Neuroanatomic basis for traction-free preservation of the neural hammock during athermal robotic radical prostatectomy

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Purpose of review
Much of the progress achieved in the past two decades in improving potency outcomes after radical prostatectomy has resulted from an improved appreciation of the anatomic basis of the nerves responsible for erection. We review the current literature evaluating the neuroanatomy of prostate and operative strategies for better preservation of sexual function.

Recent findings
Recent studies suggest an alternative and more complex course of nerves than previously described. Periprostatic nerves can be divided into three broad surgically identifiable zones: the proximal neurovascular plate, the predominant neurovascular bundle, and the accessory neural pathways. Better appreciation of the variable and often invisible anatomical course of the cavernosal nerves continues to engender innovations in surgical technique to optimize their preservation.

Summary
Improved anatomic understanding has optimized surgical technique in order to improve potency outcomes following radical prostatectomy.

Keywords
athermal, hammock, nerve-sparing, neuroanatomy, potency, prostate cancer, prostatectomy, robotic, traction-free

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Introduction

Prostate cancer is the commonest nondermatologic cancer in western men [1••]. The advent of prostate-specific antigen screening has resulted in a downward stage migration of prostate cancer, with prostate cancer patients being diagnosed at a younger age with early organ-confined disease. Preservation of sexual function has become an increasing priority for these men in considering radical prostatectomy as a treatment option. Despite advances in technique and surgical technologies, return of erectile function sufficient for sexual intercourse at 1 year after surgery varies from 15–87% in contemporary series of radical prostatectomy [2,3••,4]. Data from the Prostate Cancer Outcomes Study suggest that sexual dysfunction following radical prostatectomy has a significant impact on quality of life for men, impacting everyday interactions with women and affecting patients' perceptions of their masculinity, particularly in younger men [5,6].

Risk factors for postprostatectomy erectile dysfunction

Penile erection is a complex event dependent on vascular and neurogenic factors. Penile tumescence is a direct result of increased arterial blood flow and engorgement of the corpora cavernosa and spongiosum with occlusion of the subtunical venules to retain blood during continued erectogenic stimulation. The arterial supply of the penis is provided by the internal pudendal arteries, which are the terminal branches of the internal iliac artery. In the flaccid state, penile blood flow is reduced due to tonic contraction of the vascular smooth muscle. During tumescence, however, autonomic nerve-induced relaxation of the vascular and corporal smooth muscle results in rapid arterial filling and engorgement of the cavernosal sinusoids. This is brought about by cholinergic and nonadrenergic noncholinergic mechanisms involving the release of nitric oxide, which causes production of intracellular cyclic GMP and subsequent depletion of

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intracellular calcium in vascular smooth muscle. The expanding sinusoids within the corpora cavernosa compress the subtunical venules against the tunica albuginea, trapping venous flow to maintain erection [7].

Sexual dysfunction following radical prostatectomy is believed to be multifactorial. Quinlan *et al.* [8] first reported in 1991 that patient age, clinical and pathologic stage of cancer, as well as preservation of the neurovascular bundles (NVBs) are significantly associated with recovery of potency after radical prostatectomy. More recent studies by Rabbani [9] and Dubbelman [10] further supported the observations that patient age, their preoperative potency status, and the aggressiveness of nerve-sparing were most predictive of potency recovery after surgery. Surgeon experience and surgical volume, intraoperative NVB injury, penile ischemia and subsequent fibrosis, and venoocclusive disease are further variables for successful return of sexual function following surgery [7].

Anatomic basis of erectogenic nerve preservation

Much of the progress achieved in the past two decades in improving potency outcomes after radical prostatectomy has resulted from an improved appreciation of the anatomic basis of the nerves responsible for erection.

Neurovascular bundles and cavernosal nerves

The autonomic nervous system is directly responsible for penile erection. The inferior hypogastric (pelvic) plexus (IHP) is responsible for the mechanisms of erection, ejaculation, and urinary continence. The IHP contains sympathetic and parasympathetic components. The sympathetic fibers arise from the T11–L2 ganglia, whereas the parasympathetic fibers originate from the ventral rami of S2, S3, and S4. The IHP is a dense network of neural fibers located within a fibrofatty, subperitoneal plate between the urinary bladder and rectum [11].

In 1982, Walsh and Donker [12] first published their seminal study detailing the anatomy of the nerves supplying the corpora cavernosa in male stillborns. Subsequent cadaveric and intraoperative studies by Walsh and colleagues [13,14] at the Johns Hopkins Institute further elucidated that the NVB run posterolateral to the prostate between two layers of lateral pelvic fascia – the prostatic fascia medially and levator fascia laterally. The NVBs comprise the cavernosal nerves directly responsible for erectile function, which originate from the most inferior portion of the IHP, as well as arterial branches from the inferior vesical artery, itself off the internal iliac artery, and veins that drain into the internal iliac and other pelvic veins. The majority of the cavernous nerve fibers, approximately 6-mm wide, then run caudally at the 3 and 9 o'clock positions of the membranous urethra beneath the striated external urethral sphincter at the prostatic apex.

Variations of course of neurovascular bundles

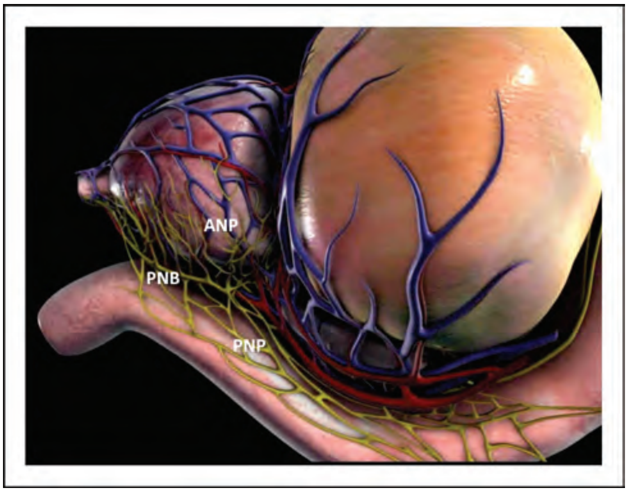
More recent studies suggest that the course of the NVBs is more complex than previously described by Walsh. In 2003, Tewari *et al.* [15] first noted that there are several smaller nerves, which ramify in the prostatic and Denonvilliers' fasciae. The exact physiologic role of these smaller nerves in erection is not well defined but they do exist and may contribute to the neural impulses to the cavernous tissue [15]. In 2004, Costello *et al.* [16] demonstrated in cadaveric dissections that the NVBs descend posterior to the seminal vesicles, converging at the midprostatic level and then diverging on approaching the prostatic apex, being hard to distinguish. Tewari and Clayman have talked about a hammock-like distribution of the NVB on the lateral surface of the prostate, demonstrating that the NVB is more a network of multiple fine dispersed nerves than a distinct structure [personal communication]. Kiyoshima *et al.* [17] also described that the dispersed nerve fibers are located between the prostatic capsule and the lateral pelvic fascia. Similarly, Eichelberg *et al.* [18] demonstrated that only 46–66% of all nerves were found in the classical posterolateral location relative to the prostate, whereas 21–29% were found on its anterolateral surface.

The trizonal neural hammock concept

Tewari *et al.* [19] proposed that the periprostatic nerves consistently fall into three broad surgically identifiable zones: the proximal neurovascular plate (PNP), the predominant neurovascular bundle (PNB), and the accessory neural pathways (Fig. 1) [20] and that nerves are arranged all around the prostate as a 'neural hammock' (Fig. 2). They coined the term 'tri-zonal neural hammock' to describe the architecture for these nerves. For lack of better scientific term we can call it 'Cupid's Neural Hammock'. The PNBs are usually located in a posterolateral groove on the side of the prostate. Significant variations in the location, shape, course, and composition of these bundles occur. They can be widespread on the rectum, Denonvilliers' fascia, and lateral pelvic fascia, or they can be circumscribed on the posterolateral groove enclosed in the triangular space enclosed by the prostatic, levator, and Denonvilliers' fasciae [15]. The PNB is closely related to the prostatic pedicle and prostatic fascia, and its branches can sometimes be intermingled with the lateral pedicles of the prostate (Fig. 3) [20]. Tissue planes also may be obliterated due to periprostatic inflammation, tumor-induced desmoplastic reaction, or extraprostatic extension, and resolving hemorrhage can also make operative dissection difficult.

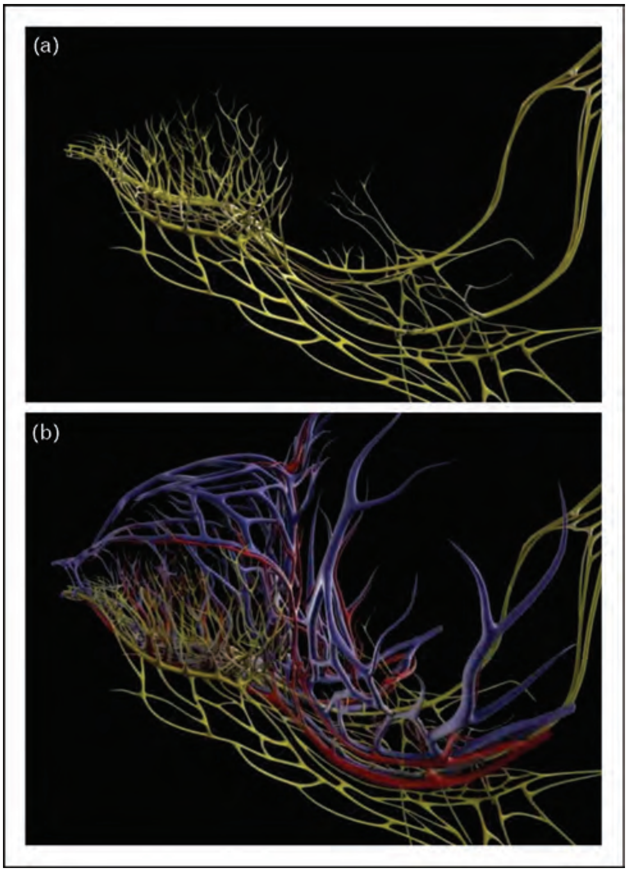
Correlating anatomic findings from cadaveric dissections with intraoperative video footage and final histology

Figure 1 Medical animation showing the proximal neurovascular plate, accessory neurovascular plate, and predominant neurovascular bundle



ANP, accessory neurovascular plate; PNB, predominant neurovascular bundle; PNP, proximal neurovascular plate.

Figure 2 Medical animation. (a) Showing the neural hammock. (b) Showing plexus of arteries, veins along with neural hammock (prostate removed)



slides, accessory neural pathways have been observed in several locations around the prostate; specifically, between the prostatic and levator fasciae, posterior to the prostate and in the layers of Denonvilliers' fascia, between the prostatic capsule and prostatic fascia, and even in the prostatic capsule itself [15–18,21]. The superficial layer of Denonvilliers' fascia has cross-communicating fibers between the left and right NVB. Distally, these bundles coalesce to form a retroapical plexus [20]. In up to 35% of cases, this distal plexus penetrates the rectourethralis muscle (Fig. 4). As this area is the final exit pathway for the cavernous and retroapical nerves, these delicate structures may easily be damaged during urethral transection and anastomosis.

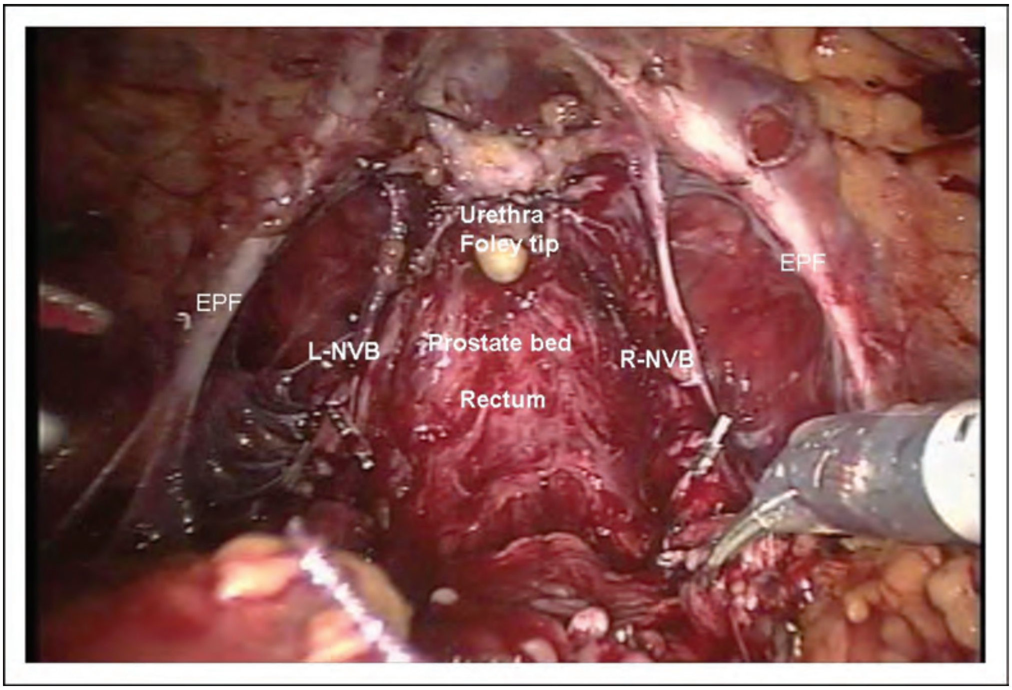
Fascial planes surrounding the prostate capsule

Correlating their intraoperative observations during robotic-assisted radical prostatectomy (RARP) with radical prostatectomy specimens viewed at final histopathology, it was recognized that numerous nerve bundles are present in the different layers of fascia enveloping the prostate [15,21]. The lateral pelvic fascia (LPF) – a multilayered fascial covering – surrounds the prostatic capsule. The medial, well-defined component of the LPF is known as the prostatic fascia, and directly wraps around the prostate capsule. The 'veil of Aphrodite' technique of robotic prostatectomy described by Menon and colleagues is based on dissection medial to the prostatic fascia [21,22]. The laterally defined part of LPF is the levator fascia, which lies on the levator muscles. Interposed between the prostatic fascia and the levator fascia are the periprostatic venous plexus and the neurovascular tissue that travel distally to supply the sphincter, urethra, and cavernous tissue. These neural fibers can travel close to the vessels, or occasionally, independently, on the surface of the prostate or laterally on the rectum. Some of these vessels remain subcapsular for a short distance before dipping into the prostatic tissue. Excessive blunt dissection of these vessels can create an artificial transcapsular plane resulting in a capsular incision and a subsequent positive surgical margin.

Operative strategies for preservation of sexual function

Postprostatectomy erectile dysfunction arises chiefly from injury to the erectogenic nerves, as evidenced by studies reporting a correlation between the number of preserved NVBs and recovery of potency [7,10,23]. Diminished innervation of the corpora cavernosal tissue prevents the release of nitric oxide from nonadrenergic noncholinergic nerves, decreases the production of cyclic nucleotides within the vascular smooth muscle, and causes impairment of vascular engorgement. Vascular injury, namely arterial insufficiency and venoocclusive

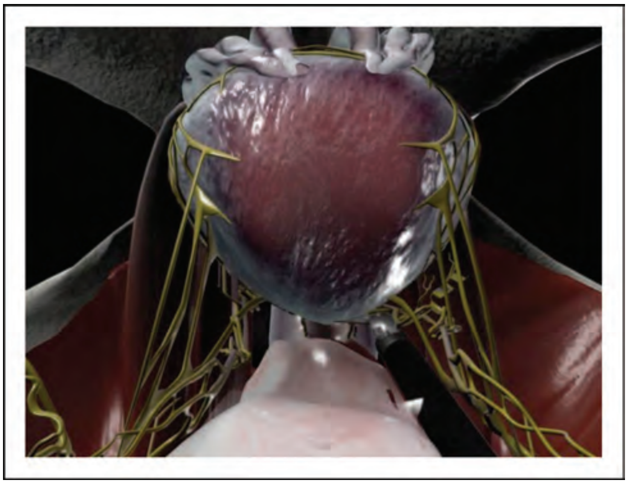
Figure 3 View of the neurovascular bundles in the prostatic fossa after removal of the prostate gland



Note that the neurovascular bundles (NVBs) are closely related to the prostatic pedicle and prostatic fascia, and its branches can sometimes be intermingled with the lateral pedicles of the prostate. EPF, extraprostatic fascia; L-NVB, left neurovascular bundle; R-NVB, right neurovascular bundle. Reproduced with permission from [20].

leakage, have also been proposed as possible etiologies for postprostatectomy erectile dysfunction, although the evidence for this is still in its infancy [24–26]. In their systematic review of the literature, Montorsi *et al.* [27] concluded that properly selected patients undergoing nerve-sparing radical prostatectomy by experienced surgeons should be able to achieve unassisted or medically assisted erections following surgery.

Figure 4 Medical animation demonstrating the retroapical region of prostate



Maneuvers in radical retropubic prostatectomy

On the basis of their anatomic elucidations of the NVBs, Walsh proposed the following maneuvers to avoid inadvertent NVB injury during open retropubic radical prostatectomy:

(1) Securing venous back bleeding on the anterior prostate after ligation and division of the dorsal venous complex – this should be achieved with a V-shaped running suture instead of apposing the edges toward the midline, as the latter causes medial displacement of the NVB at the apex, making accurate dissection difficult.
(2) Transecting the membranous urethra at the lateral edges only, as well as refraining from blind dissection of the prostatic apex.
(3) Releasing the lateral pelvic fascia, which facilitates dissection of the posterolateral groove between the prostate and the rectum posteriorly, and aids in appreciation of the NVBs.
(4) Avoiding excessive traction on the NVBs during the posterolateral dissection by gently rolling the prostate from side to side.
(5) Careful dissection of the seminal vesicles to avoid injury to distal branches of the IHP.

Alternative approaches to preservation of the NVBs described by Ruckle and Zincke [28], and Klein [29] involve incising the lateral pelvic fascia medial to the NVBs on the anterolateral prostate prior to apical dissection and division of the dorsal venous complex. Use of surgical loupes for optical magnification of the operative field has also been reported to improve earlier return of potency and lower rate of positive surgical margins following open radical prostatectomy [30,31].

Alternatives to electrocautery

Collateral thermal injury to the NVBs during radical prostatectomy is a well recognized phenomenon. Tissue coagulation is achieved with temperatures above 45°C; tissue denaturation occurs at 57–60 °C; and protein coagulation at temperatures above 65°C [32]. Ong and colleagues [33] elegantly demonstrated a decrease in erectile function following application of thermal energy to the NVBs in a canine model. In their series of RARP, Ahlering *et al.* [34] reported that avoidance of thermal energy results in nearly a five-fold improvement in early return of sexual function, and that thermal injury induces a pronounced but mostly recoverable injury after 2 years from time of surgery. Recently, Mandhani *et al.* [35] also reported that bipolar cautery during RARP causes a significantly higher and more persistent rise in temperature of tissues within 1 cm of its use, compared with monopolar cautery applied at the same distance, challenging the widely held belief that bipolar cautery causes less collateral tissue damage. Using a porcine model, Khan *et al.* [36] also demonstrated that the lateral prostatic pedicles serve as a heat sink during bladder neck transection using cautery, protecting the NVBs from thermal injury.

Various alternatives to thermal energy have been proposed during RARP. Ahlering *et al.* [37] reported their experience placing laparoscopic bulldog clamps on the lateral pedicles 1 cm from the prostate, followed by division of the lateral pedicles with cold scissors. After mobilization of the NVB off the prostatic capsule, FloSeal was applied along its entire length and the NVB covered with a dry 1 × 4 cm sheet of Gelfoam. The bulldog clamps were sequentially withdrawn following completion of prostatectomy, and 3-0 figure-of-eight sutures used for hemostasis of bleeding from the lateral pedicles. In the same year, Chien *et al.* [38] reported 47% of patients returning to baseline potency at 1 month after RARP using an antegrade dissection of the NVB that avoided the use of clips or monopolar cautery.

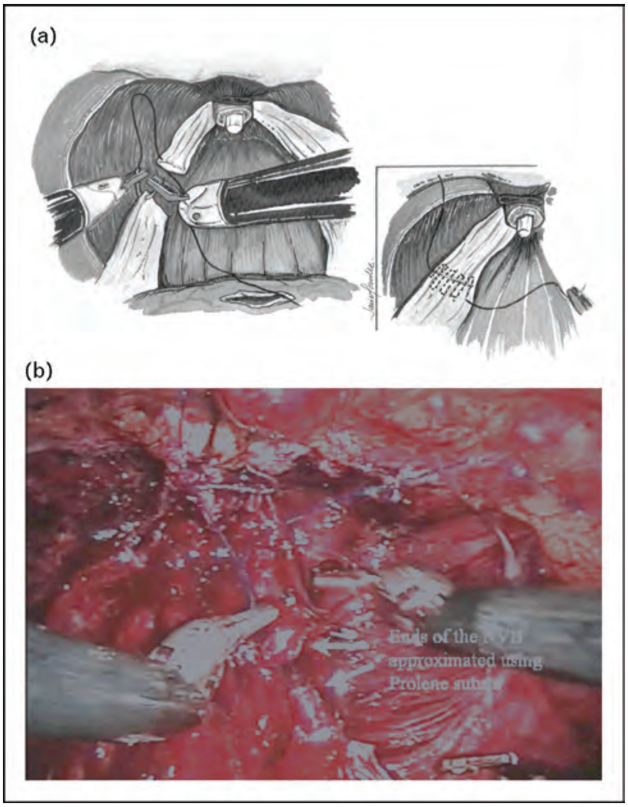
Gill and colleagues [39,40] from the Cleveland Clinic reported a different approach to lateral pedicle ligation during laparoscopic radical prostatectomy. In their antegrade technique, the lateral prostatic pedicles were first controlled with atraumatic bulldog clamps, and then divided using cold scissors and the NVBs preserved with blunt and sharp dissection. Hemostasis was then secured with superficial suturing of the transected pedicle. Using real-time Doppler transrectal ultrasound guidance, they demonstrated that application of bulldog clamps on the lateral pedicles did not impair blood flow through the NVBs throughout this maneuver. More recently, these investigators reported their preliminary experience comparing the KTP laser against ultrasonic shears and athermal cold Endoshear scissors dissection of the lateral pelvic fascia during laparoscopic unilateral NVB mobilization in a canine radical prostatectomy model [41•]. Measuring peak intracavernous pressure upon cavernous nerve stimulation both acutely and at 1 month follow-up in 36 dogs, they found that the KTP laser was comparable to the athermal technique, and superior to the ultrasonic shears, for preserving cavernous nerve function. In addition, intraoperative thermography revealed less collateral thermal spread from the KTP laser than from the ultrasonic shears. These animal studies suggest laser energy as a less traumatic alternative for periprostatic fascial dissection, and their feasibility in human trials is awaited.

Nerve reconstruction

Nerve grafts have been used for decades to replace damaged or divided sensorimotor nerves. In 1991, Quinlan *et al.* [42] first reported successful return of erectile function in rats using interposition cavernous nerve grafts after iatrogenic denervation. Kim *et al.* [43,44] subsequently reported excellent results using bilateral sural interposition nerve grafts (SNG) in 23 preoperatively potent patients with aggressive cancer undergoing nonnerve-sparing retropubic radical prostatectomy with deliberate wide NVB resection, compared with a control group of 12 men undergoing similar surgery who did not have SNG. Of the patients receiving bilateral SNG, 26% had spontaneous medically unassisted erections sufficient for penetrative intercourse; 26% reported spontaneous erections insufficient for intercourse; and 43% had intercourse with sildenafil. The greatest return of potency occurred at 18-month follow-up, although none of the patients reported erections before 5 months. This technique was subsequently adopted for both laparoscopic [45] and RARP [46], with similar encouraging results. However, results of a randomized phase II trial by investigators at M.D. Anderson Cancer Center, Houston, in a cohort of 107 men undergoing unilateral nerve-sparing radical prostatectomy, failed to demonstrate any additional improvement of potency with unilateral sural nerve grafting at 2 years following surgery [47••].

Martinez-Salamanca *et al.* [48] reported an alternative approach of nerve advancement using end-to-end reconstruction of the NVB after partial resection in clinically high-risk patients with MRI evidence of extracapsular extension of disease, most of whom had T3 disease at final histology. In these patients who demonstrated

Figure 5 Proximal and distal ends of the neurovascular bundle



(a) Pictorial representation of the nerve advancement technique following partial neurovascular bundle resection. (b) Intraoperative view of approximation of cut ends of neurovascular bundle (NVB) using 6-0 polypropylene suture with da Vinci robotic assistance. Reproduced with permission from [48].

fibrotic tissue around the NVBs, athermal partial resection of the NVBs was performed outside the lateral pelvic fascia. The proximal and distal ends of the NVB were then mobilized off and approximated without tension using 6-0 polypropylene interrupted sutures (Fig. 5). At a median of 20-month follow-up, five of these seven patients reported recovery erections with or without phosphodiesterase inhibitors, with a median sexual health inventory for men (SHIM) score of 18.

Connolly *et al.* [49] reported significant recovery of erectile function in adult male Sprague–Dawley rats with bilateral cavernous nerve excision, using acellular nerve matrices processed from donor rat corporal nerves for interposition nerve grafting. Subsequent electromyography of the acellular nerve grafts at 3 months after surgery demonstrated adequate intracavernosal pressures, confirming their feasibility as an alternative to autologous nerve grafts in aiding recovery of cavernosal nerve function. Other innovative approaches being developed in animal models include use of embryonic stem cells [49] and growth factors [50] to augment cavernous nerve regeneration. Although exciting, final applicability of these new strategies in humans remains to be seen.

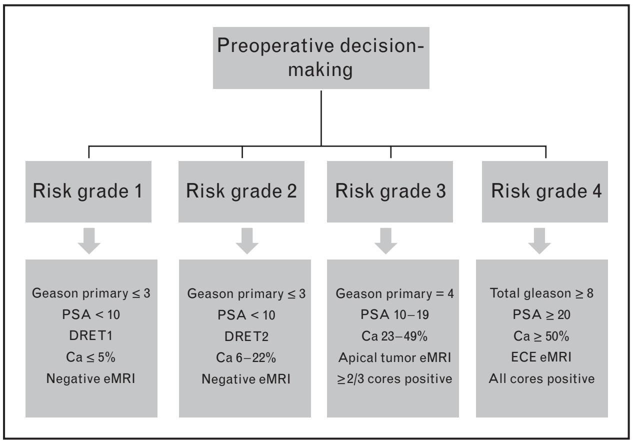
Periprostatic planes of fascial dissection

Recent anatomic studies by Tewari *et al.* [15], Costello *et al.* [16], Takenaka *et al.* [51] and Kiyoshima *et al.* [17] demonstrated significant variation of the periprostatic nerves from the classical description of the distinct NVBs found in the posterolateral grooves of the prostate, as described by Walsh. Correlating their intraoperative observations during RARP with histologic specimens, Menon and colleagues from the Vattikuti Institute of Prostatectomy, Detroit, recognized that numerous nerve bundles are present in the different layers of fascia enveloping the prostate. Deviating from Walsh's accepted technique [14] of leaving prostatic fascia on the prostatectomy specimen, Savera *et al.* [21] and Kaul *et al.* [52] adopted an aggressive approach to nerve-sparing termed the 'veil of aphrodite' technique, wherein the prostatic fascia is dissected down to the glistening prostatic capsule surface, and the veil of periprostatic tissue teased away in a relatively avascular plane. In their cohort of 154 men, 112 had preoperative SHIM scores of 22 or more, 69% reported postoperative SHIM of 22 or more (either with or without medical assistance) at 12-month follow-up, with a positive margin rate of 5% in pathological stage T2 cancer [53]. Adopting this aggressive intrafascial approach of dissection down to the shiny prostatic capsule for laparoscopic radical prostatectomy, Stolzenburg *et al.* [54] also reported return of potency in 89.7% of their patients aged less than 55 years at 12 months following surgery, with margin positivity rates of 4.5% in pT2 and 29.4% in pT3 disease. Interestingly, Nielsen *et al.* [55] also adopted a similar approach by performing high anterior release of the levator fascia during bilateral nerve-sparing retropubic radical prostatectomy, and reported improved sexual function without compromise of surgical margins. Many investigators however believe that high anterior release primarily works by avoiding traction on NVBs (ERUS meeting, Bordeaux, France, Anatomy panel 2010: C.C. Abbou, F. Montorsi, A. Tewari, T.E. Ahlering, A. Costello, S. Droupy, D. Murphy, A. Villers, J. Walz).

Balancing nerve preservation with cancer control: risk-stratified approach

In attempting to balance the competing goals of cancer clearance with preservation of potency, a risk-stratified approach toward nerve-sparing according to the patient's likelihood of ipsilateral extraprostatic extension (EPE) is adopted at our institution (Fig. 6) [56••]. The patient's prostate-specific antigen, Gleason score, percentage of cancer in the biopsy, number of positive cores, presence of unilateral versus bilateral positive cores (used as a surrogate for high-volume cancer or multifocality), clinical stage, and findings of the endorectal MRI in

Figure 6 Risk-stratified algorithm for nerve-sparing athermal nerve-sparing robotic radical prostatectomy



DRE, digital rectal examination; ECE, extracapsular extension; PSA, prostate-specific antigen. Reproduced with permission from [56••].

terms of cancer localization, volume, status of capsule, and periprostatic tissue are parameters that are used to select patients for a nerve-sparing prostatectomy. Our approach to nerve-sparing during robotic prostatectomy involves varying degrees of preservation of the nerve fibers in the various fascial planes (Figs 7 and 8). We refer to them as follows:

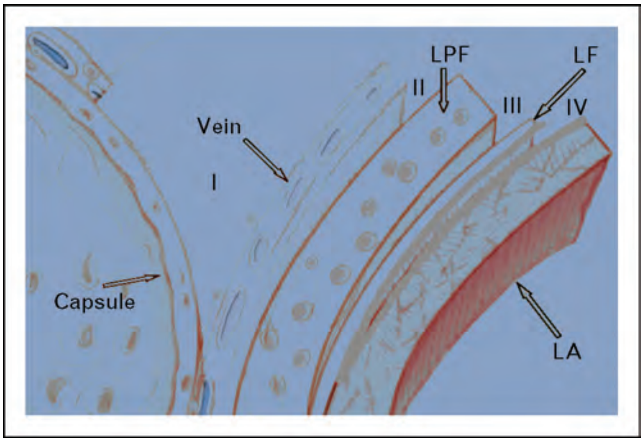
Grade 1 nerve-sparing

Incision of the Denonvilliers' and prostatic fascia is taken just outside the prostatic capsule. We perform this only for patients with no to minimal risk of EPE.

Grade 2 nerve-sparing

Incision through the Denonvilliers' (leaving deeper layers on the rectum) and LPF is taken just outside the layer of veins of the prostate capsule – this preserves most large neural trunks and ganglions, and is used for patients at low risk for EPE.

Figure 7 Layers of fascia enveloping prostatic capsule, demonstrating the planes of dissection for differing grades (I–IV) of nerve-sparing



LA, levator ani; LF, levator fascia; LPF, lateral pelvic fascia.

Grade 3 (partial/incremental) nerve-sparing

Incision is taken through the outer compartment of LPF removing the prostatic fascia while leaving behind the levator fascia. All layers of Denonvilliers' fascia are also excised. This is performed for patients with moderate risk of EPE because some of the medial trunks are sacrificed, whereas lateral trunks are preserved.

Grade 4 (nonnerve-sparing)

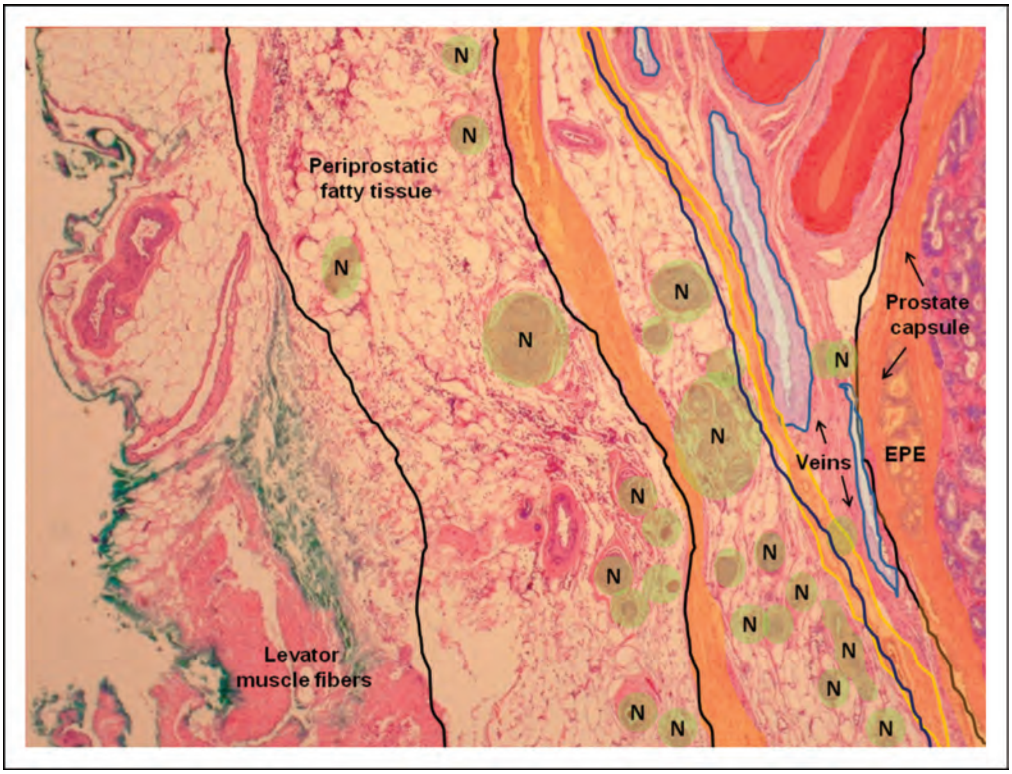
These patients have high risk of EPE, and are not candidates for nerve-sparing. Here, we perform wide excision of the LPF (prostatic and levator fasciae) and Denonvilliers' fascia, and thus remove the majority of the periprostatic neurovascular tissue. In selected patients, we attempt nerve advancement of the identifiable ends of the NVB.

In addition, we have adopted the following modifications to our athermal robotic nerve-sparing technique: minimizing periprostatic dissection to avoid traction/transection of the delicate nerves; limiting dissection to the midline during bladder neck transection, as this will protect the PNP from thermal/ mechanical injury; adopting athermal dissection of the seminal vesicles, as this should cause the least damage to the PNP and hypogastric nerve; and avoiding use of cautery during the posterolateral prostatic dissection.

Traction-free, athermal preservation of neural hammock during robotic prostatectomy

We have utilized existing anatomic and published wisdom to optimize our nerve-sparing approach [15,16,20,21,51]. The basic tenets are as follows: it is anatomic, trizonal, avoids/minimizes the periprostatic dissection and manipulation, attempts to preserve the neural hammock, risk-stratified, based on intraoperative visual cues, traction-free, athermal, utilizes current knowledge about periprostatic spaces and fascial layers, involves midline entry into the appropriate periprostatic space and then marches laterally (under vision and avoids all nerves as they enter the plane from lateral aspect), ensures safety of inferior hypogastric plexus by delicate dissection of the seminal vesicles using our medial avascular space concept, involves development of small vascular pedicles to avoid neural injury during pedicle control, is cognizant of variations in distal periapical neural architecture and releases the nerves under vision by retro/ circum-apical approach, because it attempts to maintain integrity of the entire hammock (anatomically and functionally; including arteries and veins), it may be preserving perfusion to penile and neurovascular tissue, and

Figure 8 Histology of non-nerve-sparing radical prostatectomy specimen with wide excision of adjacent tissue



Note the distribution of nerve (N) fibers (highlighted in green) in the periprostatic fascial layers. The collapsible veins on the prostate capsule (outlined in blue) are a distinct anatomic landmark – most of the periprostatic nerve fibers lie lateral to these veins. Notice also the area of extraprostatic extension of cancer (EPE) through the prostate capsule adjacent to these veins.

finally, uses modified posterior reconstruction techniques to include a lip of rectourethralis muscle or fascia during the anastomosis to avoid suture entrapment of the nerves.

Technical steps for nerve-sparing

The initial steps of robotic prostatectomy have been described before [19,56••,57–59,60••]. We start the procedure transperitoneally, drop the bladder and expose the anterior surface of the bladder and prostate. The endopelvic fascia is minimally incised and the bladder neck is entered in the midline. Care is taken to avoid injury to PNP or the proximal part of the hammock. The catheter is gently retracted to expose and deliver the vas deferens and seminal vesicles more anteriorly. Using sharp scissors and curved graspers we separate the capillaries and veins from the underlying vasa deferentia and anterior surface of the seminal vesicles. Soon the catheter is exchanged for cut ends of vasa deferentia, which are now used to further expose the seminal vesicles. The seminal vesicles are encased in their own fascial compartment and most of the vessels and nerves travel or enter at the tip or lateral aspect. Therefore, the medial avascular compartment is a logical entry point to start the intrafascial dissection during nerve-sparing procedure. Obviously the entire fascia is left on the seminal vesicles if the patient has more aggressive cancer and thus, is not a candidate for nerve sparing. The medial avascular plane is slowly developed and seminal vesicles are exposed anteromedially. Care is taken during the lateral dissection by minimizing the traction and small pedicle clipping to preserve delicate PNP and hypogastric branches.

Inside-out approach for nerve hammock release

At this time both seminal vesicles and vasa deferentia are lifted up and Denonvilliers' fascia is tented and entered in the midline by a sharp incision. On the basis of the predetermined cancer variables we enter the appropriate fascial plane within the layers of Denonvilliers' fascia and very gently (using sharp dissection) expand the retroprostatic space. The individual small arterial and venous bleeders are either controlled and cut or cold cut based on intraoperative judgment. The space is first extended distally to expose the under surface of prostatourethral junction. Dissection of this plane is slowly carried laterally on the side which has lesser predicted cancer based on preoperative assessment. By now we are freeing the PNB from the posterolateral aspect of prostate. Further dissection actually creates a plane between the neurovascular hammock and the lateral aspect of prostate. This plane is easier to develop distally because there are few perforating vessels in the capsule. These perforating vessels are identified and sharply cut. Some of them actually require a clip and most stop bleeding within a few seconds. A similar plane is developed to the contralateral side to release the entire posterior aspect of the hammock. So far we have not applied any traction to the hammock and at this stage of the dissection, the hammock is only attached to the prostate at the base where large branches of the inferior vesicular artery form the pedicle and enter the prostate and seminal vesicles via the base. The hammock is also adhered to the prostate bilaterally at the anterolateral edge where the fascial compartments fuse with the endopelvic fascia and anterior fibromuscular stroma of the prostate. This early release of the hammock posteriorly actually minimizes the traction on neural tissue and better defines the pedicle. The pedicle has two distinct components – a medial one which enters the base of seminal vesicle and medial aspect of prostatic base and a more lateral one which contains larger vessels entering the posterolateral and anterolateral corners of the prostate base. The neurovascular hammock is intermingled with these two components of the pedicle and has already been separated by our approach of midline entry into the periprostatic plane and gentle release from medial to lateral and then anterior aspect of the prostate. The medial pedicle is controlled using one to three small 5-mm clips and sharply cut. Sharp dissection is important because it avoids traction on the nerves, inadvertent development of capsular flaps and iatrogenic positive margins. Sharp dissection however requires appreciation of appropriate surgical planes and requires visual cues to recognize various structures and pathologies (inflammation, extraprostatic extension, etc.) [56••]. Next, the lateral pedicle is similarly controlled and cut in small parts. Once the entire pedicle is cut, the rest of the hammock is easily released and its anterolateral edge is either clipped or controlled using 4-0 suture to minimize bleeding from the anterolateral edge of the hammock which mostly is made up of periprostatic veins. We often see an anterolateral arterial trunk that travels from a proximal to distal aspect and disappears in the pelvic floor possibly supplying the urethra or penis. A special attempt is made in separating this artery from the prostatic pedicle to which it is intimately attached. Preservation of this and additional arterial trunks maximizes the viability of neurovascular tissue, as some of them may be vasa nervosum or significant arterial supply to the cavernous tissue. Traction on these vessels could actually produce distal ischemic changes as noted in our penile oxygenation studies [61•].

Next, surgical attention is directed towards the distal aspect of the anterolateral edge of hammock which is freed under vision from the prostatic apex. The prostate is now lifted up and using the 30° lens facing upward we release the distal 1 cm of the hammock and care is taken to void any traction or blunt dissection. This is the final common pathway of the pelvic nerves while they are exiting the pelvis. There are one or two periapical arteries that are controlled and cut. The retroapical plexus (part of the distal neural hammock) is left untouched and dropped posteriorly. The urethral-apical junction is identified and transected as described in our retroapical technique [60••]. Once the prostate is freed it is packed in the EndoCatch bag and the surgical field is inspected for significant bleeding. The bleeders are picked up by curved needle tips and either clipped or sutured using a figure-of-eight stitch. If during nerve sparing, there occurs a need for retracting the hammock we use similar curved needle points or 4-0 sutures to minimize tissue trauma and traction. Finally, lymph node dissection is performed, followed by anastomosis and total anatomic reconstruction. During reconstruction we especially keep an eye on the location of the retroapical plexus so as to avoid inadvertent inclusion in the suture. The operation is completed after placing a pelvic drain. Using this traction-free approach in a cohort of 54 men, 96.8% men who were preoperatively potent had successful return of sexual functions by 1 year [61•].

Conclusion

Much of the progress achieved in the past two decades in improving potency outcomes after radical prostatectomy has resulted from an improved appreciation of the anatomic basis of the nerves responsible for erection. Recent studies suggest alternative and more complex course of nerves than previously described. Better appreciation of the variable and often invisible anatomic course of the cavernosal nerves continues to engender innovations in surgical technique to optimize their preservation. This in turn improves potency outcomes following radical prostatectomy which is highly desired in this current age of improved life expectancy and heightened patient expectations.

Summary

Recent studies suggest alternative and more complex course of nerves than previously described.

Better appreciation of anatomic course of the cavernosal nerves continues to engender innovations in surgical technique to optimize their preservation.

Such advances in surgical technique can improve potency outcomes following radical prostatectomy.

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