Pelvic Floor Muscle Function and Its Relationship with Post-Prostatectomy Incontinence

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Abstract

Objectives Post-prostatectomy incontinence (PPI) is a common condition, but the underlying mechanisms are not completely understood. Transperineal ultrasound (TPUS) assessment of voluntary pelvic floor muscle (PFM) function may be associated with PPI. This study investigates the relationship between PPI and pre- and postoperative displacement of anatomical landmarks related to PFM function.

Methods This was a prospective longitudinal cohort study of 40 patients undergoing robotic-assisted radical prostatectomy (RARP) by a high-volume single surgeon. All patients underwent PFM training pre- and postoperatively. TPUS was used to obtain sagittal images of pelvic structures during maximal voluntary PFM contractions: (1) preoperatively, (2) 3 weeks postoperatively, and (3) 6 weeks postoperatively. TPUS images were analyzed to calculate displacement of anatomical landmarks associated with activation of striated urethral sphincter (SUS), bulbocavernosus muscle (BC), and puborectalis muscle (PR). Continence was assessed at 3 and 6 weeks postoperatively, defined as use of ≤ 1 pad/day. The relationship of continence to the displacement of SUS, BC, and PR was analyzed.

Results SUS, BC, and PR displacement decreased significantly 3 weeks postoperatively ($P = 0.042$, $P = 0.002$, $P < 0.001$, respectively). Continent men exhibited significantly greater SUS displacement (median, 5.13 mm) than incontinent men (median, 3.90 mm) 3 weeks postoperatively ($P = 0.029$). Between 3 and 6 weeks following RARP, there was significant increase in SUS, BC, and PR displacement ($P = 0.003$, $P = 0.030$, $P < 0.001$, respectively).

Conclusions A significant decrease in PFM function occurs following RARP, with a subsequent recovery of postoperative PFM function between 3 and 6 weeks post-procedure in men who undergo PFM training. SUS activation was significantly greater in continent patients compared to incontinent patients at 3 weeks following RARP.

Introduction

Post-prostatectomy incontinence (PPI) is a predictable consequence following radical prostatectomy. The incidence of PPI has been reported to occur in 59% to 63% of patients in the first 6 weeks following surgery[1–3]. The severity of PPI and the variation in the recovery of continence give rise to a significant clinical management issue. Despite the high incidence of PPI, the etiology of PPI and the variable time course for recovery are not well understood.

Key Words

prostatectomy, prostate cancer, urinary incontinence, pelvic floor, muscle contraction

Competing Interests

None declared.

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Abbreviations

BC bulbocavernosus muscle
BMI body mass index
ICC intraclass correlation coefficient
ICIQ-UI SF International Consultation on Incontinence Questionnaire–Urinary Incontinence Short Form
IQR interquartile range
PFM pelvic floor muscle
PPI post-prostatectomy incontinence
PR puborectalis muscle
PSA prostate-specific antigen
RARP robotic-assisted radical prostatectomy
SUS striated urethral sphincter
TPUS transperineal ultrasound

PPI typically occurs when urethral closure pressure is exceeded by bladder pressure. Inadequate urethral sphincter function (insufficiency) can lead to a reduction in urethral pressure and incomplete sphincter closure[4–8]. Urethral pressure can increase with voluntary contraction of the muscles that comprise the pelvic floor, including, the striated urethral sphincter (SUS), the bulbocavernosus muscle (BC), and the puborectalis muscle (PR)[9]. Contraction of the SUS results in dorsal displacement of the membranous urethra; BC contraction causes compression of the urethra at the bulb of the penis; and PR contraction results in ventrocaudal motion of the urethra to compress the urethra against the pubic symphysis[10–13]. Activation of the SUS, BC, and PR results in the displacement of anatomical landmarks including posterior displacement of the mid-urethra (in the case of SUS), anterior displacement of the bulb of the penis (BC), and anterior-superior displacement of the anorectal junction (PR)[11,12]. Using noninvasive transperineal ultrasound (TPUS) imaging, activation of the SUS, BC, and PR can be reliably measured and has been validated against electromyography (EMG) recordings[14,15].

The assessment of PFM function using TPUS prior to and following radical prostatectomy provides the opportunity to better understand the role of PFM function in continence recovery[16–19]. To date, the time course of pre- and postoperative activation of the SUS, BC, and PR and the association with return to continence have not been well described. Therefore, the aim of this study was to investigate the relationship between PPI and displacement of anatomical landmarks related to PFM activation before and at 3 and 6 weeks following robot-assisted radical prostatectomy (RARP).

Materials and Methods

Participant selection

This prospective longitudinal cohort study included patients who underwent RARP performed by a high-volume surgeon at a metropolitan center. Consecutive patients were prospectively recruited during an initial consultation prior to RARP between February and November 2019. Patients with a history of pad usage, pelvic surgery, or pelvic radiotherapy and patients who were unable to attend all physiotherapy consultations were excluded. This study was approved by the Western Sydney Local Health District Human Research Ethics Committee (ETH02769) and all patients gave written informed consent.

Experimental protocol

At the time of recruitment, each patient's demographic information, including age, body mass index (BMI), and prostate cancer characteristics (prostate-specific antigen [PSA] and histopathology) were collected. The patients were referred to a men's health continence physiotherapist 1 month before RARP for the prescription of a preoperative PFM training program[20]. The International Consultation on Incontinence Questionnaire–Urinary Incontinence Short Form (ICIQ-UI SF) was completed preoperatively. Postoperatively, patients were reviewed by a physiotherapist at 3 and 6 weeks following RARP. During these postoperative continence reviews, daily pad usage was recorded, and an individualized PFM training program was prescribed[20].

Pelvic floor muscle training

Patients underwent a progressive individualized 6-week pre- and postoperative PFM training program that focussed on the activation and training of the SUS[13]. TPUS was used to teach voluntary PFM activation and to provide visual biofeedback feedback to the patient and physiotherapist to maximize SUS activation[11,17].

TPUS assessment

All patients underwent TPUS imaging upon completion of the preoperative PFM training program and within 1 week of surgery and at 3 and 6 weeks postoperatively. TPUS was performed by 2 experienced physiotherapists using a Philips iU22 ultrasound machine (Philips Healthcare; Australia) in greyscale cine-loop format. At each review (preoperatively, and 3 and 6 weeks postoperatively), with each patient in a standing position, a curved array ultrasound transducer (7.0 MHz) was aligned on the perineum in the midsagittal plane so that the pubic symphysis, urethra, penile bulb, and anorectal angle were visible[11–13]. Following a standardized verbal instruction: "Contract your pelvic floor muscles as strongly as you can and hold," TPUS data were recorded while the patients performed 2 sustained maximal voluntary PFM contractions with a 10-second rest interval between the 2 contractions.

TPUS analysis

InteleViewer digital imaging and communications in medicine (DICOM) viewer software (Intelerad Medical Systems Inc.; Montreal, Canada) was used to analyze single-image frames from the cine-loop TPUS data. The displacement of anatomical landmarks from the resting to the contracted position included posterior displacement of the mid-urethra (SUS), anterior displacement of the bulb of the penis (BC), and anterior-superior displacement of the anorectal junction (PR) [11,12]. The mean displacement of the 2 SUS, BC, and PR voluntary PFM contractions was used for the analysis of PFM function. A random subset of the data (10 participants) was reanalyzed after 3 weeks by the same assessor to determine the test-retest reliability of the TPUS image analyses of the SUS, BC, and PR displacement measurements at each time point.

Statistical analysis

The median and interquartile range (IQR) were used to describe continuous variables. Pre- and postoperative SUS, BC, and PR displacement were compared using a one-way repeated measures analysis of variance (ANOVA). Patients were categorized based on their continence status at 3 and 6 weeks following RARP, defined as use of ≤ 1 pad daily. SUS, BC, and PR displacement measurements were compared as continuous variables using a Mann-Whitney U test between continent and incontinent patients. Test-retest reliability was determined using the intraclass correlation coefficient (ICC) with a 2-way mixed model for absolute agreement. ICC values were interpreted as poor (< 0.5), moderate (0.5 to 0.75), good (0.75 to 0.9), and excellent (> 0.9)[21]. *P*-values < 0.05 were considered statistically significant. IBM SPSS Statistics Version 28 (IBM, Armonk, United States) was used for the statistical analysis.

Results

In this study, 52 consecutive patients were recruited, with 12 patients lost to follow-up. A total of 40 patients completed all experimental protocol procedures and were included in the analysis. The patients' demographic, clinical, and operative characteristics are summarized in Table 1. While 5 patients had a preoperative ICIQ-UI SF score > 0 (range, 3–8), they reported no symptoms of stress urinary incontinence or pad usage. These patients all reported episodes of urge urinary incontinence occurring less than once per week, with the ICIQ-UI SF score predominately determined by question 5 on the ICIQ-UI: "Overall, how much does leaking urine interfere with your everyday life?". Excluding these 5 patients from the analysis did not change the results of our investigation.

The return to continence rate following RARP was 70% (n = 28) at 3 weeks and 95% (n = 38) at 6 weeks postoperatively. At 3 weeks following RARP, there was a significant decrease in SUS, BC, and PR displacement (Table 2). Between 3 and 6 weeks following RARP, there was a significant increase in SUS, BC, and PR displacement (Table 2). At 6 weeks following RARP, there was no significant difference between preoperative and postoperative SUS and BC displacement but there was significantly less PR displacement ($P < 0.001$) (Table 2).

Continent patients (n = 28) had significantly greater SUS displacement (median, 5.1 mm) compared to patients who were incontinent (n = 12) (median,

TABLE 1.

Demographic, clinical, and operative characteristics

Characteristic	
Age (median, IQR)	66 (60–72)
BMI (kg/m^2) (median, IQR)	28.2 (26.4–32)
PSA (ng/mL) (median, IQR)	7 (4.3–9.2)
Prostate weight (g) (median, IQR)	35 (30–50)
ISUP grade, n (%)	
2	21 (52.5)
3	12 (30)
4	2 (5)
5	5 (12.5)
Clinical stage, n (%)	
T2	16 (40)
T3	24 (60)
D'Amico risk group, n (%)	
Intermediate	16 (40)
High	24 (60)
Nerve-sparing procedure, n (%)	
Not performed	2 (5)
Unilateral	13 (32.5)
Bilateral	25 (62.5)

BMI: body mass index; IQR: interquartile range; ISUP: International Society of Urological Pathology; PSA: prostate-specific antigen.

TABLE 2.

Pelvic floor muscle displacement prior to and 3 and 6 weeks following RARP

	Displacement (median, IQR) (mm)			*P*-value		
	Preoperative	3 weeks Preoperative	6 weeks Preoperative	Preoperative vs. 3 weeks	Preoperative vs. 6 weeks	3 weeks vs. 6 weeks
SUS	5.7 (4.0–7.3)	4.6 (3.4–6.6)	5.7 (4.3–7.9)	**0.042**	1.00	**0.003**
BC	5.3 (3.8–7.0)	3.8 (2.4–5.4)	4.4 (3.7–5.7)	**0.002**	0.24	**0.030**
PR	6.2 (3.8–7.9)	2.9 (2.0–5.0)	4.2 (3.3–6.4)	**< 0.001**	**< 0.001**	**<. 0001**

BC: bulbocavernosus muscle; IQR: interquartile range; PR: puborectalis muscle; RARP: robotic-assisted radical prostatectomy; SUS: striated urethral sphincter.

TABLE 3.

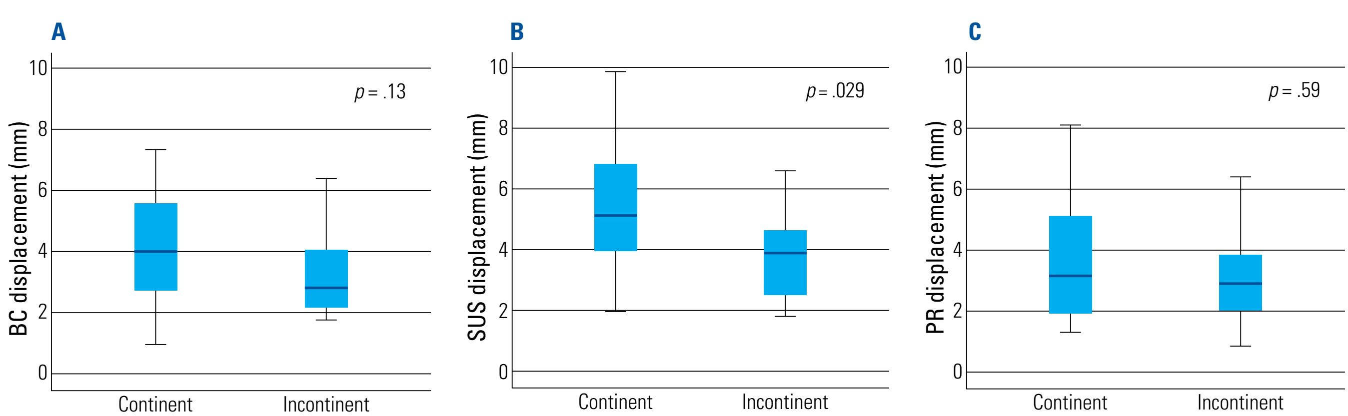
Postoperative pelvic floor muscle displacement in continent and incontinent men at 3 and 6 weeks following RARP

		Displacement (median, IQR) (mm)			*P*-value
		All participants	Continent (Pad number ≤ 1)	Incontinent (Pad number > 1)	
SUS	**3 weeks**	4.6 (3.4–6.6)	5.1 (3.9–6.8)	3.9 (2.5–4.6)	**0.029**
	6 weeks	5.7 (4.3–7.9)	5.7 (4.2–7.9)	6.4 (5.4–7.4)	0.34
BC	**3 weeks**	3.8 (2.4–5.4)	4.0 (2.7–5.6)	2.8 (2.1–4.3)	0.13
	6 weeks	4.4 (3.7–5.7)	4.4 (3.6–5.6)	5.5 (4.3–6.7)	0.26
PR	**3 weeks**	2.9 (2.0–5.0)	3.1 (1.9–5.1)	2.9 (2.0–4.2)	0.59
	6 weeks	4.2 (3.3–6.4)	4.2 (3.2–6.4)	4.3 (3.3–5.2)	0.78

BC: bulbocavernosus muscle; IQR: interquartile range; PR: puborectalis muscle; RARP: robotic-assisted radical prostatectomy; SUS: striated urethral sphincter.

FIGURE 1.

Pelvic floor muscle displacement in continent and incontinent men 3 weeks following RARP. (A) SUS, (B) BC, and (C) PR



3.9 mm) ($P = 0.029$) at 3 weeks following RARP (**Table 3, Figure 1**). Continent patients had greater median BC and PR displacement than incontinent patients 3 weeks postoperatively; however, this did not reach statistical significance ($P = 0.13$ and 0.59, respectively) (**Table 3, Figure 1**). At 3 weeks following RARP, there were no significant differences in age ($P = 0.99$), BMI ($P = 0.83$), prostate weight ($P = 0.94$), tumor volume ($P = 0.072$), or nerve-sparing status ($P = 0.50$) between continent and incontinent men. At 6 weeks following surgery, there was no significant difference between SUS, BC, and PR displacement between continent (n = 38) and incontinent men (n = 2).

There was good test-retest reliability of PFM displacement measures, with ICC ranging from 0.86 to 0.99 ($P < 0.001$) (**Table 4**).

Discussion

Our study investigated pre- and postoperative voluntary PFM function and PPI at 3 and 6 weeks following RARP. TPUS was used to measure displacement of anatomical landmarks that are associated with PFM activation. Our primary findings were (1) a significant decrease in PFM function at 3 weeks following RARP, (2) a significant increase in postoperative PFM function between weeks 3 and 6, and (3) SUS activation was significantly greater in continent patients compared to incontinent patients at 3 weeks following RARP. The pre- and postoperative TPUS assessment of PFM function and its relationship with return to continence adds new knowledge to our understanding of the etiology and clinical management of PPI.

TPUS is a noninvasive and accessible imaging modality that can provide clinicians with the ability to reliably assess PFM function prior to and following RARP, and thereby assess the effects of RARP and PFM training on continence recovery. Milios et al. (2019) demonstrated that PFM training results in an improvement in the speed and endurance of PFM contractions postoperatively. Men who did not undergo PFM training had greater 24-hour pad weights; however, the authors did not correlate PFM function with continence status[16]. There is a paucity of knowledge in the literature regarding pre- and postoperative PFM function, with only a handful of studies comparing PFM between time points. Colarieti et al. (2022) demonstrated the feasibility and technique of TPUS assessment of men prior to and following RARP but similarly did not correlate PFM function with continence status[17]. Stafford et al. (2022) investigated SUS, BC, and PR function at 2 weeks pre- and postoperatively in men who had undergone PFM training. SUS activation was significantly greater in continent men[18]. We also observed a significant difference in SUS activation between continent and incontinent patients at 3 weeks following RARP. We used pad number as an objective measure of continence. The daily number of pads is widely used in clinical practice and has been correlated with 24-hour pad weight[22,23]. Our pre- and postoperative TPUS assessment of PFM function provides further evidence that SUS activation may contribute to early continence recovery. PPI occurs when urethral pressure is less than bladder pressure, which can occur due to urethral sphincter insufficiency following radical prostatectomy[24]. Urodynamic inves-

TABLE 4.

Test-retest reliability coefficients for pelvic floor muscle displacement measures

		ICC	95% CI	*P*-value
	Preoperative	0.88	0.52–0.97	< 0.001
SUS	3 weeks	0.99	0.95–0.98	< 0.001
	6 weeks	0.93	0.77–0.98	< 0.001
	Preoperative	0.97	0.79–0.99	< 0.001
BC	3 weeks	0.95	0.80–0.99	< 0.001
	6 weeks	0.86	0.52–0.96	< 0.001
	Preoperative	0.96	0.66–0.99	< 0.001
PR	3 weeks	0.93	0.74–0.98	< 0.001
	6 weeks	0.89	0.51–0.98	< 0.001

BC: bulbocavernosus muscle; CI: confidence interval; ICC: intraclass correlation coefficient; PR: puborectalis muscle; SUS: striated urethral sphincter.

tigations before and after radical prostatectomy report on the importance of urethral sphincter closure and the capacity of the SUS to increase urethral pressure[4–8]. The SUS forms a muscular coat in an omega-shaped loop that surrounds the entire length of the membranous urethra[25]. Activation of the SUS following radical prostatectomy is important for increasing urethral pressure due to removal of the prostatic urethra containing smooth muscle[26].

Our longitudinal study design incorporated standardized pre- and postoperative (3 and 6 weeks) TPUS assessments of PFM function at uniform time points. While we identified a decrease in PFM function at 3 weeks following RARP, SUS and BC activation had returned to preoperative levels at 6 weeks, with a 95% continence recovery rate. This provides novel insight into the pattern of perioperative PFM function. It is important to consider the surgical factors that may contribute to the reduction in PFM function in the early postoperative period, including trauma during prostate resection and temporary disruption to the sphincteric innervation (neuropraxia)[27]. The mechanisms underlying recovery of PFM function are likely to include minimal intraoperative trauma to SUS and BC fibers, full postoperative recovery of any neuropraxia, and the targeted PFM training program. By targeting and training the SUS rather than the PR and the anal sphincter, we reasoned that the PFM training program would have a direct effect on increasing urethral pressure and therefore an earlier return to continence. We hypothesize that the effects of the pre- and postoperative PFM training were able to be maximized due to optimal surgical and postoperative recovery factors. However, we did not include a control group of patients that underwent RARP and were not given comprehensive PFM training. Hence, we are unable to draw conclusions regarding whether the PFM training or intraoperative or postoperative recovery factors were responsible for recovery of PFM function at postoperative 6 weeks. Future randomized controlled trials will help to determine how these factors contribute to continence recovery[28]. Furthermore, there was less PR displacement at 6 weeks following surgery, which is consistent with recent studies[18,19]. This reduction in PR displacement may be due to either reduced PR activation or reduced capacity for PR displacement postoperatively. PR displacement may be affected by intraoperative disruption of pelvic fascial structures, including Denonvilliers' fascia, periprostatic fascia, endopelvic fascia, and puboprostatic ligaments[27].

There is emerging evidence that high-volume centers and greater surgeon experience with an annual surgical case load of greater than 50 cases results in improved PPI recovery time[29,30]. Furthermore, the increasing use of robotic surgery and improvements in surgical technique have accelerated continence recovery following radical prostatectomy[3]. Hence, variation among surgeons and techniques must be considered when conducting comparative analysis of factors influencing PPI rates, and efforts should be made to decrease the heterogeneity of the study cohort. We attempted to minimize possible confounding factors of surgical expertise and technique by limiting our series to participants who underwent RARP by a single high-volume robotic surgeon. Meanwhile, previous studies have reported differing surgical approaches and techniques[10,16,18] and unspecified number and expertise of surgeons[10,17–19].

Our study has several limitations. While a single surgeon series was chosen to reduce the confounding effect of surgeon experience and differing surgical technique, it may not be representative of a broader RARP population. A larger, multicenter study with high-volume surgeons should be considered to confirm our findings. Furthermore, all patients in our study underwent a PFM training program, hence, our findings can be applied only to men who have had PFM training, particularly a program targeted for SUS activation. There was a 23% loss to follow-up, as these patients did not return to complete their postoperative PFM training program. The postoperative training program may have been bothersome for patients to attend. It is unclear whether return of continence status contributed to why these patients did not complete the postoperative PFM training program. Our study focuses on the early postoperative period, as 95% of participants had ≤ 1 pad usage daily at postoperative 6 weeks. While we demonstrated that SUS activation is important in early postoperative continence control, we cannot comment on the importance of SUS activation in long-term follow-up. A longer study period would be useful in providing more longitudinal data on long-term PPI rates and whether PFM function continues to increase in continent patients following RARP.

Conclusions

A significant decrease in PFM function occurs following RARP, with a subsequent significant recovery of postoperative PFM function between 3 and 6 weeks in men who undergo a PFM training program. SUS activation was significantly greater in continent patients compared to incontinent patients at 3 weeks following RARP.

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