Relationship Between the Integrity of the Pelvic Floor Muscles and Early Recovery of Continence After Radical Prostatectomy

Cheryn Song, Chin Kyung Doo, Jun-Hyuk Hong, Myung-Soo Choo, Choung-Soo Kim and Hanjong Ahn*

From the Department of Urology, University of Ulsan College of Medicine, Asan Medical Center, Seoul, Korea

Purpose: We investigated how the preoperatively estimated integrity of pelvic floor muscles related to the recovery of continence after radical prostatectomy.

Materials and Methods: A total of 94 patients underwent magnetic resonance image of the prostate and urodynamic studies before undergoing radical prostatectomy and evaluation of voiding symptoms before, and 3 and 6 months after surgery. Incontinence was defined as any unwanted urine leakage. On the magnetic resonance image the thickness of the levator ani and pelvic diaphragm, and prostate volume were measured to correlate with continence status.

Results: Incontinence was noted in 41.5% and 15.9% of the patients at 3 and 6 months, respectively. Recovery of continence 3 months after RP was related to the thickness of the pelvic diaphragm on sagittal imaging (p = 0.017), the ratio of the levator ani on the axial image to prostate volume (p = 0.047), functional urethral length (p = 0.007) and incontinence before surgery (p = 0.009). Recovery at 6 months was related to neurovascular bundle sparing (p = 0.013) and marginally to the pelvic diaphragm on sagittal imaging (p = 0.059). On multivariate analysis the pelvic diaphragm on sagittal imaging (HR 2.455, 95% CI 0.894–6.739, p = 0.008) and the ratio of the levator ani on the axial image to prostate volume (HR 1.886, 95% CI 0.952–3.736, p = 0.011) significantly predicted continence at 3 months, while at 6 months only the pelvic diaphragm on sagittal imaging showed a significant relationship (p = 0.024).

Conclusions: Pelvic diaphragm thickness and the ratio of levator ani thickness to prostate volume are independent factors predictive of post-prostatectomy incontinence. Patients with better developed pelvic floor muscles, especially in relation to the size of the prostate, can be expected to achieve earlier recovery of continence after radical prostatectomy.

Key Words: prostate, prostatectomy, urinary incontinence, pelvic floor, muscles

Radical prostatectomy is the definitive treatment of choice for patients with localized prostate cancer and it is an integral part of comprehensive treatment for patients with locally advanced prostate cancer.[1] Through the expansion of anatomical knowledge and advancement of surgical technique morbidity and issues affecting quality of life after the surgical procedure have consistently decreased. Nonetheless, post-prostatectomy incontinence is reported in 6% to 20% of the patients and it remains the most troubling side effect of the operation.[2–4] The actual incidence may vary depending on the definition of urinary incontinence and timing as well as on the method of evaluation, and yet it is agreed that a substantial proportion of patients always experience incontinence. Intriguingly it is also accepted that there always is a group of patients without any urine leakage from the early postoperative period. If progressive recovery of continence 9 to 12 months after surgery is due to functional adaptation of the remaining structures in the continence mechanism, immediate continence control should be achieved according to the factors intrinsic to each patient, which are predetermined before prostatectomy.

Delancey originated the hammock theory explaining female stress urinary incontinence.[5] In his theory loosening of the various pelvic floor muscles and adjacent fascia supporting the pelvic organs accounts for urinary incontinence. In light of this theory we conjectured that the continence mechanism in men shortly after prostatectomy could similarly be explained since we have noted considerable differences among patients in the bulk and compactness of the pelvic muscles during surgical dissection. We investigated how the preoperatively estimated integrity and intrinsic development status of the pelvic floor muscles are related to the recovery of continence after RP.

MATERIALS AND METHODS

Between September 2003 and December 2004, 94 patients with a mean age of 65 years (range 50 to 77) who underwent RP agreed to participate in the current prospective study and provided written informed consent. One to 2 weeks before operation systematic multichannel urodynamic study with pressure flow study according to the standards of the International Continence Society[6] and MRI of the prostate were performed in all patients. To evaluate voiding symptoms and urinary incontinence each patient was interviewed by a single specialist nurse before the operation, which was

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* Correspondence: Department of Urology, University of Ulsan College of Medicine, Asan Medical Center, 388-1 Poongnap-dong, Songpa-gu, Seoul, Republic of Korea 138-736 (telephone: 822-3010-3733; FAX: 822-477-8928; e-mail: hjahn@amc.seoul.kr).

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repeated at 3 and 6 months using the International Continence Society Questionnaire for Male. For the current analysis incontinence was defined as any unwanted urine leakage (score 1 or greater on the questionnaire).

MRI images were reviewed separately by 2 of us (CS and CKD) blinded to clinical and pathological findings as well as to postoperative continence status. LA thickness was measured from the maximal length converging on the urethra on the coronal image or on the axial image immediately caudal to the prostate apex. PD thickness was measured on the coronal and sagittal images. PSc was measured as the distance between the urethral midline and the lateral margin of the converging LA muscle on the coronal image (fig. 1). Prostate volume was calculated on the axial image by volumetric conversion after measuring the area on each section. Mean values of each of the 2 independently read parameters were used for statistical analysis.

Student's t test was used to compare urodynamic and MRI parameters between continent and incontinent patients at each corresponding time point. The chi-square test was used to analyze clinical and surgical factors, and multiple regression analysis was used for multivariate analysis. Using the ROC curve we determined cutoff values for predicting continence status. To confirm interrater reliability between the 2 MRI measurements we performed α scale reliability analysis using a 2-way random effects model for absolute agreement definition. Intraclass correlation coefficients for LAc, LAa, PDc, PDs and PSC were 0.9171, 0.8753, 0.9642, 0.8986 and 0.8862, respectively. All statistical analysis was done using SPSS®, version 11.5 with $p \leq 0.05$ considered significant.

RESULTS

Median serum prostate specific antigen was 9.3 ng/ml (range 1.8 to 42.0) and median Gleason score was 7. Pathological stage was T2 in 57 patients (60.6%) and T3 in 37 (39.4%). Average ± SD prostate volume estimated on MRI was 28.06 ± 11.25 ml. Table 1 lists thickness parameters measured on MRI and their volume adjusted counterparts. Incontinence was noted in 15.9%, 41.5% and 15.9% of the patients before, and 3 and 6 months after surgery with concomitant urge incontinence in 12.8%, 8.5% and 3.2%, respectively.

TABLE 1. *Thickness parameters and volume adjusted counterparts measured on MRI*

Parameters	Mean ± SD
Pelvic floor thicknesses ($\times 10^{-2}$ mm):	
LAc	177.1 ± 37.0
Coronal PSc	113.6 ± 29.6
PDc	83.1 ± 22.9
PDs	93.2 ± 30.2
LAa	131.5 ± 26.2
Prostate vol (ml)	28.1 ± 11.3
Vol adjusted parameters ($\times 10^{-2}$ mm/ml):	
LAc/prostate vol	7.12 ± 2.83
PSc/prostate vol	4.58 ± 1.99
PDc/prostate vol	3.32 ± 1.24
PDs/prostate vol	3.70 ± 1.45
LAa/prostate vol	5.30 ± 2.17

Recovery of Continence 3 Months After RP

All thickness parameters tended to be higher in patients without incontinence, although significance was observed only in PDs ($p = 0.017$, fig. 2). Similarly of volume adjusted thickness parameters only volume adjusted LAa showed a significant difference between the continent and incontinent groups ($p = 0.047$, fig. 2). Incontinence before surgery also contributed to persistent incontinence at 3 months ($p = 0.009$). On urodynamic study functional urethral length was longer and continent zone area was larger in patients who were continent at 3 months ($p = 0.007$ and 0.012, respectively, table 2). Patient age, clinical/pathological stage and neurovascular bundle sparing status were similar and did not show a significant relationship with continence recovery at 3 months.

Recovery of Continence 6 Months After RP

Of the thickness parameters and volume adjusted parameters only PDs showed a marginal difference between continent and incontinent patients (103.6×10^{-2} vs 84.8×10^{-2} mm, $p = 0.059$). Preoperative incontinence also showed marginal significance ($p = 0.050$). Notably neurovascular bundle sparing contributed significantly to continence recovery at 6 months (no vs unilateral vs bilateral sparing $p = 0.013$). Urodynamic parameters and clinical/pathological stage was similar among the patients.

Multivariate Analysis

PDs (HR 2.455, 95% CI 0.894–6.739, $p = 0.008$) and LAa/prostate volume (HR 1.886, 95% CI 0.952–3.736, $p = 0.011$) significantly predicted continence at 3 months, while at 6 months only PDs showed a significant relationship (HR 3.120, 95% CI 0.946–10.295, $p = 0.024$). Return of continence 3 months after surgery could be expected when PDs was 0.875 cm or higher (75.9% sensitivity and 57.8% specificity) or the LAa-to-prostate volume ratio was 4.693 cm/ml or higher (64.7% sensitivity and 52.6% specificity). When

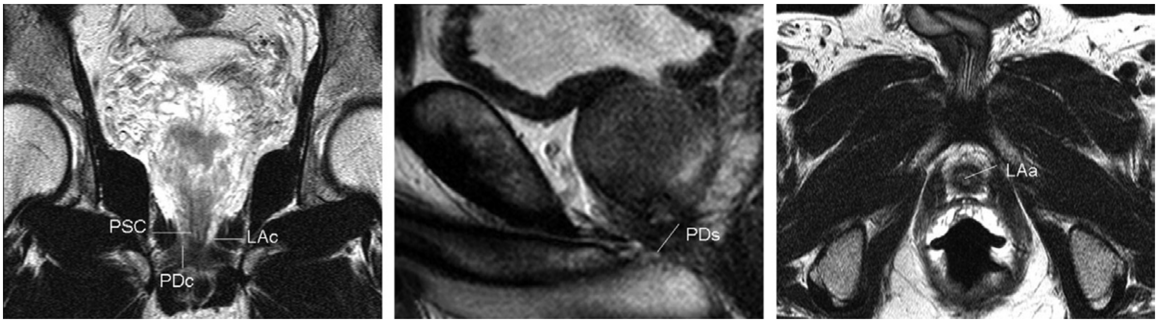

FIG. 1. MRI shows measurement of pelvic floor muscle thickness parameters

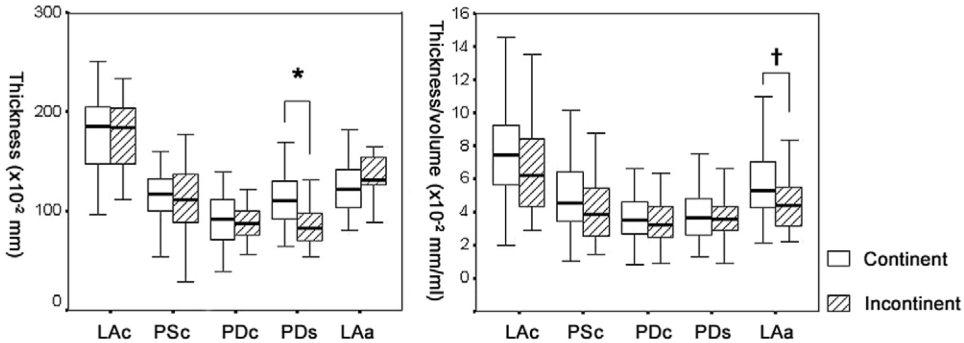

FIG. 2. Thickness parameters and prostate volume adjusted thickness parameters in continent vs incontinent patients 3 months after RP. Asterisk indicates p = 0.017. Dagger indicates p = 0.047.

PDs was 0.855 cm or higher, continence at 6 months could be expected (68.4% sensitivity and 59.5% specificity).

DISCUSSION

In the course of apical and urethral dissection during RP it may be noted that the pelvic floor muscles converging on these structures are densely packed and tightly adherent in some patients, while in others they are more loose arrays abutting the urethra and are easily wiped off. Moreover, although almost every patient regains full bladder control 9 to 12 months after surgery, there are always patients who are continent even immediately after catheter removal. We verified whether such intrinsic differences in the development status of the pelvic floor muscles supporting the urethra affect the recovery or interval to recovery of continence after RP.

Our results show that the degree of pelvic floor muscle development determines the recovery of continence 3 months after RP, which agrees with the anatomical understanding of the male urethral sphincter complex. The male sphincteric complex consists of the proximal sphincter unit (bladder neck, prostate and prostatic urethra to the verumontanum) and the distal sphincter unit (rhabdosphincter, paraurethral skeletal musculature and supporting fascial investments).[7] After radical removal of the prostate gland continence control is determined by the integrity of the remaining distal sphincteric unit, of which paraurethral support by the LA and its voluntary contractile pressure have the most significant role in the immediate postoperative period.

In this context the impact of Kegel exercises targeted to enhance the pelvic floor musculature and increase urethral resistance on post-RP incontinence was investigated in previous studies.[8,9] Notably the beneficial effect of these exercises was unvaryingly limited only to early recovery with most study participants regaining continence 1 year postoperatively regardless of the exercise. Difference in the continence rates between patients on and not on exercise was maximum at 3 months and significant until 6 months but similar thereafter. These results are in accordance with the current study, confirming that the intrinsic integrity of the pelvic floor muscles determine and voluntary contraction exercises promote early recovery of continence.

Alternatively surgical modification to preserve the rhabdosphincter has also been shown to promote early recovery. Rocco et al reported that restoring the posterior aspect of the urethral sphincter before urethrovesical anastomosis markedly decreased time to continence.[10]

Six months after RP continence was most closely related to neurovascular bundle sparing status, while other anatomical variables were not as contributory. Neurovascular bundle sparing was reported to result in an improved continence rate[11,12] and its relationship to intraurethral pressure was demonstrated.[13] By preserving the pelvic plexus and branches providing autonomic and/or motor innervation to the rhabdosphincter during nerve sparing prostatectomy earlier recovery of sphincteric function can be anticipated with functional recovery of these nerves.[14] Based on observations of the recovery of erectile function after nerve sparing prostatectomy the restoration of this spared nerve function occurred a median of 12 months after surgery, which is the postulated time required for functional recovery from neuropraxic injury, in addition to anatomical integrity.[13] In the same manner the return of neural control of the urethral sphincter may require a certain period, as demonstrated in the current study. Moreover, we believe that the surgical technique of sparing the neurovascular bundles may help decrease iatrogenic mechanical injury to the rhabdosphincter.

Recent evidence supports the notion that post-RP incontinence is in large part secondary to intrinsic sphincter

TABLE 2. *Urodynamic parameters in continent vs incontinent patients at each postoperative time*

Urodynamic Parameters	3 Mos Continent	3 Mos Incontinent	3 Mos Sig.	6 Mos Continent	6 Mos Incontinent	6 Mos Sig.
No. pts (%)	55 (58.5)	39 (41.5)		79 (84.1)	15 (15.9)	
Max urethral closing pressure (cm H_2O)	65.6 ± 18.9	62.1 ± 15.2	0.334	66.1 ± 17.9	60.2 ± 15.1	0.255
Functional urethral length (mm)	49.4 ± 20.8	40.5 ± 9.1	0.007	46.1 ± 17.7	41.3 ± 8.5	0.324
Continent zone area (cm H_2O/mm)	1035.5 ± 467.7	830.3 ± 284.3	0.012	984.1 ± 443.6	836.5 ± 254.3	0.099
Max cystometric capacity (ml)	391.3 ± 87.6	394.2 ± 99.9	0.882	387.7 ± 82.5	388.2 ± 121.3	0.988
No. detrusor instability (%)	24 (45.3)	18 (46.2)	0.844	28 (35.4)	8 (53.3)	0.162
No. decreased compliance (%)	10 (18.9)	6 (15.4)	0.811	11 (13.9)	3 (20.0)	0.892

deficiency.[15,16] Coakley et al measured membranous urethral length on preoperative MRI and noted that a longer membranous urethra was associated with more rapid return of continence.[17] It is conceivable that they could not determine a significant, distinctive cutoff from their results because it could not be predicted how much of the preoperatively measured urethral length would remain after prostatectomy. Continence is maintained by the structures that remain after RP. The pelvic floor muscles not only remain relatively unaffected by the surgical procedure, but they also become the key structures in the continence mechanism after surgery. Our urodynamic parameter results (that functional urethral length and continent zone area are significantly related to continence at 3 months but not independently predictive) can similarly be explained. The timing of continence evaluation is also worth mentioning because these anatomical factors were determinants only of early recovery, becoming relatively insignificant with increasing time after surgery.

Another factor in continuous debate is whether a larger prostate does[18] or does not[15,19] adversely affect continence. Our results demonstrate that, rather than absolute prostatic size, the relative ratio of prostate volume to its supporting pelvic floor muscles is the pivotal factor for early continence control and patients with thicker pelvic floor muscles in relation to prostate sizes can be expected to recover continence at 3 months. However, in our study the volume adjusted parameter showed lower significance than the MRI parameter statistically. This may be attributable to the small prostates with little variability (mean volume 28 ± 11 ml) of our study participants, which is a finding common in Asian men.[20]

CONCLUSIONS

PD thickness and the ratio of LA thickness to prostate volume, as measured on prostate MRI, are independent preoperative factors predictive of early recovery from post-prostatectomy incontinence. Patients with better developed pelvic floor muscles, especially in relation to the size of the prostate, can be expected to achieve earlier recovery of continence after RP.

Abbreviations and Acronyms

LA	=	levator ani
LAa	=	axial LA
LAc	=	coronal LA
MRI	=	magnetic resonance image
PD	=	pelvic diaphragm
PDc	=	coronal PD
PDs	=	sagittal PD
PSc	=	periurethral sphincter complex
RP	=	radical prostatectomy

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