalities such as CT (computed tomography), MRI (magnetic resonance imaging), PET-CT (positron emission tomography with computed tomography), and bone scintigraphy are crucial for detecting cancer metastases, evaluating the involvement of local and distant lymph nodes, and identifying the presence of bone metastases². Therapeutic approaches for prostate cancer should be carefully tailored to each patient, taking into account various factors such as the patient's age, cancer stage, and any existing comorbidities. For patients with a life expectancy of less than five years, aggressive treat-

ment options are generally not pursued⁵. In these cases, regular monitoring of PSA levels and periodic digital rectal examinations (DRE) are recommended⁴. Asymptomatic patients are typically monitored, while symptomatic patients are managed with palliative care. Radical prostatectomy remains a well-established treatment option for patients with localized prostate cancer². This paper provides a comprehensive analysis of laparoscopic, robotic-assisted, and open radical prostatectomy, evaluating the effects of both laparoscopic and robotic-assisted methods in comparison to open radical prostatectomy.

Literature Review

Perioperative characteristics comparing robotic-assisted radical prostatectomy (RARP)/laparoscopic radical prostatectomy (LRP) with open radical prostatectomy (ORP) include operative time, blood loss, transfusion rate, hospitalization duration, catheterization duration, and overall complications. Numerous studies have reported the mean operative time along with standard deviations. A meta-analysis indicated that RARP/LRP required more operative time than ORP. Additionally, the meta-analysis revealed that RARP/LRP was associated with a shorter hospitalization duration (MD -1.18, 95 % CI -2.18 to -0.19, $P = .02$) based on two studies when compared to ORP⁶⁻⁸.

Intraoperative complications

Typical intraoperative complications of radical prostatectomy include bleeding, vascular injury, small bowel lesions, ureteral injuries, rectal lesions, nerve damage, and positional injuries⁹. Vascular injury can occur in all three surgical approaches. In open radical prostatectomy, injury to the Santorini plexus and other venous plexuses in the pelvic floor is possible. The risk of bleeding is higher when nerve-sparing techniques are used, as surgeons may avoid thermal coagulation to preserve the nerves¹⁰. In robotic-assisted and laparoscopic procedures, the creation of pneumoperitoneum increases the risk of vessel injury during the insertion of the gas insufflation cannula (Veress needle) or the trocar. If vascular damage occurs during the perioperative period, hemorrhage is typically managed with atraumatic forceps and absorbable materials¹¹. As with all

Table 1. Characteristics of studies included in the systematic review and meta-analysis²³

First author	Year	Country	Study design	Level of evidence	Cases, n	Age, years median/mean	BMI, Kg/m ² median/mean	PSAng/ml median/mean
Yaxley	2016	Australia	RCT	1b	RARP, 163 ORP, 163	–	–	7.41 ± 4.10 7.57 ± 4.07
Coughlin	2018	Australia	RCT	1b	RARP, 163 ORP, 163	–	–	7.41 ± 4.10 7.57 ± 4.07
Guazzoni	2006	Italy	RCT	1b	LRP, 60 ORP, 60	62.99 ± 8.2 62.9 ± 7.4	–	6.9 ± 2.9 6.5 ± 3
Wallerstedt	2015	Sweden	Prospective	2b	RARP1, 847 ORP, 778	63 (37–75) 63 (42–75)	25.9 (18.8–54.3) 26.2 (18.2–38.2)	6.1 (0.09–20) 6.2 (0.7–20)
Haglund	2015	Sweden	Prospective	2b	RARP1, 847 ORP, 778	63 (58–66) 63 (59–67)	25.9 (24.1–28.0) 26.2 (24.5–28.1)	6.1 (4.5–8.9) 6.2 (4.5–9.0)
Sooriakumaran	2018	Sweden	Prospective	2b	RARP1, 792 ORP, 753	63.3 (58.4–66.9) 63.5 (59.3–67.3)	25.9 (24.1–28.0) 26.2 (24.5–28.1)	6.1 (4.5–8.9) 6.1 (4.5–8.9)
Forsmark	2018	Sweden	Prospective	2b	RARP1, 835 ORP, 803	63 64	–	–
Jacobsen	2007	Canada	Prospective	2b	LRP, 67 ORP, 172	62.3 ± 6.4, 60.9 ± 6.6 63.7 ± 5.7	26.9 ± 6.4, 27.5 ± 2.8 28.1 ± 4.0	6.9 ± 2.0, 7.2 ± 3.0 9.8 ± 8.2
Jurczok	2007	Germany	Prospective	2b	LRP, 163 ORP, 240	62.9 (42–74) 64.8 (52–76)	–	7.9 (2.4–10.2) 7.25 (4.4–11.3)
Dahl	2009	USA	Prospective	2b	LRP, 104 ORP, 102	59.5 59.9	–	–
Ficarra	2009	Italy	Prospective	2b	RARP, 103 ORP, 105	61 (57–67) 65 (61–69)	26 (24–28) 26 (24–28)	6.4 (4.6–9) 6 (5–10)
Pierro	2011	Switzerland	Prospective	2b	RARP, 75 ORP, 75	62.8 (58.4–67.0) 64.3 (59.1–68.0)		7.72 (5.6–12.1) 7.57 (5.1–10.4)
Magheli	2014	Germany	Prospective	2b	LRP, 171 ORP, 168	62.3 ± 5.7 62.6 ± 5.4	–	9.2 ± 6.9 10.1 ± 11.9
Ong	2016	Australia	Prospective	2b	RARP, 885 ORP, 1117	62.1 ± 6.7 62.3 ± 6.7	–	5.5 (4.3–7.8) 6.1 (4.6–8.5)
Barocas	2009	USA	Prospective	2b	RARP, 1413 ORP, 491	61 ± 7.3 62 ± 7.3	–	5.4 (4.3–7.4) 5.8 (4.6–8.4)

surgical procedures, bleeding is a major risk factor. Studies comparing open surgery to robotic-assisted and laparoscopic approaches demonstrate that blood loss is significantly higher in open radical prostatectomy. For instance, a Swedish study from 2015 reported an average blood loss of 683 ml in open surgery, compared to 185 ml in robotic-assisted surgery¹². In a 2010 Swedish study involving 1,738 participants, 170 patients required a blood transfusion. Among those, 23% of patients who underwent open prostatectomy required a transfusion, compared to only 4.8% of

those who underwent robotic-assisted surgery¹³. Rectal injuries, though rare, can result in serious complications. Factors such as a high Gleason score, advanced tumor stage, and inexperience of the surgeon can contribute to the severity of these injuries. In some cases, the prostate may adhere to the anterior rectal wall due to prior prostatitis or inflammatory reactions following prostate biopsy, rather than an advanced tumor stage. Rectal injuries often occur during the transection of Denonvilliers fascia or when dividing the final attachments to the prostate¹⁴. Early

detection and prompt treatment are essential to prevent significant morbidity and mortality. The incidence of ureteral injuries varies with the surgical technique used. For example, during robotic-assisted radical prostatectomy (RARP), the injury rate is between 0.1% and 0.3%, while laparoscopic surgery has an injury rate of 0.8%, and open surgery ranges from 0.1% to 0.8%. Ureteral injuries are typically identified after the surgery. Common causes of nerve injuries include entrapment, stretching, thermal injury, and transection¹³. During surgery, it may be necessary to convert laparoscopic or robotic-assisted techniques to an open approach. Data from the National Inpatient Sample (NIS) database between 2004 and 2010 indicate that conversion occurred in 1.8% of radical prostatectomy cases, often due to factors such as adhesions, anemia, high body mass index (BMI), and surgeon experience. Patients who undergo conversion tend to experience higher complication rates and longer hospital stays. Proper patient positioning is crucial for all surgical procedures, including RARP. Unlike open prostatectomy, RARP requires the patient to be positioned in Trendelenburg, which is less physically demanding for the surgical team¹¹. However, when performing laparoscopic or robotic-assisted procedures, the potential risks of prolonged operative time-such as nerve injuries or compartment syndrome-must be carefully considered¹⁰.

EARLY POSTOPERATIVE COMPLICATIONS

Urinary dysfunctions and Erectile dysfunction

Urinary tract complications are common following radical prostatectomy, with issues such as urinary tract infections, urinary retention, and strictures frequently occurring. A national cohort study by Sujenthiran et al., conducted between 2008 and 2012, examined the incidence of these complications within the first two years post-surgery, comparing three different surgical approaches. The study included 4,947 men who underwent robotic-assisted radical prostatectomy (RARP), 5,479 men who had laparoscopic radical prostatectomy (LRP), and 6,873 men who underwent open radical prostatectomy (ORP).

Over the study period, the choice of surgical approach shifted significantly. At the start of the study, ORP was the preferred method in 61.3% of cases, while RARP was used in 24.8% and LRP in 14%. However, after five years, the use of open surgery decreased substantially, with only 28.4% of patients undergoing ORP. In contrast, the use of LRP increased to 40.1%, while RARP increased to 31.4%. This indicates a notable shift in the preference for surgical methods over time. The study also assessed the impact of different surgical techniques on urinary complications. Within the first two years post-surgery, 10.5% of patients who underwent robotic-assisted surgery required an intervention, while the percentages were higher for laparoscopic radical prostatectomy (15.8%) and open radical prostatectomy (19.1%) until 2019. These findings suggest that RARP is associated with a lower incidence of urinary complications compared to LRP and ORP. Furthermore, regarding stricture-related complications, RARP exhibited the lowest rate at 3.3%, compared to 5.7% for LRP and 6.9% for ORP. These results indicate that RARP not only presents a lower overall incidence of complications but also demonstrates a significantly lower rate of stricture-related complications compared to LRP and ORP¹⁵. Several studies, including those by Rechtman et al., Alessandro et al., Luciani et al., and Stolzenburg et al., have examined continence following radical prostatectomy, typically using patient-reported questionnaires and follow-up assessments at 3, 6, and 12 months post-surgery^{6, 16–18}. A comparison of continence rates across four studies reveals that two of the studies did not show significant differences in continence outcomes between surgical techniques after 12 months, while one study did. Furthermore, two of the four studies also compared continence rates at 3- and 6-months post-surgery, and both arrived at similar conclusions. The studies by Rechtman et al. and Alessandro et al. found no significant differences in continence rates after 12 months^{16, 17}. However, Luciani et al. demonstrated clear differences between surgical techniques, with continence rates after one year as follows: 80% for RARP patients, 72% for LRP patients, and 68% for those who underwent open surgery¹⁸. Additionally, Alessandro et al.

compared continence rates between LRP and ORP after 3, 6, and 12 months. At 3 months, 88.9% of LRP patients were continent, compared to 75.7% of ORP patients. After 6 months, the continence rates were 92.6% for LRP and 87.8% for ORP, suggesting that laparoscopic approaches yield better outcomes in the short term¹⁷. In another study, Stolzenburg et al. analyzed continence rates between RARP and LRP in a cohort of 622 patients, with 511 undergoing RARP and 111 undergoing LRP⁶. After 3 months, 54% of RARP patients and 46% of LRP patients achieved continence, with no longer requiring pads or safety measures. The study also found that RARP patients were more likely (56% to 58%) to experience reduced pad usage, decreased urine leakage, lower leakage volume, and less disruption to daily activities compared to LRP patients. Moreover, the bilateral nerve-sparing technique demonstrated a significant difference, with continence rates of 66% for RARP compared to 50% for LRP⁶. When considering the psychological impact of incontinence, most patients experience stress incontinence rather than urgency incontinence. This type of incontinence leads to uncontrollable urine loss under stress, which can result in depression, shame, reduced self-esteem, and social isolation. Incontinence can significantly impact a patient's daily life, making it crucial to carefully evaluate the best surgical approach for each individual^{16, 19}.

During radical prostatectomy, damage to the vessel-nerve bundle that supplies the corpus cavernosum can impair oxygenation, leading to apoptosis of smooth muscle cells. This can result in an increase in collagen fibers and fibrosis of the corpus cavernosum, which reduces the tissue's elasticity and impairs erectile function. As a consequence, patients may experience diminished quality of life and strained relationships. To aid in penile rehabilitation, phosphodiesterase-5 inhibitors, such as Sildenafil, are often used. Erectile dysfunction (ED) can be caused by various factors, including age, chronic medical conditions, and preoperative erectile function. Recovery of erectile function can take up to 40 months following the operation¹⁹. Stolzenburg et al. compared potency recovery rates between patients who underwent robotic-assisted radical prostate-

tomy (RARP) and laparoscopic radical prostatectomy (LRP). Three months post-operation, 18% of RARP patients demonstrated recovery of potency, compared to just 6.7% of LRP patients. Additionally, the use of uni- or bilateral nerve-sparing techniques during surgery can improve recovery from erectile dysfunction. After 12 months, the potency recovery rates for LRP and open approaches were 52.9% and 45%, respectively. Furthermore, RARP was shown to reduce the likelihood of erectile dysfunction by more than 40% compared to LRP⁶.

Hospital Stay

The duration of hospital stays has become an economically significant factor in contemporary healthcare, especially regarding radical prostatectomy procedures. A study conducted in Germany in 2004 found that the average hospitalization period for patients undergoing open surgery was 11.2 days, while those who underwent laparoscopic surgery had a slightly longer hospitalization period of 12.4 days²⁰. In a European study conducted in 2010, minimal variations in hospitalization duration were observed across different surgical techniques. The shortest hospital stay was recorded for robotic-assisted radical prostatectomy (RARP) at 7.8 days, followed by laparoscopic radical prostatectomy (LRP) with 8.4 days, while open surgery required nearly 10 days¹³. However, a more recent study conducted in 2016 showed further reductions in hospitalization duration. The open surgery approach still had the longest stay at 5.54 ± 1.41 days, while LRP patients had an average hospitalization period of 4.35 ± 0.54 days¹⁷. Overall, surgical techniques for radical prostatectomy have evolved significantly, leading to a substantial decrease in the length of hospital stays. In 2004, patients typically required more than 10 days in the hospital following surgery. By 2016, however, due to advancements in surgical technology and techniques, patients are often discharged within 5-6 days post-operation¹⁷.

Postoperative Pain

The 2010 European study assessed postoperative pain levels across different surgical approaches for radical prostatectomy. The study involved 315

Table 2. Surgical modality types with blood transfusion rate and postoperative pain in different surgical approach¹¹

Outcome	No. (%)			RARP vs ORP		RARP vs LRP	
	ORP (n=315)	LRP (n=276)	RARP (n=816)	aOR (95%CI) ^a	P value	aOR (95% CI) ^a	P value
Perioperative outcome							
BT incidence	76 (24.1)	35 (12.7)	59 (7.2)	0.25 (0.17-0.36)	<.001	0.58 (0.37-0.91)	.02
Moderate postoperative pain							
Day1	114 (36.1)	67 (24.2)	250 (30.6)	0.84 (0.67-0.95)	.01	1.07 (0.58-1.13)	.18
Week1	82 (26.0)	64 (23.2)	163 (20.0)	0.65 (0.35-0.82)	.03	0.62 (0.46-0.82)	<.001
Week12	10 (3.2)	14 (5.1)	17 (2.1)	0.74 (0.33-1.67)	.46	0.40 (0.19-0.85)	.02
Severe postoperative pain							
Day1	201 (63.8)	189 (68.5)	456 (55.9)	0.72 (0.55-0.86)	.01	0.69 (0.50-0.96)	.03
Week1	138 (43.8)	139 (50.4)	342 (41.9)	0.90 (0.69-0.97)	.04	0.73 (0.55-0.97)	.03
Week12	0	0	0	NA	NA	NA	NA

patients who underwent open radical prostatectomy (ORP), 276 who underwent laparoscopic radical prostatectomy (LRP), and 816 who underwent robotic-assisted radical prostatectomy (RARP). One day after surgery, 36.1% of ORP patients reported moderate pain, while 63.3% reported severe pain. In contrast, 30.6% of RARP patients experienced moderate pain, and 55.9% reported severe pain. Patients who underwent LRP reported intermediate levels of pain severity. However, the differences between the surgical techniques became more noticeable after the first day post-surgery. One week postoperatively, the percentage of patients experiencing severe pain showed only slight differences across the groups. In the ORP group, 26% still reported moderate pain, while 43.8% reported severe pain. Among RARP patients, 20% reported moderate pain, and 41.9% reported severe pain. Interestingly, the highest percentage of patients reporting severe pain was observed in the LRP group, both one day and one-week post-surgery. At the 12-week mark, the percentage of patients reporting moderate pain was highest in the LRP group at 5.1%, followed by 3.2% in the ORP group and 2.1% in the RARP group. Notably, none of the patients reported severe pain at 12 weeks postoperatively¹³.

Blood loss and transfusions

A comparative analysis conducted in 2017 at a single regional centre examined surgical outcomes across three different techniques, with

each technique applied to 100 patients. The results demonstrated that patients who underwent open radical prostatectomy (ORP) and laparoscopic radical prostatectomy (LRP) experienced significantly higher blood loss, with an average of 600 ml, compared to the robotic-assisted radical prostatectomy (RARP) group, which had an average blood loss of 400 ml. As a result, the transfusion rate was 21% for ORP and LRP patients, significantly higher than the 6% rate observed in RARP patients¹⁷. A smaller study conducted in 2016 yielded similar results, with LRP patients experiencing a blood loss of 366.67 ± 142.75 ml and ORP patients losing 572.73 ± 174.13 ml. The transfusion rate was 7.4% for LRP patients and 27.3% for ORP patients¹⁸. Other studies have suggested that both RARP and LRP procedures result in significantly less blood loss and a lower need for transfusions compared to ORP, attributed to improved visualization and more precise tissue dissection¹⁷.

Operation time

Two studies, conducted in 2006 and 2016, respectively, compared the surgical duration of open surgery and laparoscopic surgery. The average surgical time for open surgery was reported as 170 ± 34 minutes in 2006 and 152.28 ± 27.44 minutes in 2016. In contrast, laparoscopic radical prostatectomy (LRP) required significantly more time, with an average of 235 ± 49 minutes in 2006 and 188.51 ± 27.50 minutes in 2016^{17,21}. A more recent study from 2022, conducted by a Eu-

Table 3. Biochemical recurrence rates in comparative studies between RARP/LRP and ORP²³

First author	Cases, n		Follow-up, month	BCR definition, ng/ml	Overall BCR rate, n/N (%)
Coughlin	RARP, 157	ORP, 151	24 months	PSA \geq 0.2	4(2.5)/13 (8.6)
Sooriakumaran	RARP, 1778	ORP, 755	3 months	PSA \geq 0.2	48(2.7)/37 (4.9)
Sooriakumaran	RARP, 1780	ORP, 737	12 months	PSA \geq 0.2	89(5.0)/14 (1.9)
Sooriakumaran	RARP, 1793	ORP, 752	24 months	PSA \geq 0.2	208(11.6)/91 (12.1)
Dahl	LAP, 101	ORP, 101	12 months	PSA \geq 0.2	7(6.9)/2 (2.0)
Pierro	RARP, 75	ORP, 75	3 months	PSA \geq 0.2	9(12.0)/7 (9.3)
Pierro	RARP, 45	ORP, 75	12 months	PSA \geq 0.2	5(11.1)/10 (13.3)
Ong	RARP, 885	ORP, 1117	24 months	PSA \geq 0.2	108(12.2)/223 (20.0)
Barocas	RARP, 1413	ORP, 491	36 months	PSA \geq 0.2	226(16.0)/81 (16.5)

ropean research team, reviewed 1742 articles on perioperative outcomes and complications from eight databases between 2000 and 2020. This study found that the average surgical time for open surgery was 169.53 minutes, while laparoscopic surgery took an average of 214.92 minutes, and robotic-assisted surgery (RARP) averaged 199.78 minutes²².

Prostate specific survival

According to a 2019 meta-analysis and systematic review conducted by Cao et al²³, there appears to be no significant difference in the rate of positive surgical margins between LRP/RARP and ORP. The review found that 22.3% of LRP/RARP patients had positive surgical margins, while the rate for ORP was slightly higher at 28.6%. However, when positive surgical margins were analyzed based on tumor staging, there were differences between the techniques. For tumors below stage T2, the rate of positive surgical margins was similar for all three techniques, at 14.7%. But for tumors at stage T3 and above, LRP/RARP had a rate of 41.4%, while ORP had a rate of 50.1%, indicating a greater likelihood of positive surgical margins with larger tumors. Overall, these findings suggest that the difference in positive surgical margins between LRP/RARP and ORP is not significant, but the likelihood of positive margins is affected by tumor stage²³. In a study conducted by Alessandro et al. in 2016, it was found that there was no significant difference between LRP/RARP and ORP in terms of the percentage and number of positive cutting edges¹⁷. The study found that these factors were similar in both

techniques, as well as in relation to preoperative prostate-specific antigen levels, pathological T stage, and Gleason score. These findings suggest that LRP/RARP and ORP may be similarly effective in achieving negative surgical margins.²³ In Table 3 is visible biochemical recurrence rates in comparative studies between RARP/LRP and ORP¹⁷.

DISCUSSION

Over two decades ago, the RARP system was introduced into surgical practice and has since gained increasing popularity. Although the RARP system is now used in many hospitals, there is still room for further expansion. In the United States, approximately 65% of hospitals utilize RARP, whereas in Europe, only 17% do so²⁴. One of the primary reasons for this disparity is the high cost of the system, along with the fact that its benefits over other surgical techniques are not always deemed significant enough. Due to limited funding, many smaller clinics are still unable to access the RARP system. As a result, open surgery and laparoscopy remain preferred options, as they are more cost-effective. Despite this, the RARP system offers distinct advantages, such as smaller incisions, a reduced risk of infection, and a 3D view that provides a better overview of small vessels and nerves, thereby minimizing the risk of bleeding and other intraoperative injuries²². However, the RARP system is not autonomous and requires specialized training for operation. Its seven degrees of freedom allow it to perform with greater precision than a human surgeon, reducing the risk of tremors and

minimizing the physical strain on the surgeon. Additionally, the operation only requires two people-the surgeon and the assistant, reducing the cost of personnel. However, operating times tend to be longer, and additional effort is needed for cleaning the robot's instruments thoroughly²⁵. Laparoscopy has also become a standard procedure for a wide range of surgeries, making these two minimally invasive techniques a preferred alternative to open surgery. Over the past 20 years, three different surgical techniques for

Laparoscopic surgery demonstrated superior outcomes compared to the open approach, while the open technique had the shortest operative time among all methods. Differences in hospital stay across techniques were minimal

radical prostatectomy have been compared to determine the most optimal procedure for both patients and surgeons. These analyses have primarily focused on perioperative and postoperative complications, comparing factors such as urinary dysfunction, hospital stay, blood loss, transfusion rates, and operation time. Given that minimally invasive techniques provide better tissue visualization and safer dissection, it is often assumed that RARP and LRP offer better outcomes than ORP in all aspects. However, it is essential to consider the learning curve and the surgeon's experience when evaluating surgical techniques¹³. Notably, the learning curve for open procedures is steeper compared to that of RARP or laparoscopy. Despite the availability of modern technologies, open procedures are still considered a safe and reliable option. Thanks to improved visibility, typical intraoperative complications-such as significant bleeding, vascular injuries, small bowel lesions, ureteral injuries, and nerve damage can be avoided or minimized with minimally invasive techniques. However, new potential complications, such as the creation of pneumoperitoneum (which does not typically occur in open surgery), should be considered. Additionally, factors such as surgeon inexperience and patient characteristics-such as an increased BMI, significantly enlarged prostate, or advanced age

can lead to various complications¹⁷. While some studies have found no significant differences between surgical techniques, others have identified variations in postoperative complications. However, the studies consistently show nearly identical results concerning urinary incontinence and strictures^{25, 26}. Some studies, such as those by Sujenthiran et al. and Luciani et al, demonstrate clear advantages of robotic-assisted radical prostatectomy over the other two techniques^{15, 18}. Alessandro et al., however, did not find any differences after a 12-month period but noted better outcomes within the first 3-6 months when compared to open surgery¹⁷. Erectile dysfunction is one of the most significant complications from the patient's perspective, and nerve-sparing techniques are ideal for achieving the fastest recovery of erectile function. Among the available techniques, RARP has been shown to provide the best results, especially when compared to LRP. While the differences between LRP and ORP outcomes are minimal after 12 months, RARP shows significantly better results than LRP as early as three months post-surgery²⁶. From an economic standpoint, the length of hospital stays for patients has become an increasingly important factor. A study conducted in 2004 and 2006 found that patients stayed in the hospital for approximately 11 days after open surgery and 12 days after minimally invasive procedures^{20, 21}. However, in a more recent 2016 study, hospital stays were slightly reduced after open surgery compared to minimally invasive procedures⁷. Some authors have been unable to account for factors such as surgeon experience, hospital volume, and the use of nerve-sparing techniques, all of which can significantly influence outcomes. These factors may have a more substantial effect than the choice of RARP, LRP, or ORP²⁴. Additionally, it is worth noting that urinary incontinence and erectile dysfunction were reported as binary outcomes, despite the fact that both conditions vary widely in terms of severity and impact on quality of life. Furthermore, neither preoperative urinary nor sexual function was considered in the analysis²⁶. Nowadays, patients are typically hospitalized for a maximum of 5 to 6 days, which reflects the ongoing development of surgical techniques and a reduction in associated compli-

cations¹⁷. The lack of available data highlights the limited research on the same complications when comparing all three or just two of the surgical techniques. Even when multiple studies investigate the same complication using the same surgical technique, different outcomes may be observed²⁷.

CONCLUSION

There are several ways to perform prostate cancer surgery, including open surgery, laparoscopic surgery, and robotic-assisted techniques. The aim of this study was to compare these three approaches and determine which results in the fewest complications for prostate cancer patients. After analysing multiple studies conducted in Europe and other regions over a 20-year period, it can be concluded that all three surgical techniques are generally safe. Initially, the differences between them, particularly between open and robotic-assisted procedures, were not significant. However, over time, these differences have become more pronounced, especially regarding erectile dysfunction, potency, and prostate cancer-specific mortality. Robotic-assisted radical prostatectomy was found to have moderately fewer complications and more advantages, but its limitations should also be considered. Overall, the study suggests that the open approach has the highest rate of complications, while laparoscopy offers a satisfactory balance as a minimally invasive technique with lower complication rates. The analysis revealed differences between the surgical approaches, especially in terms of urinary dysfunction, erectile dysfunction, blood loss, and transfusion rates. These findings demonstrated that the RARP technique is a modern, advanced method when compared with the other two, with laparoscopy showing better results than the open approach. There were only slight differences between the techniques in terms of hospital stay. The robotic-assisted technique resulted in a shorter hospital stay compared to laparoscopy and the open approach, which showed only a slightly extended stay of about one day. The open approach was superior only in terms of operation time, followed by robotic-assisted surgery and laparoscopy, respectively. In

the coming years, more efforts should be made to make minimally invasive surgical techniques even more appealing to surgeons. Further studies should be conducted to determine whether more clinics are adopting modern technologies and to reduce complication rates even further.

Conflicts of Interest: Authors declare no conflicts of interest.

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