Title

Multi-institutional Outcomes and Associations After Excision and Primary Anastomosis for Radiotherapy-associated Bulbomembranous Urethral Stenoses Following Prostate Cancer Treatment

Authors

Voelzke, BB
Leddy, LS
Myers, JB
et al.

Publication Date

2021-06-01

DOI

10.1016/j.urology.2020.11.077

Peer reviewed

Reconstructive Urology

Multi-institutional Outcomes and Associations After Excision and Primary Anastomosis for Radiotherapy-associated Bulbomembranous Urethral Stenoses Following Prostate Cancer Treatment

BB Voelzke*, LS Leddy, JB Myers, BN Breyer, NF Alsikafi, JA Broghammer, SP Elliott, AJ Vanni, BA Erickson, JC Buckley, LC Zhao, T Wright, and KF Rourke, for the Trauma and Urologic Reconstructive Network of Surgeons (TURNS)**

OBJECTIVE To evaluate the outcomes of excision and primary anastomosis (EPA) for radiation-associated bulbomembranous stenoses using a multi-institutional analysis. The treatment of radiation-associated urethral stenosis is typically complex owing to the adverse impact of radiation on adjacent tissue.

METHODS An IRB-approved multi-institutional retrospective review was performed on patients who underwent EPA for bulbomembranous urethral stenosis following prostate radiotherapy. Preoperative patient demographics, operative technique, and postoperative outcomes were abstracted from 1/2007–6/2018. Success was defined as voiding per urethra without the need for endoscopic treatment and a minimum follow-up of 12 months.

RESULTS One hundred and thirty-seven patients from 10 centers met study criteria with a mean age of 69.3 years (50-86), stenosis length of 2.3 cm (1-5) and an 86.9% (119/137) success rate at a mean follow-up 32.3 months (12-118). Univariate Cox regression analysis identified increasing patient age ($P = .02$), stricture length ($P < .0001$) and combined modality radiotherapy ($P = .004$) as factors associated with stricture recurrence while body mass index ($P = .79$), diabetes ($P = .93$), smoking ($P = .62$), failed endoscopic treatment ($P = .08$) and gracilis muscle use ($P = .25$) were not. On multivariate analysis, increasing patient age (H.R.1.09, 95%CI 1.01-1.16; $P = .02$) and stenosis length (H.R.2.62, 95%CI 1.49-4.60; $P = .001$) remained associated with recurrence. Subsequent artificial urinary sphincter was performed in 30 men (21.9%), of which 25 required a transcorporal cuff and 5 developed cuff erosion.

CONCLUSIONS EPA for radiation-associated urethral stenosis effectively provides unobstructed instrumentation-free voiding. However, increasing stenosis length and age are independently associated with surgical failure. Patients should be counseled that further surgery for incontinence may be necessary. UROLOGY 00: 1–6, 2021. © 2021 Elsevier Inc.

Radiation is one of the most common modalities used to treat localized prostate cancer. An analysis of prostate cancer treatment trends from 2004-2012 data in the National Cancer Database revealed that while radical prostatectomy is the most common treatment modality (52% in 2012), external beam radiotherapy (EBRT) and brachytherapy (BT) are used in the treatment of 32% of men with prostate cancer.[1] As a

* Current Address: Spokane Urology, Spokane, WA

** Current Address: Memorial Sloan Kettering Cancer Center; 1275 York Ave, New York, NY 10065

From the Department of Urology, University of Washington School of Medicine, Seattle, WA; the Division of Urology, University of Utah, Salt Lake City, UT; the Department of Urology, University of California-San Francisco Medical Center, San Francisco, CA; the UroPartners, Chicago, IL; the Department of Urology, University of Kansas Medical Center, Kansas City, KS; the Department of Urology, University of Minnesota, Minneapolis, MN; the Department of Urology, Lahey Clinic, Burlington, MA; the Department of Urology, University of Iowa, Iowa City, IA; the Department of Urology, University of California-San Diego, San Diego, CA; the Department of Urology, New York University Langone Health, New York City, NY; the Elson S. Floyd College of Medicine, Washington State University, Spokane, WA; and the Division of Urology, University of Alberta, Edmonton, AB, Canada

Address correspondence to: Keith Rourke, M.D., F.R.C.S.C., Division of Urology, University of Alberta, Kipnes Urology Centre, 7th floor, Kaye Edmonton Clinic, 11400 University Avenue, Edmonton, AB, Canada T5R5V2 E-mail: krourke@ualberta.ca

Submitted: October 12, 2020, accepted (with revisions): November 30, 2020

https://doi.org/10.1016/j.urology.2020.11.077
0090-4295

consequence of treatment, urethral stenosis occurs in 1-3% of men after primary EBRT, 4%-9% after brachytherapy, and likely higher rates after combination treatment with both BT and EBRT.[2-4] Urethral stenosis may also occur in up to 40% of patients receiving adjuvant or salvage radiation after radical prostatectomy.[3]

The majority of radiotherapy-associated urethral strictures/stenoses occur in the bulbomembranous urethra and are typically refractory to endoscopic treatment.[3] While the urethroplasty experience in this setting remains limited, excision and primary anastomosis (EPA) is the most commonly utilized technique.[5-7] This surgical preference is likely related to several factors including potential impairment of graft take due to a diseased peri-urethral milieu after radiation, often short stenosis length and challenging location deep within the male pelvis. We present a multicenter retrospective review of outcomes following EPA for radiotherapy-associated urethral strictures following prostate cancer treatment. Specifically, our objective is to examine the success rate of EPA in this setting as well as factors associated with stricture recurrence using an *a priori* model. We hypothesize that high rates of urethral patency can be achieved in properly selected patients but there will be a need for ancillary surgical maneuvers during reconstruction, and significant risk of postoperative treatment for other radiation related factors such as incontinence.

METHODS

An IRB-approved multi-institutional (10 center) retrospective review was performed of consecutive prostate cancer patients undergoing EPA urethroplasty following radiotherapy between January 2007 and June 2018.

Inclusion criteria were a minimum of 12 months of follow up with a minimum of an office visit or telephone call, for select patients who could not return for an office visit. When possible, the referring physician was contacted to gather clinical information. Patients with radiotherapy-induced urethral strictures following prostate cancer treatment who were not deemed to be surgical candidates for anastomotic urethroplasty were excluded at the discretion of the surgeon. Success was defined as voiding per urethra without the need for additional endoscopic procedures or intermittent self-catheterization. Cystoscopy, uroflowmetry, post-void residual bladder ultrasound, and/or subjective questionnaires were utilized to assess voiding status following urethroplasty.

Preoperative evaluation included retrograde urethrogram, cystoscopy and voiding cystourethrogram (VCUG) to assess stenosis length, location, tissue integrity, assess sphincteric function and evaluate bladder capacity. Preoperative hyperbaric oxygen therapy was performed at the treating surgeon's discretion. Preoperative suprapubic catheter placement was performed in the setting of recurrent urinary retention or based on the individual preference of some surgeons. Urethral catheter duration following urethroplasty was at the surgeon's discretion. A voiding trial with or without cystourethrogram was performed 3-6 weeks after urethroplasty. If there was contrast extravasation noted during VCUG, the urethral catheter and/or suprapubic catheter remained until the contrast extravasation resolved.

Anastomotic urethroplasty was performed via a perineal approach, with a concomitant abdominal surgery performed, if necessary. Urethral mobilization was performed in all patients with additional ancillary maneuvers such as division of the intracoproral space, infrapubectomy or corporal rerouting when necessary to achieve a tension-free anastomosis. Gracilis muscle flap interposition to fill dead space and support the anastomosis was utilized at the discretion of the treating surgeon. When desired, additional surgery to treat stress incontinence (i.e., artificial urinary sphincter) was performed at a minimum of three months following anastomotic urethroplasty once urethral patency was established. The decision to proceed with incontinence surgery was based on the degree of incontinence and patient preference in a shared decision making model of care.

Predictor variables were determined *a priori* and assessed for effect on surgical outcome: age, body mass index (BMI), diabetes, current smoking status, >1 radiation modality, history of endoscopic procedure prior to urethroplasty, salvage prostatectomy for prostate cancer, gracilis muscle flap use, and stenosis length. The primary endpoint was urethral patency at 12 months. Secondary endpoints of urinary continence and need for post-operative incontinence surgery was also assessed. Significant stress incontinence was defined as requiring >1 pad/day.

SPSS24 was utilized for statistical computations and comparisons. Statistical significance was defined as $p<0.05$ for all analyses.

RESULTS

There were 137 men that met study criteria and were included in the analysis. Cohort demographics are outlined in Table 1. The mean age of the cohort was 69.3 years (range 50-86) and the majority had a history of prior failed endoscopic stricture treatment (83.2%, 114/137). Brachytherapy was the most common etiology (43.8%), followed by external beam radiotherapy (38.0%), and combined modality radiotherapy (9.5%). Prior transurethral resection of the prostate (TURP) was performed in 16.8% of patients and radical prostatectomy had been performed prior to radiotherapy in 14.6% of patients. Mean stenosis length was 2.3 cm (range 1-5).

Operative techniques and postoperative outcomes are presented in Table 2. At a mean follow-up of 32.3 months, overall success was 86.9% (119/137) (12-118 months) (Fig. 1). The mean time to failure was 16.4 months (1-36) confirmed with cystoscopy. The most common adjunctive operative maneuver beyond urethral mobilization was splitting of the corporal bodies (71.5%), followed by partial perineal prostatectomy with resection of prostate tissue (37.2%) and partial pubectomy (12.4%). Gracilis muscle flap interposition was utilized in 23.4% of patients and at the discretion of the surgeon. Patients undergoing gracilis muscle interposition flap had longer strictures (2.7 cm versus 2.2 cm; $P = .003$) and were more likely to require corporal splitting (84.4% versus 67.6%; $P = .05$) than those without an interposition flap but did not differ by age (69.3 years versus 69.3 years; $P = .99$), BMI (27.4 vs 28.8; $P = .21$), pubectomy status (15.6% vs 12.4%; $P = .63$), diabetes (15.6% vs 24.8%; $P = .34$), smoking status (9.4% vs 9.5%; $P = .98$) or combined radiation etiology (12.5% vs 8.6%; $P = .51$).

Twenty-two patients (16.1%) experienced a 90-day complication following surgery including eight Clavien 1 complications: separation of perineal wound ($n = 3$), clot retention requiring catheter irrigation ($n = 3$), acute renal insufficiency resolving with admit/hydration ($n = 1$), and ileus resolving with hydration

Table 1. Cohort demographics

Factor	*N* (%)
Number of patients	137
Patient Age (years)	Mean 69.3±7.7 Median 69.0 (50-86)
Diabetes	31 (22.6%)
Body Mass Index (BMI)	Mean 28.5±5.5 Median 27.5 (12-50)
Active Smoker	13 (9.5%)
Previous Smoker	52 (38.0%)
Failed Endoscopic Treatment	114 (83.2%)
Etiology by Type of Radiotherapy	
Brachytherapy (BT)	60 (43.8%)
External Beam Radiotherapy (EBRT)	52 (38.0%)
Combined Radiation (EBRT + BT)	13 (9.5%)
HD-EBRT	7 (5.1%)
HDR-BT	4 (2.9%)
Proton Beam	1 (0.7%)
Pre-operative Adjuvant Treatments	
Cryotherapy	3 (2.2%)
TURP	23 (16.8%)
Radical Prostatectomy	20 (14.6%)
Hyperbaric Oxygen	9 (6.6%)
Radiation + Other Treatment	19 (13.9%)
Urethral Involvement / Stenosis Location	
Mid-Bulbar	2 (1.5%)
Proximal Bulbar	105 (76.6%)
Membranous	128 (93.4%)
Prostatic	72 (52.6%)
Bladder Neck	13 (9.5%)
Rectourethral Fistula	3 (2.2%)
Perineal fistula	1 (0.7%)
Stenosis Length (cm)	Mean 2.3±0.8Median 2.0 (1-5)

*EBRT, external beam radiation therapy; BT, brachytherapy; HDR-BT, high dose rate brachytherapy; HD-EBRT, high dose external beam radiotherapy

Table 2. Surgical techniques and postoperative outcomes

Factor	*N* (%)
Surgical Technique	
Corporal Splitting	98 (71.5%)
Corporal Re-routing	0 (0%)
Partial Pubectomy	17 (12.4%)
Complete Pubectomy	1 (0.7%)
Partial Prostatectomy	51 (37.2%)
Salvage Prostatectomy	3 (2.2%)
Gracilis muscle flap	32 (23.4%)
Abdominal Procedure Required	8 (5.8%)
Operative Time (minutes)	Mean 176.3±62.6 Median 150 (90-420)
Estimated Blood Loss (ml)	Mean 255.2±253.8 Median 200 (20-1750)
Success	119 (86.9%)
Follow-up (months)	Mean 32.3±24.5 Median 25 (12-118)
Incontinence (>1 pad/day)	44 (32.1%)
Artificial Urinary Sphincter	30 (21.9%)
Trans-corporal Cuff Placement	25/30 (83.3%)
Cuff Size (cm)	Mean 4.57 Median 4.5 (4-6)
Urethral Erosion	5/30 (16.7%)
Length of Follow-up after AUS	Mean 19.9±21.6 Median 11.3 (2-82)

($n = 1$). There were twelve Clavien 2 complications including acute epididymo-orchitis ($n = 4$), wound infection (2), urinary tract infection (3) and one pneumonia all requiring antibiotics. Additionally, one patient developed transient urinary retention requiring catheterization in the early postoperative period and another a transient perineal fistula that healed with prolonged catheter drainage. There was one Clavien 3a complication: a wound infection requiring drain placement by interventional radiology and a single Clavien 4a complication: a pulmonary embolus.

Significant stress incontinence (>1 pad/day) following urethroplasty was present in 32.1% of patients (44/137). When comparing patients who did *not* have a history of prior radical prostatectomy and/or endoscopic prostate surgery (ie, patients at lower risk for expected baseline incontinence prior to EPA), the rate of incontinence was 18.0% (18/100) versus 70.3% (26/37) in those who had prior prostate surgery ($P < .0001$). As a subgroup, patients with a history of salvage/adjuvant radiotherapy after radical prostatectomy had a 65.0% (15/20) rate of incontinence postoperatively but not a statistically significant higher rate of recurrent stenosis (25.0% vs 11.1%; $P = .09$)

Subsequent artificial urinary sphincter (AUS) was performed in 30 men (21.9%), 25 of these required a transcorporal cuff. Ultimately, 5 patients developed cuff erosion (16.7%) with a mean of 19.9 months of follow-up (2-82). Of the five cuff erosions, four were placed via a transcorporal technique. Among the five AUS cuff erosions, all patients had a subsequent AUS placed after successful urethral healing. Of the five who underwent repeat AUS placement, two developed repeat AUS cuff erosion.

Univariate Cox regression analysis was performed to analyze factors associated with surgical failure (Table 3). Cox regression analysis identified increasing patient age ($P = .02$), stricture length ($P < .0001$) and combined modality radiotherapy ($P = 0.004$) as factors associated with stricture recurrence while body mass index ($P = .79$), diabetes ($P = .93$), smoking ($P = .62$), failed endoscopic treatment ($P = .08$) and gracilis muscle use ($P = .25$) were not. On multivariate analysis (Table 3), increasing age (Hazard Ratio 1.09, 95%CI 1.01-1.16; $P = .02$) and stricture length (H.R.2.62, 95%CI 1.49-4.60; $P = .001$) remained associated with recurrence.

Among the 18 failures, one patient underwent revision EPA which was successful. The remaining patients underwent the following management: indwelling suprapubic catheter ($n = 7$), intermittent endoscopic treatment (2), self-dilation (4), ileal conduit (3), and Indiana pouch (1).

DISCUSSION

We present an 86.9% rate of success following EPA for radiotherapy induced urethral stenosis among patients with a minimum of 12-months follow-up from ten reconstructive centers. This is consistent with published success rates for posterior EPA urethroplasty in the *non-radiated* patient population with a reported range from 86-97%.[8-10] This series also compares favorably with the 70%-91% success rates of other series describing

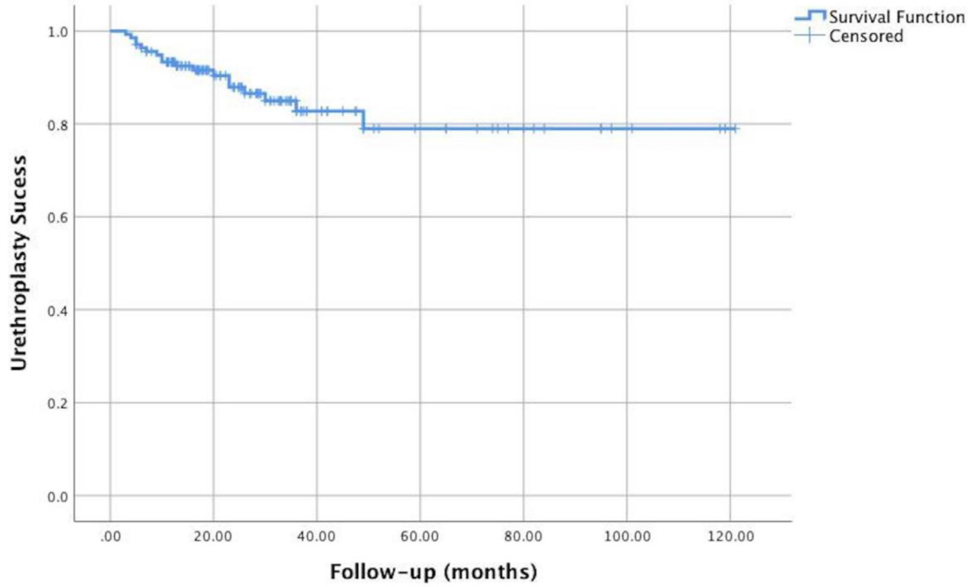

Figure 1. Kaplan-Meier survival curve of excision and primary anastomosis for radiotherapy-associated bulbomembranous urethral stenoses following prostate cancer treatment. (Color version available online.)

anastomotic urethroplasty for radiotherapy-induced urethral strictures.[5-7,11,12] While with any urethroplasty technique there can be a progressive rate of stricture recurrence over time, our mean follow-up of 32.3 months provides some evidence of procedural durability.[12] Our series complements these publications as the largest described series of urethroplasty for radiation induced urethral stenosis. Unique to this study was an analysis of factors associated with failure while also illustrating several important considerations about the complexity of post-RT EPA urethroplasty. In our series, urethral stenoses spanning from the proximal bulbar urethra to the bladder neck, most commonly involving the membranous urethra (93.4%), and strictures up to 5 cm in length were reconstructed using an anastomotic technique.

Multivariate Cox regression analysis of *a priori* risk factors demonstrated that increasing stenosis length and increasing patient age were independently associated with surgical failure. It has been well established that increasing stricture length is associated with urethroplasty failure in non-radiated bulbar urethroplasty with or without tissue transfer.[13] Likewise, advanced patient age has also been shown to be associated with stricture recurrence after urethroplasty particularly in the elderly although this association is less consistently established.[14,15] While multimodal radiation treatment was associated with recurrent

Table 3. Univariate Cox regression analysis of factors associated with stricture recurrence following EPA for radiation induced urethral stenosis

	Univariate Analysis			Multivariate Analysis	
Factor	N (%) (for categorical variables)	*P*-Value	Hazard Ratio (95% CI)	*P*-Value	Hazard Ratio (95% CI)
Age (years)		**.02***	1.08 (1.02-1.15)	**.02***	1.09 (1.01-1.16)
Body Mass Index (BMI)		.79	0.99 (0.91-1.08)		
Diabetes	4/31 (12.9%) vs. 14/106 (13.2%)	.93	1.05 (0.35-3.21)		
Current Smoker	1/13 (7.7%) vs. 17/124 (13.7%)	.62	0.60 (0.08-4.53)		
Combined Modality Radiotherapy	5/13 (38.5%) vs. 13/124 (10.5%)	**.004***	4.68 (1.66-13.25)	.30	2.08 (0.53-8.26)
Prior Endoscopic Procedure	13/114 (11.4%) vs. 5/23 (21.7%)	.08	0.39 (0.14-1.12)		
Salvage prostatectomy	3/3 (100%) vs. 116/134 (86.6%)	.71	0.05 (0.00-2000.00)		
Gracilis Muscle Flap (GMF)	5/32 (15.6%) vs. 13/105 (12.4%)	.25	1.86 (0.64-5.40)		
Stricture length (cm)		**<.001***	2.73 (1.61-4.62)	**.001***	2.62 (1.49-4.60)

* *P*<.05.

stenosis on univariate analysis, it was not associated on multivariate assessment. Additional factors including body mass index and use of a gracilis muscle flap were also not associated with surgical failure. Hopefully, these associations will improve the ability of urologists to properly counsel and select patients for urethroplasty in the setting of radiotherapy-associated urethral stenosis. Anecdotally, recurrent radiation stenosis after urethroplasty may be amenable to endoscopic procedures than the pre-operative state due to a reduction in fibrosis compared to the pre-operative state.[7]

The majority of patients in our study required adjunctive surgical maneuvers beyond a standard anastomotic urethroplasty. These maneuvers included, corporal splitting (71.5%), partial prostatectomy (37.2%), partial pubectomy (12.4%) and gracilis muscle flap (23.4%). Gracilis muscle flap utilization was employed at the discretion of the surgeon and was most frequently performed with longer stenoses and when further adjuvant steps beyond urethral mobilization such as corporal splitting were necessary during the EPA. We readily acknowledge that the decision to place a gracilis flap is not standard practice, as evidenced by a lack of association with surgical outcomes; however, there may be value in a select subgroup of patients. Such patients might include those with both poor tissue vascularity (i.e., dual radiation, cardiovascular disease) and a large dead space in the perineum after scar excision and/or following partial/complete pubectomy (i.e. to reduce risk of pubic osteomyelitis). Use of gracilis has been helpful particularly when performing a ventral only with buccal mucosa for long, high risk urethral strictures including those with radiotherapy etiologies.[16] Prediction of which adjunctive maneuvers will be necessary is not possible prior to surgery, highlighting the need for an experienced reconstructive surgeon and pre-operative patient counseling.

The post-operative incontinence rate (>1 pad per day) in this series was 32.1%, which is near the upper limit of that reported in prior series with rates of 7% to 35.7%.[5,6,11,12] However, the definition of incontinence can be quite narrow or broad, limiting the ability to compare outcomes across manuscripts. When limited to patients with an intact bladder neck prior to urethroplasty, (ie, patients without a history of radical prostatectomy or endoscopic prostate surgery), the rate of post-operative stress urinary incontinence in our series was 18.0% when compared to 70.3% in those with prior bladder neck resection. This highlights the importance of limiting transurethral prostatic and bladder neck resection in men with membranous strictures after radiotherapy as it appears that the internal sphincter mechanism remains functional, and sufficient, in the majority (over 80%) of patients. This rate of post-operative stress urinary incontinence in patients with an intact bladder neck, and therefore presumably functional internal sphincter, simultaneously highlights the need for preoperative discussion of the risk of urinary incontinence with all radiated patients. This is in contrast to non-radiated posterior urethroplasty (pelvic fracture urethral distraction defect) patients who have very low rates of de novo incontinence after EPA.[17] The higher rates of de novo post-operative stress urinary incontinence compared to the non-radiated patients are likely the result of radiotherapy-associated internal sphincter insufficiency.

An AUS was placed in 21.9% (30/137) of patients in the series with a 16.7% rate of cuff erosion. Men with a prior history of pelvic radiation appear to have an increased risk of cuff erosion. Multiple publications have reported AUS erosion rates of 3.4%-23% in this high-risk population.[18-21] The question of whether a prior urethroplasty affects the rate of AUS erosion has yet to be definitively answered. Data from UCSF noted that prior urethroplasty led to an eight-fold increase in the risk of AUS failure, while a separate multi-institutional did not find prior urethroplasty to be a risk factor.[18,20]

A transcorporal technique was used for 83.3% of AUS devices placed in this series. This is a helpful technique for patients who have undergone prior urethral mobilization as it avoids a repeat dissection of the delicate plane between corpus spongiosum and corpus cavernosum. It also augments urethral circumference that is often decreased in patients after radiotherapy. This technique may be associated with improved outcomes in patients with a “fragile urethra”.[22] Transcorporal cuff placement remains an option even after corporal spitting during EPA urethroplasty by performing corporotomies distal to the split corporal bodies so that the final location of the cuff is more distal than typical cuff placement.

The retrospective nature of this work has inherent limitations, most notably lack of data with regard to pre-operative urinary and sexual function. In future, the use of validated questionnaires will allow for objective data collection with regard to sexual function, continence and pre- and post-operative quality of life. This will improve our ability to characterize the bladder storage symptoms that occur as a result of the radiotherapy and determine how surgical reconstruction impacts quality of life. This study also represents a diverse group of patients with radiation induced urethral stenosis requiring a variety of reconstructive techniques and is not a uniformly heterogeneous population of patients. However, this is often the cases in clinical practice and highlights the individualized approach that these patients may require. Additionally, this study did not address the pre-operative decision making undertaken by urologists with regard to the health and function of the bladder. Patients with poor preoperative bladder capacity and compliance should be counseled toward urinary diversion, as reconstruction of their urethra and possible AUS placement will not compensate for compromised urine storage. Our definition of success of symptom-free spontaneous voiding function not requiring intervention may not have detected asymptomatic cystoscopic recurrences. Further study of this growing population will improve the predictive value of the statistical model.

CONCLUSION

This multi-center retrospective analysis demonstrates EPA urethroplasty after prostate radiotherapy produces an 87% rate of urethral patency. Ancillary surgical maneuvers are frequently required for surgical success in these complex patients. Increasing stenosis length and patient age are independently associated with urethroplasty failure. Additionally, pre-operative counseling should include a discussion of the risk of de novo stress incontinence, even in patients with an intact bladder neck.

References

1. Gray PJ, Lin CC, Cooperberg MR, et al. Temporal trends and the impact of race, insurance, and socioeconomic status in the management of localized prostate cancer. *Eur Urol*. 2016;71:729–737.
2. Blackwell RH, Kandabarow AM, Gupta GN, et al. Long-term incidence of hematuria, urethral stricture and bladder cancer after radiation therapy for prostate cancer. *Urology Practice*. 2015;2:349–358.
3. Herschorn S, Elliott S, Coburn M, et al. SIU/ICUD consultation on urethral strictures: posterior urethral stenosis after treatment of prostate cancer. *Urology*. 2014;83(3 Suppl):S59–S70.
4. Awad MA, Gaither TW, Osterberg EC, et al. Prostate cancer radiation and urethral strictures: a systematic review and meta-analysis. *Prostate Cancer Prostatic Dis*. 2018 Jun;21:168–174. https://doi.org/10.1038/s41391-017-0028-3.
5. Glass AS, McAninch JW, Zaid UB, et al. Urethroplasty after radiation therapy for prostate cancer. *Urology*. 2012;79:1402–1405.
6. Hofer MD, Zhao LC, Morey AF, et al. Outcomes after urethroplasty for radiotherapy induced bulbomembranous urethral stricture disease. *J Urol*. 2014;191:1307–1312.
7. Keith CG, Davenport MT, Kavoussi M, Yi YA, Bergeson RL, Morey AF. Long-term outcomes of anastomotic urethroplasty for radiation-induced strictures. *World J Urol*. 2019. https://doi.org/10.1007/s00345-019-03028-7. Epub ahead of print. PMID:31781894.
8. Cooperberg MR, McAninch JW, Alsikafi NF, et al. Urethral reconstruction for traumatic posterior urethral disruption: outcomes of a 25-year experience. *J Urol*. 2007;178:2006–2010. discussion 2010.
9. Kizer WS, Armenakas NA, Brandes SB, et al. Simplified reconstruction of posterior urethral disruption defects: limited role of supracrural rerouting. *J Urol*. 2007;177:1378–1381. discussion 1381-1372.
10. Webster GD, Ramon J. Repair of pelvic fracture posterior urethral defects using an elaborated perineal approach: experience with 74 cases. *J Urol*. 1991;145:744–748.
11. Fuchs JS, Hofer MD, Sheth KR, et al. Improving outcomes of Bulbomembranous urethroplasty for radiation-induced urethral strictures in post-urolume Era. *Urology*. 2017;99:240–245.
12. Rourke K, Kinnaird A, Zorn J. Observations and outcomes of urethroplasty for bulbomembranous stenosis after radiation therapy for prostate cancer. *World J Urol*. 2016;34:377–382.
13. Chapman D, Kinnaird A, Rourke K. Independent predictors of stricture recurrence following urethroplasty for isolated bulbar urethral strictures. *The J Urol*. 2017;198(5):1107–1112.
14. Viers BR, Pagliara TJ, Rew CA, et al. Urethral reconstruction in aging male patients. *Urology*. 2018;113:209–214.
15. Levy M, Gor RA, Vanni AJ, et al. The impact of age on urethroplasty success. *Urology*. 2017;107:232–238.
16. Rozanski AT, Vanni AJ. Ventral buccal mucosa graft urethroplasty with gracilis muscle flap for high risk, long segment urethral strictures: A 20-Year Experience. *Urology*. 2020;140:178–180. https://doi.org/10.1016/j.urology.2020.03.008. Epub 2020 Mar 17. PMID:32197989 .
17. Chung PH, Esposito P, Wessells H, et al. Incidence of stress urinary incontinence after posterior urethroplasty for radiation-induced urethral strictures. *Urology*. 2018;114:188–192.
18. Brant WO, Erickson BA, Elliott SP, et al. Risk factors for erosion of artificial urinary sphincters: a multicenter prospective study. *Urology*. 2014;84:934–938.
19. Gomha MA, Boone TB. Artificial urinary sphincter for post-prostatectomy incontinence in men who had prior radiotherapy: a risk and outcome analysis. *J Urol*. 2002;167(2 Pt 1):591–596.
20. McGeady JB, McAninch JW, Truesdale MD, et al. Artificial urinary sphincter placement in compromised urethras and survival: a comparison of virgin, radiated and reoperative cases. *J Urol*. 2014;192:1756–1761.
21. Walsh IK, Williams SG, Mahendra V, et al. Artificial urinary sphincter implantation in the irradiated patient: safety, efficacy and satisfaction. *BJU Int*. 2002;89:364–368.
22. Redmond EJ, Tong S, Zemp L, et al. Improved artificial urinary sphincter outcomes using a trans-corporal cuff placement in patients with a "fragile urethra. *Canadian Urol Assoc J*. 2020. https://doi.org/10.5489/cuaj.6431. Online ahead of print.