Anatomic Restoration Technique: A Biomechanics-based Approach for Early Continence Recovery After Minimally Invasive Radical Prostatectomy

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Despite refinements in surgical technique over the past decade, urinary incontinence following radical prostatectomy remains a frustrating and costly side effect that significantly impairs patients' quality of life. With the increasing popularity of radical prostatectomy as a first-line treatment for early prostate cancer, and with more patients being diagnosed and treated at a younger age, post prostatectomy incontinence remains a significant issue. Reported risk factors include increasing patient age, bladder dysfunction before surgery, previous transurethral resection of the prostate for obstructive symptoms, anastomotic stricture, surgical technique, and surgeon experience.[1,2]

Beginning in 2006, our group has made stepwise progress in overcoming this problem through technical innovations borne from study of real-time intraoperative video and cadaveric anatomy, histopathologic analysis of final prostatectomy specimens, and data analysis of functional outcomes.[3-7] We have developed a paradigm of 7 key principles based on possible biomechanical forces acting on the urethral rhabdosphincter and newly fashioned anastomosis that we believe will hasten early continence recovery after radical prostatectomy[8] (Table 1 and Fig. 1).

Our current technique of total anatomic restoration of the vesicourethral junction has evolved through a series of stepwise modifications during the past 4 years in our cohort of nearly 1300 patients. In 2005, we performed conventional vesicourethral anastomosis during robotic-assisted laparoscopic radical prostatectomy.[9] In 2006, we incorporated anterior reconstruction into our approach by preserving the puboprostatic collar and performing puboperineoplasty.[4,5] We subsequently incorporated the principles of posterior bladder neck reinforcement[10] and reconstruction of Denonvilliers musculofascial plate (PRDMP)[11-13] in 2007 to arrive at our current technique of total anatomic restoration of the vesicourethral junction[6] (Fig. 2). We postulate that the overall biomechanical effects of our composite approach are threefold. First, it provides circumferential dynamic suspensory support for the urethral sphincter complex. Second, it avoids pelvic prolapse and downward pressure of the bladder on the healing anastomosis during micturition. Third, tension at the anastomosis is relieved, with improved mucosal apposition (Fig. 3).

Since we first described our total restoration technique,[6] we have 6-month follow-up data of our total anatomic restoration technique for 530 patients to date (Table 2). We defined continence as 0 pads or 1 dry pad for reassurance. The continence rate for the total reconstruction group and our cohort of patients who underwent conventional anastomosis at 1, 6, 12, and 24 weeks after robotic-assisted radical prostatectomy was 38.6% and 13.2%, 82.6% and 35.2%, 90.5% and 50.2%, and 97.5% and 62.0%, respectively, a significantly improved rate ($P < .0001$). In our cohort of obese patients, the continence rate of those who underwent total anatomic reconstruction was significantly improved compared with that of those who underwent standard anastomosis (34.9% vs 14.0% , 67.2% vs 40.3%, 89.7% vs 61.4%, and 98.3% vs 73.7% at 1, 6, 12, and 24 weeks, respectively; $P < .01$). The mean interval to continence for obese patients was 3.5 weeks in the total reconstruction group and 24.1 weeks in the conventional anastomosis group.[14] Also, the incidence of anastomotic strictures was 0.6% vs 3.7% and that of urinary leaks requiring inpatient therapeutic intervention was 0.3% vs 2.3% in the total reconstruction cohort compared with the conventional anastomosis group. We have also reported our experi-

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Table 1. Principles and steps of anatomic restoration technique for early continence recovery after radical prostatectomy

Seven Principles for Early Continence Recovery	Seven Key Steps of Anatomic Restoration Technique
1. Preserve anterior fibrotendinous support structures 2. Optimize functional membranous urethral length 3. Reinforce unstable posterior bladder neck in unsupported retrotrigonal fossa left by excised seminal vesicles 4. Reinforce posteriorly deficient Ω-shaped remnant of urethral sphincteric complex for suspensory support 5. Fashion tension-free, stable vesicourethral anastomosis 6. Prevent urethral stump recession and optimize mucosal coaptation 7. Prevent pelvic descent and downward pressure of bladder on anastomosis during micturition	a. Preserve arcus tendineus during endopelvic fascia dissection (Delaney principle) b. Perform puboprostatic ligament-sparing suture during control of dorsal venous complex, with 0-0 Vicryl suture on CT-1 needle (Vaughan, Jr principle) c. Precise apical dissection and preparation of thick and long remnant urethral stump (Myers principle) d. Dissect retrotrigonal layer behind bladder neck and reinforce with buttressing 0-0 Vicryl suture on CT-1 needle after seminal vesicle excision (modified Pagano/Libertino principle) e. Suture distal flap of Denonvilliers fascia to reinforced posterior bladder neck close to urethral stump with 0-0 Vicryl suture on CT-1 needle (modified Rocco/Bartsch principle) Tension taken off vesicourethral anastomosis by steps e, f, and g (Mundy urethroplasty principles[8]) f. Running continuous anastomotic suture through posterior Denonvilliers musculofascial plate (modified Van Velthoven/Menon principle) g. "Hitch" bladder up to arcus tendineus and puboprostatic collar with running 0-0 Vicryl suture on CT-1 needle (modified Lapides principle)

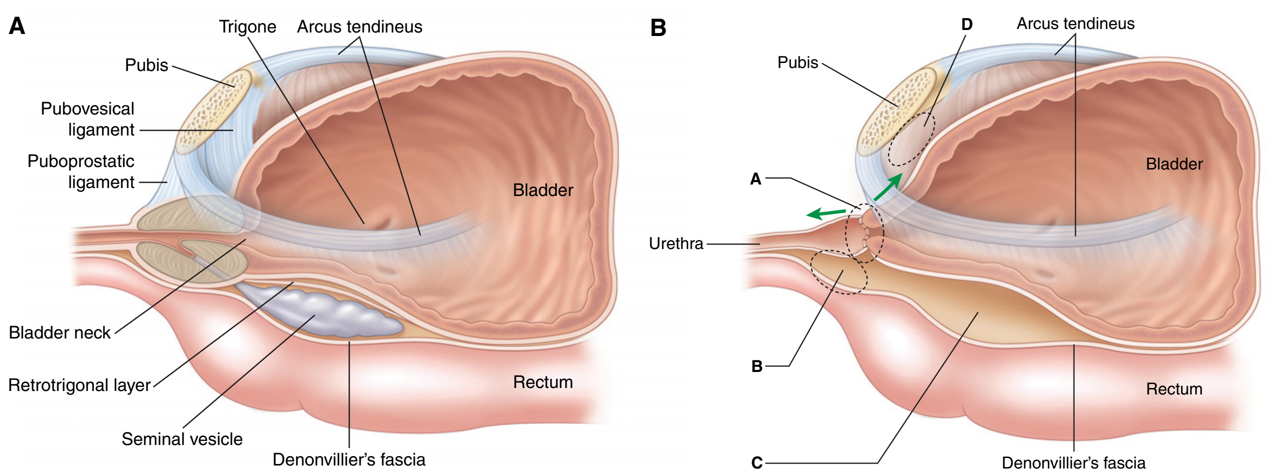

Figure 1. **(A)** Normal pelvic anatomy of human prostate, demonstrating its relationship to surrounding supporting structures (sagittal view). Note, puboprostatic and pubovesical ligaments anteriorly and seminal vesicles lying behind posterior bladder neck in retrotrigonal fossa. **(B)** Points of postulated biomechanical instability associated with conventional vesicourethral anastomosis (sagittal view). Tension on vesicourethral anastomosis from spontaneous urethral stump recession into the pelvic floor (A). Posteriorly deficient Ω-shaped urethral rhabdosphincter lies unsupported posteriorly, impairing efficient contraction of the sphincter mechanism (B). Posterior bladder neck lies unsupported in retrotrigonal fossa created by excision of seminal vesicles (C). Anterior and lateral bladder neck also unsupported (D).

ence with total anatomic restoration conferring an earlier return to continence in men with a short urethral sphincter length (<14 mm) on preoperative endorectal magnetic resonance imaging.[7] In this subset of patients previously identified as having a significantly delayed return of continence,[15] the median interval to continence recovery was 3.6 weeks in our reconstructed group compared with 25.3 weeks in the conventional anastomosis group.

At 12 months after surgery, 17.8% of our patients who had undergone conventional anastomosis and 8.7% of those who had undergone anterior reconstruction only had incontinence refractory to pelvic floor exercises with or without biofeedback. We suspect the primary reason for this refractory incontinence was injury and stress to the urethral rhabdosphincter, which becomes the chief mechanism responsible for continence after robotic-assisted prostatectomy. Excessive excision, traction, and thermal injury to the urethral sphincter during apical dissection, as well as tension on the constructed vesicourethral anastomosis from stump recession, urinoma, or clot formation, are all possible contributory factors.

We attribute our improved leak and stricture rates to the superior mucosal coaptation and the minimization of

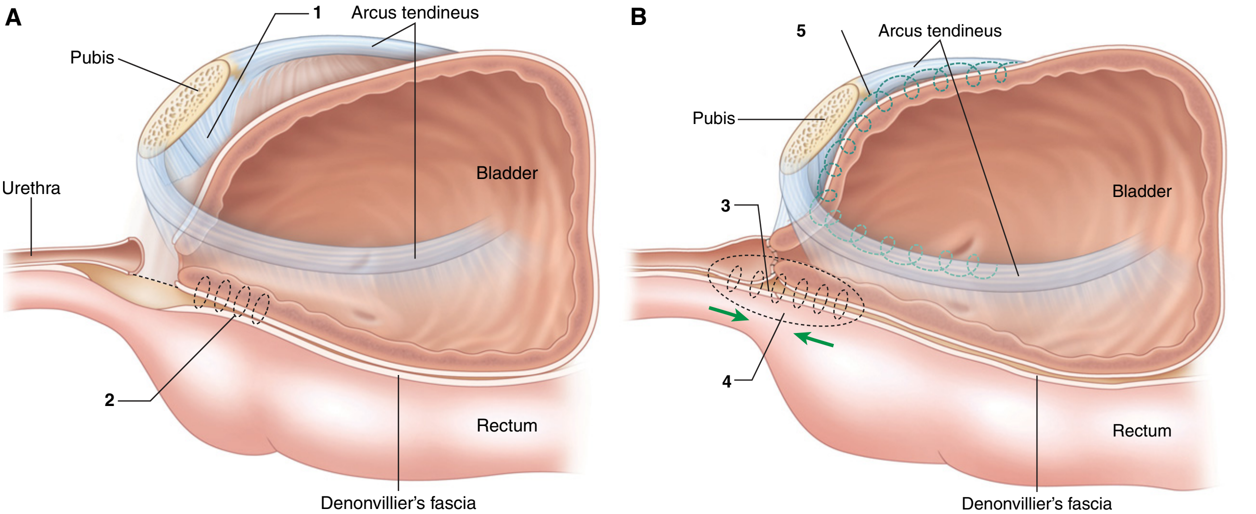

Figure 2. **(A)** Anatomic restoration of vesicourethral junction. (1) Preservation of anterior support structures (ie, puboprostatic ligaments and arcus tendineus); and (2) posterior bladder neck reinforced with 0-0 Vicryl suture, obliterating retrotrigonal space. **(B)** Anatomic restoration of vesicourethral junction. (3) Posteriorly deficient urethral rhabdosphincter reinforced against Denonvilliers musculofascial plate; (4) Denonvilliers musculofascial plate reconstructed, preventing urethral stump recession, relieving tension on anastomosis, and improving mucosal coaptation at anastomosis; and (5) anterior suspension sutures to arcus tendineus and puboprostatic ligaments to alleviate downward prolapse of bladder on anastomosis.

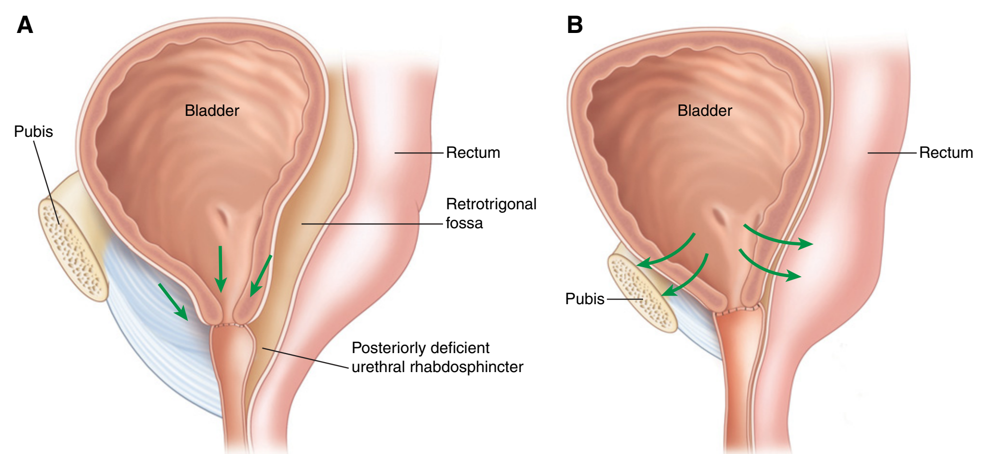

Figure 3. Biomechanical forces acting on vesicourethral anastomosis in upright position. **(A)** In conventional vesicourethral anastomosis, pelvic descent of bladder presses on unsupported anastomosis. During micturition, contractile forces generated by detrusor musculature directed inferiorly at anastomosis (green arrows), causing additional stress on continence mechanism. **(B)** In our technique, bladder is "hitched up" anterolaterally by suspension sutures through arcus tendineus, ameliorating downward tension on healing anastomosis. During micturition, same contractile forces (green arrows) dissipated away from anastomosis and urethral rhabdosphincter.

tension (and possible distraction caused by hematoma formation) at the anastomosis. We also suspect that when obese patients micturate in the upright position, the increased downward pressure from their intra-abdominal viscera places increased stress on the newly fashioned vesicourethral anastomosis compared with their nonobese counterparts. Hence, by dissipating these forces and circumferentially reinforcing the healing anastomosis, the benefits of anatomic restoration have been most apparent in obese men. No other significant differences were found in the clinicopathologic characteristics (ie, age, body mass index, prostate volume, preoperative prostate-specific antigen level, and International Prostate Symptom Score) of our patients undergoing either technique on multivariate analysis.

Various investigators have advocated PRDMP as an alternative technique for early continence recovery.[11-13] This approach centers on the premise that the musculofascial plate provides a fixation point for the posteriorly deficient urethral rhabdosphincter. Disruption during radical prostatectomy results in loss of the posterior insertion of the sphincter, overall pelvic descent of the sphincteric complex, and perineal prolapse. Rocco et al.[11] first described their results with PRDMP in a series of 161 patients who had undergone open radical prostatectomy and later reported their experience with 31 patients undergoing PRDMP dur-

Table 2. Outcomes of PRDMP and total anatomic restoration technique in minimally invasive radical prostatectomy

	PRDMP in Minimally Invasive Radical Prostatectomy vs Control (Nguyen et al.[14])		Single-Layer vs Double-Layer Anastomosis (Menon et al.[8])		Anatomic Restoration Technique vs Conventional Anastomosis (Tewari et al.[6])	
Variable	Standard Reconstruction Group (n = 32)	PRDMP Group (n = 32)	Single-Layer Anastomosis (n = 57)	Double-Layer Anastomosis (n = 59)	ART Group (n = 530)	Conventional Anastomosis (n = 215)
Mean age (y)	57.2	58.1	59.2	60.1	60.2	64.3
Mean BMI (kg/m^2)	28.3	27.4	27.9	27.9	26.7	28.8
Mean operative time (min)	281.0 (P = .048)	247.2*	158	171	180	187
Estimated blood loss (mL)	499.4	440.6	NA	NA	140	150
Continence rate postoperatively (%)						
1 wk	3.0	34.0*	26.0	34.0	38.6	13.2*
4-6 wk	17.0	56.0*	74.0	80.0	82.6	35.2*
12 wk	NA	NA	NA	NA	90.5	50.2*
24 wk	NA	NA	NA	NA	97.5	62.0*
52 wk	NA	NA	NA	NA	NA	82.2
Mean interval to continence (wk)						
Sphincter length <14 mm	NA	NA	NA	NA	3.6	25.3
Sphincter length >14 mm	NA	NA	NA	NA	2.7	12.2
Anastomotic stricture rate (%)	NA	NA	NA	NA	0.6	3.7*
Clinically significant anastomotic leak rate (%)	NA	NA	NA	NA	0.3	2.3*

PRDMP = posterior bladder neck reinforcement and reconstruction of Denonvilliers musculofascial plate; ART = anatomic restoration technique; NA = not applicable.
* Statistically significant difference (P <.05) between reconstructed and control groups.

ing transperitoneal laparoscopic radical prostatectomy.[12] However, these results were not reproduced as successfully in the Cleveland Clinic experience of PRDMP in 32 patients who underwent minimally invasive radical prostatectomy, with or without robotic assistance[13] (Table 2).

Menon et al.[8] recently published their early experience comparing double-layer and single-layer anastomosis during robotic-assisted radical prostatectomy in a prospective randomized fashion. In their cohort of 116 patients, they found no significant differences between the 2 groups with and without reconstruction of the periprostatic tissues. The robust methodology of their well-designed trial highlights one of the limitations in the analysis of our own results—that of comparing our continence results with the anatomic restoration technique against historical controls in a nonrandomized fashion. Given the evolving nature of our continence techniques, surgeon experience undoubtedly contributed in some measure to the superior results obtained with our current anatomic restoration technique, although given the lead surgeon's (A.T.) experience of >1000 robotic prostatectomies before this series at our institution, it is difficult to attribute these differences entirely to the learning curve effect. Also, 3 important differences between our anatomic restoration technique and that of Menon et al.[8] with the double-layer anastomosis should be mentioned. First, Menon et al.[8] only reconstructed the puboprostatic ligaments, with no involvement of the arcus tendineus for anterolateral support to the bladder neck. Second, the double-layer anastomosis omits reconstruction of the retrotrigonal layer, leaving a potential fossa that could impede efficient contraction of the unsupported bladder neck posteriorly. Third, patients with large median lobes or large prostate volume were not excluded from our analysis, factors that have been described as potentially adversely affecting continence recovery.

CONCLUSIONS

Exciting advances in real-time bioimaging, mathematical modeling of organ function using state-of-the-art three-dimensional bioengineering computer platforms, and development of novel biomaterials for added mechanical support could soon provide much-needed breakthroughs in improving the overall biomechanical foundations of urinary micturition and storage in these patients. Until then, we recommend our paradigm of anatomic restoration targeted at optimizing mucosal coaptation and suspensory support for the urethral rhabdosphincter, while minimizing tension on the anastomosis. Our experience with total anatomic restoration during robotic prostatectomy in a cohort of >500 men appears to deliver better outcomes with minimal morbidity, is easy to perform, and does not add significantly to the intraoperative console time.

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