Cancer control and the preservation of neurovascular tissue: how to meet competing goals during robotic radical prostatectomy

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Accepted for publication 27 September 2007

Study Type – Therapy (case series)
Level of Evidence 4

OBJECTIVE

To present early functional and oncological data for the athermal trizonal nerve-sparing technique of robotic radical prostatectomy (RP), that addresses the concerns about deviations from the principles of open RP and revisits the anatomical foundations of this surgery from the robotic perspective.

PATIENTS AND METHODS

The study involved close collaboration between the Cornell Institute of Robotic Surgery in New York, USA, and the Institute of Urology at the University of Innsbruck in Austria. The cadaveric studies and standardization of the athermal technique were conducted at Innsbruck, and the technique was used in 215 patients in New York.

RESULTS

The athermal technique addresses concerns about the use of thermal energy and bulldog clamps during nerve sparing, and emphasizes the importance of the trizonal neural architecture. We analysed the surgical outcomes of 215 consecutive patients from January 2005. The operative duration was 120–240 min and the mean blood loss was 150 mL. In patients potent before RP the potency rate at 1 year after bilateral nerve-sparing was 87%. The overall surgical margin rate was 6.5% and positive margin rates for organ-confined cancer were 4.7%.

CONCLUSION

We describe the athermal technique of robotic RP and introduce the concept of trizonal nerve preservation. The immediate oncological and sexual outcomes were encouraging.

KEYWORDS

athermal, neuroanatomical map, prostate cancer, robotic prostatectomy

INTRODUCTION

Surgery for prostate cancer (radical prostatectomy, RP) is challenging, with the competing goals of cancer control and maintenance of erection. The surgeon's ability to develop a precise plane between the nerves and the prostatic capsule is hampered in RP because it is difficult to recognize microscopic invasion of neurovascular tissue by the cancer. These challenges are amplified in robotic surgery, where there is no tactile feedback. Several experts in prostate cancer have voiced concerns about deviating from the principles of open RP during robotic surgery, e.g. about the use of thermal energy during nerve sparing, and the inability to examine the specimen before completing the surgery.

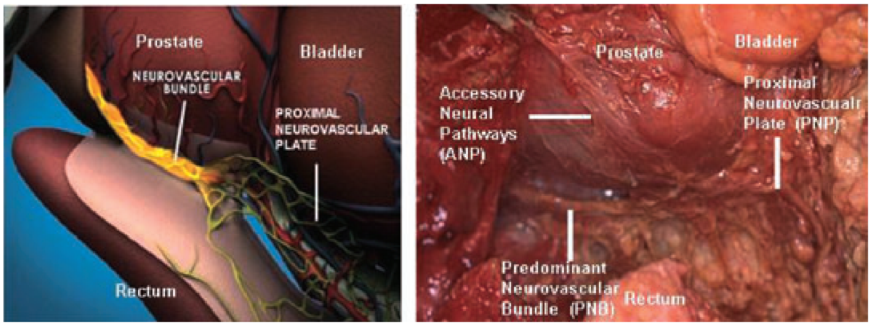
The present study was designed to address these concerns, and included the following broad aims: (i) to revisit the anatomical foundations and to create a neurovascular map related to the steps of robotic RP; (ii) to abstain from using electrocautery and/or bulldog clamps on the neurovascular tissue; (iii) to devise strategies for deciding during robotic RP about the excision of nerve bundles; (iv) to standardise the steps of robotic RP based on the anatomical studies; and (v) to collect data on the oncological and functional outcomes.

To meet these goals, we present the athermal trizonal (AT) nerve-sparing technique of robotic RP [1]. This new technique is unique in several important ways. In particular, it addresses concerns about the use of thermal energy and bulldog clamps during nerve sparing, it incorporates steps to preserve and handle the trizonal neural structures, and it presents a simplified manoeuvre to identify the bladder neck.

PATIENTS AND METHODS

This study was conducted by the Cornell Institute of Robotic Surgery (New York, NY) in close collaboration with the Institute of Urology at the University of Innsbruck in Austria.

FIG. 1. The trizonal neural architecture around the prostate comprising the PNP, the PNVB and the ANP. Fresh cadaveric dissection.



The anatomical data for this study were obtained using 10 fresh and two fixed cadaveric dissections at the two institutions. For the cadaver studies, we selected male cadavers, aged >40 years, with no previous pelvic or urethral surgery. Cadavers were frozen <12–36 h after death and stored at –20 °C until dissection. No macroscopic tumours were evident in the abdominal and pelvic regions of these cadavers. The cadavers were dissected using a high-power operating microscope, and they were documented using still and video cameras.

For the studies on patients, the Cornell robotic team visited Innsbruck to perform and standardize the AT technique in 15 patients. The Cornell team then performed 215 consecutive modified AT robotic RPs at the New York centre (between 1 January 2005 and 31 December 2005); all procedures were recorded digitally in three dimensions.

Baseline demographic data were collected prospectively before RP and included age, race, body mass index, serum PSA level, prostate volume, Gleason score, TNM clinical staging, comorbidities, the IPSS and International Index of Erectile Function (IIEF) score, and previous surgery. Intraoperative data included estimated blood loss, the various steps of the operation, complications, and video recording. Finally, postoperative variables included any decline in the haematocrit, hospital stay, pathological stage, Gleason score, margin rates, PSA level, continence status, and sexual function. Potency after RP was defined as the return of erections sufficient for vaginal penetration.

Patients completed standardized forms before and after RP (the Expanded Prostate Cancer Index Composite and the IIEF) and were followed at 1, 3, 6 and 12 months after RP.

RESULTS

Relevant neurovascular tissue around the prostate can be grouped into three broad zones: the proximal neurovascular plate (PNP), the predominant neurovascular bundle (PNVB), and accessory neural pathways (ANP) [1]; Fig. 1 shows these regions.

The PNP is an integrating centre for the processing and relay of erectogenic neural signals; it is lateral to the bladder neck and seminal vesicle, and is closely intermingled with the branches of the inferior vesical vessels. As a result, it can be damaged during posterolateral incision of the bladder neck, lateral dissection of the seminal vesicle and/or mass clipping or cautery of prostatic pedicles.

The PNVB is the classical bundle that carries neuronal impulses to cavernous tissue; it varies in shape and size from the proximal to distal end, and in 65% of cases the PNVB has a medial extension behind the prostate.

The ANP lie within the layers of levator fascia and/or lateral pelvic fascia on the anterolateral or posterior aspect of the prostate. In 35% of cases the ANP form a plexus near the apex. This plexus might serve as a neural pathway for both cavernous tissue and the urethral sphincter.

The prostatic capsule is surrounded by prostatic fascia, lateral pelvic fascia, levator fascia, and finally levator muscles (Fig. 2). Interposed between the prostatic fascia and lateral pelvic fascia are the neurovascular

FIG. 2. Endorectal MRI and three-dimensional representation of fascia around the prostate.

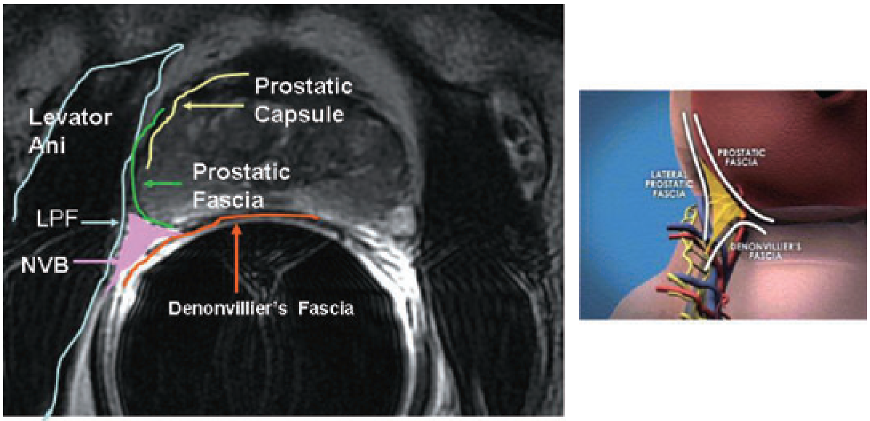


FIG. 3. Bilateral incision in the endopelvic fascia with intact puboprostatic ligaments.

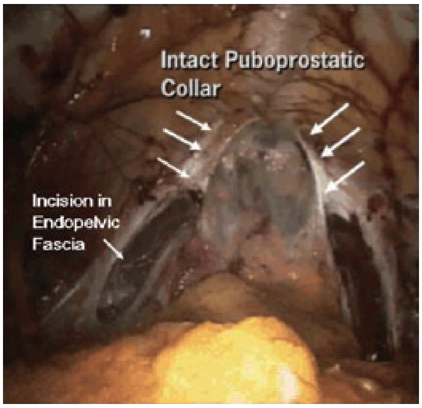
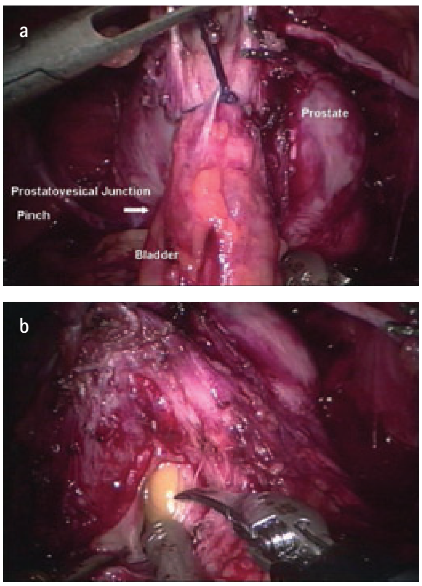


FIG. 4. (a) The bladder-neck pinch; (b) Transection of the anterior bladder neck.



tissue and the periprostatic venous plexus, which travel distally to supply the sphincter, urethra and cavernous tissue. These neural fibres usually travel close to the vessels, but occasionally they can travel independently on the surface of the prostate, or laterally on the rectum. Some of these vessels are also subcapsular for a short distance before dipping into the prostatic tissue. Accordingly, excessive blunt dissection of these vessels can create an artificial transcapsular plane, resulting in a capsular incision. Proper nerve-sparing should leave an intact capsule, preferably covered by a 'safety layer' of prostatic fascia (and some veins). During aggressive nerve-sparing, a plane is developed deep into the prostatic fascia and veins, which provides maximum chances for potency, but also increases the risk of capsular incision.

STANDARDIZATION OF TECHNIQUE

The following modifications in technique were tailored to several factors: specifically, our understanding of trizonal neural architecture, the effect of thermal energy on neural tissue [2], compensatory manoeuvres necessary to operate in a visually rich three-dimensional platform, and the authors' patient selection protocol for nerve-sparing and wide excision.

The approach can be transperitoneal or extraperitoneal. The retropubic space is developed and the anterior surface of the prostate, endopelvic fascia, apex, and prostatovesical junction are de-fatted. Important landmarks, e.g. puboprostatic ligaments, the arcus tendineus and the prostatovesical junction, are identified.

We sharply incise the endopelvic fascia, leaving the condensed lateral tendon (arcus tendineus) intact. Dissection is kept to a minimum, and a plane is developed either within the lateral pelvic fascia or within the levator fascia. The incision is limited to the proximal third of the prostate, with the distal limit at the sickle-shaped extension of the puboprostatic ligaments (Fig. 3). We avoid over-zealous dissection at all cost, especially avoiding the PNP and periprostatic plexus. The distal plane of dissection must be extended sufficiently to allow for the secure placement of the dorsal venous suture.

Disconnection of bladder from prostate; 'the bladder neck pinch'

In the original description of the bladder neck dissection, surgeons were encouraged to start in the distinct lateral plane demarcated by fat between the bladder and prostate [3]. Unfortunately, such an approach could place at risk the PNP, and vessels of the prostatic pedicle. To prevent this, we use the bimanual bladder-neck pinch technique [4]. A back-bleeding suture is placed on the anterior surface of the prostate and, for traction, a superficial suture is placed on the bladder. Next, robotic forceps and scissors trap the prostate on both sides and pull on the Foley catheter with gentle distal traction, proximally and medially, until the junction of prostate can be identified, with a collapsed bladder. The anterior bladder neck is then incised until the Foley catheter is seen; the catheter is then delivered from the bladder and, finally, the posterior bladder neck is incised (Fig. 4a,b). We take every precaution to preserve the anatomical bladder neck as far as possible, and to avoid injury to the ureteric orifices. The retrotrigonal layer, which is now exposed, is cut to reveal the vasa and the seminal vesicles [5]. Electrocautery is avoided from this point onwards.

Dissection of vas deferens and seminal vesicles

Anatomically, the vas and seminal vesicles are enclosed by the retrotrigonal layer anteriorly, neurovascular tissue and prostatic pedicle laterally, rectum and Denonvilliers' fascia posteriorly, trigone and bladder base superiorly, and prostatic base inferiorly. Both the vas and seminal vesicles have their own sheaths and blood supply. We begin the dissection by opening the retrotrigonal layer and exposing the anterior surface of the vasa. We next develop a plane within the sheath and isolate the vasa proximally, where they are relatively separate from the seminal vesicles. The vasa are then grasped, and surrounding vessels are controlled with 5-mm surgical clips. The proximal vasa are clipped with haemostatic clips and divided.

The seminal vesicle sheath surrounds the vesicles and most of the vessels travel through the sheath. We thus commence the dissection by developing the relatively avascular medial plane and extracting the vesicles from this sheath. As we come close to the tip, we bunch together, as a pedicle, the seminal vesicular blood supply, and control it with a 5-mm locking clip. To protect the PNP and vessels lying laterally, we do this part of the dissection athermally. Thus we develop small pedicles and control them with 5-mm surgical clips, or suture them close to the surface of the seminal vesicle. Both the seminal vesicles and vasa are lifted up to expose the posterior surface of the prostate.

Separation of the prostate from the rectum

In our anatomical dissections we identified communicating nerve fibres that cross over to the other side at various levels through the layers of Denonvilliers' fascia. These fibres form a distal plexus behind the apex and membranous urethra [1] (Fig. 5). We leave behind a partial thickness of Denonvilliers' fascia over the rectum in low-risk patients who are candidates for nerve sparing. This has not compromised the margin positive rate in these patients. However, we always excise the entire fascia in patients who are not candidates for nerve sparing, have an abnormal DRE, or whose biopsy shows high-volume cancer (more than two positive cores or >22% cancer in each core), a Gleason sum of 7, or apical cancers.

Control of the prostatic pedicles

The prostatic pedicle includes arteries and veins entering the prostate, and is intermixed with the PNP. There are two distinct components to the prostatic pedicle: (i) the medial component, which supplies the base of the seminal vesicles and prostate; and (ii) the lateral component, which enters the prostate at its base on the posterior lateral aspect. The lateral component is the predominant pedicle, the shape, thickness and width of which vary, based on the anatomical variations and size of the prostate.

Traction on the vas and seminal vesicles causes prostatic pedicles to become more prominent. When the prostate is lifted upwards, the medial pedicle is identified and kept close to the prostate with a clip. We then focus on the lateral pedicles. Starting medially, we develop two to four small pedicles close to the prostate (and control them with 5-mm clips). This exposes the undersurface of the prostate and gently separates the PNP from the dissection zone. A slight contralateral traction exposes the few remaining vessels entering the prostate, which are then clipped and cut (Fig. 6).

Release of the NVB

When the prostate is freed from the vascular pedicle it becomes more mobile and can be rotated to expose the neurovascular triangle. The neurovascular triangle is a potential avascular triangle bounded posteriorly by Denonvilliers' fascia, laterally by the levator fascia, and medially by the prostatic capsule covered by prostatic fascia [6]. Once this triangular space springs open, the rest of the dissection becomes very elegant, and is achieved simply by pushing the prostate away from the NVBs. Doing so athermally, with clips, preserves the tissue's texture, and prevents coagulation and desiccation.

The extent of the cancer dictates the positioning of the plane relative to the prostate. We develop a very close plane (just on the prostatic capsule) for aggressive nerve-sparing (intrafascial) (Fig. 7). However, most typically, we develop a close plane (outside the prostatic fascia but within the lateral pelvic fascia) for safe nerve-sparing (interfascial) (Fig. 8), and in some situations we develop a plane far from the prostate (leaving a few medial layers of lateral pelvic fascia on the specimen), allowing for only partial or incremental nerve-sparing.

Menon *et al.* [7] elegantly described the extent of the preserved fascia and enclosed nerves (Veil of Aphrodite). They recommend that the incision be quite anterior, to handle those nerve fibres that deviate anteriorly while destined to continue as cavernous nerves beyond the pelvic hiatus. Thus in the trizonal approach we incorporate this recommended anterior incision. In addition, in patients with

FIG. 5. *Posterior dissection; separation of the prostate from the rectum; the distal apical plexus is formed posteriorly from cross-communicating fibres from the NVBs. LA, levator ani.*

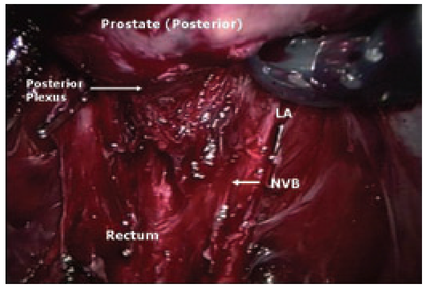


FIG. 6. *Dissection of left NVB.*

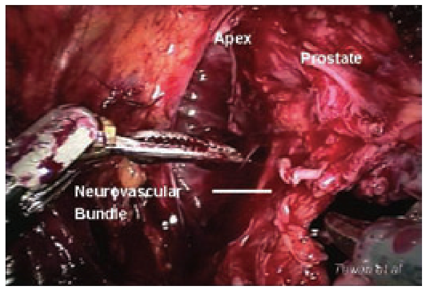


FIG. 7. *Aggressive (intrafascial) nerve-sparing at the left apex, showing the plane developed on the prostatic capsule.*

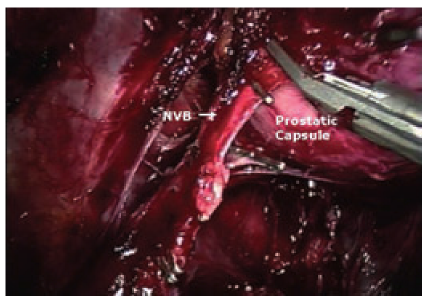


FIG. 8. *Interfascial nerve-sparing at the right apex, showing the plane developed between the prostatic fascia and lateral pelvic fascia.*

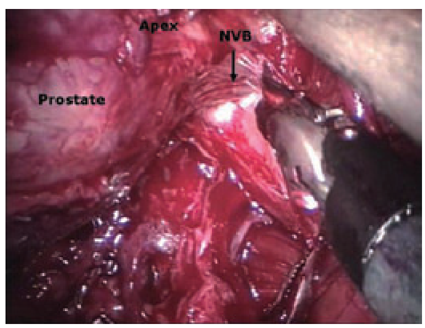


TABLE 1
The characteristics and outcomes of the patients treated with RP

Variable	Value
Baseline	
Median (SD, range) age, years	60 (6, 45–75)
n (%):	
PSA, ng/mL, before RP	
<2.5	19 (8.9)
2.6–4.0	43 (20.2)
4.1–10.0	135 (63.4)
10.1–20.0	12 (5.6)
>20	4 (1.9)
Biopsy Gleason score	
6	154 (72.6)
3 + 4	36 (17.0)
4 + 3	12 (5.7)
≥8	10 (4.7)
Clinical stage	
T1a-b	1 (0.5)
T1c	159 (74.6)
T2a	29 (13.6)
T2b	10 (4.7)
T2c	12 (5.6)
T3a	1 (0.5)
T3c	1 (0.5)
Median (SD) estimated blood loss, mL	150 (195)
Intraoperative blood transfusion	0
After RP	
Pathological stage	
pT2a	37 (17.3)
pT2b	7 (3.3)
pT2c	144 (67.3)
pT3a	16 (7.5)
pT3b	8 (3.7)
pT4	2 (0.9)
Capsular invasion	36 (17.0)
Perineural invasion	104 (48.0)
High-grade PIN	55 (26.0)
Overall positive margins	14 (6.5)
Positive margin in organ-confined cancers	9 (4.8)

PIN, prostatic intraepithelial neoplasia.

low-risk cancer, we preserve the retroapical plexus by leaving a distal layer of superficial Denonvilliers' fascia. These two modifications maximize the preservation of accessory nerves responsible for sexual function. Our AT approach minimizes damage to all three neural zones including the PNP, the PNVB and the ANP.

In robotic surgery, NVBs are usually released antegradely. However in patients with large prostates (>100 g) or wide prostatic pedicles, we initially release the NVBs retrogradely, up to the pedicles. We then release the NVBs antegradely until the prostate is only attached to the body by a clearly defined and controlled pedicle, at which point the prostate is released.

With the prostate freed all around, we embark on distal dissection of the apex. Apical dissection is the most critical step in robotic RP, affecting the apical margin rate, continence and sexual function. There are significant anatomical variations in prostatic apical shape, and in its relationship to the distal sphincter complex, nerves and urethra. Variations in shape can significantly affect the level of membranous urethral transection. Unrecognized variations could either result in apical positive margins or loss of significant urethral length. Our continence preservation technique and associated results were described previously [8].

Examining the RP specimen during RP aids in deciding how to handle the NVB. In three kinds of patients we remove the specimen immediately after apical transection, i.e. those with high-grade cancers, with a preoperative endorectal MRI report of suspicious capsular penetration, and those who have poorly developed planes between the prostatic and lateral pelvic fascia. In all other cases we remove and examine the specimen after the anastomosis. Intraoperative frozen sections are taken of suspicious areas, and if these, or findings on palpation, suggest involvement of the NVB with cancer, we place clips on the NVBs near the base and at the apex, excising them widely.

Table 1 summarizes some of the outcomes in 215 consecutive patients undergoing robotic RP by one surgeon (A.T.) between January and December 2005. The mean age of the patients was 60 years, the operative duration was 120–240 min, the mean blood loss was 150 mL, and 3% required a blood transfusion after RP. The mean haemoglobin and haematocrit at discharge were 13 g/dL and 38%, respectively; the mean (range) duration of catheterization was 7 (4–14) days.

The serum PSA level was <10 ng/mL in 92.5% of patients; 72.6% had a Gleason score of 6 and 4.7% of ≥8 (≈47% had a Gleason score of ≤6). There was capsular invasion in 36 patients (17%), perineural invasion in 104 (48%), and high-grade prostatic intraepithelial neoplasia in 55 (26%). Surgical margins were positive in 14 patients (6.5%) and there were 16 positive margins. There was PSA recurrence in 7% of patients overall. In all, 182 patients (85%) had bilateral nerve-sparing using the AT technique, 24 (11%) had incremental nerve-sparing and another nine (4%) had wide excision. Of patients aged <70 years who were potent before RP (Sexual Health in Men score >22) and who had bilateral nerve-sparing surgery, 87% (89/102) were potent at 1 year after RP.

DISCUSSION

We describe the AT robotic technique of RP and introduce the concept of trizonal nerve preservation. The early functional and oncological outcome data are encouraging.

CONFLICT OF INTEREST

A. Tewari and G. Bartsch are Study Investigators funded by Sponsor.

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Abbreviations: **RP**, radical prostatectomy; **PNP**, proximal neurovascular plate; **(P)NVB**, (predominant) neurovascular bundle; **ANP**, accessory neural pathways; **AT**, athermal trizonal; **IIEF**, International Index of Erectile Function.