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Surgery in Motion

Technical Refinement and Learning Curve for Attenuating Neurapraxia During Robotic-Assisted Radical Prostatectomy to Improve Sexual Function

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Abstract

Background: While radical prostatectomy surgeon learning curves have characterized less blood loss, shorter operative times, and fewer positive margins, there is a dearth of studies characterizing learning curves for improving sexual function. Additionally, while learning curve studies often define volume thresholds for improvement, few of these studies demonstrate specific technical modifications that allow reproducibility of improved outcomes.
Objective: Demonstrate and quantify the learning curve for improving sexual function outcomes based on technical refinements that reduce neurovascular bundle displacement during nerve-sparing robot-assisted radical prostatectomy (RARP).
Design, setting, and participants: We performed a retrospective study of 400 consecutive RARPs, categorized into groups of 50, performed after elimination of continuous surgeon/assistant neurovascular bundle countertraction.
Surgical procedure: Our approach to RARP has been described previously. A single-console robotic system was used for all cases.
Outcome measurements and statistical analysis: Expanded Prostate Cancer Index Composite sexual function was measured within 1 yr of RARP. Linear regression was performed to determine factors influencing the recovery of sexual function.
Results and limitations: Greater surgeon experience was associated with better 5-mo sexual function ($p = 0.007$) and a trend for better 12-mo sexual function ($p = 0.061$), with improvement plateauing after 250–300 cases. Additionally, younger patient age (both $p < 0.02$) and better preoperative sexual function (<0.001) were associated with better 5- and 12-mo sexual function. Moreover, trainee robotic console time during nerve sparing was associated with worse 12-mo sexual function ($p = 0.021$), while unilateral nerve sparing/non–nerve sparing was associated with worse 5-mo sexual function ($p = 0.009$). Limitations include the retrospective single-surgeon design.
Conclusions: With greater surgeon experience, attenuating lateral displacement of the neurovascular bundle and resultant neurapraxia improve postoperative sexual function. However, to maximize outcomes, appropriate patient selection must be exercised when allowing trainee nerve-sparing involvement.

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1. Introduction

Opponents of prostate-specific antigen screening and aggressive treatment of low-risk prostate cancer contend that treatment-related sequelae and the costly treatment of the side-effects may be worse than a potentially indolent disease process [1,2]. For instance, the likelihood of postprostatectomy erectile dysfunction ranges from 7% to 80% [3,4], contributing to treatment regret [5,6]. This marked variation in postprostatectomy sexual function may be attributable to differences in patient selection, varying definitions of *potency*, biases stemming from varying methods of data collection (physician- vs patient-reported outcomes with or without validated quality-of-life instruments), and, most important, heterogeneous surgical techniques [3,7,8].

Surgical techniques to preserve erectile function have continued to evolve since Walsh's initial description of nerve-sparing prostatectomy approximately 30 yr ago [9]. With improved knowledge of pelvic anatomy and the advent of greater magnification during open radical prostatectomy or robot-assisted radical prostatectomy (RARP), there has been greater emphasis on full nerve sparing compared with partial nerve sparing, or on achieving the intrafascial dissection plane compared with the interfascial dissection plane during nerve sparing [10–12]. This emphasis is epitomized by histologic studies correlating recovery of sexual function with the amount of residual neurovascular bundle tissue resected with the prostate [13,14]; however, there is less emphasis on minimizing stretch neuropathy and neurapraxia that adversely affects recovery of sexual function. We recently described earlier recovery of sexual function through the elimination of active assistant and/or surgeon neurovascular bundle countertraction during RARP [15]. However, additional subtle technical refinements improve sexual function, and this paper describes and demonstrates maneuvers to further attenuate neurapraxia during nerve-sparing RARP and improve sexual function outcomes.

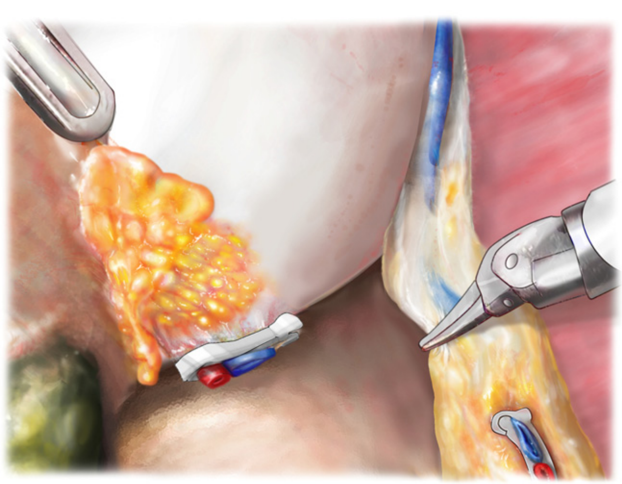

Fig. 1 – Prior technique of intermittent blunt dissection associated with transient cross-tension and lateral displacement of the neurovascular bundle as it is peeled away from the prostate during right nerve-sparing dissection.

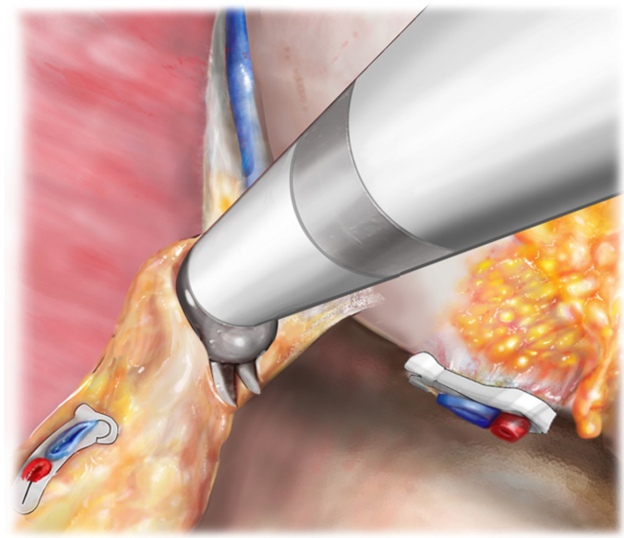

Fig. 2 – Prior technique of peeling with intermittent blunt dissection associated with transient stretch of the left neurovascular bundle.

2. Methods

2.1. Technical modification

Our approach to RARP has been described previously. A single-console robotic system was used for all cases. After eliminating continuous lateral displacement of the neurovascular bundles by the assistant and robotic surgeon to facilitate nerve-sparing dissection with countertraction [15], we focused on reducing the lateral neurovascular bundle displacement that occurs with intermittent blunt dissection resulting from a peeling motion (Figs. 1 and 2). This reduction was accomplished bilaterally with greater reliance on spreading the robotic scissors longitudinally medial to the neurovascular bundle, followed by sharp dissection (Fig. 3). In addition, during left apical nerve-sparing dissection, the robotic Maryland dissector is spread open just enough to allow sharp dissection of the medial border of the neurovascular bundle away from the left apex (Fig. 4).

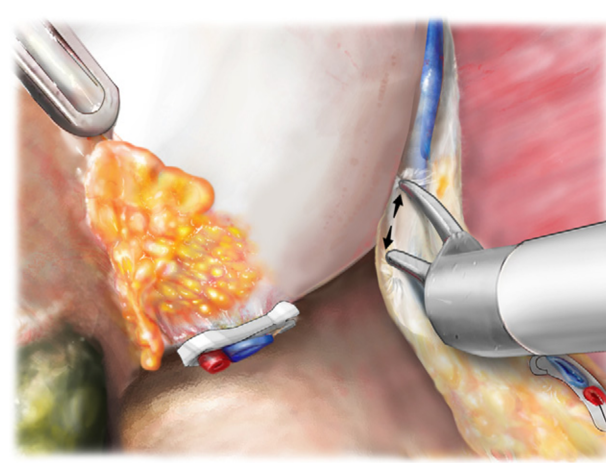

Fig. 3 – Modified right nerve-sparing dissection with spreading of scissors longitudinally along the medial edge of the neurovascular bundle to set up sharp dissection.

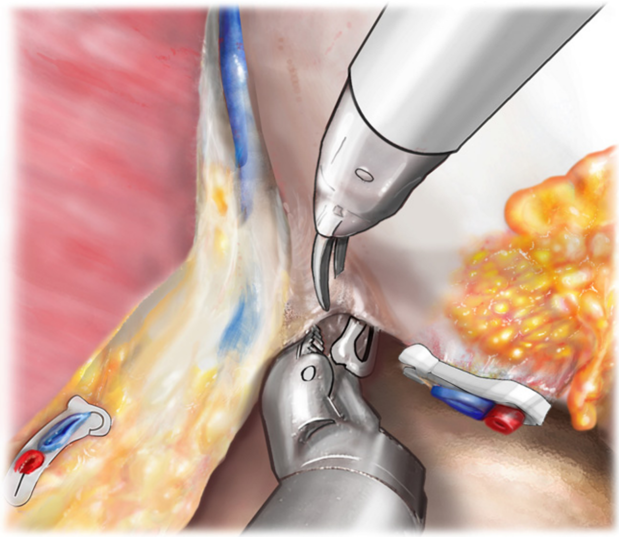

Fig. 4 – Modified left apical nerve-sparing dissection with minimal spreading of the Maryland dissector to facilitate sharp dissection and minimize lateral displacement of the left neurovascular bundle.

2.2. *Data collection*

All RARPs were performed by the senior author (J.C.H.); prior training comprised logging 76 open radical prostatectomies during residency training and 11 mo of focusing on RARP without performing nerve sparing during fellowship. After training, the first 127 cases were performed with harmonic scalpel ligation of the lateral prostatic pedicles, followed by transition to 10-mm Hem-o-Lok clip (Teleex Medical, Durham, NC, USA) ligation and another 554 cases to achieve a consistent nerve-sparing plane and eliminate active continuous lateral tension on the neurovascular bundle during nerve sparing, as determined by video review. Subsequently, 400 consecutive men underwent RARP from August 2009 to March 2011 with evolution of the aforementioned technique [15]. Residents and fellows were allowed robotic console time in the following progression, advancing after demonstration of stepwise proficiency: (1) entry into the retropubic space, (2) anterior anastomosis, (3) seminal vesicle dissection, (4) defining the posterior and anterior prostate contours, (5) selective suture ligation of dorsal venotomies, (6) posterior anastomosis, (7) apical dissection, (8) bladder-neck sparing, (9) lateral pedicle ligation, and (10) antegrade nerve sparing.

Data were prospectively collected and entered by research personnel uninvolved with clinical care into an institutional review board–approved Microsoft Access database. Thirty-nine men with seminal vesicle or extraprostatic extension (9.8%) received adjuvant radiation and/or hormonal therapy and were excluded from analysis of sexual function recovery. The Expanded Prostate Cancer Index Composite (EPIC) was administered at 5- and 12-mo postoperative follow-up appointments and by telephone, with response rates of 92% and 89%, respectively, within 30 d of these assessment points. The EPIC is scored from 0 to 100, with higher scores representing better outcomes [16]. To enhance clinical interpretability and present potency outcomes in addition to a continuous sexual function measures, we dichotomized responses to the EPIC item concerning erection quality to define *potency* as erections firm enough for sexual activity or intercourse. There were no differences in baseline responder and nonresponder demographics, tumor characteristics, or baseline sexual function scores [15].

2.3. *Statistical analysis*

Subjects were categorized by groups of 50 to assess change in mean sexual function scores with greater surgeon experience. In bivariable analyses, linear regression was used to assess trends in continuous variables over sequential groups of 50 subjects; the Cochran-Armitage trend test was used to assess trends in categorical variables over sequential groups of 50 subjects. In multivariable analyses, linear regression analyses was performed a priori with covariates that may affect sexual function, such as patient age, baseline sexual function, extent of nerve sparing (bilateral, unilateral, none), and trainee surgeon

Table 1 – Characteristics of the study population by sequential groups of 50 subjects

	1–50	51–100	101–150	151–200	201–250	251–300	301–350	351–400	*p* value
Preoperative continuous variables, mean ± standard deviation									
Age	59.2 ± 6.8	60.1 ± 7.2	61.0 ± 5.6	58.8 ± 6.5	59.1 ± 6.2	59.4 ± 6.9	59.2 ± 6.2	59.8 ± 6.9	0.702
Baseline sexual function	62.4 ± 31.0	64.1 ± 33.6	76.0 ± 22.0	74.7 ± 29.1	74.7 ± 30.1	75.2 ± 25.7	75.2 ± 31.4	76.8 ± 23.8	0.004
Body mass index, kg/m^2	30.5 ± 5.5	30.2 ± 5.4	28.3 ± 4.6	28.0 ± 4.3	27.6 ± 3.8	29.3 ± 4.4	28.5 ± 4.8	27.7 ± 5.8	0.007
PSA, ng/ml	4.7 ± 2.3	6.3 ± 5.9	6.7 ± 4.2	5.7 ± 2.9	5.3 ± 1.9	5.5 ± 2.2	6.8 ± 4.5	5.8 ± 3.6	0.675
Intraoperative/pathologic characteristics, *n* (%)									
Trainee robotic console nerve- sparing participation	0 (0.0)	6 (12.0)	5 (10.0)	7 (14.0)	1 (2.0)	9 (18.0)	11 (22.0)	27 (54.0)	<0.001
Nerve sparing									
None	2 (4.0)	5 (10.0)	3 (6.0)	2 (4.0)	7 (14.0)	2 (4.0)	2 (4.0)	1 (2.1)	0.121
Unilateral	9 (18.0)	5 (10.0)	4 (8.0)	3 (6.0)	2 (4.0)	2 (4.0)	7 (14.0)	3 (6.3)	
Bilateral	39 (78.0)	40 (80.0)	43 (86.0)	45 (90.0)	41 (82.0)	46 (92.0)	41 (82.0)	44 (91.7)	
Positive surgical margin	5 (10.0)	9 (18.0)	7 (14.0)	5 (10.0)	8 (16.0)	9 (18.0)	8 (16.0)	8 (16.0)	0.539
Gleason score									
≤6	13 (26.0)	18 (36.0)	16 (32.0)	12 (24.0)	11 (22.0)	13 (26.0)	12 (24.0)	17 (35.4)	0.814
7	37 (74.0)	28 (56.0)	32 (64.0)	36 (72.0)	36 (72.0)	34 (68.0)	34 (68.0)	28 (58.3)	
8–10	0 (0.0)	4 (8.0)	2 (4.0)	2 (4.0)	3 (6.0)	3 (6.0)	4 (8.0)	3 (6.3)	
Stage									
T2	42 (84.0)	42 (84.0)	44 (88.0)	41 (83.7)	36 (72.0)	39 (78.0)	43 (86.0)	43 (86.0)	0.754
T3a	6 (12.0)	7 (14.0)	4 (8.0)	5 (10.2)	11 (22.0)	7 (14.0)	6 (12.0)	4 (8.0)	
T3b	2 (4.0)	1 (2.0)	2 (4.0)	3 (6.1)	3 (6.0)	4 (8.0)	1 (2.0)	3 (6.0)	

PSA = prostate-specific antigen.

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participation at the robotic console during nerve sparing and surgeon experience. Unilateral nerve sparing and non–nerve sparing were categorically collapsed because of the relative infrequency of these approaches. Because the sexual function curve may not be a linear function of surgeon experience, we also considered models with quadratic or logarithmic terms in surgeon experience and chose the model with the best fit [17]. The adjusted sexual function outcomes were plotted along with surgeon experience. All analyses were performed with SAS 9.2 (SAS Institute Inc., Cary, NC, USA).

3. Results

Over the study period, subjects increasingly presented with better baseline sexual function ($p = 0.004$) and lower body mass index ($p = 0.007$); however, other demographic and tumor characteristics did not differ (Table 1). In terms of intraoperative characteristics, there was greater trainee participation at the robotic console during nerve sparing with increasing surgeon experience ($p < 0.001$). However, there was no variation in use of bilateral nerve sparing compared with unilateral nerve sparing and non–nerve sparing, number of positive surgical margins, and pathologic stage and grade.

In unadjusted analysis, 5-mo sexual function improved with greater surgeon experience ($p = 0.011$), with a range of 20.2 points and a 17.9-point increase from the first to last 50 men (Table 2). Similarly, 5-mo potency improved ($p = 0.008$), with a range of 33.3%, increasing from 0% to 15.8% from the first to last 50 men. Additionally, there was improved 12-mo sexual function with greater surgeon experience ($p = 0.030$), with a range of 21.8 and a 17.8-point increase from the first to last 50 men; there was parallel improvement in 12-mo potency ($p = 0.010$), with a range of 44.5%, increasing from 14.8% to 31.3% from the first to last 50 men.

In adjusted analyses (Table 3), greater surgeon experience was associated with better 5-mo sexual function (parameter estimate [PE]: 5.21; 95% confidence interval [CI], 1.4–9.02) and with a trend for better 12-mo sexual function (PE: 0.06; 95% CI, 0–0.12). Additionally, trainee robotic console involvement during nerve sparing was associated with worse 12-mo sexual function (PE: −12.58; 95% CI, −23.23 to −1.92). Older patient age was associated with worse 5-mo sexual function (PE: −0.49; 95% CI, −0.09 to −0.08) and worse12-mo sexual function (PE: −0.72; 95% CI, −1.25 to −0.19). Conversely, better baseline sexual function was associated with better 5-mo sexual function (PE: 0.31; 95% CI, 0.21–0.40) and better 12-mo sexual function (PE: 0.40; 95% CI, 0.27–0.52). Finally, non–nerve sparing/unilateral nerve sparing versus bilateral nerve sparing was associated with worse 5-mo sexual function (PE: −9.90; 95% CI, −17.27 to −2.53). Five-month and 12-mo unadjusted and adjusted mean sexual function performance curves are presented in Figures 5 and 6, respectively.

4. Discussion

The detrimental effect of neural stretch injury has been quantified in other surgical fields. Wall et al. demonstrated that a 6% nerve stretch may result in a 70% reduction of

Table 2 – Sexual function outcomes by sequential groups of 50 subjects

	1–50	51–100	101–150	151–200	201–250	251–300	301–350	351–400	*p* value
EPIC sexual function									
mean ± standard deviation									
5 mo, *n*	43	47	42	47	46	47	47	46	
	14.6 ± 17.9	22.2 ± 21.6	26.5 ± 19.6	28.7 ± 22.7	31.2 ± 31.4	34.8 ± 33.7	30.2 ± 29.1	32.5 ± 31.4	0.011
12 mo, *n*	45	45	46	45	42	31	–	–	
	26.7 ± 18.6	28.5 ± 19.7	29.0 ± 22.1	33.3 ± 23.9	48.5 ± 36.9	44.5 ± 32.0	–	–	0.030
Potency in previously potent, *n* (%)									
5 mo	0 (0.0)	3 (10.7)	2 (6.5)	4 (11.1)	10 (33.3)	10 (27.8)	6 (19.4)	6 (15.8)	0.008
12 mo	4 (14.8)	7 (26.9)	6 (17.1)	10 (28.6)	16 (59.3)	10 (31.3)			0.010

EPIC = Expanded Prostate Cancer Index Composite.

Table 3 – Multivariable analysis of factors associated with 5- and 12-mo sexual function

Covariates (referent)	5-mo sexual function	*p* value	12-mo sexual function	*p* value
Surgeon experience, PE (95% CI)*	5.21 (1.40–9.02)	0.007	0.06 (0.00–0.12)	0.061
Trainee robotic console nerve-sparing participation, PE (95% CI)	−1.80 (−8.16 to 4.55)	0.577	−12.58 (−23.23 to −1.92)	0.021
Non–nerve sparing/unilateral nerve sparing (bilateral), PE (95% CI)	−9.90 (−17.27 to −2.53)	0.009	−7.49 (−16.90 to 1.92)	0.120
Age, PE (95% CI)	−0.49 (−0.90 to −0.08)	0.019	−0.72 (−1.25 to −0.19)	0.018
Baseline sexual function, PE (95% CI)	0.31 (0.21–0.40)	<0.001	0.40 (0.27–0.52)	<0.001
Assistant surgeon training (PGY6), PE (95% CI)				
PGY2	−2.35 (−13.21 to 8.51)	0.670	4.21 (−8.00 to 16.42)	0.498
PGY3	−4.40 (−12.61 to 3.81)	0.292	−1.62 (−11.22 to 7.98)	0.740
PGY5	−1.18 (−8.80 to 6.44)	0.761	2.58 (−9.80 to 14.95)	0.682

PE = parameter estimate; CI = confidence interval; PGY = postgraduate year.
* Modeled as a logarithmic and linear term at 5 and 12 mo, respectively.

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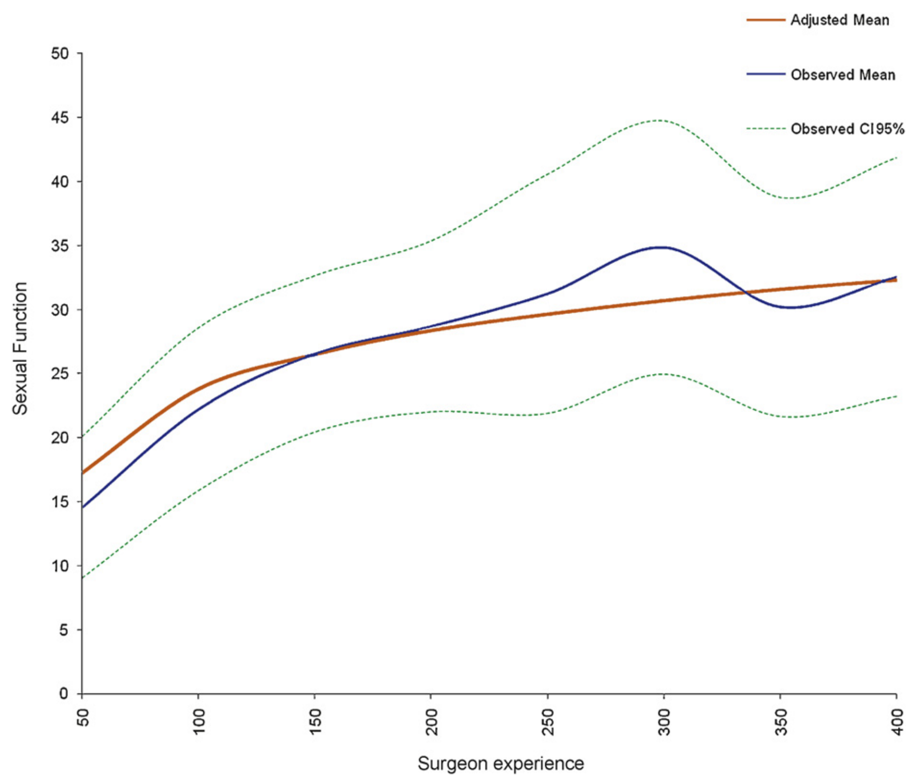

Fig. 5 – Improved 5-mo postprostatectomy sexual function associated with transition from blunt to predominately sharp neurovascular bundle dissection with minimization of lateral neurovascular bundle displacement; adjusted curve controls for surgeon experience, trainee nerve-sparing participation, non–nerve sparing/unilateral nerve sparing compared with bilateral nerve sparing, patient age, and baseline sexual function.

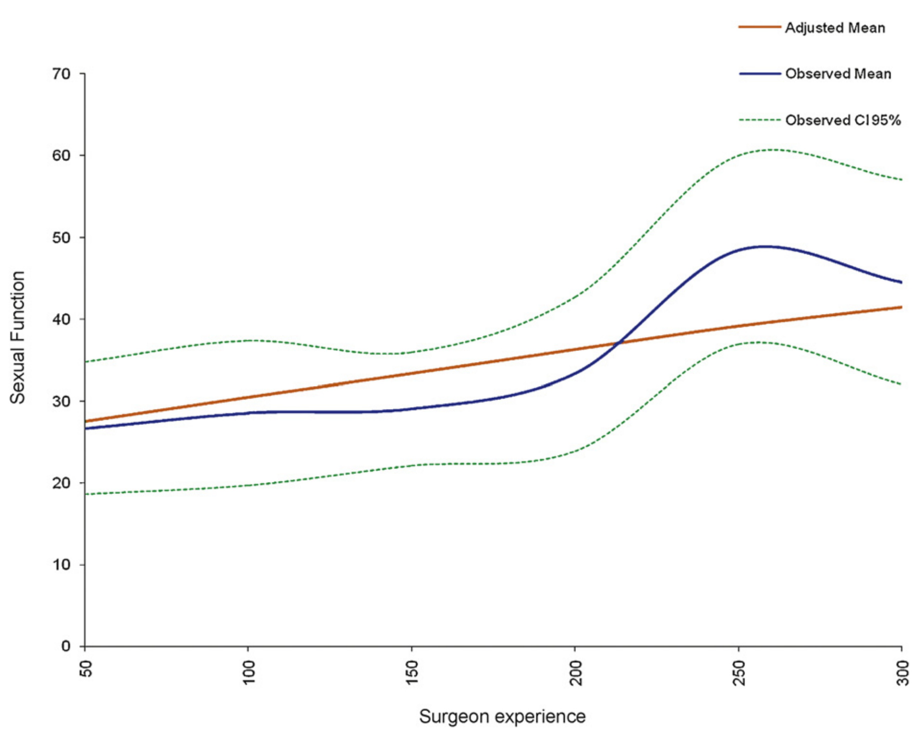

Fig. 6 – Improved 12-mo postprostatectomy sexual function associated with transition from blunt to predominately sharp neurovascular bundle dissection with minimization of lateral neurovascular bundle displacement; adjusted curve controls for surgeon experience, trainee nerve-sparing participation, non–nerve sparing/unilateral nerve sparing compared with bilateral nerve sparing, patient age, and baseline sexual function.

action potentials, and a 12% nerve stretch for more than an hour resulted in indefinite complete loss of nerve conduction [18]. For instance, accessory nerve traction during head and neck surgery leads to postoperative shoulder disability [19]. For radical prostatectomy, the detrimental effect of neurovascular bundle stretch injury has been mentioned [20–24], and we previously quantified the earlier recovery of sexual function with avoidance of continuous assistant/surgeon countertraction of the neurovascular bundle [15].

Our study has several important findings. First, we demonstrate additional technical refinements to minimize lateral displacement of the neurovascular bundle, resulting in earlier and better recovery of sexual function. Comparison of the first and last 50 men reveals an improvement of approximately 18 points at both 5 and 12 mo after prostatectomy. This finding is both statistically and clinically significant, as a minimally important difference of 10–12 points in the EPIC sexual function scale is of clinical significance [25]. Additionally, younger patient age and better baseline sexual function are associated with better post-prostatectomy sexual function, as demonstrated by others [3].

Second, we quantify a learning curve and demonstrate technical modifications for improved recovery of sexual function that includes 413 RARPs to consistently achieve the nerve-sparing dissection plane, 268 RARPs to become independent of continuous countertraction to facilitate nerve-sparing dissection, and 400 RARPs to attenuate transient lateral displacement of the neurovascular bundle [15]. While RARP learning curves have been characterized for reducing operating time, blood loss, and positive surgical margins and for improving urinary continence, no studies have demonstrated a learning curve for improving sexual function [26]. In fact, Zorn et al. demonstrated improvement in the previously mentioned metrics over 700 RARPs without a change in sexual function outcomes [26]. While Vickers et al. contend that outcomes improve with greater surgeon experience and illustrate the potential pitfall of concluding that there is significant improvement following the implementation of a new technique [27], it is unclear what specific modifications may contribute to continuous improvement of outcomes. Conversely, our video and corresponding outcomes demonstrate that subtle refinement in surgical technique typically occurs gradually over time, in contrast to analyses that dichotomize pretechnique modification and post-technique modification. Moreover, while many learning curve papers pronounce a volume threshold beyond which outcomes improve, few describe specific technical modifications associated with better outcomes during mastery of the learning curve.

Third, trainee robotic console involvement during nerve sparing was associated with worse 12-mo sexual function despite explicit intraoperative instruction, underscoring the learning curve for optimizing recovery of sexual function, and this finding has implications for training during RARP. We did not have a dual-console robotic system, which facilitates attending surgeon intercession. Additionally, selecting men with baseline erectile dysfunction when allowing trainee participation during nerve sparing may maximize sexual function outcomes, which contrasts with prior studies that did not demonstrate a negative impact of trainee robotic console involvement on other outcomes, such as operative time, estimated blood loss, and number of positive surgical margins [28,29]. Our findings also highlight a need for robotic surgery simulator development to improve RARP sexual function outcomes by quantifying and reducing instrument excursion during blunt dissection and resultant neurovascular bundle displacement. Moreover, longer follow-up is needed to characterize the effect of trainee RARP nerve-sparing involvement on long-term sexual function outcomes.

Our study must be considered within the context of the study design. First, although data were prospectively collected, this is a single-surgeon retrospective study subject to inherent biases rather than a randomized controlled trial. However, surgical randomized controlled trials are difficult to implement, as surgeons become biased to certain techniques with more experience, and there is difficulty in achieving investigator and patient equipoise. Moreover, multisurgeon randomized controlled trials are limited because of heterogeneity in surgical technique; however, we used third-party collection of self-reported quality-of-life outcomes with validated instruments. Second, aside from review of intraoperative video, current technology does not allow quantification of the degree of neurovascular bundle stretch. However, real-time quantification of achieving the optimal nerve-sparing dissection plane is similarly limited to intraoperative surgeon subjectivity, without postoperative histologic examination. Third, while our technical modification over several hundred RARPs improved sexual function outcomes, this threshold may be shorter for others who are emphatic about avoiding neurovascular bundle stretch. Finally, additional follow-up is needed to assess long-term sexual function, as recovery plateaus at or beyond 24 mo after prostatectomy [30].

5. Conclusions

Intermittent stretch of the neurovascular bundle when peeling off the neurovascular bundle results in delayed or diminished sexual function following RARP. Subtle technical refinement to attenuate lateral displacement of the neurovascular bundle and resultant stretch neuropathy improves sexual function within 12 mo of RARP.

Author contributions: J.C. Hu had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Hu, Duclos.
Acquisition of data: Alemozaffar, Borza, Yu, Kowalczyk.
Analysis and interpretation of data: Lipsitz, Hevelone, Hu, Duclos.
Drafting of the manuscript: Hu, Alemozaffar, Kowalczyk, Duclos.
Critical revision of the manuscript for important intellectual content: Hu, Lipsitz, Alemozaffar.
Statistical analysis: Duclos, Hevelone, Lipsitz.
Obtaining funding: Hu.
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Appendix A. Supplementary data

The Surgery in Motion video accompanying this article can be found in the online version at doi:10.1016/j.eururo.2012.02.053 and via www.europeanurology.com.

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