Surgical Technique to Overcome Anatomical Shortcoming: Balancing Post-Prostatectomy Continence Outcomes of Urethral Sphincter Lengths on Preoperative Magnetic Resonance Imaging

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Purpose: Shorter urethral sphincter length on preoperative endorectal magnetic resonance imaging has been associated with an increased risk of postoperative urinary incontinence as well as longer time to achieve continence. We determined that our techniques of anatomical reconstruction for restoring the continence mechanism could markedly improve continence outcomes, especially in patients with a shorter urethral sphincter.

Materials and Methods: Our cohort consisted of 274 patients who underwent robotic radical prostatectomy, as performed by a single surgeon, and for whom preoperative magnetic resonance imaging and postoperative evaluations were available. All sphincter lengths were measured on T2-weighted images as the distance from the prostatic apex to the penile bulb, cross-referencing all 3 planes. Continence was defined as zero pads or a liner used for security reasons only.

Results: The 2 surgical modifications considerably hastened the return of continence at 6 months. The continence rate in the shorter sphincter group (less than 14 mm) was 47% for the control technique, 81% for anterior reconstruction and 90% for total reconstruction. The continence rate in the longer sphincter group (more than 14 mm) was 80% for the control technique and 83% for anterior reconstruction, while it approached 99% for total reconstruction. With the control technique the average time to achieve continence was significantly different between the shorter and longer sphincter groups (25 vs 12 weeks, $p = 0.037$). The significance disappeared for anterior reconstruction (7.4 vs 6.2 weeks, $p = 0.27$) and total reconstruction (3.6 vs 2.7 weeks, $p = 0.13$).

Conclusions: The results of this study are encouraging for patients with a short urethral sphincter who are considering radical prostatectomy.

Key Words: urethra, prostatectomy, robotics, urinary incontinence, magnetic resonance imaging

Robotic radical prostatectomy has become a widely accepted modality for the definitive treatment of localized prostate cancer. Despite recent advances in anatomical knowledge and improvements in surgical technique post-prostatectomy urinary incontinence remains a major drawback that can be debilitating to patient quality of life. The incidence in the literature is 2.5% to 69%, which reflects the lack of a standard definition of continence and a uniform method of assessment.[1–3] Although most patients eventually achieve urinary continence, the time to complete continence varies widely among patients and surgical techniques from zero week to as long as 2 years.[4] The probable etiology of post-prostatectomy incontinence includes injury to the arterial supply, causing sphincter ischemia, nerve damage or damage to the integrity of the pelvic floor muscles and sphincteric muscle.[5] Preserving adequate urethral sphincter length is crucial for maintaining the continence mechanism after surgery.[6,7]

Endorectal MRI allows a detailed look at the anatomy essential to prostatectomy, including a depiction of the membranous urethra (urethral sphincter).[8] On preoperative endorectal MRI a longer membranous urethra has been associated with significantly more rapid return of urinary continence after radical prostatectomy.[9] A short membranous urethra is an anatomical handicap that creates concern in patients who are considering surgery as an option for localized prostate cancer.

In 2006 we described a novel approach for anterior reconstruction and restoration of the urinary mechanism.[10] To our knowledge we now introduce the concept of total reconstruction with the addition of the posterior reinforcement stitch based on the concepts of Pagano[11] and Rocco[12] et al. Our goal is to restore adequate functional length of the urethral sphincter following robotic prostatectomy even in patients with a short sphincter on preoperative MRI. We performed this study to determine whether our surgical technique could overcome the anatomical disadvantage by narrowing the discrepancy in the time to return of continence between patients with a long and a shorter urethral sphincter.

MATERIALS AND METHODS

Patients

This study, which was approved by Weill Cornell institutional review board, included 286 patients who underwent robotic prostatectomy, as performed by a single surgeon (AT), for newly diagnosed prostate cancer from June 2005 to June 2007 and for whom preoperative endorectal MRI images of the prostate were available. Mean patient age was 62.6 years (range 43 to 80). Mean prostate specific antigen at

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diagnosis was 5.65 ng/ml (range 0.5 to 23.4) and mean prostate volume was 37.5 cc (range 12.6 to 175.8).

MRI Technique

MRI was performed on a 1.5 Tesla high field strength scanner with an endorectal probe. Axial T1-weighted spin-echo with respiratory gating was obtained from kidneys to include the symphysis pubis. This was done with a field of view of 36 cm, 8 mm thickness and a 2 mm gap. Other series included axial T1 spin-echo with a small field of view of 14 cm, 3 mm thickness and a 1 mm gap as well as axial T2 and coronal T2 fast recovery, fast spin-echo with a small field of view, 14 cm, 3 mm thickness and a 1 mm gap, and sagittal T2 fast recovery, fast spin-echo with a field of view of 24 cm, 3 mm thickness and a 1 mm gap. Repetition time/effective echo time for T1 small field of view was 683/18 and for T2 it was 3,657/106. There was a 31 kHz bandwidth in all series.

MRI Interpretation

All MRI images were reviewed from compact discs by a single reader (LN) blinded to all other clinical and pathological findings. The length of the urethral sphincter was measured as the distance from the prostatic apex to the entry of the urethra into the penile bulb.[8] Urethral sphincter anatomy was studied using 3-cross referenced planes of T2-weighted images, that is on the midline sagittal plane with coronal reference and on the coronal plane with axial reference (figs. 1 and 2). The area of interest was magnified and grayscale was adjusted. The margin of error was ±2 mm secondary to slice and gap thickness.

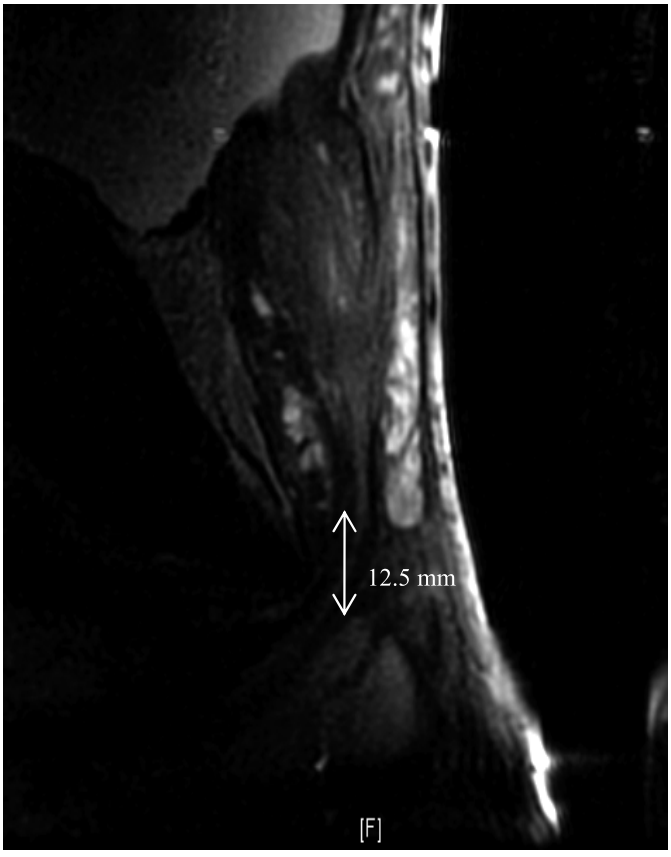

FIG. 1. Double-headed arrow indicates urethral sphincter length

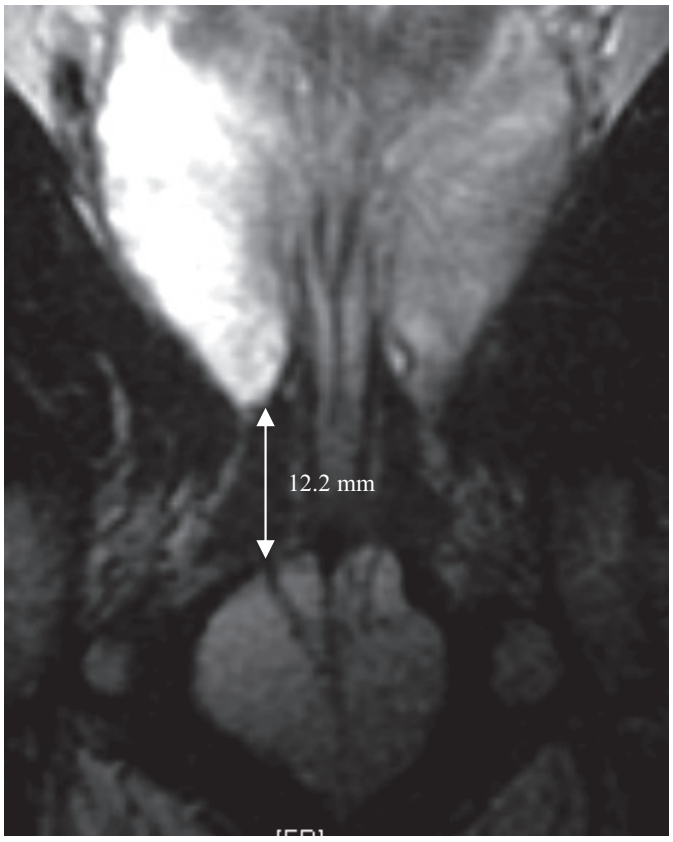

FIG. 2. Double-headed arrow indicates urethral sphincter length

Surgical Technique

Preoperatively MRI images were used to guide the surgeon decision regarding the extent of surgical margin basing on tumor location and the possibility of extracapsular extension. Surgical approaches for preserving the continence mechanism were modified in each successive calendar year. In 2005 we used our previously described technique of apical dissection and urethrovesical anastomosis in robotic radical prostatectomy.[13] In 2006 a novel modification to achieve early urinary continence was performed, that is anterior reconstruction with preservation of the puboprostatic collar.[10] In 2007 total reconstruction was done with the addition of posterior reinforcement based on the principles of Pagano[11] and Rocco[12] et al. This reinforcing stitch is a midline suturing of the right and left detrusor flaps behind the bladder neck to create a thick muscular bladder neck. The retrotrigonal flap is then sutured into the posterior bladder neck and cinched down to the distal Denonvilliers' layer with a single 3-zero polyglactin suture.

Postoperative Evaluation

Postoperative evaluation was done by questionnaires or telephone interviews. The number of weeks to stable postoperative continence was recorded in 274 patients (96%). A total of 12 men could not be contacted due to relocation. Continence was defined as achieving zero pad use or a liner used for security reasons only.

Statistical Analysis

SPSS® linear regression was used to look at the relationship between sphincter length and the continence rate at 6-month

followup as well as the relationship between sphincter length and the number of weeks to stable continence in patients who eventually achieved continence. Patients were then divided into 2 groups according to urethral sphincter length using the average length of 14.0 mm as the cutoff. The 137 group 1 patients with a shorter sphincter were compared with the 137 in group 2 with a longer sphincter in terms of the continence rate and time to complete continence. Differences between the 2 groups for each technique (control, anterior reconstruction and total reconstruction) were analyzed for significance using the Excel® t test of 2 samples, assuming unequal variance. Significance was considered at $p \leq 0.05$.

RESULTS

In the 274 patients who underwent preoperative MRI and clinical followup average urethral sphincter length was 13.8 mm, the average continence rate at 6 months was 85.6% and median time to continence was 3 weeks (range 0 to 56). Using the enter method a significant model emerged ($F_{1,271} = 21.976$, $p < 0.0005$) for urethral sphincter length as a predictor of the probability of achieving continence at 6 months (adjusted R^2 0.075, beta = 0.274, fig. 3). With the same statistical method another significant model emerged ($F_{1,242} = 5.063$, $p = 0.025$) for urethral sphincter length as a predictor of time needed to achieve continence (adjusted R^2 0.016, beta = −0.143).

Using 14 mm as a cutoff point patients were categorized into group 1 with a shorter sphincter or group 2 with a longer sphincter. Mean age, body mass index, prostate specific antigen, International Prostate Symptom Score, clinical stage distribution, pathological stage and pathological Gleason score were not significantly different between the 2 groups. Prostate volume was significantly greater in the group with a longer sphincter (40.1 vs 34.6 cc, $p = 0.025$). The distribution of biopsy Gleason scores was also significantly different between the 2 groups with group 2 having a higher percent of Gleason score 6 or less (table 1). In each group the percent of patients who achieved continence was plotted against time in weeks by the different techniques (figs. 4 and 5). In addition, the number of weeks required to attain continence was plotted against the different techniques according to group (table 2 and fig. 6).

TABLE 1. *Cohort characteristics*

Variables	Group 1	Group 2	p Value
No. pts	137	137	
Mean ± SD age	62.6 ± 6.6	62.6 ± 7.1	0.493
Mean ± SD body mass index (kg/m^2)	26.5 ± 3.2	27.2 ± 4.3	0.102
Mean ± SD prostate specific antigen (ng/ml)	5.9 ± 3.4	5.4 ± 2.4	0.123
Mean ± SD International Prostate Symptom Score	7.2 ± 6.8	8.5 ± 7.3	0.167
Mean ± SD prostate vol (cc)	34.6 ± 19.6	40.1 ± 25.4	0.025
% Biopsy Gleason:			0.023
6 or Less	55.64	67.42	
7 (3 + 4)	27.82	21.97	
7 (4 + 3)	8.27	6.06	
8 or Greater	8.27	4.55	
% Clinical stage:			0.497
T1c	77.14	76.11	
T2	20.00	22.12	
T3	2.86	1.77	

DISCUSSION

In the first part of analysis our data validated previous studies showing that urethral sphincter length on preoperative endorectal MRI correlated positively with the patient probability of being continent at 6 months and correlated negatively with the number of weeks needed to achieve continence (fig. 3). Although our results showed small beta values, they were nonetheless significant.

In the second part of the analysis we divided our patient cohort into 2 groups to compare the effect of surgical techniques in patients with a shorter vs longer sphincter. Figures 4 and 5 show how successive surgical techniques incrementally improved the percent of continent patients at any given time in each of the 2 groups. In patients in the shorter sphincter group the surgical modifications considerably hastened the return of continence at 6 months from 47% with the control technique to 81% with anterior reconstruction and 90% with total reconstruction. Although improvement was not as drastic, it could also be seen in the longer sphincter group at 6 months, from 80% with the control technique to 83% with the anterior technique and approaching 99% with total reconstruction. Figure 6 and table 2 show the number of weeks needed to attain continence in the 2 sphincteric groups for each technique. With the control technique the return to continence was significantly slower in group 1 than in group 2 (25 vs 12 weeks, $p = 0.037$). This disparity disappeared with the introduction of anterior re-

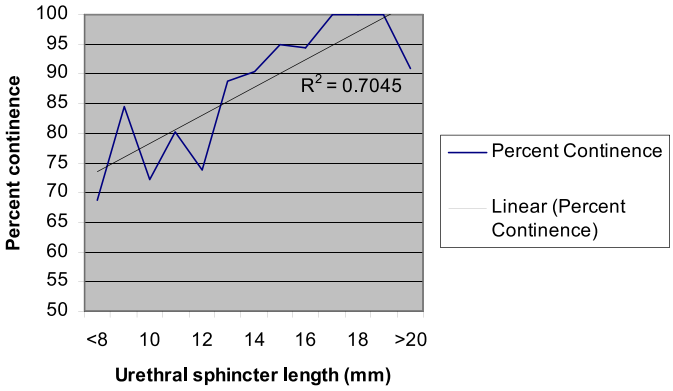

FIG. 3. Continence at 6 months

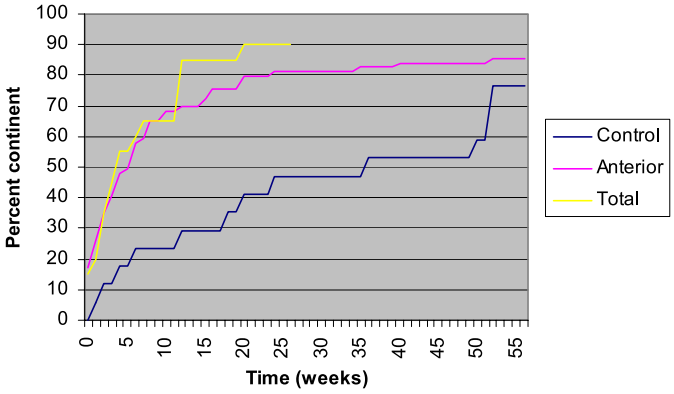

FIG. 4. Group 1 with urethral sphincter length less than 14 mm

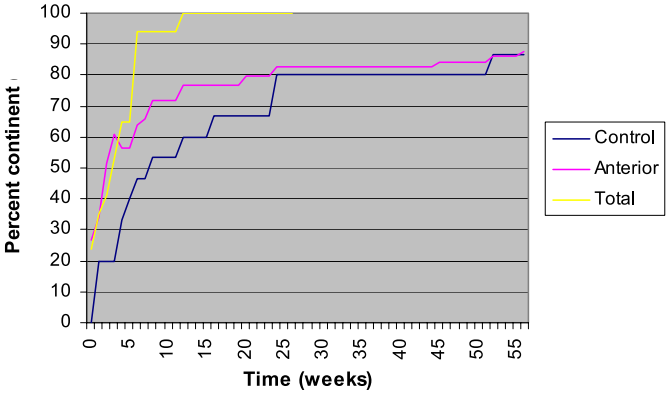

FIG. 5. Group 2 with urethral sphincter length greater than 14 mm

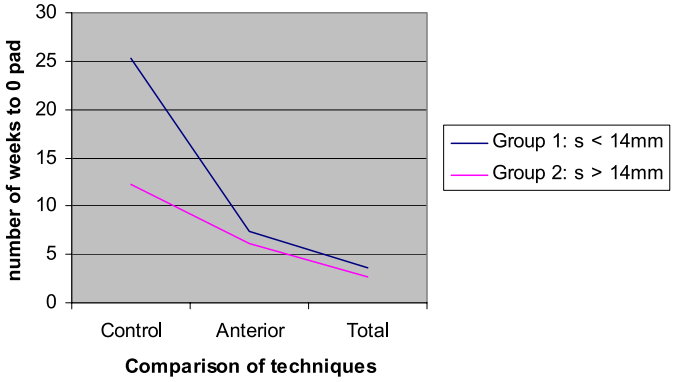

FIG. 6. Time to continence. *s*, urethral sphincter length

construction (7.4 vs 6.2 weeks, p = 0.270). Furthermore, average time to continence continued to decrease with total reconstruction to 3.6 weeks in the shorter sphincter group and 2.7 weeks in the longer sphincter group (p = 0.128).

In the past many groups have looked at the relationship between functional urethral length and post-prostatectomy continence. In a series of 34 patients divided into 3 groups according to the degree of post-prostatectomy urinary continence a statistically significant difference was found between the groups for mean functional urethral length.[14] In another study of 63 patients who underwent urodynamic examination before radical retropubic prostatectomy the amplitude of preoperative maximal voluntary sphincteric contraction was significantly higher in the postoperatively continent group (125 vs 96.5 cm H_2O, p <0.0001).[15] Together these data suggest that the main cause of incontinence after prostatectomy is a function of sphincteric deficiency.

Groups at several academic centers have suggested surgical modifications to preserve functional urethral length, hence, improving continence. In a subset of 17 patients Connolly et al noted that anterior bladder neck tube reconstruction significantly increased functional urethral length, as demonstrated using urodynamic assessment (4.6 vs 3.4 cm, p <0.01).[16] In a series of 161 patients Rocco et al observed that careful reconstruction of the posterior rhabdosphincter markedly increased the continence rate at 3 months from 46% in the control group to 86% in the experimental group.[12] Our surgical techniques work in part by restoring the functional length of the urethral sphincter. Anterior reconstruction provides support to the anastomosis, while the modified stitch of Pagano[11] and Rocco[12] et al supports the bladder neck and sphincter, respectively.

The anatomical urethral sphincter is an omega-shaped muscle consisting of a striated part and a smooth part.[17] On coronal plane MRI it can clearly be seen as a cylindrical configuration abutting the prostatic apex superiorly, bounded by the convexity of the penile bulb inferiorly and flanked by the edges of the puboperinealis laterally.[8] Previously Coakley et al reported that patients with a shorter urethral sphincter on preoperative MRI are at a major disadvantage in terms of postoperative continence.[9] In a series of 180 patients with an average urethral sphincter length of 14 mm (range 6 to 24) 89% with a sphincter length of greater than 12 mm achieved continence at 1 year of followup compared to 77% with a sphincter length of less than 12 mm. In patients who have a stronger preference for surgery as opposed to radiotherapy as definitive treatment for localized prostate cancer, having a shorter urethral sphincter length on MRI would result in a dismal outlook. However, our results demonstrate that with the concept of anterior reconstruction and total reconstruction their continence fate would not be significantly different from that of patients with a longer sphincter.

TABLE 2. *Time to continence*

	No. Pts	Mean Wks		p Value
		Group 1	Group 2	
Control	32	25.3	12.2	0.037
Anterior	134	7.4	6.2	0.27
Overall	108	3.6	2.7	0.128

This study is not without a number of shortcomings. Ours was an anatomical assessment of the length of the urethral sphincter. However, to determine functional urethral sphincter length urodynamic study would have further substantiated the findings. Since we only examined the anatomical length of the urethral sphincter preoperatively, a correlation between postoperative functional length and continence cannot be postulated. Ideally we would be able to use the length of the postoperative sphincter on MRI to verify that urethral sphincter length and function are directly related. It is also possible that the improvement in continence rates during successive calendar years was a result of the progression of surgeon skill in dissection to be able to avoid damage to the urethral sphincter and not a function of anterior or total reconstruction. Postoperative evaluation was based on questions and not on any objective urodynamic measurements. Therefore, it could have been subject to recall bias.

CONCLUSIONS

We performed a study to determine whether our surgical modifications that aim to restore functional urethral length not only hasten the return of continence, but also balance the time to continence between patients who have a shorter urethral sphincter and those with a longer urethral sphincter, as measured on endorectal MRI. Our initial results are encouraging. These results would benefit patients with a short preoperative urethral sphincter and their surgeons who are making the decision for definitive treatment for prostate cancer.

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Abbreviations and Acronyms

MRI = magnetic resonance imaging

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