A review of technical progression in the robot-assisted radical prostatectomy

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Abstract: Since the advent of the robotic surgery, its implementation in urology has been both wide and rapid. Particularly in extirpative surgery for prostate cancer, techniques in robotic-assisted radical prostatectomy have—and continue to—evolve to maximize functional and oncologic outcomes. In this review, we briefly present a historical perspective of the evolution of various robotic techniques, allowing us to contextualize contemporary robotic approaches to radical prostatectomy.

Keywords: Techniques; robotic prostatectomy; advancements

Introduction

The robot-assisted radical prostatectomy (RARP) was first reported by Binder and Kramer in 2001 (1). Since its initial descriptions, the technique was rapidly adopted and has become the most commonly offered surgical treatment for prostate cancer (2). As the robotic approach became more popular and various techniques evolved, greater emphasis was made to improve functional urinary and sexual outcomes while maintaining oncologic control. Greater understanding of the periprostatic anatomy combined with developing surgical techniques with the robotic platform have allowed the previously "cookie cutter" radical prostatectomy to become a surgery that is tailored to the specific needs of the patient to maximize outcomes (3). In this review, we aim to highlight various techniques in the robotic era that have been developed to optimize functional outcomes in the radical prostatectomy patient.

Anterior versus posterior approach

The earliest RARP technique was naturally derived directly from the laparoscopic approach, which was popularized in the late 1990's and early 2000's as the Montsouris Technique (4,5). This transperitoneal approach, which involved early posterior dissection and release of the vas deferens and seminal vesicles prior to opening the space of Retzius, was eventually coined as the "posterior approach", given the stark contrast to the open technique as described by Dr. Walsh (6). After gaining early experience with a robotic Montsouris approach, Dr. Menon's team in Detroit described a more anatomical approach that was more closely derived from the open retropubic experience and was later formalized as the Vattikuti Institute Prostatectomy (7,8). This minimally invasive departure from the "posterior" Montsouris Technique involved opening the space of Retzius as the first step, much like the open approach, and was eventually coined as the "anterior approach". Although neither of these approaches were associated with superior outcomes, this early divergence in two distinctly different techniques formed two schools of thought regarding preference of technique.

Bladder neck preservation (BNP)

BNP aims at improving urinary functional outcomes

in post-prostatectomy patients but have remained controversial as it is weighed against the risk of increased positive margin rates. Two meta-analyses reported conflicting findings of BNP with one study in 2013 demonstrating good continence and equivalent oncologic outcomes (9), and another in 2017 demonstrating possible increases in base-positive margins (10). The 2013 analysis by Smolski *et al.* included 31 original studies and two review articles involving BNP verses bladder neck reconstruction in open, laparoscopic and robotic radical prostatectomies. Overall, BNP was found to have no effect on positive surgical margins and BNP was associated with improved overall continence and improved early continence. The 2017 analysis by Bellangino *et al.* included 15 studies which reported overall and site-specific positive surgical margin rates following BNP prostatectomy and included open (8 studies), laparoscopic (3 studies), robotic (3 studies) and both open and robotic (1 study) approaches. Overall, the data suggested that BNP may be associated with an increase of base-positive margins. However, in regards to both analyses, deriving a conclusion without delving into individual patient consideration would be too much of an oversimplification, and BNP remains an oncologically investigated technique.

Deliveliotis (2002) first reported cases utilizing BNP with improved early return to continence in open radical prostatectomy patients (11). One of the major challenges of a BNP in RARP was that the surgeon could not rely on palpation of the foley catheter and balloon to localize the bladder neck and urethra. The standard technique of bladder neck dissection in RARP was imprecise and often resulted in a wide bladder neck that required reconstruction (typically by means of a tennis racquet repair). Freire *et al.* (2009) was the first to describe a technique of BNP in RARP which utilized the fourth robotic arm to provide anterocephalad tension on the bladder. The traction allowed for delineation of a detrusor "ridge" where the bladder tissue ends and prostatic tissue begins and served as an anatomic landmark for the dissection. After the bladder neck was dissected 270 degrees anteriorly, the foley catheter was then passed through the opening and tension held on the catheter by the assistant using a laparoscopic grasper. In Freire's description, the functional outcomes of patients undergoing BNP (n=348) were compared to those with the standard technique bladder neck dissection (n=271). They observed 94.1% of the BNP group reported improved urinary function scores at 24 months versus 86.8 in the standard technique group, and 65.6% of the BNP group reported complete continence (defined as zero pads per day) at 4 months *vs.* 26.5% of the standard technique group (12). Hashimoto *et al.* (2018) performed a retrospective multivariate analysis on 199 RARP patients comparing the anterior BNP technique with a lateral BNP technique, which was first reported by Jeong *et al.* and known as ultradissection of the lateral bladder neck. The results of this analysis found the lateral BNP technique to be independently associated with urinary continence recovery (P<0.01) with good oncologic outcomes (13,14).

Rhabdosphincter reconstruction:

In 2001, Rocco *et al.* presented a modification of the Walsh RP in which they aimed to improve urinary continence outcomes in prostatectomy patients by fixing the posterior bladder wall to the Denonvilliers' fascia at the posterior semicircumference of the sphincter prior to initiating the vesicourethral anastomosis (15). This became colloquially known as the "Rocco stitch". The anatomical rational that drove the technique was the hypothesis that post-operative urinary incontinence was due to sphincter insufficiency driven by the natural caudal retraction of the urethral sphincter complex which shortened the urethral sphincter length. When compared to the traditional RP patients, they found that post-operatively patients experienced a shorter time of return to continence. Coughlin *et al.* was the first to report the application of rhabdosphincter reconstruction in the RARP in 2008 with similar early return to continence (16). It is important to note that early return to continence has not been consistently validated in future studies. In 2008, Menon conducted a randomized control trial in 116 patients in which 57 patients underwent RARP without rhabdosphincter reconstruction and 59 patients with, and found no difference in early return to continence rates between the two groups (17).

Apical dissection

Due to the difficulty delineating prostatic tissue from the urethral sphincter complex, the prostatic apex was traditionally regarded as the anatomic location in which positive surgical margins were the most common. Therefore, a robust prostatic apical dissection was developed and has evolved since the days of open radical prostatectomy with the goal of reducing positive surgical margin rates (18). Menon (2004) was the first to describe apical dissection in RARP, and since that time there has

been progression of various apical dissection techniques (19). While initially the priority was to avoid positive surgical margins, the apical dissection has proven utility in the improvement of functional urinary outcomes as well.

Tewari *et al.* (2010) described the retro-apical technique which was performed with concomitant urethral transection in 209 patients. They hypothesized that a meticulous dissection of the prostatic apex would obviate the demarcation of the urethral-prostatic junction to allow for precise transection of the urethra whilst preserving urethral length. This differed from the traditional practice in which bulky urethral tissue was often divided sharply without delineating the urethral-prostatic junction. Tewari's apical dissection technique was retrospectively reviewed against 1665 previous patients with conventional dissection and resulted in a significantly lower rate of positive margins at 1.4% versus 4.4% (P=0.04) despite a higher percentage of aggressive cancers in the retro-apical cohort (20). Although preserving urethral length has been shown to improve continence and time to return to continence, this outcome was not analyzed in the study (21).

In 2018, Bianchi *et al.* proposed a novel "collar" technique, which aimed to preserve maximal length of the urethra in order to analyze effects on rates of positive surgical margins (primary outcome) as well as urinary continence (secondary outcome). The technique involved incising the superficial urethral sphincter complex slightly distal to the prostatic apex to expose the smooth muscle and transecting the urethra at the level of the smooth muscle (lissosphincter) proximally towards the apex to create a "collar". The results reported lower rates of positive surgical margins in the collar group (5.6%) compared to the control group of a standard apical dissection (9.9%). However, despite the extended urethral length achieved by this technique, there was similar continence recovery in both groups (22).

Neurovascular bundle preservation

Nerve sparing (NS) technique was first described by Walsh in his seminal paper in 1981, which delineated the anatomy of the pelvic plexus and how avoiding injury to the neurovascular bundle could aim to preserve erectile function in post-prostatectomy men (23). Menon *et al.* (2003) was the first to describe a "standard" NS approach robotically, in which an anatomical triangular tunnel was described (consisting of the periprostatic fascia splitting and fusing with Denonvillier's fascia) and surgically preserved in order

to avoid damaging the posterolateral neurovascular bundle with similar goals (8). However, this paper was written to describe the technical feasibility of the then-novel RARP rather than reporting outcomes and no data regarding erectile function preservation was presented at that time. Since then, there have been numerous descriptions of different NS techniques which will be generally accounted for below. With regards to urinary continence, there have been discussion regarding whether NS technique attributes to improved outcomes with the suggestion that the meticulous dissection that results from NS may be what accounts for such findings rather than the act of preserving the neurovascular bundle preservation itself (24,25). To best understand the described techniques, we suggest reading the individual references and studying the associated videos that may be available.

Veil of Aphrodite

Based on nerve staining anatomical studies which showed presence of nerves lateral and anterior to the prostatic capsule, Menon *et al.* (2004), further expounded on NS techniques when he described a method of micro-dissecting the lateral prostatic fascia from the capsule, leaving a lateral curtain of tissue along with athermal preservation of the neurovascular bundle; this was coined the "veil of Aphrodite" (26). By 2012, this lateral dissection plane was described to extend anteriorly and medially to include the dorsal venous complex structures, creating the so-called "super veil"— reserved for those with relative lower risk disease and who desired maximal preservation of potency (27). Although, not delineated in this paper, but a prior study by the same group showed that in men with a preoperative Sexual Health Inventory for Men (SHIM) score of >17, 42% of these patients had postoperative SHIM scores between 18–25, 19% with scores 12–17, 14% with scores 8–11 and 25% with scores <7 demonstrating favorable sexual outcomes at 18 month follow-up (28). However, these studies did not demonstrate a significant overall improvement in SHIM scores and ability to achieve sexual penetration when comparing "standard veil" versus "super veil" groups.

Interfascial and intrafascial dissection

Owing to the visual magnification afforded by laparoscopic techniques, Martínez-Piñeiro *et al.* (2006) first characterized an interfascial plane—an avascular plane between the prostatic and Denonvillier's fascia. Likewise, an intrafascial

plane immediately under the prostatic fascia was also described (29). While dissection of the interfascial plane is more commonly adopted, an athermal intrafascial robotic (AIR) technique was developed with hopes of maximizing NS capabilities. Potdevin *et al.* performed a retrospective review comparing two cohorts of interfascial (n=77) and intrafascial (n=70) techniques (30). The result was a shorter time to continence and potency as well as an absolute increase in potency in the AIR technique group. However, it was associated with higher rates of positive surgical margins indicating the importance of patient selection for this approach.

Athermal dissection

Gill (2007) initially presented an athermal technique for the NS dissection in which bulldog clamps were used over the prostatic pedicles while the prostatic fascia was dissected and hemostasis achieved with suture ligation. In that study, 76 patients were followed for at least 1 year showing that patients undergoing athermal dissection (n=64) had a 1-year successful intercourse rate of 70% versus the thermal-energy based technique cohort (n=22) of 36% (P=0.04) (31). It has since been accepted that cautery in the vicinity of the neurovascular bundle should be avoided when possible to prevent collateral damage to surrounding nerves.

Neural hammock preservation

In 2011, Tewari *et al.* redefined the prostatic neurovascular network more as a hammock-like distribution of nerves underlying the prostate as opposed to the traditional view of a cord-like "bundle". A novel technique of NS was described which included athermal, traction-free dissection of the neurovascular hammock. This technique was risk-stratified in 2,317 patients (with degree of NS depending on clinical grade and stage of disease). The analysis indicated statistically significant improvement of potency and return to baseline SHIM with more aggressive NS techniques (32).

Athermal early retrograde nerve release

In 2009, Coughlin described a robotic NS technique of an athermal release of the neurovascular bundle in a retrograde fashion from the prostatic apex to the base. Prior to this description, this approach of NS was limited to the open radical prostatectomy (33). Couglin's technique emphasized an early neurovascular bundle release prior to ligation of the prostatic pedicles with the aim of early NS to mitigate injury to the neurovascular bundles that was commonly experienced during prostatic pedicle ligation. By integrating the benefits of robotic surgery with open surgical principles, this "hybrid technique" aimed for maximal neurovascular preservation and functional outcomes. This technique was validated and replicated in a review of 12,000 prostatectomies. In this review, overall positive surgical margins were found to be 14–20.8% for pT2–pT3 stage diseases; 1-year continence rates were >90%; and potency rates at 3, 6, 12 and 18 months were 38.8%, 65.4%, 73.9% and 95% respectively (34). The authors noted that early return to continence was not appreciated in their analysis.

Retzius-sparing approach

Bocciardi's group (2010) was the first to describe a case series of 5 patients that underwent a Retzius-sparing approach for RARP, in which an intrafascial prostatectomy was performed via access through the Douglas space. This approach maintains the bladder in its orthotopic configuration within the space of Retzius unperturbed, hence preserving anterior bladder support, dorsal venous complex structures and posterior-lateral structures involved with urinary continence and possibly potency. This posterior space is then developed laterally and anteriorly, while staying within the intrafascial plane, theoretically resulting in a superior neural and vascular preserving dissection (35). Bocciardi *et al.* later followed with a series of 200 patients with a minimum of 1-year follow-up, the approach was found to be oncologically and technically feasible (36). This approach has been replicated and validated to report improved short term continence return, urinary function and subjective symptom reports (37,38). The limitations of this approach involve the technical complexity of such meticulous dissection and its associated steep learning curve involved to achieve optimal outcomes.

Partial prostatectomy

The robot-assisted partial prostatectomy (RAPP) was developed as a surgical version of energy-based prostatic ablation for localized disease where carcinoma arose in the anterior and medial transition zones near the external sphincter and neurovascular bundles. Such anterior prostate cancers (APC) are being discovered with the recent adaption of magnetic resonance imaging (MRI) and

subsequent targeted prostate biopsies, and account for up to 19% of new prostate cancer diagnoses (39). Postoperatively, oncologic outcomes can be followed by prostate-specific antigen (PSA) values and recurrence can be treated with salvage RP or ablative techniques when indicated. The earliest case series of RAPP was reported by Villers (2017) in highly selective population of 17 patients with favorable intermediate-risk prostate cancer and reported an 86% 2-year recurrence-free survival rate with 100% continence and 83% potency at 3 months (40). Given the stringent selective inclusion criteria for this patient population, it remains an investigated technique.

Conclusions

The RARP has evolved tremendously since its conception in earliest reports. Its wide adaption within the urologic community has resulted in numerous novel approaches with the aims of improving patient outcomes while maintaining oncological success. Continued refinement and development of these techniques are still on the horizon. It has become apparent that various technical modifications are optimal for select patient populations as many studies risk-stratify cohorts by sexual function, urinary symptomatology and pre-operative oncologic grade and staging. Some approaches are intuitive such as limited NS in patients with limited pre-operative sexual function. However, as refinements to various techniques continue to evolve while our understanding of the complex periprostatic anatomy expands, technical mastery of this operation continues to be elusive and increasingly difficult for surgeons to learn. Even still, novel tools such as improved imaging modalities and newer generations of robotic platforms are becoming integrated into the standard of care for prostate surgery, and the ceiling to success of surgical treatment for prostate cancer—if it exists to begin with —continues to rise. What will not change is that improved outcomes for radical prostatectomy has and always will be attainable to the surgeon who focuses on increasing their experience, honing their techniques and maintaining a diligence for excellence.

Footnote

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