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ORIGINAL ARTICLE

Artificial urinary sphincter longevity following transurethral resection of the prostate in the setting of prostate cancer

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Abstract

Purpose Refractory urinary incontinence after channel transurethral resection of the prostate (cTURP) (TURP in the setting of prostate cancer) is a rare occurrence treated with artificial urinary sphincter (AUS). We sought to characterize those patients receiving AUS after cTURP and understand device longevity.

Materials and methods We identified patients who underwent cTURP and AUS placement in SEER-Medicare from 2002 to 2014. We analyzed factors affecting device longevity using multivariable Cox proportional hazard models. We performed propensity matching to accurately compare patients receiving AUS after cTURP to those receiving AUS after radical prostatectomy (RP).

Results For patients undergoing cTURP, 201 out of 56,957 ultimately underwent AUS placement (< 0.5%). AUS after cTURP incurred a 48.4% rate of reoperation versus 30.9% after RP. Importantly, patients undergoing cTURP were significantly older than those undergoing RP [75 vs. 71 years of age ($p < 0.01$)]. At 3 years after insertion, 28.2% of patients after RP required reoperation compared to 37.8% of patients post-cTURP ($p < 0.01$). There were no detectable differences in revision rates for those patients who underwent traditional vs. laser cTURP. Patients with a history of radiation therapy had significantly shorter device survival. Even after propensity matching, patients receiving AUS after cTURP incurred more short-term complications compared to AUS after RP. Differences in device longevity were diminished after propensity match.

Conclusions In the SEER-Medicare population, AUS after cTURP remains rare. While there is an increased risk of infectious complications, AUS after cTURP fared similarly to AUS after RP in terms of device longevity. A history of radiation therapy leads to worse outcome for all patients.

Keywords Transurethral resection of prostate · Artificial urinary sphincter · Complications · Radiation · Explantation · Thermotherapy

Introduction

Stress urinary incontinence (SUI) after transurethral resection of prostate (TURP) in the setting of prostate cancer is a rare but dreaded complication [1, 2]. Certainly TURP may unmask irritative urinary symptoms which may be addressed with medical therapy, but delayed or long-term incontinence presents a clinical challenge. Contemporary rates of persistent SUI after TURP for benign prostatic hyperplasia (BPH) have previously been reported as 0.5–2.2% [3, 4]. Damage to the sphincter may be the mechanism of injury [4, 5]. Incontinence after channel TURP (cTURP), or a TURP performed in the setting of prostate cancer, is thought to be higher than for BPH, but incidence rates remain unknown [6]. Incidence may be higher due to effects on bladder functioning by the prostate cancer itself, pre-existing LUTs, obscured surgical planes during resection, or patient differences such as age or comorbidity [7].

Treatment of incontinence post-cTURP depends on symptom severity, duration, and patient preference. In severe and persistent cases, urodynamics and cystoscopy should

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be considered to rule out bladder neck contracture, residual obstructing tissue, or detrusor instability prior to further therapy [3]. Small case series have previously explored the utility of slings for SUI after TURP, with mixed results [8, 9]. A recent meta-analysis identified only 23 patients who received slings after TURP [10]. Any conclusions regarding male slings therefore are hampered given small sample sizes and lack of long-term follow-up.

Ultimately, the gold standard treatment for severe urinary incontinence after invasive procedures remains artificial urinary sphincter placement (AUS) [11]. To our knowledge, there are no studies that explore incident rates, patient characteristics, or device outcomes for those patients who suffer from SUI after cTURP and ultimately are treated with AUS. Data from the 1990s, in single surgeon series, suggest AUS in this setting attains high patient satisfaction with 90% improved continence and a 25% revision rate [12]. Contemporary findings, including any effect of laser prostate tissue removal on ultimate AUS function, are completely absent in the literature. We hypothesize that patients who undergo AUS placement after cTURP would have higher comorbidity and higher reoperation rates than those individuals that receive AUS in the more typical post-prostatectomy setting. Our objective is to better characterize this special population of patients.

Materials and methods

Using the SEER-Medicare files from 2001 to 2014, we included all patients who underwent TURP as defined by procedure codes [Current Procedural Terminology (CPT®): 52601, 52648, 52647, 52630, or 52620]. Our methodology has been published previously: we assessed the prostate cancer files and included patients with a prior diagnosis of prostate cancer using International Statistical Classification of Diseases (ICD-9) codes [13]. Given these patients' underlying diagnosis of prostate cancer, we define their TURP as a channel TURP. Surgical codes for prostatectomy were required [CPT®: 55866, 55810, 55812, 55815, 55840, 55842, 55845, or 60.5] for our control group.

In all cases, we limited our query to patients with appropriate codes for insertion of AUS (ICD-9 58.93 or CPT 53445) with appropriately matched diagnosis codes of incontinence (ICD-9 788.30, 788.32, 788.33 788.37, 788.39). For our control group, patients with a history of TURP prior to prostatectomy were excluded. Likewise, patients with a history of sling placement were excluded from analysis. We further limited the study group to those patients with at least 1 year of data after implantation of AUS. Patient enrollment in both Medicare Part A and B was required, as well as not being a member of an HMO, to capture complete data on such patients. We derived Charlson Comorbidity Index scores from hospital and physician claims [14].

We also studied patient factors including pathologic stage and grade of prostate cancer, history of radiation or brachytherapy (RT), and history of ablative thermotherapy (transurethral microwave thermotherapy), TUNA (transurethral needle ablation), or TUMT (transurethral microwave thermotherapy). Patients with a history of thermotherapy were ultimately dropped from the multivariate analysis given low patient numbers and limitations of Seer-Medicare data-use agreement ($n = 44$). We defined reoperation by CPT codes (53446, 53447, 53448, or 53449]. For the purposes of the manuscript, revision and explantation are collectively referred to as reoperation. We collected data on the incidence of short-term complications following initial AUS placement using CPT and ICD-9 codes. On secondary analysis, we also studied urethral interventions preceding AUS by 5 years, such as urethrotomy or endoscopic bladder neck contracture treatment. A summary of all utilized codes can be found in Appendix I.

The project was approved by SEER-Medicare data-use agreement and granted IRB exemption given anonymized data. Using the SAS 9.3 (Cary, NC, USA) statistical program, we analyzed patient and pathologic characteristics using Chi square analysis, Kruskal–Wallis or Wilcoxon rank-sum tests where appropriate. Trends over time were evaluated using the Cochran—Armitage trend test. Kaplan–Meier survival curves and the log-rank test were used to compare device survival curves and time until reoperation. A multivariable Cox regression was used for multivariable analysis of device survival. We utilized a propensity score matching method to compare patients who underwent AUS after cTURP and RP, respectively. The propensity score was based on year of implant, age, race, Charlson Comorbidity Index score, type of cancer, history of RT, history of androgen deprivation, and region. Twenty-two patients with a history of cTURP were excluded given incomplete characteristics on which to match. All tests were two tailed, and a threshold of $p < 0.05$ was considered significant for statistical analyses.

Results

Our strict study criteria were met by 56,957 men who underwent cTURP between 2002 and 2014. Ultimately, 201 (0.35%) underwent AUS placement. Gleason score and cancer stage were unknown in 42% of this cohort. Similarly, 54% had unknown PSA values. Gleason score of 6, 7, and 8 or greater consisted of 28.8, 17.1 and 12.6% of the cohort. A traditional monopolar or bipolar cutting loop was used in 62.3% of cases as based on CPT coding with the balance

performed by laser energy. There were no significant differences among patient characteristics based on the methodology of tissue removal (all $p > 0.05$). In the unmatched population, patients undergoing cTURP were significantly older than those undergoing RP and more likely diabetic (Table 1).

We discovered an overall reoperation rate of 48.4% for patients undergoing AUS after cTURP. In comparison, reoperation for AUS after RP was found to be 30.9% ($p < 0.01$) (Table 2). Median time from AUS placement to reoperation was 7 months (IQR 3–27) for patients after cTURP vs. 12 months (IQR 3–32) for patients after RP ($p < 0.01$) (Fig. 1a). AUS longevity was 1.3 years longer on average for patients without a history of RT (Fig. 1b).

cTURP patients had higher baseline comorbidity and older age when compared to those undergoing RP. We therefore performed a propensity match to more accurately compare patients receiving AUS after cTURP to those receiving AUS after RP (Table 1). The resulting population of patients in the matched RP cohort were older and more comorbid than the RP population at large. AUS devices placed in this population had similar longevity to those placed after cTURP (55.9% vs. 64.0% device survival at 5 years [log-rank = 0.16]). For all patients receiving AUS, predictors of earlier device failure included a history of RT, having AUS surgery earlier in our study period, and a history of smoking (Table 3). Having undergone a cTURP vs. RP did not affect device survival in the multivariate model. Of note, thermotherapy was the strongest univariate predictor for reoperation (HR 2.21 [95% CI 1.43–3.42; $p < 0.01$]).

There was a higher proportion of patients experiencing complications following AUS after cTURP compared to those patients undergoing AUS after RP up to 90 days after surgery (Supplemental Table 1). In the matched cohort, patients receiving AUS after cTURP incurred

Table 1 Patient characteristics in overall and propensity score-matched cohorts

	Non-matched			Propensity score matched[a]		
	cTURP (138)	RP (1097)	*p* value	cTURP (116)	RP (116)	*p* value
Age at AUS placement	75.3 ± 5.9	71.1 ± 5.0	< 0.01	74.5 ± 4.7	74.5 ± 5.7	0.68
Median follow-up (Yrs)	4.0	4.5	< 0.01	3.5	3.9	0.74
Caucasian	117 (84.8)	954 (87.0)	0.48	101 (87.1)	99 (85.3)	0.7
Charlson Index score						
0	44 (31.9)	526 (48.0)	< 0.01	41 (35.3)	50 (43.1)	0.83
1	39 (28.3)	298 (27.2)		35 (30.2)	32 (27.6)	
2+	55 (39.9)	273 (24.9)		40 (34.5)	34 (29.3)	
Smoker	26 (18.8)	148 (13.5)	0.09	21 (18.1)	17 (14.7)	0.48
History of diabetes	50 (36.2)	303 (27.6)	0.03	39 (33.6)	35 (30.2)	0.57
Obese	[b]	[b]	0.98	[b]	[b]	0.52
History of RT	78 (56.5)	183 (16.7)	< 0.01	60 (51.7)	63 (54.3)	0.69
History of androgen deprivation	59 (42.8)	198 (18.1)	< 0.01	46 (39.7)	48 (41.4)	0.79
History of thermotherapy	21 (16.9)	23 (2.2)	< 0.01	[c]	[c]	[c]

[a]Also matched by region and year of AUS placement

[b]Fields less than $n = 11$ censored per SEER-Medicare data agreement

[c]Excluded from matched population given SEER-Medicare data agreement limitations

Table 2 AUS device survival

	1-year survival Estimate (%) ± SE	3-year survival Estimate (%) ± SE	5-year survival Estimate (%) ± SE
RP[a]	86.2 ± 1.0	75.7 ± 1.4	69.1 ± 1.6
HX RT	82.5 ± 2.8	69.0 ± 3.8	58.1 ± 5.3
No prior treatment	87.0 ± 1.1	77.0 ± 1.5	70.8 ± 1.7[c]
cTURP[b]	75.4 ± 3.7	66.5 ± 4.3	51.6 ± 5.3
HX RT	74.4 ± 4.9	65.2 ± 5.8	50.2 ± 7.0
No prior treatment	76.7 ± 5.5	68.2 ± 6.3	53.5 ± 7.8

[a]5 year survival comparison of RP vs cTURP (log-rank < 0.01)

[b]There was no difference in survival between traditional cutting loop vs. laser TURP in the unmatched analysis ($p = 0.64$) or the matched analysis ($p = 0.28$)

[c]For RP: no prior treatment compared to HX RT ($p = 0.05$)

Fig. 1 AUS surival

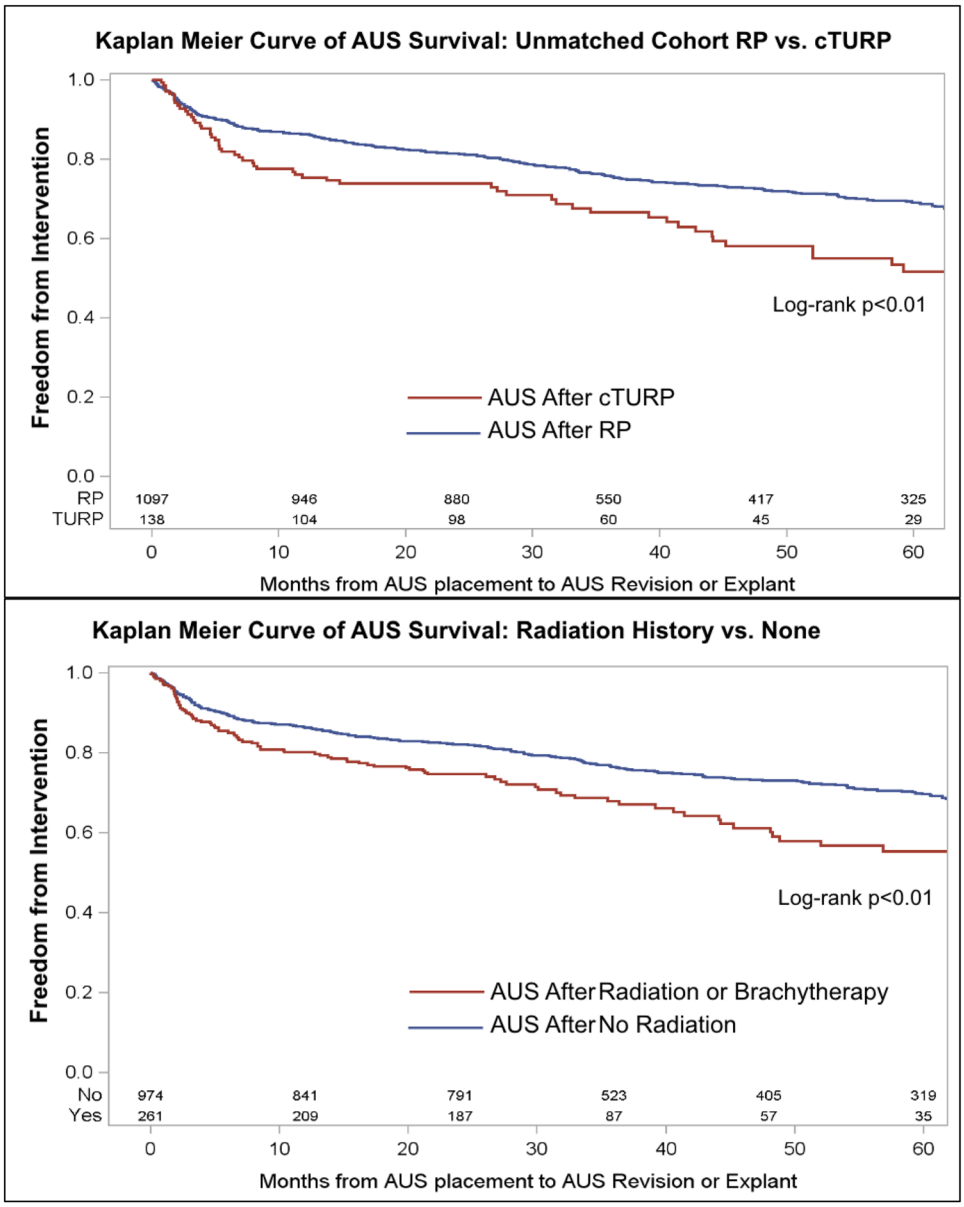

Table 3 Multivariable factors associated with device survival

Characteristic	Hazard ratio (95% CI)	*p* value
Age at AUS placement	0.99 (0.97–1.01)	0.50
Year of AUS placement	0.95 (0.91–0.98)	< 0.01
Caucasian race	1.11 (0.83–1.48)	0.48
Northeast region (ref west)	1.29 (0.96–1.75)	0.10
Midwest region (ref west)	1.11 (0.80–1.55)	0.56
Southeast region (ref west)	1.14 (0.88–1.48)	0.31
HX smoking	1.38 (1.04–1.82)	0.02
CDCC 1 (ref 0)	1.19 (0.93–1.52)	0.17
CDCC 2+ (ref 0)	1.25 (0.96–1.62)	0.09
HX RT	1.44 (1.08–1.92)	0.01
HX androgens	1.09 (0.83–1.43)	0.55
cTURP (ref RP)	1.29 (0.94–1.78)	0.12

more infectious complications by 90 days (28.5% vs. 15.7%, $p = 0.04$). Likewise, patients with a history of RT had higher rates of complications. Of note, there was no difference in device survival, revision rates, or complications based on whether cTURP was performed with laser energy vs. traditional cutting loop. Of patients with a history of RT, 49% had a urethral procedure such as urethrotomy or bladder neck contracture treatment prior to AUS compared to 32.9% of those without radiation ($p < 0.01$). In the matched population, 59.5% of cTURP patients had preceding urethral procedures compared to only 39.7% in the RP group ($p < 0.01$). (Supplemental Table 2).

Discussion

In our study population, 0.35% of cTURP patients developed incontinence and elected to undergo AUS. At initial glance, the procedure incurs significantly higher reoperative rates than AUS after RP (48.4% after cTURP vs. 30.9% after RP [$p < 0.01$]). Once matched to appropriate RP patients, such differences are negated. Differences in post-operative infectious complication rates remained after matching. A history of radiation therapy, independent of procedure preceding the TURP, reduces time until reoperation and increases 90 days complications. Our data suggests that the risk of incontinence is similar between laser and traditional TURP, and that the methodology does not impact AUS device survival or complications.

Prior randomized trials comparing surgical techniques to treat BPH often find mild, transient urge incontinence symptoms. For example, a trial of 100 patients undergoing TURP reported 5% mild urge incontinence at 12 months, but only 2% required pads [15]. Similarly, the GOLIATH study reported a 3% rate of incontinence for both Greenlight and for traditional TURP at 1 year. This was tolerated by patients without intervention [16]. The incidence of severe incontinence is very low and follow-up short in these randomized trials. Included patients are often young and TURP is not performed in the setting of cancer. In retrospective review, Rassweiler et al. estimated < 0.5% of patients developed severe incontinence after TURP based on over 8000 patients from 2000 to 2005, similar to our finding of 0.35% in the SEER population [4].

The strength of our study is the ability to focus on a unique patient population, those getting TURP in the setting of prostate cancer for which little literature currently guides management. Prior to this work, one of the largest, contemporary cohorts of patients described with persistent severe incontinence after TURP consisted of only 81 patients accrued by a single center over a 19 year period [17]. Based on urodynamics, Bruschini et al. estimated that bladder dysfunction was the cause of incontinence in 25% of these patients and incontinence risk increased by 5.3% for each year added to a patients age [17]. We know prostate cancer treatment leads to significant negative perturbations in urinary-related QOL. Punnen et al. reported worsened urinary problems and a decline in urinary function for all patients independent of treatment type for prostate cancer, but less so for external beam radiation [18]. Similarly, Kopp et al. reported in an elderly population of 5990 that 17% of patients used pads after prostate cancer treatment, and 10% described it as a large problem [19]. AUS placement leads to improvements in urinary QOL and overall satisfaction, with degradation of benefits over time [20].

At first glance, AUS after cTURP resulted in quicker revision surgery and more complications than patients receiving AUS after RP, but these patient populations are dramatically different. Patients who underwent cTURP and required AUS were older, had higher rates of diabetes, higher baseline comorbidities, more likely smokers, and more likely to have undergone radiation, thermotherapy or prior urethral procedure. Given older age, preexisting bladder dysfunction likely plays a pivotal role [17, 21]. Diabetes is an independent risk factor for device failure and studies suggest a 2.3 increased risk for erosion or infection requiring reoperation for affected patients [22]. Prior research is mixed regarding the impact of radiation on revision surgery or urethral erosion [23]. Though our study was not designed specifically to assess the impact of radiation on device longevity, it is worth noting that device survival was 1.3 years longer on average in patients without a history of radiation. While revision rates of surgery and device survival were similar after matching, rates of infectious complications essentially remained doubled for those undergoing AUS after cTURP. Patients undergoing cTURP may be at a higher risk of infection given baseline voiding dysfunction, history of indwelling catheters, higher post-void residuals and being more likely to have undergone previous urethral procedures. Similarly, radiation history is associated with more endoscopic urethral procedures which may confound conclusions as to whether radiation is truly a cause of altered device longevity in these patients vs. prior endoscopic treatments.

Our work strongly suggests that thermotherapy negatively impacts device survival, albeit data limitations prevented a hearty analysis. In a multicenter study on TUNA, Zlotta et al. reported 23.3% of patients seek additional therapy for LUTS at 5 years, so the population of patients seeking TURP post-thermotherapy may continue to grow [24]. Further research in this special population is needed; we do not understand how prior thermotherapy treatment affects continence during prostate cancer treatment.

In contrast to prior work, we find that more recent AUS placement was weakly protective against re-intervention [12]. Additional surgeon experience, reflected by additional years of data, may reduce reoperation. The corollary of inflatable penile prosthesis surgery provides some evidence to this effect [25]. Inhibizone was available as early as April 2008 and use of the coating has had a positive impact at least in penile prosthesis surgery [26]. Moreover, 3.5 cm cuffs were first introduced in September 2009 with often debated effects on reoperation rates [27]. Limitations of our dataset include the inability to know if and when these technologies were reflected in our cohort.

SUI after cTURP represents a large challenge for the practioner, especially given our findings that AUS complication rates are higher than in the general RP population. As such, great care should be taken to avoid the dreaded

complication of SUI after cTURP. Vigilance is required during endoscopic resection of prostate, particularly at the level of the verumontanum which represents the most proximal portion of the rhabdosphincter. Anteriorly, the veru may not be readily visible. If the verumontanum itself is resected, it may be challenging for the surgeon to maintain a consistent position at the distal-most extent of resection [4, 5]. Moreover, these landmarks may be obliterated in the prostate cancer patient who has received radiation. The effect of radiation on bladder functioning is well established and considering urodynamics prior to TURP in such patients may be of benefit [18, 21] In this setting, a small, hypocompliant bladder with hyperactive detrusor may ultimately compromise AUS function [18]. Prostate cancer itself, BMI, or pre-existing LUTs may directly impact bladder functioning irrespective of treatment [7].

In addition to technique, patient selection is key to reduce incontinence. It is suspected that preexisting detrusor overactivity and older age contribute to the risk of incontinence after TURP [19, 21] In a study of over 2000 nursing home residents, 94% of those who had a pre-operative Foley continued to require a catheter drainage 1 year after TURP [28]. Armed with this data, physicians should continue to evaluate the risks and benefits of treatment and offer surgical therapy to only those most likely to benefit. New techniques such as water-induced thermotherapy may one day supplant TURP due to less morbidity, shorter procedure time, or avoidance of anesthesia [29, 30] Endoscopic prostate enucleation may also alter the long-term risks of incontinence. The risk of long-term SUI after these newer procedures is thus far unknown, and work such as ours using large databases may be required to accurately assess incidence rates. Furthermore, data on these techniques applied to the prostate cancer population is lacking.

Despite our large population, our study only captures a small percentage of all TURPs in the USA, given the limitations of the Seer-Medicare file. Moreover, due to the nature of our strict criteria, patients that underwent TURP and/or AUS prior to age 65 years were not captured in this study. All of our captured patients who underwent TURP and later AUS also had underlying prostate cancer. As such, our data represent an older and more comorbid patient population than those receiving TURP in the general population for BPH; hence, our results are not generalizable. A cTURP may vary wildly in the extent of resection based on surgeon preference and we unfortunately have no operative details to correct for surgical technique. Patients with advanced cancer may have distorted anatomy making SUI more likely vs. a patient with Gleason 6 disease who essentially receives a normal TURP. Both of these types of patients are included and subgroup analysis is unfortunately impossible given SEER-Medicare data agreement limitations. We also lack data on antibiotic usage and radiation treatment details. The SEER-Medicare database shares limitations of other large databases, in particular, coding error or error of omission may lead us to underestimate revision or complication rates. We hope our use of very strict criteria for the study cohort mitigated this effect. We lack data on the severity of urinary incontinence, pad weights, duration of symptoms, concomitant, quality of life or pre-existing urinary dysfunction that may have been present prior to treatment. Likewise, the quality of our propensity match is hindered by the variables available for comparison, and unmeasured differences between groups may bias our results. We acknowledge that a more appropriate comparator group would be of AUS after benign TURP, but the non-cancer 5% Medicare file did not contain enough cases for comparison. Given coding of prostate enucleation was only first introduced 1 January 2008 [CPT 52649], we may have inadvertently included such patients in our analysis prior to that date if they were coded as TURP. Likewise, newer therapies such as water-induced thermotherapy were not studied.

Conclusion

Severe urinary incontinence after cTURP requiring AUS is a rarity in the SEER-Medicare population. While at first glance, AUS after cTURP incurs reduced device survival, such differences are eliminated with propensity matching to patients undergoing AUS after RP. Therefore, well-established patient-related factors such as age, smoking, pre-existing bladder dysfunction, presence of diabetes, history of radiation and others likely drive outcomes rather than the procedure preceding the AUS.

Author contributions JM had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. JM, AC and SF: protocol/project development. KK: data collection or management. KK, AC, JM and WB: data analysis. All authors were involved in drafting and critical revision of the manuscript. KK and others: statistical analysis.

Compliance with ethical standards

Conflict of interest All authors have no disclosure of potential conflicts of interest.

Ethical statements This research was given IRB exemption and received additional SEER-Medicare exemption, as anonymous data were used.

References

1. Gratzke C et al (2015) EAU Guidelines on the assessment of non-neurogenic male lower urinary tract symptoms including benign prostatic obstruction. Eur Urol 67(6):1099–1109

2. Ficarra V et al (2012) Systematic review and meta-analysis of studies reporting urinary continence recovery after robot-assisted radical prostatectomy. Eur Urol 62(3):405–417
3. Theodorou C, Moutzouris G, Floratos D, Plastiras D, Katsifotis C, Mertziotis N (1998) Incontinence after surgery for benign prostatic hypertrophy: the case for complex approach and treatment. Eur Urol 33(4):370–375
4. Rassweiler J, Teber D, Kuntz R, Hofmann R (2006) Complications of transurethral resection of the prostate (TURP)—incidence, management, and prevention. Eur Urol 50(5):969–980
5. Pickard R (2007) Male incontinence: pathophysiology and management. Indian J Urol IJU 23(2):179–180
6. Mazur AW, Thompson IM (1991) Efficacy and morbidity of 'channel' TURP. Urology 38(6):526–528
7. Heesakkers J, Farag F, Bauer RM, Sandhu J, De Ridder D, Stenzl A (2017) Pathophysiology and contributing factors in postprostatectomy incontinence: a review. Eur Urol 71(6):936–944
8. Friedl A et al (2017) The adjustable transobturator male system in stress urinary incontinence after transurethral resection of the prostate. Urology 109:184–189
9. Kretschmer A et al (2016) Long-term outcome of the retrourethral transobturator male sling after transurethral resection of the prostate. Int Neurourol J 20(4):335–341
10. Hogewoning CRC, Meij LAM, Pelger RCM, Putter H, Krouwel EM, Elzevier HW (2017) Sling surgery for the treatment of urinary incontinence after transurethral resection of the prostate: new data on the virtue male sling and an evaluation of literature. Urology 100:187–192
11. Yafi FA, Powers MK, Zurawin J, Hellstrom WJG (2016) Contemporary review of artificial urinary sphincters for male stress urinary incontinence. Sex Med Rev 4(2):157–166
12. Gundian JC, Barrett DM, Parulkar BG (1993) Mayo Clinic experience with the AS800 artificial urinary sphincter for urinary incontinence after transurethral resection of prostate or open prostatectomy. Urology 41(4):318–321
13. Cohen AJ, Kuchta K, Park S, Milose J (2018) Patterns and timing of artificial urinary sphincter failure. World J Urol 36:939–945
14. Klabunde CN, Potosky AL, Legler JM, Warren JL (2000) Development of a comorbidity index using physician claims data. J Clin Epidemiol 53(12):1258–1267
15. Kuntz RM, Ahyai S, Lehrich K, Fayad A (2004) Transurethral holmium laser enucleation of the prostate versus transurethral electrocautery resection of the prostate: a randomized prospective trial in 200 patients. J Urol 172(3):1012–1016
16. Bachmann A et al (2015) A European multicenter randomized noninferiority trial comparing 180 W GreenLight XPS laser vaporization and transurethral resection of the prostate for the treatment of benign prostatic obstruction: 12-month results of the goliath study. J Urol 193(2):570–578
17. Bruschini H, Simonetti R, Antunes AA, Srougi M (2011) Urinary incontinence following surgery for BPH: the role of aging on the incidence of bladder dysfunction. Int Braz J Urol 37(3):380–386 **(discussion 387)**
18. Punnen S, Cowan JE, Chan JM, Carroll PR, Cooperberg MR (2015) Long-term health-related quality of life after primary treatment for localized prostate cancer: results from the CaPSURE registry. Eur Urol 68(4):600–608
19. Kopp RP et al (2013) The burden of urinary incontinence and urinary bother among elderly prostate cancer survivors. Eur Urol 64(4):672–679
20. Viers BR, Linder BJ, Rivera ME, Rangel LJ, Ziegelmann MJ, Elliott DS (2016) Long-term quality of life and functional outcomes among primary and secondary artificial urinary sphincter implantations in men with stress urinary incontinence. J Urol 196(3):838–843
21. Polland A et al (2017) Preoperative symptoms predict continence after post-radiation transurethral resection of prostate. Can J Urol 24(4):8903–8909
22. Viers BR et al (2016) The impact of diabetes mellitus and obesity on artificial urinary sphincter outcomes in men. Urology 98:176–182
23. Kaufman MR et al (2017) Prior radiation therapy decreases time to idiopathic erosion of artificial urinary sphincter: a multi-institutional analysis. J Urol 199:1037–1041
24. Zlotta AR, Giannakopoulos X, Maehlum O, Ostrem T, Schulman CC (2003) Long-term evaluation of transurethral needle ablation of the prostate (TUNA) for treatment of symptomatic benign prostatic hyperplasia: clinical outcome up to 5 years from three centers. Eur Urol 44(1):89–93
25. Onyeji IC et al (2017) Impact of surgeon case volume on reoperation rates after inflatable penile prosthesis surgery. J Urol 197(1):223–229
26. Wilson SK, Zumbe J, Henry GD, Salem EA, Delk JR, Cleves MA (2007) Infection reduction using antibiotic-coated inflatable penile prosthesis. Urology 70(2):337–340
27. Simhan J et al (2015) 3.5 cm artificial urinary sphincter cuff erosion occurs predominantly in irradiated patients. J Urol 193(2):593–597
28. Suskind AM, Walter LC, Zhao S, Finlayson E (2017) Functional outcomes after transurethral resection of the prostate in nursing home residents. J Am Geriatr Soc 65(4):699–703
29. Gilling P, Anderson P, Tan A (2017) Aquablation of the prostate for symptomatic benign prostatic hyperplasia: 1-year results. J Urol 197(6):1565–1572
30. Umari P et al (2017) Robotic assisted simple prostatectomy versus holmium laser enucleation of the prostate for lower urinary tract symptoms in patients with large volume prostate: a comparative analysis from a high volume center. J Urol 197(4):1108–1114

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