International Urology and Nephrology
https://doi.org/10.1007/s11255-019-02322-y

UROLOGY - ORIGINAL PAPER

The mechanical stop test and isovolumetric detrusor contractile reserve are associated with immediate spontaneous voiding after transurethral resection of prostate

Amy D. Dobberfuhl[1] · Xinyuan Zhang[1] · Craig V. Comiter[1]

Received: 25 July 2019 / Accepted: 18 October 2019

Abstract

Purpose To identify urodynamic factors associated with the mechanical stop test and immediate spontaneous voiding following transurethral resection of prostate (TURP).

Methods We identified 90 men who underwent TURP over a 12-month period. Forty-three (mean age 68 years) underwent urodynamic evaluation prior to TURP. Isovolumetric detrusor contractile pressure (P_{iso}) was obtained using the mechanical stop test during the voiding phase, and used to calculate detrusor contractile reserve ($P_{res} = P_{iso} - P_{det}@Q_{max}$). Primary outcome was spontaneous voiding after TURP.

Results Preoperative catheter-free spontaneous voiding was present in 63% of men (27/43) with a urodynamic (mean ± SD): Q_{max} 6.2 ± 2.7 mL/s, $P_{det}@Q_{max}$ 102 ± 47 cmH_2O, P_{iso} 124 ± 49 cmH_2O, P_{res} 22 ± 16 cmH_2O, bladder outlet obstruction index (BOOI) 90 ± 49, and bladder contractility index (BCI) 132 ± 44. The remaining 16 catheter-dependent men demonstrated a urodynamic (mean ± SD): Q_{max} 3.6 ± 3.3 mL/s, $P_{det}@Q_{max}$ 87 ± 38 cmH_2O, P_{iso} 99 ± 51 cmH_2O, P_{res} 10 ± 18 cmH_2O, BOOI 82 ± 36, and BCI 106 ± 48. Following TURP, 67% of men voided spontaneously with their first void trial, and in receiver operator analysis of urodynamic measures ($P_{det}@Q_{max}$, P_{iso}, P_{res}, BOOI and BCI), only P_{res} was significantly associated with immediate spontaneous voiding after TURP (threshold $P_{res} \geq 9$ cmH_2O, AUC = 0.681, $p = 0.035$).

Conclusions In men who underwent TURP, a $P_{res} \geq 9$ cmH_2O was associated with immediate spontaneous voiding and may be easily incorporated into the postoperative pathway.

Keywords Follow-up studies · Male · Muscle contraction · Prostatic hyperplasia · Urologic surgical procedures

Abbreviations

BCI	Bladder contractility index ($BCI = P_{det}@Q_{max} + 5 \times Q_{max}$)
BOOI	Bladder outlet obstruction index ($BOOI = P_{det}@Q_{max} - 2 \times Q_{max}$)
$P_{det}@Q_{max}$	Detrusor pressure at maximum flow
P_{iso}	Isovolumetric detrusor contraction pressure
P_{res}	Detrusor contractile reserve pressure ($P_{res} = P_{iso} - P_{det}@Q_{max}$)
PVR	Post-void residual
Q_{max}	Maximum flow rate
TURP	Transurethral electrosurgical resection of prostate

Background

The Functional Classification of Voiding, originally described by Alan Wein in 1981, characterizes lower urinary tract dysfunction into either a failure to store or a failure to empty, which may result from either a disorder of the bladder, the outlet or combination of both [1]. The indications for performing pressure flow urodynamics have been outlined in joint guidelines from the International Continence Society (ICS), American Urological Association (AUA), and Society of Urodynamics, Female Pelvic Medicine & Urogenital

✉ Amy D. Dobberfuhl
adobber@stanford.edu

Xinyuan Zhang
xinyuan@stanford.edu

Craig V. Comiter
ccomiter@stanford.edu

1 Department of Urology, Stanford University School of Medicine, 300 Pasteur Drive, Grant S-287, Stanford, CA 94305, USA

Published online: 31 October 2019

Reconstruction (SUFU) [2, 3]. Urodynamic evaluation is typically reserved for situations when it is important to determine if urodynamic obstruction is present and particularly when invasive, potentially morbid or irreversible treatments are considered [3]. By quantifying maximum flow rate (Q_{max}, mL/s) and detrusor pressure at maximum flow ($P_{det}@Q_{max}$, cmH_2O), the bladder outlet obstruction (BOO) index ($BOOI = P_{det}@Q_{max} - 2 \times Q_{max}$) stratifies men into three groups, [> 40 obstructed; 20–40 equivocal; < 20 not obstructed] with high pressure and low flow pathognomonic for obstruction [4]. Similarly, the bladder contractility index ($BCI = P_{det}@Q_{max} + 5 \times Q_{max}$) stratifies men by detrusor contractile strength [> 150 strong; 100–150 normal; < 100 weak], with a low detrusor contractile pressure diagnostic of detrusor underactivity (DU, BCI < 100) [4, 5].

As a component of pressure flow urodynamics, the mechanical stop test has been advocated as a useful adjunct to assess isovolumetric bladder contractility (P_{iso}); and is particularly useful for assessing bladder contractility in the setting of post-prostatectomy incontinence, when outlet resistance is exceptionally low [6–9]. Following occlusion of the outlet, detrusor pressure at maximum flow ($P_{det}@Q_{max}$) will typically rise up to the isovolumetric contraction pressure (P_{iso}), and the difference between P_{iso} and $P_{det}@Q_{max}$ may be calculated as the isometric detrusor contractile reserve (P_{res}). The term P_{res} has not been previously defined in the published literature. While the mechanical stop test is commonly performed for post-prostatectomy incontinence, outcomes associated with this test in men undergoing transurethral electrosurgical resection of the prostate (TURP) have not been reported. We sought to identify urodynamic factors associated with the mechanical stop test and spontaneous voiding following TURP.

Methods

After obtaining institutional review board approval, we identified 90 men who underwent TURP by a single surgeon at our institution over a 12-month period as outlined in our patient flow chart (Fig. 1). A retrospective chart review of each medical record was performed for the 43 men who underwent preoperative urodynamic pressure flow evaluation. Data were manually recorded into REDCap (Research Electronic Data Capture) [10]. Extracted data included: baseline patient characteristics, alpha blocker use, 5-alpha reductase inhibitor use, anticholinergic use, preoperative spontaneous voiding, and preoperative urodynamic findings.

Urodynamic reports and tracings were reviewed for urethral pressure profile length, maximal closure pressure, volume at first and strong desire, bladder capacity, the presence of detrusor overactivity, Q_{max}, $P_{det}@Q_{max}$, P_{iso}, PVR,

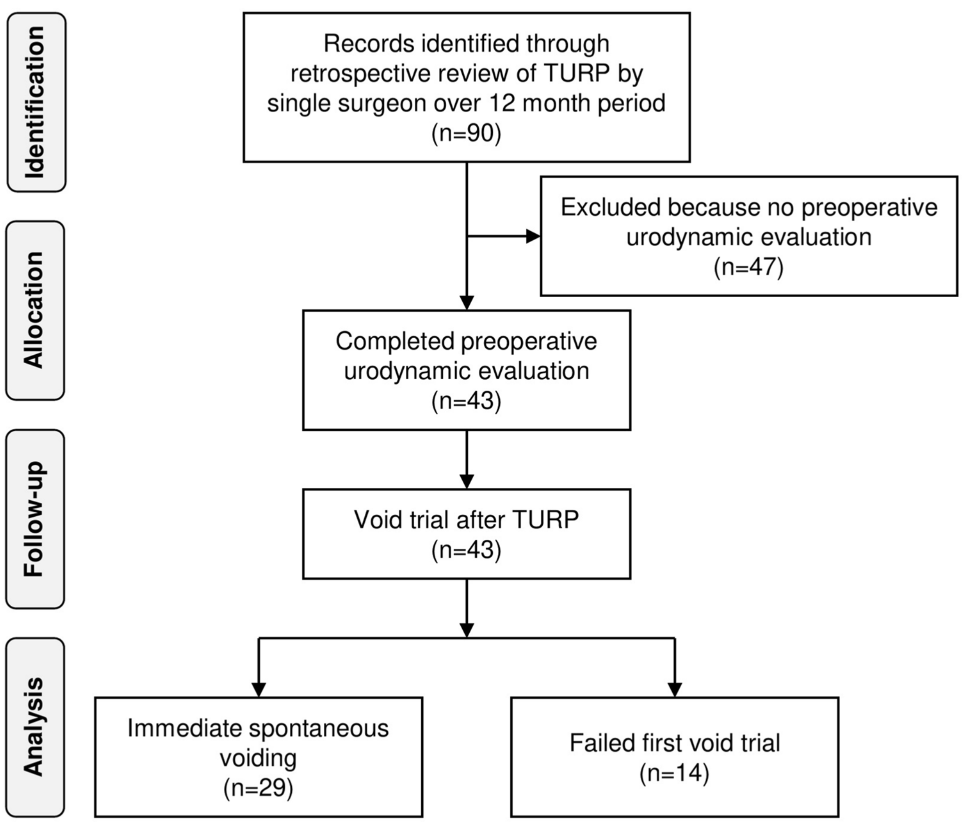

Fig. 1 Patient flow chart (identification, allocation, follow-up, analysis)

and valsalva straining to void. Isometric detrusor pressure (P_{iso}) was obtained in all men via the mechanical stop test according to standards previously published by the primary surgeon and other investigators [6–9, 11]. The mechanical stop test was performed by temporarily occluding the urethra by the surgeon's hand during the voiding phase of urodynamic pressure flow evaluation. The mechanical stop test was performed early after the initiation of flow, shortly after the patient demonstrated maximum flow. Men were instructed to continue to void during this phase. Immediately following occlusion, P_{det} typically rises up to a plateau, and at this point of peak isovolumetric detrusor contraction, P_{det} was recorded as P_{iso}. Detrusor contractile reserve (P_{res}) was then calculated by subtracting detrusor pressure at maximum flow from P_{iso} ($P_{res} = P_{iso} - P_{det}@Q_{max}$). Additionally, standard indices were calculated including BOOI and BCI, with a BCI less than 100 classified as DU [12]. All men underwent TURP, and operative reports were reviewed for surgical parameters (estimated blood loss, resected prostate chip weight) and the presence of anatomic findings (bladder trabeculation, bladder diverticulum, median lobe, lobar coaptation, intravesical prostate).

Following surgery, men typically underwent void trial on postoperative day 1. Postoperative surgical records were reviewed for our primary outcome of interest, the ability to spontaneously void after surgery without the need for intermittent catheterization or indwelling catheter. Data were analyzed for our primary outcome spontaneous voiding after surgery and the binary categorical strata preoperative spontaneous voiding using Chi square (categorical variables), *t* test (continuous variables), and receiver operator performance methods (response variable = postoperative spontaneous voiding). Tabulated data are presented as mean ± standard deviation (SD). A p value < 0.05 was defined as significant.

Results

Of the 90 men who underwent TURP by a single surgeon over a 12-month period, there were 43 men (mean age 68 ± SD 7.9) who had preoperative urodynamic tracings available for review (Table 1). Baseline characteristics included the use of alpha blockers in 81% (35/43), 5-alpha reductase inhibitors in 42% (18/43), and anticholinergics in 14% (6/43). Prior to TURP, 63% (27/43) of men were emptying their bladder by spontaneous void, 19% (8/43) were dependent on intermittent catheterization, and 19% (8/43) required an indwelling catheter for urinary retention. Men who were able to void spontaneously for free uroflowmetry prior to surgery ($n = 27$) demonstrated a mean free uroflow: Q_{max} 8.8 ± 4.2 mL/s (IQR 6.0–11.0); voided volume 149 ± 150 mL (IQR 50–303); PVR 139 ± 249 mL (IQR 0–175).

When stratified by preoperative voiding status (Table 1), the 27 men who were voiding spontaneously had a urodynamic: $P_{det}@Q_{max}$ 102 ± 47 cmH_2O (IQR 75–107); Q_{max} 6.2 ± 2.7 mL/s (IQR 4.0–7.5); and P_{iso} 124 ± 49 cmH_2O (IQR 86–140). These men had a mean BOOI 90 ± 49; BCI 132 ± 44 and detrusor contractile reserve (P_{res}) of 22 ± 16 cmH_2O. In the remaining 16 men who were catheter dependent, all were able to void a small amount (mean void volume 102 mL) at time of urodynamics with a mean: $P_{det}@Q_{max}$ 87 ± 38 cmH_2O (IQR 68–105); Q_{max} 3.6 ± 3.3 mL/s (IQR 1.0–4.3); and P_{iso} 99 ± 51 cmH_2O (IQR 69–121). The group of men who were catheter dependent had a mean BOOI 82 ± 36; BCI 106 ± 48 and a detrusor contractile reserve (P_{res}) of 10 ± 18 cmH_2O. When stratified by preoperative voiding status, the only characteristics which were statistically different between groups were anticholinergic use ($p = 0.011$), urodynamic Q_{max} ($p = 0.014$), the presence of valsalva voiding ($p = 0.024$), and detrusor contractile reserve ($p = 0.045$).

Men were followed for a mean longest follow-up of 77 ± 85 days. Following TURP, 67% (29/43) of men voided spontaneously at discharge (Table 2). The remaining 14 men failed their first void trial. When stratified by preoperative voiding status, there was no significant difference in urodynamic characteristics ($P_{det}@Q_{max}$, P_{iso}, BOOI, BCI and P_{res}) among those men who failed their first void trial, when stratified by their ability to void prior to surgery. In the longest follow-up, 95% of men were voiding spontaneously. In the remaining men who were unable to void spontaneously at longest follow-up, there were no repeat TURP procedures performed.

To identify urodynamic factors associated with immediate postoperative spontaneous voiding, a receiver operator analysis was performed for the response variable postoperative spontaneous voiding and the urodynamic measures ($P_{det}@Q_{max}$, P_{iso}, BOOI, BCI and P_{res}). The receiver operator curve was generated for each urodynamic measure (Fig. 2). Threshold levels were then identified which maximized sensitivity and specificity to the upper left hand corner of each receiver operator curve (Table 3). Of all urodynamic measures, isovolumetric detrusor contractile reserve (P_{res}) was the only measure which was significantly associated with immediate postoperative spontaneous voiding ($p = 0.035$). This was associated with a P_{res} threshold ≥ 9 cmH_2O. Of the remaining urodynamic measures ($P_{det}@Q_{max}$, P_{iso}, BOOI and BCI), the BCI trended to be associated but did not reach statistical significance, where sensitivity and specificity were maximized at the threshold of BCI ≥ 120 ($p = 0.064$).

Table 1 Characteristics (baseline, urodynamic, surgical) stratified by preoperative voiding status ($n=43$)

	Overall ($n=43$)	Preoperative spontaneous voiding?		
		Yes ($n=27$)	No ($n=16$)	p value
Baseline characteristics				
Age (years, mean ± SD)	68 ± 7.9	68 ± 7.6	66 ± 8.3	0.263
Alpha blocker (n, %)	35 (81%)	23 (85%)	12 (75%)	0.446
5-alpha reductase inhibitor (n, %)	18 (42%)	11 (41%)	7 (44%)	0.852
Anticholinergic (n, %)	6 (14%)	6 (22%)	0 (0%)	0.011
Preoperative spontaneous void (n, %)	27 (63%)	27 (100%)	–	–
Preoperative intermittent catheterization (n, %)	8 (19%)	–	8 (50%)	–
Preoperative indwelling catheter (n, %)	8 (19%)	–	8 (50%)	–
Free uroflow Q_{max} (mL/s, mean ± SD)	8.8 ± 4.2	8.8 ± 4.2	–	–
Free uroflow voided volume (mL, mean ± SD)	149 ± 150	149 ± 150	–	–
Free uroflow PVR (mL, mean ± SD)	139 ± 249	139 ± 249	–	–
Preoperative urodynamics				
UPP length (mm, mean ± SD)	43 ± 15	45 ± 15	39 ± 15	0.385
UPP closure pressure (cmH_2O, mean ± SD)	88 ± 27	89 ± 29	86 ± 21	0.726
First desire volume (mL, mean ± SD)	226 ± 170	212 ± 187	250 ± 140	0.460
Strong desire volume (mL, mean ± SD)	310 ± 190	289 ± 208	344 ± 155	0.323
Bladder capacity (mL, mean ± SD)	396 ± 241	364 ± 245	450 ± 232	0.258
Detrusor overactivity (n, %)	31 (72%)	22 (81%)	9 (56%)	0.103
Q_{max} (mL/s, mean ± SD)	5.2 ± 3.2	6.2 ± 2.7	3.6 ± 3.3	0.014
$P_{det}@Q_{max}$ (cmH_2O, mean ± SD)	97 ± 44	102 ± 47	87 ± 38	0.322
P_{iso} (cmH_2O, mean ± SD)	114 ± 50	124 ± 49	99 ± 51	0.132
Valsalva voiding (n, %)	18 (42%)	8 (30%)	10 (63%)	0.024
BOOI ($P_{det}@Q_{max} - 2 \times Q_{max}$, mean ± SD)	87 ± 44	90 ± 49	82 ± 36	0.543
BCI ($P_{det}@Q_{max} + 5 \times Q_{max}$, mean ± SD)	123 ± 46	132 ± 44	106 ± 48	0.083
$P_{res} = P_{iso} - P_{det}@Q_{max}$ (cmH_2O, mean ± SD)	18 ± 17	22 ± 16	10 ± 18	0.045
Surgical characteristics				
Trabeculation (n, %)	43 (100%)	27 (100%)	16 (100%)	–
Diverticulum (n, %)	4 (9%)	3 (11%)	1 (6%)	0.583
Median lobe (n, %)	26 (61%)	17 (63%)	9 (56%)	0.676
Bi-lobar coaptation (n, %)	21 (49%)	13 (48%)	8 (50%)	0.910
Tri-lobar coaptation (n, %)	20 (47%)	12 (44%)	8 (50%)	0.734
Intravesical prostate (n, %)	17 (40%)	8 (30%)	9 (56%)	0.099
Estimated blood loss (mL, mean ± SD)	105 ± 57	102 ± 57	112 ± 59	0.597
Resected chip weight (g, mean ± SD)	18 ± 12	17 ± 10	18 ± 16	0.775

BCI bladder contractility index, *BOOI* bladder outlet obstruction index, $P_{det}@Q_{max}$ detrusor pressure at maximum flow, P_{iso} isovolumetric detrusor contraction pressure, P_{res} detrusor contractile reserve pressure, *PVR* post-void residual, Q_{max} maximum flow rate, *SD* standard deviation, *UPP* urethral pressure profilometry

Discussion

Several efforts have been made to identify non-invasive measures of lower urinary tract function, which currently include post-void residual, uroflowmetry, detrusor wall thickness, near-infrared spectroscopy, and penile compression release [13, 14]. While useful for screening for BOO, there has been very limited assessment of these measures in a prospective approach to determine their ability to measure detrusor contractility independent from the degree of obstruction. In a recent systematic review of non-invasive tests for diagnosing BOO in men with lower urinary tract symptoms conducted by the European Association of Urology [13], Malde et al. identified 42 studies recruiting a total of 4444 patients for which the diagnostic accuracy of the index test was assessed using invasive urodynamics as the reference standard. They found that the difficulty of differentiating DU from BOO arises from the finding that weakening of the bladder contraction may occur independently of the presence or absence of BOO; as such, urodynamic pressure

Table 2 Postoperative follow-up stratified by preoperative and postoperative voiding status ($n=43$)

	Overall	Preoperative spontaneous voiding?		
	($n=43$)	Yes ($n=27$)	No ($n=16$)	p value
Follow-up (days, mean ± SD)	77 ± 85	79 ± 87	73 ± 84	0.809
Immediate spontaneous voiding (mean ± SD)	($n=29$)	($n=20$)	($n=9$)	
$P_{det}@Q_{max}$ (cmH_2O)	100 ± 46	105 ± 46	90 ± 49	0.452
P_{iso} (cmH_2O)	120 ± 54	127 ± 48	106 ± 66	0.402
BOOI	89 ± 46	93 ± 47	81 ± 45	0.552
BCI	128 ± 50	136 ± 43	112 ± 62	0.314
P_{res} (cmH_2O)	20 ± 17	22 ± 14	16 ± 22	0.439
Failed first void trial (mean ± SD)	($n=14$)	($n=7$)	($n=7$)	
$P_{det}@Q_{max}$ (cmH_2O)	90 ± 39	93 ± 53	87 ± 22	0.784
P_{iso} (cmH_2O)	102 ± 40	114 ± 51	90 ± 24	0.308
BOOI	81 ± 41	81 ± 57	82 ± 23	0.967
BCI	112 ± 38	124 ± 48	100 ± 21	0.261
P_{res} (cmH_2O)	12 ± 17	21 ± 20	4 ± 7	0.073

BCI bladder contractility index, *BOOI* bladder outlet obstruction index, $P_{det}@Q_{max}$ detrusor pressure at maximum flow, P_{iso} isovolumetric detrusor contraction pressure, P_{res} detrusor contractile reserve pressure

flow evaluation of the bladder remains the gold standard for assessing bladder contractility and magnitude of BOO.

In our study of men who underwent urodynamics followed by a de-obstructive outlet procedure, we assessed the performance of the mechanical stop test in predicting spontaneous voiding following TURP. With an outlet obstruction alone, a de-obstructive procedure such as TURP is expected to improve spontaneous voiding, whereas in men who do not meet the diagnostic criteria for obstruction (BOOI ≤ 40) and who have a hypocontractile detrusor (BCI < 100), a de-obstructive procedure would only address the outlet and do nothing to improve contractility. These men with a weak bladder (BCI < 100) are at increased risk of failure to void spontaneously after TURP. In a recent study published by Dobberfuhl et al., of 122 men who underwent preoperative urodynamic evaluation followed by TURP, in those men with detrusor underactivity (BCI < 100) who were catheter dependent, 57% of men were still able to recover spontaneous voiding after TURP, and as such may still benefit from outlet de-obstruction surgery [15]. In our present study, we found that detrusor contractile reserve ($P_{res} \geq 9$ cmH_2O) was more useful than the other urodynamic indices, and could serve as a useful binary predictor which may help stratify men who would be more likely to spontaneously void immediately following TURP.

There are several important points which should be acknowledged when interpreting and generalizing our results. First and foremost is the patient selection and small sample size ($n=43$) and potential for surgeon selection bias towards only assessing the utility of isovolumetric contractility in those men who followed through with TURP. Despite a relatively small sample, we observed a statistically significant association between contractile reserve ($P_{res} \geq 9$ cmH_2O) and spontaneous voiding following TURP. Preoperative characteristics of our sample need to be considered when generalizing our findings to other men with urinary retention who are considering TURP. Additional limitations of our approach include selection bias, since not all men who underwent urodynamics received TURP, and not all men who underwent TURP were followed up at equal intervals and for equal durations of time after surgery. The strength of our approach is the simplicity of our primary outcome, the single surgeon sample and the granularity of detail which was systematically quantified via direct chart and urodynamic tracing review.

Additional considerations include the effect of preoperative anticholinergics on detrusor contractility, as 6 out of 43 men (16%) were using anticholinergics at baseline. Indications for anticholinergics were for the treatment of overactive bladder, and typically these were discontinued prior to TURP. Human bladder contraction is mediated mainly through stimulation of muscarinic receptors in the detrusor muscle [16]. Anticholinergics are the drugs of choice for treatment of detrusor overactivity by blocking the effects of acetylcholine in the urothelial and myocyte signaling pathway, reducing bladder tone and increasing cystometric bladder capacity during the storage phase [17, 18]. At high doses, anticholinergics reduce detrusor contractility during the voiding phase, which could lead to urinary retention [18]. The use of anticholinergics has been shown to moderately reduce Q_{max}, $P_{det}@Q_{max}$, and BCI in short-term urodynamic studies [19]. Currently, there is insufficient data on the effect of anticholinergics on parameters such as P_{iso} and P_{res}. Our present study was not powered to assess the isolated effect of anticholinergics on detrusor contractility at the time of urodynamic pressure flow evaluation.

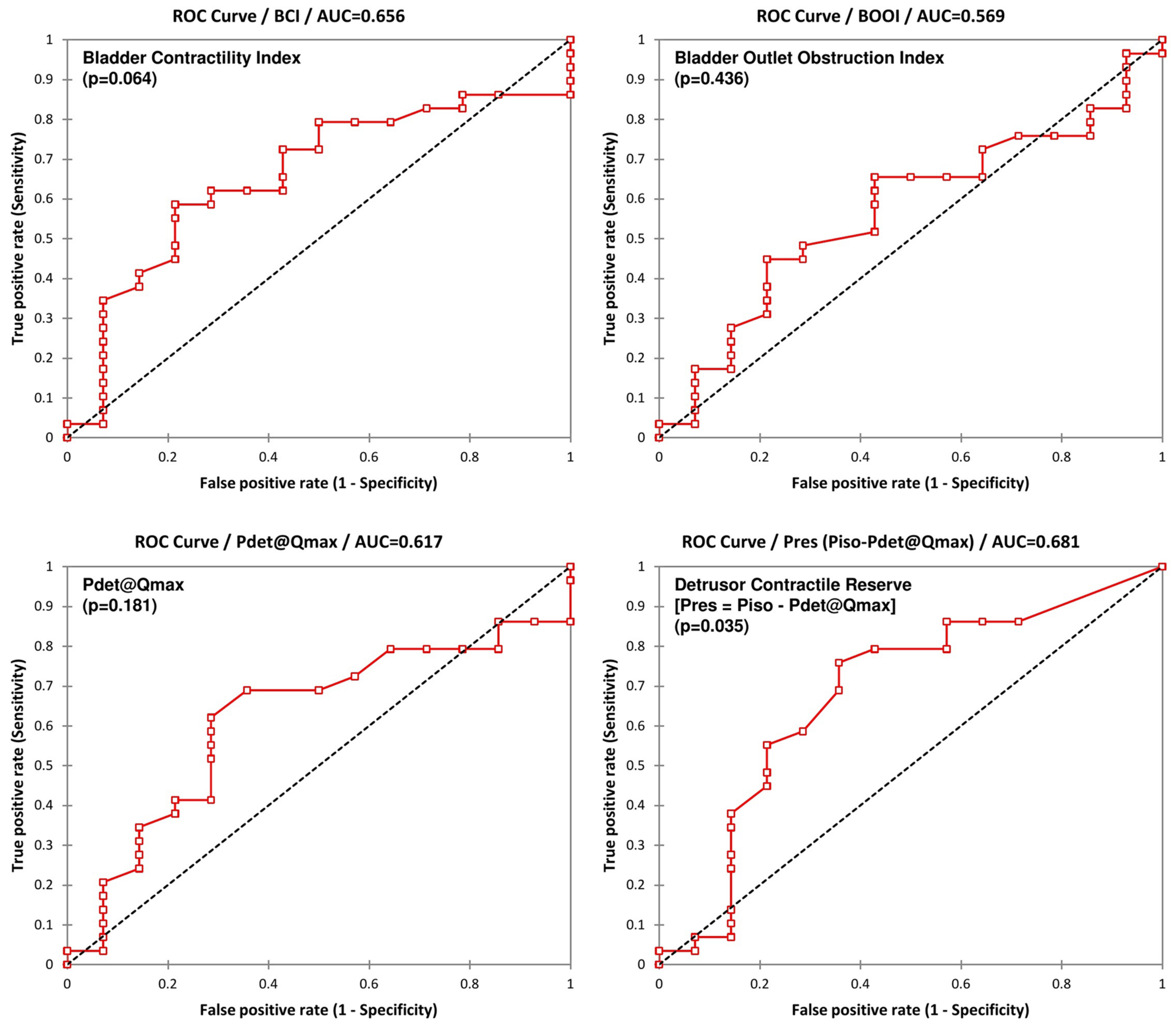

Fig. 2 Receiver operator analysis for bladder contractility index (BCI), bladder outlet obstruction index (BOOI), detrusor pressure at maximum flow ($P_{det}@Q_{max}$) and detrusor contractile reserve pressure ($P_{res}=P_{iso} - P_{det}@Q_{max}$). Response variable = immediate post-operative spontaneous voiding. *AUC* area under the curve, *BCI* bladder contractility index, *BOOI* bladder outlet obstruction index, $P_{det}@Q_{max}$ detrusor pressure at maximum flow, P_{iso} isovolumetric detrusor contraction pressure, P_{res} detrusor contractile reserve pressure, *ROC* receiver operator curve

Table 3 Cutpoint analysis of urodynamic factors associated with immediate postoperative spontaneous voiding

	Threshold level	Sensitivity/specificity		Likelihood ratios		ROC analysis	
		Sn	Sp	LR+	LR−	ROC AUC	*p* value
$P_{det}@Q_{max}$	81 cmH_2O	0.621	0.714	2.172	0.531	0.617	0.181
P_{iso}	100 cmH_2O	0.655	0.643	1.834	0.536	0.615	0.188
BOOI	86	0.448	0.786	2.092	0.702	0.569	0.436
BCI	120	0.586	0.786	2.736	0.527	0.656	0.064
P_{res}	9 cmH_2O	0.759	0.643	2.124	0.375	0.681	0.035

AUC area under the curve, *BCI* bladder contractility index, *BOOI* bladder outlet obstruction index, *LR+* positive likelihood ratio, *LR−* negative likelihood ratio, $P_{det}@Q_{max}$ detrusor pressure at maximum flow, P_{iso} isovolumetric detrusor contraction pressure, P_{res} detrusor contractile reserve pressure, *ROC* receiver operator curve, *Sn* sensitivity, *Sp* specificity

In our study of men who underwent urodynamics followed by TURP, we found that $P_{res} \geq 9$ cmH_2O was associated with a significant probability of spontaneous voiding following TURP. Compared to other methods that have been associated with outcomes in men following TURP (post-void residual, uroflowmetry, detrusor wall thickness, near-infrared spectroscopy, and penile compression release [13, 14]), the mechanical stop test and detrusor contractile reserve calculation achieved similar sensitivity, specificity and predictive values. The mechanical stop test may be easily performed at the time of preoperative urodynamics, and the result incorporated into the postoperative management algorithm. Given the simplicity of performing the mechanical stop test during the voiding phase of urodynamics, future clinical research should prospectively evaluate the utility of measuring isovolumetric contractile reserve at the time of urodynamics in men considering a de-obstructive procedure and use P_{res} to select men in whom an outpatient void trial would be a more efficient use of resources.

Conclusions

In men who underwent TURP, a $P_{res} \geq 9$ cmH_2O was associated with immediate spontaneous voiding. Our findings may be easily incorporated into the postoperative care pathway by helping to set postoperative expectations and identify men who are more likely to void spontaneously immediately after surgery.

Author contributions ADD: Protocol/project development, data collection, data analysis, manuscript writing/editing; XZ: Manuscript writing/editing; CVC: Protocol/project development, manuscript writing/editing.

Funding This study was funded by author (ADD) support from the KL2 component of the Stanford Clinical Translational Science Award to Spectrum (NIH 5KL2TR001083-05) and NIH Extramural Loan Repayment Program for Clinical Researchers (NIH 1L30DK115056-01).

Compliance with ethical standards

Conflicts of interest Dr. Dobberfuhl has received research grants from the National Institutes of Health, SUFU Foundation Study of Chemodenervation, and Stanford Women's Health & Sex Differences in Medicine. Dr. Comiter has received research grants from the SUFU Foundation Study of Chemodenervation and is a consultant for Neuspera Medical Systems. The authors declare that they have no conflicts of interest in relation to the content of the manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

References

1. Wein AJ (1981) Classification of neurogenic voiding dysfunction. J Urol 125(5):605–609
2. Gammie A, Clarkson B, Constantinou C, Damaser M, Drinnan M, Geleijnse G, Griffiths D, Rosier P, Schäfer W, Van Mastrigt R, International Continence Society Urodynamic Equipment Working Group (2014) International Continence Society guidelines on urodynamic equipment performance. Neurourol Urodyn. 33(4):370–379
3. Winters JC, Dmochowski RR, Goldman HB, Herndon CDA, Kobashi KC, Kraus SR, Lemack GE, Nitti VW, Rovner ES, Wein AJ, American Urological Association, Society of Urodynamics, Female Pelvic Medicine & Urogenital Reconstruction (2012) Urodynamic studies in adults: AUA/SUFU guideline. J Urol. 188(6):2464–2472
4. Abrams P (1999) Bladder outlet obstruction index, bladder contractility index and bladder voiding efficiency: three simple indices to define bladder voiding function. BJU Int. 84(1):14–15
5. D'Ancona C, Haylen B, Oelke M, Abranches-Monteiro L, Arnold E, Goldman H, Hamid R, Homma Y, Marcelissen T, Rademakers K, Schizas A, Singla A, Soto I, Tse V, de Wachter S, Herschorn S, Standardisation Steering Committee ICS and the ICS Working Group on Terminology for Male Lower Urinary Tract & Pelvic Floor Symptoms and Dysfunction (2019) The International Continence Society (ICS) report on the terminology for adult male lower urinary tract and pelvic floor symptoms and dysfunction. Neurourol Urodyn. 38(2):433–477
6. Griffiths CJ, Harding C, Blake C, McIntosh S, Drinnan MJ, Robson WA, Abrams P, Ramsden PD, Pickard RS (2005) A nomogram to classify men with lower urinary tract symptoms using urine flow and noninvasive measurement of bladder pressure. J Urol. 174(4 Pt 1):1323–1326 **(discussion 1326; author reply 1326)**
7. Comiter CV, Sullivan MP, Schacterle RS, Yalla SV (1996) Prediction of prostatic obstruction with a combination of isometric detrusor contraction pressure and maximum urinary flow rate. Urology. 48(5):723–729 **(discussion 729-730)**
8. Blake C, Abrams P (2004) Noninvasive techniques for the measurement of isovolumetric bladder pressure. J Urol 171(1):12–19
9. Elliott CS, Comiter CV (2012) Maximum isometric detrusor pressure to measure bladder strength in men with postprostatectomy incontinence. Urology. 80(5):1111–1115
10. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG (2009) Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 42(2):377–381
11. Harding CK, Robson W, Drinnan MJ, Ramsden PD, Griffiths C, Pickard RS (2006) Variation in invasive and noninvasive measurements of isovolumetric bladder pressure and categorization of obstruction according to bladder volume. J Urol 176(1):172–176
12. Oelke M, Rademakers KLJ, van Koeveringe GA (2014) Detrusor contraction power parameters (BCI and W max) rise with increasing bladder outlet obstruction grade in men with lower urinary tract symptoms: results from a urodynamic database analysis. World J Urol 32(5):1177–1183
13. Malde S, Nambiar AK, Umbach R, Lam TB, Bach T, Bachmann A, Drake MJ, Gacci M, Gratzke C, Madersbacher S, Mamoulakis C, Tikkinen KAO, Gravas S, European Association of Urology Non-neurogenic Male LUTS Guidelines Panel (2017) Systematic review of the performance of noninvasive tests in diagnosing bladder outlet obstruction in men with lower urinary tract symptoms. Eur Urol. 71(3):391–402

14. Luo F, Sun H-H, Su Y-H, Zhang Z-H, Wang Y-S, Zhao Z, Li J (2017) Assessment of noninvasive predictors of bladder detrusor underactivity in BPH/LUTs patients. Int Urol Nephrol 49(5):787–792
15. Dobberfuhl AD, Chen A, Alkaram AF, De EJB. Spontaneous voiding is surprisingly recoverable via outlet procedure in men with underactive bladder and documented detrusor underactivity on urodynamics. Neurourol Urodyn. 2019;20
16. Andersson K-E, Yoshida M (2003) Antimuscarinics and the overactive detrusor–which is the main mechanism of action? Eur Urol 43(1):1–5
17. Lightner DJ, Gomelsky A, Souter L, Vasavada SP (2019) Diagnosis and treatment of overactive bladder (non-neurogenic) in adults: AUA/SUFU guideline amendment 2019. J Urol 202(3):558–563
18. Andersson K-E (2011) Antimuscarinic mechanisms and the overactive detrusor: an update. Eur Urol 59(3):377–386
19. Ronchi P, Gravina GL, Galatioto GP, Costa AM, Martella O, Vicentini C (2009) Urodynamic parameters after solifenacin treatment in men with overactive bladder symptoms and detrusor underactivity. Neurourol Urodyn 28(1):52–57