**RESEARCH ARTICLE**

# Robotic radical prostatectomy in the 21st century: evolution of experience

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**Abstract**

The advent of novel technologies and surgical techniques has revolutionized urological surgery in recent years. Robot-assisted radical prostatectomy (RARP) has become the most widely used surgical approach for radical prostatectomy (RP) in the treatment of localized prostate cancer. However, the current available evidence on the benefit of RARP compared to open radical prostatectomy (ORP) is still under debate. Moreover, recent studies have proposed technical modifications of RARP to improve functional outcomes and postoperative quality of life of prostate cancer patients.

The aim of this review was to summarize the current evidence on oncological, functional and perioperative outcomes of RARP, considering the results of our series of 408 RARP performed between October 2006 and February 2015 at Clínico San Carlos Hospital, and to provide a framework on the latest and most relevant updates on RARP surgical technique modifications.

In summary, current data suggest a RARP benefit related to the advantages of minimally invasive surgery. However, functional and oncological outcomes appear to be equivalent between RARP and ORP. Recent modifications on surgical technique might further improve functional outcomes in prostate cancer patients, although long-term follow-up data are needed.

**Keywords** Prostate cancer; robot-assisted radical prostatectomy; oncological outcomes; functional outcomes; robotic surgical techniques.

## Introduction

Over the last two decades, the advent of robotics and novel technologies have challenged traditional surgical techniques on prostate cancer treatment. Robot-assisted radical prostatectomy (RARP) has been adopted as the preferred and most frequently used surgical approach for radical prostatectomy (RP) in the treatment of localized prostate cancer[1-4]. However, despite the increasing use of the robotic surgical approach, the benefit of RARP over open radical prostatectomy (ORP) with regard to oncological and functional outcomes remains unclear.

Several observational non-randomised studies, systematic reviews and meta-analyses have shown improved functional outcomes of RARP compared to ORP[5-8]. Moreover, a number of studies demonstrated better perioperative outcomes associated with RARP such as lower estimated blood loss and blood transfusions, shorter catheterization time and shorter length of hospital stay[9-12]. However, most observational studies and meta-analyses comparing oncological outcomes between robotic and open RP have failed to demonstrate RARP benefit on prostate cancer patients treatment[13-15].

Recently, in light of the lack of prospective data, a randomised controlled phase 3 trial comparing RARP and ORP has been performed[16,17]. In contrast to previous retrospective studies, this trial showed no significant differences in functional outcomes between RARP and ORP. Moreover, oncological outcomes were equivalent between the robotic and open surgical approach.

Furthermore, at the present time novel surgical technique modifications of RARP have been introduced in an effort to improve functional outcomes and postoperative quality of life of patients undergoing surgical prostate cancer treatment[18].

The present review focused on the most recent evidence on oncological, functional and perioperative outcomes of prostate cancer patients treated with RARP versus ORP, providing the results of our series: a consecutive cohort of 408 RARP performed between October 2006 and February 2015 at Clínico San Carlos Hospital (Madrid, Spain)[19].

Moreover, we analyzed latest updates on surgical technique modifications of RARP and discuss the future perspectives on this field.

## Historical evolution of robot-assisted radical prostatectomy

Radical prostatectomy is the surgical treatment of prostate cancer, which includes removal of the entire prostate gland, the capsule, a bladder neck cuff and the seminal vesicles. The first RP was performed by Billroth in 1867 using a perineal approach[20], although it would be Young in 1869 who described the technique as we know in our days and published the outcomes of the first series of 75 patients[21]. Millin refined the surgical technique using an abdominal incision from umbilicus to pubis entering the extraperitoneal space[22]. In 1980, Walsh improved and popularized the retropubic radical prostatectomy technique[23]. For the first time, the author described RP involving the management of the dorsal vein complex (DVC) and the neurovascular bundles (NVB)[24]. Retropubic surgical field was widely known and this approach presented fewer complications associated to anal sphincter injury compared to previous surgical techniques. These advantages made the retropubic approach the first choice[25]. Side effects were very common affecting more than 85% of patients, with erectile

 

dysfunction and urinary incontinence being the most frequent, the first related to direct NVB damage and the second associated to the difficulty of the vesicourethral anastomosis, which resulted in urinary extravasation, fistulas and on many occasions secondary strictures. Until 1980, RP associated high morbidity with poor quality of life outcomes, considerable blood loss and hospital stay of 3 to 4 weeks[26].

In 1994 the Food and Drug Administration (FDA) approved the prostate specific antigen (PSA) as a useful marker for both prostate cancer diagnosis and post-treatment monitoring. PSA radically modified the profile of the patient who underwent surgery because high levels of this marker anticipated 7 to 9 years the appearance of metastatic symptoms[27,28]. At the end of the 20th century, PSA in conjunction with transrectal ultrasound and the description of the zonal anatomy of the prostate represented a revolution in the diagnosis of prostate cancer and the selection of patients to treat[29]. The modifications introduced by Walsh *et al.*[23,24] also determined the evolution of perioperative and functional results. Abbou[30] performed the first laparoscopic radical prostatectomy (LRP) in 2000, but it soon became apparent that 2D imaging and worsening of the mobility of the surgeon made the learning curve extremely difficult, with LRP presenting worse functional outcomes than open surgery. On 17 July 2000 the FDA approved the Da Vinci System for abdominal surgery in humans. Subsequently, in 2001, the FDA approved the Da Vinci Robotics platform for use in urological patients. Since then, the expansion of robotic surgery is overwhelming. The 3D vision and the physiologic tremor disappearance have improved image stability. The Endowrist System improved maneuverability and precision and made robotic surgery replace the handicaps of laparoscopic surgery, while preserving the advantages of minimally invasive surgery. The first RARP in Europe were performed by Abbou in France and Binder in Frankfurt in 2001, with the particularity that these surgeons had no previous experience in laparoscopic surgery[31,32]. Vallancien was the first to carry out and publish the surgical technique in the United States (Vattikuti Institute of Urology, Detroit). This surgical team performed more than 1000 procedures in the following 3 years[33,34].

Although the initial series failed to demonstrate significant advantages associated with robotic surgery, the decrease in adverse effects inherent to the technique was soon observed, showing better outcomes in terms of intraoperative bleeding, thrombosis, urinary fistulas, stenosis and surgical recovery compared to open surgery[35]. Furthermore, although current series have not demonstrated a consistent benefit in functional or oncological outcomes associated with robotic surgery, the existing demand for this technique from both patients and professionals had made RARP the surgical approach of first choice[16,36,37].

## Surgical techniques and recent modifications

Since its description in 2001, slight technical modifications of RARP have been suggested to improve mainly functional outcomes in prostate cancer patients[18]. The Pentafecta criteria summarize the optimal outcome of RARP: negative surgical margin, absence of biochemical recurrence, no surgical complications and preservation of sexual activity and urinary continence[38].

 

- **Veil of Aphrodite Preservation (VIP Technique)**

Described by the Detroit group in 2006[39,40] and focused on the preservation of the NVB. This technique is based in an anterior incision at the prostatic lateral fascia preserving NVB at the apex. However, anatomical cadaver studies from the Melbourne group showed that most of the nerves were located at the inferolateral level of the prostate and its representation on the anterior side was minimal[41].

- **Preservation of urethral smooth muscle**

The application of this technique is based on the preservation of the maximum length of the urethra. Smooth muscle is only responsible for passive continence while the striated sphincter muscle is responsible for active continence[42]. This technique resulted in improved early continence in 406 consecutive patients compared with standard RARP: 50.1% vs 30.9% at 1 week after catheter removal ($p<0.0001$) and 96.9% vs 94.7% ($p=0.59$) at 12 months after surgery.

- **Suburethral plication ("Rocco Stitch")**

The suburethral plication technique approximates Denonvilliers' fascia from the prostate apex to the base of the bladder to stabilize the posterior region of the anastomosis. To date, this technical modification has not shown a significant impact on continence outcomes[43]. A meta-analysis published in 2012 concluded that factors predicting urinary incontinence after RARP include patient preoperative characteristics (age and preoperative continence), surgeon experience, surgical technique and the methods used to collect the report data. The posterior reconstruction with the "Rocco Stitch" appears to offer a slight advantage 1 month after surgery but not afterwards[6]. Subsequently, a prospective randomized trial found no benefit associated with rhabdosphincter reconstruction compared to standard vesicourethral anastomosis in terms of early urinary continence after RARP[44]. Similarly, a retrospective analysis performed by Woo *et al*.[45] showed no significant benefit associated with "Rocco Stitch".

Other groups have attempted anterior stabilization of the anastomosis with modest results. Suspension of the vas deferens improved early continence at 1 month (59% vs 35%, $p=0.2$). No significant differences were observed in overall urinary continence or in the use of pads[46].

- **Seminal vesicles tip preservation**

The origin of this technical modification in the literature is uncertain. A randomized controlled trial published in 2017 showed no difference in functional results, surgical margins or biochemical recurrence between standard RARP and this technique[47].

- **Prostatic vasculature as a landmark**

The prostate artery is a large tortuous vessel located in the medial portion of the NVB. In contrast, the capsular arteries are smaller than prostate artery, without tortuosity and located distally. The dissection plane is identified between one of these landmark capsular arteries and the prostate gland at the midprostate. Surgical dissection continues retrograde to the posterior plane at the base of the prostate[48].

 

- **Preservation of the dorsal venous complex and retrograde release of the neurovascular bundle**

Carvalho *et al.*[49] described this technical modification in 2018. Functional and oncological results were analyzed in 128 patients treated by a single surgeon. After opening the Retzius space, they proceed to the dissection of the anterior portion of the bladder neck sparing the endopelvic fascia. Subsequently, the dissection progresses to the posterior portion of the bladder neck, seminal vesicles and vas deferens, developing an avascular plane below the dorsal venous complex (DVC). The NVB is dissected medially to the prostate artery, fusing this plane with the posterior one.

- **Retzius-sparing robot-assisted radical prostatectomy (RS-RARP)**

The Retzius-sparing RARP (RS-RARP) was described by Galfano *et al.*[50] in 2010. This technique consists of starting the dissection at posterior peritoneum, being the seminal vesicles the first structure to be dissected. RP is performed exclusively through the pouch of Douglas space, thus avoiding any interruption of the anterior anatomic structures that surround the prostate gland such as the pubovesical ligaments, puboprostatic fascia, NVB and DVC. A randomized controlled trial performed in 2017 by Menon *et al.*[51] did not demonstrate significant benefit of this technique on functional outcomes compared to the standard approach. Furthermore, RS-RARP was described as a complex surgical technique with a difficult learning curve and was recommended to be performed only by experienced RARP surgeons[52]. In examining their own learning curve over their first 200 RS-RARP, Galfano *et al.*[53] found an improvement in the positive surgical margins (PSM) rate from the first 100 RS-RARP compared to the following 100 cases (22.1% vs 10.1%, p=0.045). In this setting, a recent systematic review[54] showed a lower PSM rate associated with standard RARP compared to RS-RARP (15.2% vs 24%; odds ratio (OR) 1.71, p=0.01), which may be related to the RS-RARP learning curve. On the other hand, the cumulative analysis showed a statistically significant advantage of RS-RARP in terms of urinary continence recovery at 1 month (OR 2.54, p=0.02), 3 months (OR 3.86, p<0.001), 6 months (OR 3.61, p=0.001) and 12 months (OR 7.29, p=0.004). Moreover, Qiu *et al.*[55] analyzed a cohort of 110 patients (55 RS-RARP vs 55 standard RARP) showing an improvement in early urinary continence associated with RS-RARP (p=0.0001), while no significant difference was observed in the overall continent rate at total follow-up (p=0.42).

In summary, most of the current studies showed a benefit in early and overall urinary continence rates associated with RS-RARP compared to standard RARP (97% vs 81.4%), reporting no significant differences in PSM rate or biochemical recurrence-free survival. Consequently, the results suggest that RS-RARP has equivalent oncological outcomes to standard RARP, although further studies with long-term follow-up are needed. In addition, available data on sexual functional outcomes after RS-RARP are limited[56].

- **Robotic perineal prostatectomy (r-RPP)**

Recently, robotic surgery has brought the perineal approach back to the scene[57]. The perineal approach may be a surgical option in patients with severe obesity,

 

cardiopulmonary comorbidities and previous abdominal surgeries since it does not require pneumoperitonea or Trendelenburg position. Perineal approach may also imply a lower risk of visceral injury, especially in patients with previous abdominal surgery and possible adhesion syndrome. The technical feasibility of lymphadenectomy through the perineal incision and the possibility of treating large prostates appear to have overcome some critical limitations of this approach.
Recently, the introduction of the Da Vinci Single-Port (SP) Surgical System (Intuitive Surgical Inc., Sunnyvale, California, USA)[58] represented an important innovation for r-RPP because it combines the benefit of a single keyhole and the possibility to triangulate the instruments. The largest series of r-RPP (n=95) currently available[59] reported an immediate and 12-month urinary continence rates of 41% and 91% respectively, preservation of erectile function in 49%, 69% and 77% of patients at 3, 6 and 12 months after surgery, respectively. Simultaneously, a retrospective analysis showed shorter operating time, lower blood loss, lower overall complication rate and lower length of stay associated with r-RPP compared to standard RARP[60].

In summary, despite surgical technical modifications, functional and oncological outcomes of RARP have hardly changed in the last ten years. In this setting, it is crucial to minimize the potential surgical mechanisms of injury including transection, traction and thermal damage. The decrease of neuropraxia through reduced traction contributes to early recovery of potency, although it has no effect on late recovery of sexual function. The apex dissection is essential due to the proximity of the nerve structures related to potency and continence. Optimal NVB release is achieved by widening Denonvilliers' fascia, leaving the lateral prostatic fascia on one side and the prostate on the other, either with an antegrade or retrograde approach. Even in locally advanced tumors, involvement of the cavernous nerve branches of the NVB, which are more than 5 mm from the capsule, is uncommon so their ipsilateral or at least contralateral preservation could be assessed based on the magnetic resonance imaging findings[26,61]. The capsular vein along the NVB is established as a landmark to differentiate intrafascial of extrafascial preservation to achieve interfascial nerve-sparing[62]. Intrafascial preservation improved potency and early continence rates at the expense of a higher PSM rate in T3 patients[63].
Finally, careful patient selection and preoperative baseline will be key factors in achieving the best surgical outcomes[64].

**Perioperative outcomes**

Minimally invasive surgery was introduced in the field of RP with the aim of reducing postoperative morbidity in the surgical treatment of prostate cancer. Several historical retrospective studies described improved perioperative outcomes in patients undergoing RARP compared to patients treated with ORP[3,65-67]. Novara *et al*.[68], performed a systematic review and meta-analysis in 2012, showing a benefit in perioperative outcomes associated with RARP compared to ORP and LRP. The authors analyzed 110 papers conducted from 2008 to 2010, demonstrating lower blood loss (95% CI 435.25-730.29; p<0.00001) and transfusion rate (95% CI 3.56-15.64; OR 7.55; p<0.00001) in RARP compared to ORP and lower transfusion rate in RARP than in LRP (95% CI 1.32-4.96; OR 2.56; p <0.005). Rates for operative time and overall complications were similar for

 

RARP, LRP and ORP. The mean complication rate associated with RARP was 9%, most of them being low grade. Subsequently, a systematic review and meta-analysis conducted by Huang *et al*.[9] compared perioperative outcomes between LRP and RARP from 24 studies, showing lower transfusion (95% CI 1.33-3.26; OR 2.08; p=0.001) and estimated blood loss rates (95% CI 6.95-144.94; p=0.03) in RARP compared to LRP. Overall complication rate was similar between robotic and laparoscopic surgical approaches (15.6% vs 18.3%, p=0.57).

At the same time, Yaxley *et al*.[16] performed the first randomised controlled phase 3 trial comparing 157 patients undergoing RARP vs 151 patients receiving ORP. The trial demonstrated lower estimated blood loss (p<0.001), shorter operative time (p<0.0001), shorter length of stay (p<0.001) and lower intraoperative adverse event rate (2% vs 8%, p=0.02) associated with RARP compared to ORP. The RARP group showed a lower overall complication rate compared to ORP, although it was not statistically significant (9% vs 4%, p=0.052). Moreover, patients who underwent RARP reported less pain during the immediate postoperative period than those receiving ORP (24 hours and 1 week; p<0.0001 and 0.002 respectively). Recently, data based on retrospective and prospective non-randomised studies corroborated the previous findings. Haese *et al*.[69], analyzed a large cohort of 10790 patients treated with RARP and ORP from 2008 to 2016, showing lower blood loss (279 vs 789 ml, p<0.001), transfusion rates (3.5 vs 0.7%, p<0.001) and time to catheter removal (12 vs 7 days, p<0.001) in RARP. Conversely, the study reported shorter operation time in ORP compared to RARP (181 vs 200 minutes, p<0.001). Pompe *et al*.[10], performed a retrospective analysis of a large series of 13924 patients receiving RP from 2005 to 2015, which corroborated improved perioperative outcomes associated with RARP: lower estimated blood loss (p<0.001), lower blood transfusion rates (OR 0.38; p<0.001) and shorter catheterization time (p<0.001).

Despite the benefit of RARP on the perioperative outcomes presented above, the impact of the robotic approach on postoperative complications remains unclear. A recent retrospective analysis[10] reported lower risk of overall complications (OR 0.84; p<0.001) and Clavien-Dindo[70] Grade II (6.8 vs 8.7%, p=0.01) and III (IIIa 2.3 vs 4.3%, p<0.001 and IIIb 1.8 vs 3.2%, p=0.003) complications in RARP patients compared to ORP. Furthermore, Gandaglia *et al*.[67], demonstrated lower readmission and overall complication rates associated with RARP. Conversely, the LAParoscopic Prostatectomy Robot Open (LAPPRO) trial, a recent prospective multicentre non-randomised study[71], analyzed 4003 RP patients showing no significant differences between RARP and ORP for overall readmission rates (8.1 vs 7.1%, p=0.285) and major postoperative complications (1.7 vs 1.9%, p=0.733) defined as Clavien-Dindo ≥IIIb. Finally, Ilic *et al*.[72] conducted a systematic review to analyze the effects of LRP and RARP compared to ORP in prostate cancer treatment. The authors reported no significant differences in overall surgical complications between robotic or laparoscopic and open surgical approaches. In our series, we reported a complication rate of 22.5% in RARP patients, most of them being low grade (92% classified as Clavien I-II)[19].

In summary, RARP is associated with lower blood transfusion rates, estimated blood loss and shorter catheterization time compared to open surgery. However, RARP impact on postoperative complications needs further evaluation. Moreover, the use of standardized

 

reporting systems is mandatory to provide conclusions on a potential benefit of the robotic surgical approach in this context.

**Oncological outcomes**

Oncological outcomes are considered the most relevant outcomes in the setting of an oncological procedure such as RP. Multiple retrospective studies[69,73-75] and a recent randomised trial[16] failed to demonstrate RARP benefit on oncological outcomes in prostate cancer surgical treatment. In 2012, Novara *et al.*[13] presented a systematic review and meta-analysis of 79 papers reporting oncological outcomes after RARP. The comparative analysis showed similar overall PSM (RARP vs ORP: OR 1.21, p=0.19; RARP vs LRP: OR 1.12, p=0.47) and biochemical recurrence (BCR)-free survival (RARP vs ORP: hazard ratio (HR) 0.9, p=0.52; RARP vs LRP: HR 0.5, p=0.14) between robotic, laparoscopic and open surgical approaches. Subsequently, other retrospective analyses reported no differences in oncological outcomes when comparing RARP to ORP. Herlemann *et al.*[73], analyzed a large cohort of patients from Cancer of the Prostate Strategic Urologic Research Endeavor (CaPSURE) who underwent RP between 2004 and 2016, showing equivalent PSM rates (18 vs 15% for pT2, and 9 vs 10% for pT3), lymph node yields (p=0.78) and 5-year BCR-free survival rates (87 vs 85%, p=0.38) in RARP patients compared to ORP. Moreover, a retrospective study conducted by Haese *et al.*[69] corroborate these findings reporting similar 4-year BCR-free survival rate in ORP versus RARP patients (90.8 vs 89.3%, p=0.12). Recently, the first randomised controlled phase 3 trial[16] comparing ORP and RARP has been presented, showing no differences in PSM rates between the two surgical approaches (15 vs 10%, p=0.2). In a subsequent analysis, Coughlin *et al.*[17] reported lower BCR rates for RARP versus ORP at 24 months of follow-up (3 vs 9%, p=0.0199). However, the authors advised caution in the interpretation of these oncological results due to the absence of standardization in postoperative management between the two groups and the use of additional oncological therapies. Furthermore, the first analysis of LAPPRO study[76] showed lower PSM rates for open surgeons in organ-confined disease (10.2 vs 17%) while lower PSM rates in pT3 tumors for RARP vs ORP (33.3 vs 48.1%). Subsequently, a recent update of the LAPPRO study[77] demonstrated no significant differences between robotic and open surgical approaches for recurrent or residual disease at 24 months of follow-up (95% CI 0.59-1.07; p=0.13). Conversely, Thompson *et al.*[78] showed a benefit associated with RARP in terms of BCR observed after the 226 first cases performed robotically by a single surgeon (95% CI 0.47-0.9; HR 0.65).

In this setting, long-term follow-up data were needed to accurately assess RARP impact on oncological outcomes. Rajan *et al.*[74], analyzed a prospective cohort of 885 patients undergoing RARP in a single European centre with a median follow-up of 10.5 years. The authors identified Gleason score, pathological T stage, PSM and preoperative PSA as independent predictors of BCR and salvage therapy-free survival. Moreover, they suggested an optimal long-term oncologic efficacy associated to RARP in prostate cancer treatment (BCR-free survival rate of 81.8% and overall survival rate of 93%). In addition, Porpiglia *et al.*[79] performed a prospective randomised study of 120 patients comparing RARP and LRP with a 5-year follow-up, reporting no differences in oncological outcomes between the two surgical approaches (5-year BCR-free

 

survival 81.6% in both groups). In our series, we reported a BCR-free survival rate of 84.8% and an overall survival rate of 97.7% at 47 months of median follow-up[19].

In summary, current available evidence showed no significant differences in oncological outcomes for RARP versus ORP. It is of note that most of the studies conducted on this regard are single-surgeon, single-centre and present a short follow-up of the oncological disease[80]. In this setting, further investigation and long-term follow-up data are needed to evaluate the benefit of RARP relative to ORP.

**Functional outcomes**

Functional outcomes after RP consist mainly of urinary continence and erectile function. Their role is essential in quality of life of prostate cancer patients after surgery. A number of historical and contemporary studies have assessed urinary continence and erectile function recovery after surgery, comparing the efficacy of different surgical approaches. Recently, the randomised controlled trial conducted by Yaxley *et al*.[16] reported no significant differences in terms of early urinary continence (p=0.09 and p=0.48) and erectile function (p=0.45 and p=0.18) recovery at 6 and 12 weeks post-surgery between RARP and ORP. Subsequently, the update performed by Coughlin *et al*.[17] confirmed the previous findings showing no differences in functional outcomes at mid-term follow-up (6, 12 and 24 months) between open and robotic surgical approaches. Conversely, the first analysis of the prospective LAPPRO study[76] demonstrated a RARP benefit on erectile function recovery at 3, 12 and 24 months in low and intermediate risk patients compared to open surgery (potency recovery from 32 to 53% vs 16 to 39% in RARP vs ORP; p<0.001). The subsequent update of these data by Nyberg *et al*.[77] showed a significant RARP benefit over ORP in terms of erectile function recovery at 24 months of follow-up (68 vs 74%, 95% CI 0.57-0.91; p=0.006). However, no differences in incontinence rates between RARP and ORP were observed (19 vs 16%, p=0.053).

Furthermore, several historical retrospective studies have provided diverging results in terms of functional outcomes after RP. Hu *et al*.[66], reported a significant benefit for open surgery over minimally invasive techniques for incontinence and potency rates. Conversely, in 2012 Ficarra *et al*.[5,6] performed a systematic review and meta-analysis of the literature showing an advantage for RARP in both incontinence and potency rates. Later, a prospective non-randomised multi-centre trial[81] analyzed 2500 patients undergoing RARP or ORP between 2008 and 2011. The results of the study showed no significant difference in postoperative incontinence rates at 12 months for RARP vs ORP (21.3 vs 20.2%, OR 1.08; 95% CI 0.87-1.34). On the other hand, there was demonstrated a RARP benefit over ORP on erectile dysfunction rates at 12 months (70.4 vs 74.7%, OR 0.81; 95% CI 0.66-0.98). Other prospective studies demonstrated better functional outcomes of RARP compared to LRP. Porpiglia et al.[79], reported a higher probability of achieving continence (OR 2.47, p<0.021) and potency (OR 2.35, p<0.028) over time in patients undergoing RARP compared to those patients receiving LRP.

Recently, contemporary retrospective studies also failed to demonstrate a consistent benefit of robotic surgery in terms of functional outcomes. Herlemann *et al*.[73], showed better early urinary continence recovery rates for ORP compared to RARP (p<0.01) but no significant differences were reported in

 

late urinary continence recovery rates or in sexual function scores between the two surgical techniques. Haese *et al*.[69], reported a small benefit on urinary continence rates at 1-year after surgery for RARP vs ORP (90.3 vs 88.8%, p=0.01), although it was not clinically significant. On the other hand, the study results showed no difference in 1-year erectile function recovery rates (83.3 vs 80.3%, p=0.3). Moreover, Capogrosso *et al*.[82], analyzed a retrospective cohort of 2364 patients treated with either open or minimally invasive RP in 2008-2015 showing no improvement in terms of recovery of erectile function after RP in the last decade. Finally, a recent analysis of the LAPPRO study[11] demonstrated no significant differences in self-assessed quality of life at 3, 12 and 24 months after RARP or ORP.

Of note, in this setting, contemporary retrospective studies evaluated the volume-functional outcome relationship for RP, suggesting that the experience of the surgeon remains a crucial factor for a successful outcome[2]. Gershman *et al*.[83], performed a retrospective analysis of a 1686 patient cohort treated with OPR, LRP and RARP by high-volume surgeons in two high-volume centers. The authors concluded that surgical technique was not associated with either functional outcome when treating prostate cancer patients in a high-volume hospital by high-volume surgeons (important urinary incontinence ORP 5.8%, LRP 5.1%, RARP 6.8%; p=0.62 and important sexual dysfunction ORP 37.2%, LRP 36.1%, RARP 37.5%; p=0.95). In addition, Thompson *et al*.[78] reported a single-surgeon RARP series demonstrating an improvement of functional outcomes as the learning curve progressed. Urinary continence and erectile function achieved better outcomes for RARP compared to ORP after 139 and 151 cases, respectively.

In summary, current evidence show comparable functional outcomes between open and robotic RP, with a small non-clinically significant benefit for RARP described in few studies[12]. In this setting, contemporary analyses are required to reassess functional outcomes in the emerging era of experienced robotic surgeons[80].

**Future perspectives**

The advent of new technologies and refinements in the surgical technique are continuously evolving. Novel surgical platforms are being developed in the field of minimally invasive surgery. In this context, a new robotic system has been recently approved by the FDA in 2018[80]. The Da Vinci SP System (Intuitive Surgical Inc)[58] consists of a 25-mm multichannel port that includes an articulating robotic camera, three 6-mm double-jointed articulating instruments, and a 6-mm accessory laparoscopic instrument[84]. This platform appears to be a feasible option in the surgical treatment of prostate cancer, offering the possibility to perform RP by either perineal or transabdominal approach and presenting potential benefits on postoperative pain, reduced number of surgical incisions and improved surgeon visualization. Moreover, Chang *et al*.[85] presented their recent experience with the Revo-i (Meere Company Inc), which consists of a control console, four-arm robotic operating cart, a vision cart and reusable endoscopic instruments[84]. The surgeons reported satisfaction with this new platform, which could reduce the cost of robotic surgery. Other new robotic systems currently under development are the Verb Surgical System (Santa Clara, CA), HUGO System (Medtronic), Avatera System (Jena, Germany), Medicaroid System, TransEnterix System (Morrisville, NC)

 

and Titan Medical (Sport Surgical System).

On the other hand, in order to improve quality of life and functional outcomes of prostate cancer patients after surgery, few authors have explored the application of new synthetic or biological materials on the neurovascular bundles after nerve-sparing RARP. Porpiglia *et al.*[86], performed a comparative analysis of 470 patients undergoing nerve-sparing RARP from 2015 to 2016, of which 136 patients underwent chitosan membrane application on the NVB showing a higher potency recovery rate at 1 month (36.76 vs 25.88%, p=0.02) and 2 months (52.2 vs 39.22%, p=0.01) after surgery.

Finally, new surgical treatment scenarios have been proposed for prostate cancer, such as the role of surgery in the treatment of oligometastatic disease[87]. In this setting, Jang *et al.*[88] conducted a retrospective study comparing oncological and perioperative outcomes of 79 oligometastatic prostate cancer patients treated with RARP or androgen deprivation therapy (ADT). The results showed longer progression-free survival (75 vs 28 months, p=0.008) and cancer-specific survival (p=0.002) in RARP-treated compared to ADT-treated patients. However, further prospective studies are needed in this setting.

## Conclusions

The advent of robotic surgery and new technologies has completely redefined the surgical treatment of prostate cancer in the last two decades.

The benefits of RARP are those related to minimally invasive techniques: lower estimated blood loss and transfusion rates and shorter catheterization time compared to open surgery. Functional and oncological outcomes appear to be comparable between the two surgical approaches based on current available evidence. Moreover, recent technical modifications to RARP have been proposed to improve functional outcomes in prostate cancer patients. However, further prospective data and long-term follow-up are needed to evaluate the clear benefit of RARP on postoperative complications, functional and oncological outcomes.

## Conflicts of interest

The authors declare no conflicts of interest.

 

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