Review Article

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Lessons learned from 12,000 robotic radical prostatectomies: Is the journey as important as the outcome?

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Robotic radical prostatectomy (RARP) is a standardized treatment for localized prostate cancer, which provides better functional outcomes and similar oncological outcomes compared to open approaches. Here, we share our experience of 12,000 RARPs by describing the outcomes of the procedure in terms of positive surgical margin (PSM), continence, and potency as well as by presenting our detailed surgical technique with recent modifications. On cancer control, the PSM rates were 5.8% and 26.1% in T2 and T3, respectively. On the premise of not compromising oncologic outcomes, a tailored approach to individual patients is essential. Even if an extracapsular extension is suspected, neurovascular bundle (NVB) tailoring can be applied using an anatomical landmark to preserve maximal nerve tissue with a negative margin. We developed a nomogram as a useful tool for deciding the degree of tailoring. For improvements of functional outcomes, we used athermal retrograde early release with a toggling technique, wherein the nerve dissection from the bottom helps with blood loss and allows for smooth NVB releasing. Additionally, we recently performed a new minimal apical dissection/lateral prostatic fascia preservation technique. As a result, our 1-week continence rate was 37% and the 6-week rate was 77.6%. In addition, the potency rates in our study were 69%, 82%, and 92% at 3 months, 6 months, and 1 year, respectively (preoperative Sexual Health Inventory for Men scores >21 & bilateral full nerve spared).

Keywords: Prostate; Prostatectomy; Prostatic neoplasms; Robotics

INTRODUCTION

Radical prostatectomy is a treatment of choice for localized prostate cancer, which has evolved from open surgery to laparoscopy and robotic radical prostatectomy (RARP) [1]. As the robotic techniques developed and surgeons' understanding of the robotic platform became profound, RARP showed better functional outcomes and comparable results for oncologic outcomes [2-4].

It is important to avoid a positive surgical margin (PSM) in prostatectomy. Currently, it is believed that nerve-sparing is not all or nothing; partial nerve preservation is possible while avoiding PSM in patients with extracapsular extension (ECE). In these cases, a tool for predicting the extent of ECE before surgery was needed to obtain a negative surgical margin; therefore, we developed a nomogram. We also validated an anatomic nerve-sparing grading system that uses landmark anatomic features during prostatectomy.

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To improve functional outcomes, we continuously developed a technique for neurovascular bundle (NVB) preservation that is basically athermal retrograde early release. This process has been performed using the up-and-down toggling technique of a 30-degree lens. Recently, we performed minimal apical dissection without opening of the endopelvic fascia and early ligation of the dorsal vein; this has improved our early functional outcomes.

In this review, we will share our experience of 12,000 RARPs, which were performed by a single surgeon (Vipul R. Patel), with regard to PSM, continence, potency, and technical principles.

POSITIVE SURGICAL MARGIN

The main outcomes of radical prostatectomy are traditionally reported as a *trifecta* of rates [5]. The three factors are urinary continence, potency, and biochemical recurrence (BCR)-free survival rates after surgery. However, since immediately after surgery we only know the PSM, rather than the BCR [6], we suggested the *pentafecta* as a new standard for reporting outcomes [7]. Although functional outcomes are coming into focus as important results after radical prostatectomy, tumor control is the most important aspect of the surgery. PSM is known to be an independent predictive factor of BCR, local recurrence, and the development of distant metastasis.

In several studies, the PSMs for pT2 and pT3 were reported to be approximately 8.92% and 33%, respectively. The results for the PSMs of representative studies are summarized in Table 1 [6,8-16]. According to our study, the overall PSM rate was 14% to 20.8%, specifically 5.8% in pT2 and 26.1% in pT3. In high-risk (D'Amico classification) patients, the overall PSM rate was 25.1%, with 8.6% in pT2, 26.6% in pT3a, and 53.3% in pT3b [17].

Efforts to reduce PSM have led to the determination of risk factors for PSM. Our previous findings demonstrated that factors that correlated with the aggressiveness of cancer, such as clinical/pathologic stage and tumor volume, were the most important predictors for PSM. In terms of preoperative factors, the clinical stage was the only significant predictive factor, with higher PSM rates for T3 versus T1c (odds ratio [OR], 10.7; $p<0.0001$) and for T2 versus T1c. With regard to perioperative variables, pathologic stage ($p<0.0001$) and percentage of tumor in the surgical specimen ($p=0.0022$) were the only independent predictive factors for PSM [18]. In high-risk patients, Kang et al. [17] reported that the only significant predictive factors of PSMs were pathological outcomes such as the percentage of tumors in the specimen and the pathological stage ($p<0.001$, both).

Therefore, to reduce PSM in high volume/stage tumors, it is necessary to remove suspected tissues soundly outside the prostate capsule. Indeed, previously, all the nerve tissue besides the lobe was radically removed to control the margin of the ECE; this approach was known as the "all-or-none" concept, in that the entire nerve bundle was either preserved or removed. However, later studies have found that even high-risk tumors are often organ-confined tumors and that even with ECE, tumors are confined within a few millimeters. Thus, it seemed unnecessary to remove all the nerve tissue of the lobe to control the margin in the patient with ECE.

To date, it has not been possible to standardize the decision-making process in terms of when to take a more or less conservative approach. Interestingly, as indicated in several papers, 85% of the ECEs are within 3 mm of the prostate capsule, and in 97.6%, within 5 mm [19]; thus, we used these statistics for our outcomes. Previously, we investigated 11,794

Table 1. Positive surgical margins (PSMs)

Reference	Number of patients	Pathological stage (%)		PSM (%)		
		pT2	pT3	pT2	pT3	Overall
Atug et al. [8]	140	87.9	9.3	18	53.8	18.5
Badani et al. [9]	2,766	77.7	22	13	35	12.3
Mottrie et al. [10]	184	62.5	37.5	2.5	37.1	15.7
Rozet et al. [11]	133	88.5	11.5	13	20.9	19.5
Murphy et al. [12]	400	70	29.8	9.6	42.3	19.2
Rocco et al. [13]	120	73	24	17	34	22
Yaxley et al. [14]	157	-	-	3	11	15
Sooriakumaran et al. [15]	1,792	70.4	29.0	17.0	33.3	21.8
Nyberg et al. [16]	1,847	70	28	-	-	22
Patel et al. [6]	4,000	76.2	22.9	5.8	26.1	10.8

-, not mentioned.

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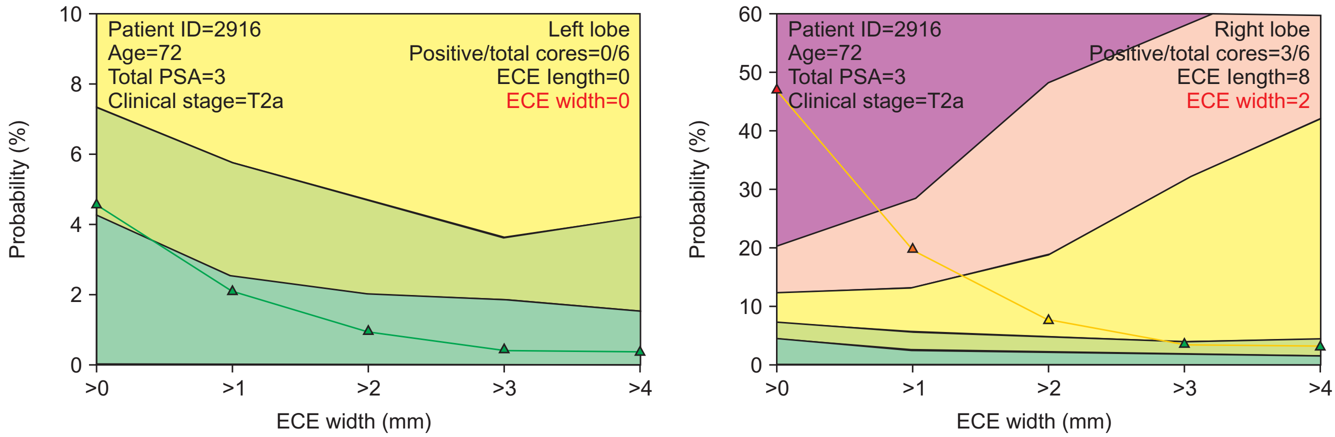

Fig. 1. Output yielded by the graphical user interface for a 72-year-old patient with T2a clinical stage and a prostate-specific antigen (PSA) level of 3 ng/mL. The left lobe had no positive cores, while the right lobe had three positive cores, all with Gleason score >7. Produced with permission from Vipul R. Patel. ECE, extracapsular extension.

Table 2. Continence outcomes

Reference	Number of patients	Age (y)	Follow-up (mo)	Definition of continence	Technique	Continence (% at n months)			
						1	3	6	12
Joseph et al. [23]	325	60	6	No pads	No reconstruction	56	93	96	-
Zorn et al. [24]	300	59	24	No pads	No reconstruction	23	47	68	90
Rocco et al. [22]	31	66	6	No pads or 1 safety pad	Posterior reconstruction	84	92	-	-
Tewari et al. [25]	182	61	6	No pads or 1 small liner	Ant/post reconstruction	83	91	97	-
Shikanov et al. [26]	380	58	24	No leak	No reconstruction	-	57	80	92
Patel et al. [27]	1,100	58	18	No pads	Ant/post reconstruction	68 (6 wk)	85	96	97
Haglind et al. [28]	1,847	63	12	<1 pad	Not mentioned	-	-	-	79
Coughlin et al. [29]	157	35–70	24	No pads	Not mentioned	-	-	84	90
Patel[a]	100	58	5	No pads	MAD/LPFP	78 (6 wk)	88	93	-

MAD/LPFP, minimal apical dissection and lateral prostatic fascia preservation technique applied.
[a]:Unpublished data.

lobes of the prostate and developed a nomogram that allows the generation of a graph showing the likely level of extension (Fig. 1). Therefore, we have a better chance of getting a negative margin considering 3 mm out during RARP [19]. This model is currently undergoing validation.

Additionally, we have studied the anatomy of the NVB and found vascular landmarks coming off the obturator nerve, in the form of small arteries, which assist in determining its location in relation to the prostate and NVB. We presented this landmark artery as a criterion for this nerve-sparing tailoring, which was pathologically validated [20].

The main point of partial nerve-sparing is margin control by sacrificing about 3 mm of nerve tissue based on the landmark artery that occupies the most medial portion of the NVB. Lateral to the plane of dissection of this artery will give the operator at least 3 mm of clearance from the prostate capsule. The anatomic grading of the proportion of NVB-saving based on the landmark artery and the grading were categorized and are described in the potency section.

CONTINENCE

Functional outcomes, such as continence and potency, were the main focus of the current study. It is not sufficient to only consider the removal of the prostate; functional outcomes that are related to the patient's quality of life must also be considered. During a decade of evolution up until the present day, we have published every technique that we perform in our surgeries.

Excellent continence outcomes have been consistently reported after RARP, with the 1-year continence rate reaching >90% in most of the large, single-center, prospective studies [2,21]. Although we previously reported a 96.4% continence rate 1 year after RARP, the early recovery of urinary continence remains a challenge (Table 2) [7,22-29].

The results for early continence outcomes have been reported by various researchers and have been shown to be approximately 58.5% at 1 month and 79% at 3 months [6]. In our study, the continence rate was 67.7% at 6 weeks postoperatively and 85.4% at 3 months postoperatively. After a recent modification of our technique, which maximized preservation of periurethral tissue around the urethral stump avoiding the classic incision of the endopelvic fascia (Fig. 2), our 1st and 6th-week continence (no pads/d) rate was increased to 37% and 77.6%, respectively (unpublished data).

Postoperative continence recovery is affected by a number of factors and possibly by both patient characteristics and surgical techniques [30]. Among the preoperative characteristics of patients, age, body mass index, prostate volume, and comorbidities are known to affect the postoperative continence recovery [31,32]. In addition, Shikanov et al. [33] reported that age (OR, 0.97; p=0.002), baseline International Prostate Symptom Score (IPSS) (OR, 0.98; p=0.02), and Sexual Health Inventory for Men (SHIM) scores (OR, 1.02; p=0.005) were independent factors for postoperative continence. With regard to surgical techniques, van der Poel et al. [34] reported that they were influenced by the amount of fascia preservation of the lateral aspect of the prostate, which was in line with our recent technique.

SURGICAL TECHNIQUES FOR CONTINENCE

1. Bladder neck reconstruction

The vesico-urethral anastomosis (VUA) is a critical step during RARP, and it is essential to reduce the bladder neck diameter before starting VUA under some circumstances, including cases with large prostates or large median lobes. Before starting the bladder neck reconstruction, it is essential to check the position of the ureteric orifices and their distance from the edge of the bladder neck. Bilateral plication over the lateral side of the bladder is subsequently performed; the suture begins laterally and runs medially until the bladder neck size matches that of the membranous urethra. The same suture then runs laterally back to the beginning of the suture and is tied [35].

We do not generally perform bladder neck preservation because it can be associated with PSM, especially in high-risk cancer, as it can increase the continence rate by reconstructing the bladder neck later. From March to November 2006, 279 patients underwent RARP at our institution; approximately 27% (74) of these patients required bladder neck reconstruction. In this group of patients, 12.7% resumed pad-free continence immediately after the removal of the Foley catheter. The short-term pad-free continence rates at 3, 6, and 12 months after surgery were 91.8%, 97.3%, and 97.3%, respectively [35].

2. Periurethral suspension stitch

The use of a periurethral retropubic suspension stitch has been described by Walsh [36] in an open radical retropubic prostatectomy series, and Patel et al. [37] were the first to describe this suspension technique in RARP. We added the periurethral suspension stitch to our standard RARP technique with the initial purpose of improving the hemostasis of the dorsal venous complex and facilitating dissection of the prostate apex and urethra. The continence mechanism is the anatomical support of the urethra by the suspension of the tissues ventral to the urethra on the fascia of the pubic bone [38]. We reported that the suspension stitch resulted in a significantly shorter interval to the recovery of continence (suspension group: median, 6 weeks; 95% confidence interval [CI], 6.387 to 8.288 vs. non-suspension group: median, 7 weeks; 95% CI, 7.558 to 11.612; log-rank test, p=0.02) and higher continence rates 3 months after the procedure (p=0.013, 94 without suspension vs. 237 with suspension) [37].

3. Posterior reconstruction

The posterior reconstruction technique was first de-

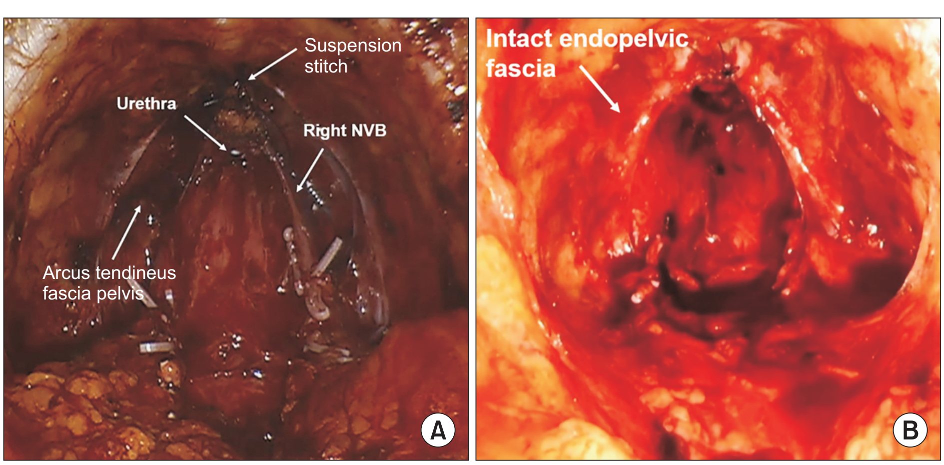

Fig. 2. (A) Left. Existing method: a suspension stitch and incised endopelvic fascia were observed. (B) Right. Minimal apical dissection: an intact endopelvic fascia was observed.

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scribed by Rocco et al. [22] in an open approach. It was further investigated and modified in detail as in a review of literature on RARP [39,40] and the most recent description of the technique was implemented in our study [38]. Briefly, we performed the first layer of the reconstruction between the remaining Denonvillier's fascia and the posterior aspect of the rhabdosphincter/posterior median raphe. The second layer of reconstruction was then performed between the bladder neck and the posterior urethra. The supposed mechanism for achieving continence is the realignment of the tissues dorsal to the bladder and urethra, which in turn provides a tension-free VUA and the ability to recreate posterior support [38] (Fig. 3).

Our modified technique for posterior reconstruction of the rhabdosphincter resulted in a significantly shorter interval to the recovery of continence and higher continence rates in the early period after catheter removal (23%/43% and 29%/52%; p=0.045 and p=0.016 at 1 and 4 weeks, respectively). A lower incidence of cystographic leaks was also observed in the posterior reconstruction group (0.4% vs. 2.1%; p=0.036) [41,42].

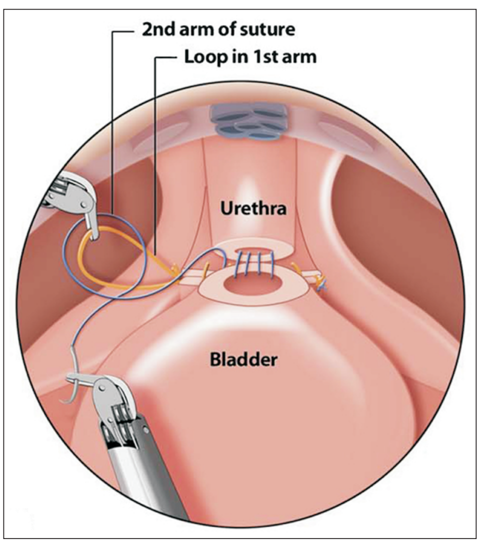

Fig. 3. Posterior reconstruction (second layer suture). The two-layer reconstruction involved the realignment of the sphincteric muscle to the Denonvillier's fascia, followed by a second suture that fixed the posterior bladder wall to the urethra. Produced with permission from Vipul R. Patel.

4. Minimal apical dissection

Recently, we modified our techniques regarding apical dissection. After the bladder is dropped, posterior dissection and retrograde nerve-sparing are done prior to opening the endopelvic fascia. Then, the endopelvic fascia is opened closer to the prostate instead of opening it closer to the pelvic sidewall, thus leaving all other tissues behind and all ligaments in place. After finishing the NVB dissection, the dorsal venous complex (DVC) is divided and sutured with running 2-0 Quill suture (Fig. 2). We compared the continence outcomes of the minimal apical dissection and lateral prostatic fascia preservation (MAD/LPFP) technique with a control group that was created by propensity-score matching from a cohort of 2,064 patients who underwent our conventional RARP (c-RALP) technique and achieved earlier continence and potency recovery. The mean time to achieve continence was 32 days in the MAD/LPFP group vs. 87 days in the c-RALP group (p<0.001), and mean time to potency was significantly shorter in the MAD/LPFP group than in the c-RALP group (37 vs. 156 days, p<0.001) (unpublished data). Continence (no pads/d) rates were 77.6% vs. 44.7% at 6 weeks and 87.9% vs. 66.7% at 3 months (MAD/LPFP vs. control group) (p<0.001, both) (Table 2, unpublished data). Similarly, de Carvalho et al. [43], using a similar technique of MAD, reported that continence was reached immediately in 85.9% of the patients and in 98.4% at 3 months postoperatively.

POTENCY OUTCOMES

Although the proficiency of the technique (learning curve) is important to maximize the functional outcome, the

Table 3. Potency outcomes of representative studies

Reference	Number of patients	Age (y)	Follow-up (mo)	Overall potency (% at n months)			
				3	6	12	18
Menon et al. [50]	1,142	60	-	-	-	70	100
Zorn et al. [24]	300	59	24	47	58	74	77
Rocco et al. [13]	120	63	12	31	43	61	-
Finley et al. [51]	62	57	> 18	32	57	77	90
Shikanov et al. [26]	380	58	24	57	63	82	-
Sooriakumaran et al. [15]	1,792	63	24	58	-	73	-
Coughlin et al. [29]	157	35–70	24	-	41	53	-
Patel et al. [27]	404	58	18	69	82	92	97

fundamentals of the technique itself could be more important. Therefore, we have focused on this aspect by continuously improving and modifying the surgical technique.

The surgical anatomy of the nerve-sparing radical prostatectomy was initially laid down by the pioneering work of Walsh and Donker [44] who documented the concept of the NVB in relation to the prostate. The preservation or return of potency post radical prostatectomy is one of the most challenging and variable parts of prostatectomy. "Nerve-sparing" means NVB preservation, which means preservation of the complex of the tissues lateral to the prostate. During this procedure, the principles of athermal and atraumatic manipulation for nerve preservation are considered to be the most important.

In many studies, age, Charlson score, baseline International Index of Erectile Function-6 (IIEF-6) score/SHIM score, and the performance of an NVB-sparing procedure were independent factors for predicting erectile function recovery [33,45]. Several factors affect the recovery of erectile function, including age, preoperative sexual function, and technical aspects during surgery; however, cavernosal nerve preservation is considered to be the most important factor for recovery [46-48]. Kang et al. [49] also showed that the surgeon's subjective NVB-sparing score system could predict potency recovery. In addition, they reported that when more than a certain amount of tissue applicable to NVB-sparing grade 3 is preserved, the preservation of more nerve tissue results in incrementally shorter times to potency recovery. In our study, by using SHIM, IIEF-6, and subjective evaluations, the potency recovery rates at 3, 6, 12, and 18 months were about 38.8%, 65.4%, 73.9%, and 95%, respectively (Table 3) [6,13,15,24,26,27,29,50,51].

TECHNIQUES OF NVB PRESERVATION

Our technique was performed in a retrograde manner, using the method of toggling. This process is not only about preserving the nerves, but also about manipulating the nerves carefully without using energy or traction and preventing the neurapraxia response.

1. Athermal retrograde approach of NVB preservation

Our techniques involve the use of an athermal technique to avoid injury of the cavernosal nerves; we believe that this technique is now performed in most institutions [52-55]. The approach to NVB-sparing can be antegrade (from the prostate base to the apex), retrograde (from the apex to the

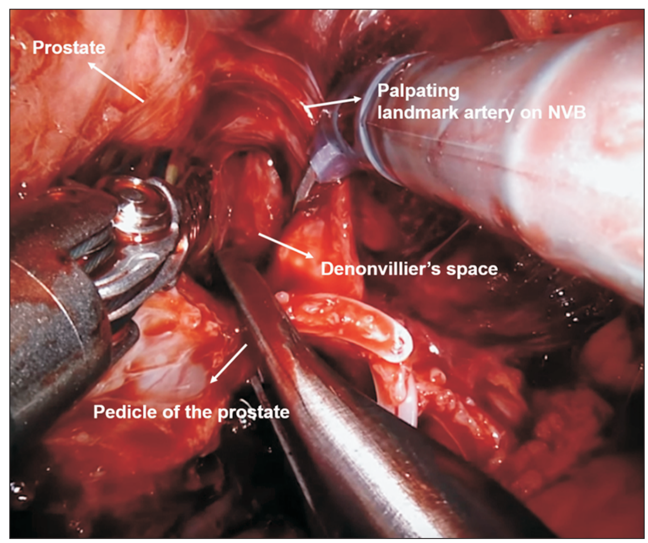

Fig. 4. Neurovascular bundle (NVB) penetration from the Denonvillier's fascia to the prostatic anterior aspect; the palpating landmark artery on the NVB is clearly observed.

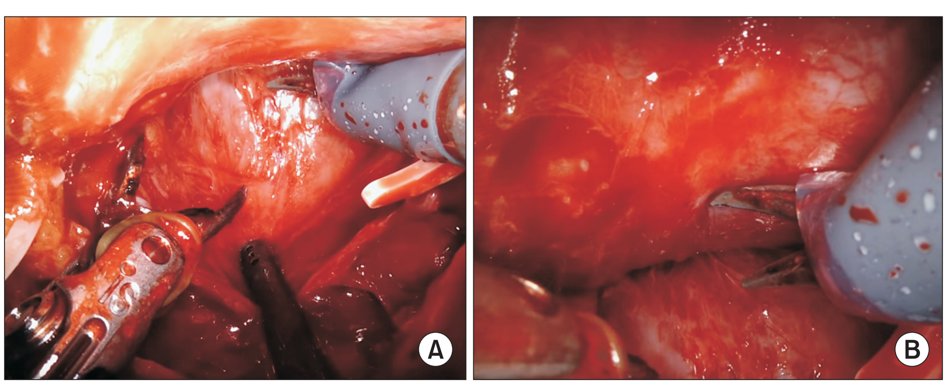

Fig. 5. (A) The 30 degrees down view is shown. The left vas deferens is retracted with the fourth arm and the right vas is retracted by the assistant. The dissection plane between the prostate fascia and the neurovascular bundle (NVB) is rarely seen in this view. (B) The 30 degrees up view is shown. In this view, we can easily access the proper plane for interfascial dissection. If the adhesion is not severe, we can see the already penetrated space between the prostatic anterior aspect and Denonvillier's fascia following separation of the NVB.

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base), or a combination of the two. The antegrade approach is a heritage of a pure laparoscopic procedure, which has various methods [56,57]. However, since all the procedures for NVB-sparing are performed from the inside, the elements of prostatic vasculature are not easily identified. There is also a high risk of falling into the intrafascial plane, which is not the natural plane between the prostate and NVB. This approach also increases the potential risk of capsular incision or PSMs [58].

The retrograde method originates from the open retropubic radical prostatectomy; the NVB approach is made from the outside, and the NVB is gently detached from the prostate. In contrast to open surgery with limited visualization, the retrograde approach during RARP allows for fine tailoring of the NVB through enhanced identification and delineation of the NVB and the surrounding tissues. Because the NVB is very close to the pedicle of the base of the prostate, we believe that releasing it in a retrograde manner can prevent inadvertent clipping and the increased risk of PSMs (Fig. 4). In addition, releasing the nerve bundles before the apex is released from the base decreases the traction and positions it in a good plane [59]. A major advantage of this technique is that the NVB is released away at the mid-prostate, where the nerves converge to form a more condensed NVB [60].

2. Toggling technique (30-degree lens up and down in DaVinci Xi)

Since we used DaVinci Xi (Intuitive Surgical, Sunnyvale, CA, USA), we could dissect the prostate using a toggling technique, which means changing the camera from 30 degrees down to up (Fig. 5).

Using this technique, the NVB can be released from below, achieving a good plane between the prostate fascia and the NVB. Through this avascular plane, the surgeon can release the NVB considerably higher into the prostate. The camera can then be flipped 180 degrees downward, and toggling can be done once again from 30 degrees up to 30 degrees down. Next, we can attend to the anterior and move into the space created posteriorly, albeit with much less bleeding (Fig. 6). Thus, this technology is most useful because understanding of the anatomy allows for better use of the technology to release the NVB and flipping of the pedicle.

3. Anatomic nerve-sparing grade

1. Grade 5 (≥95% nerve sparing): The dissection plane is at the medial side to the landmark artery, just outside the prostatic fascia between the prostate and the NVB. Intraoperatively, we can observe a pink coloration on the prostate with an absence of fatty tissue; this is the interfascial plane (Fig. 7).
2. Grade 4 (75%): The dissection plane is between the landmark artery and the prostatic capsule across the NVB. We can observe a strip of fat over the prostate with an absence of arterial vessels. In cases with a minimal ECE, this could be an adequately safe margin.

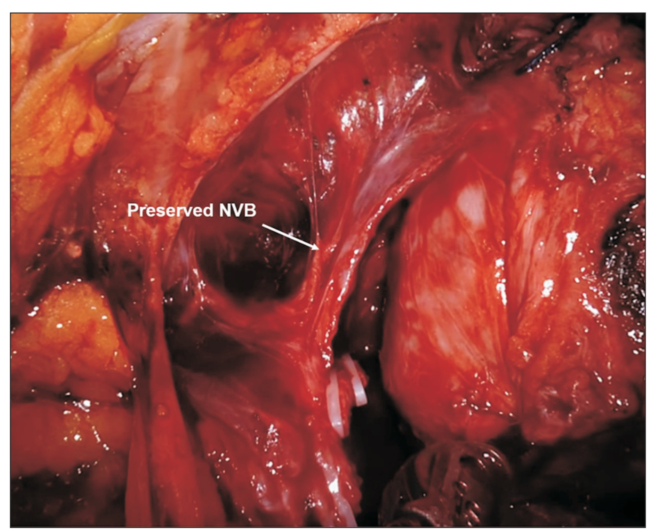

Fig. 6. Neurovascular bundle (NVB) separation. The NVB is completely and easily saved by retrograde early release on the mid-prostate level.

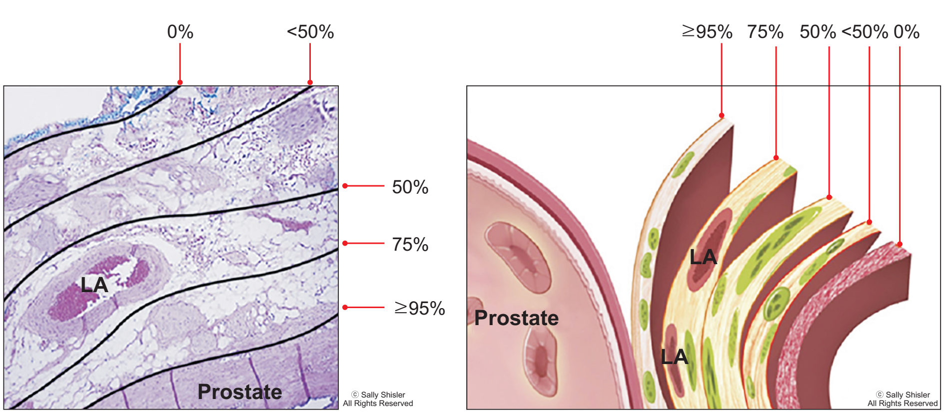

Fig. 7. Cross-section of the neurovascular bundle, represented as a histology slide (left) and a diagram (right), demonstrating our graded approach to nerve-sparing. Several degrees of partial nerve-sparing can be obtained when careful attention is given to the anatomic cues that are discussed. Produced with permission from Sally Shisler. LA, landmark artery.

3. Grade 3 (50%): The dissection plane is at the landmark artery's lateral aspect. We can observe a fat strip over the prostate, with the landmark artery.
4. Grade 2 (<50%): The dissection plane is several millimeters lateral to the artery. We can observe a thick fat strip over the prostate with embedded arteries. In this plane, the most lateral aspect of the NVB is preserved.
5. Grade 1 (0%): This represents a wide resection of the NVB. The correct plane of dissection is confirmed by the presence of the levator fascia, which is not incised.

Our study has some limitations. First, the specific data on the MAD are still being analyzed and will be reported in a future publication. Second, the 12,000 RARP procedures were performed by a single surgeon and the analysis of the learning curve was insufficient. Future data will include perioperative parameters and complication rates as well as oncologic and functional outcomes.

CONCLUSIONS

In this review, we focused on the oncologic outcomes, represented by PSM, and functional outcomes, represented by continence and potency, in terms of surgical principle and technique. This surgical journey was to improve functional outcomes while maintaining negative surgical margins. Therefore, concepts such as NVB-saving by early retrograde release, partial nerve-saving by grading system, ECE nomogram, landmark artery criterion, and MAD have been introduced and developed.

After 12,000 cases of surgery, the surgeons can still learn and improve their skills, despite there being no huge surgical advancements. All patients want the full pentafecta, but sometimes the factors that affect this pentafecta may be out of the surgeon's control. Therefore, the surgery should aim to treat each patient with a modest attitude, acknowledging that every patient is different.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

AUTHORS' CONTRIBUTIONS

Research conception and design: Sung Gu Kang and Ji Sung Shim. Data acquisition: Fikret Onol and K. R. Seetharam Bhat. Drafting of the manuscript: Ji Sung Shim. Critical revision of the manuscript: Sung Gu Kang. Supervision: Vipul R. Patel. Approval of the final manuscript: all authors.

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