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Does Preoperative Bladder Compliance Affect Long-Term Functional Outcomes after Laser Prostatectomy?

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Purpose: We assessed the effects of preoperative bladder compliance on the long-term functional outcomes, especially focused on postoperative storage symptom changes, after laser prostatectomy.

Materials and Methods: From January 2008 to March 2014, 1,608 men who underwent laser prostatectomy, including holmium laser enucleation or photo-vaporization of the prostate, were included in the analysis. We divided patients into 3 groups according to bladder compliance on a baseline urodynamic study: <12.5, 12.5–25, ≥25 mL/cmH_2O. A multivariable analysis was performed to determine the impact of bladder compliance on changes in long-term functional outcomes after laser prostatectomy.

Results: Bladder compliance was less than 12.5 mL/cmH_2O in 50 (3.1%), 12.5–25 mL/cmH_2O in 232 (14.4%) patients. As bladder compliance decreased, the baseline International Prostate Symptom (IPSS) total score and storage sub-score were increased; the voiding sub-score remain unchanged. At postoperative 12 and 36 months, absolute improvements in the IPSS total score and storage sub-score were higher in <12.5 mL/cmH_2O group compared to other groups, although those were equivalent at postoperative 1 months. On the multivariable analysis, decreased bladder compliance <12.5 mL/cmH_2O was significantly associated with superior improvement in storage sub-score at postoperative 36 months, although it was not associated with voiding sub-score.

Conclusions: In patients with preoperative bladder compliance <12.5 mL/cmH_2O, storage symptoms could be further improved at 36 months after laser prostatectomy compared to others. Thus, laser prostatectomy could be a considerable treatment option for patients with severely decreased bladder compliance

Keywords: Compliance; Laser; Prostatic hyperplasia; Prostatectomy; Urinary bladder

INTRODUCTION

Lower urinary tract symptoms (LUTS) due to benign prostate hyperplasia (BPH) rapidly increase as men age [1,2]. In the United States, over 100,000 patients with BPH annually undergo surgical treatment to alleviate LUTS [3] despite advancements in medical treatment and widespread usage of medications [4]. Although conventional transurethral resection of the prostate (TURP) has remained the cornerstone of surgical

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treatment for BPH, laser enucleation or vaporization are regarded as alternative treatment options although prostate volume and patient condition need to be considered for selecting treatment methods [5].

However, even after surgical treatment, a considerable proportion of patients with BPH still continues medical treatment due to the remaining LUTS [6]. In this regard, accurate prediction of surgical outcomes and proper patient selection are considered as one of the most important steps for BPH surgery. Consequently, numerous studies have evaluated the predictors for better functional outcomes after laser prostatectomy in BPH patients [7,8]. However, despite these advancements in the preoperative patient evaluation and selection, there were still concerns about the remaining storage symptoms after surgical treatment for BPH [9]. In addition, storage symptoms did not improve as much as voiding symptoms after surgical treatment for BPH [10], and some studies have reported that storage symptoms did not improve as much after laser prostatectomy than conventional TURP [11,12].

In this regard, several studies have evaluated the impacts of conditions related to storage symptoms on the functional outcomes after BPH surgery [13]. However, currently, there is no reliable method for predicting changes in postoperative storage symptoms after laser surgery. In this current clinical situation, a urodynamic study (UDS) could be a viable option for predicting remained storage symptoms after laser surgery although current guidelines only recommend a UDS in selected situations [5,14]. In addition to detrusor overactivity, bladder compliance is a well-known parameter derived from UDS and reported to be related to storage function of the bladder [15]. Moreover, recent study reported that patients with decreased bladder compliance before TURP reported to be associated with worse postoperative storage symptom at 2 days after catheter removal [16]. Because bladder outlet obstruction induces bladder remodeling and decreased bladder compliance could be as marker of decompensation [17], LUTS, especially storage symptom in patients with preoperative decreased bladder compliance could not be improved after TURP or laser prostatectomy. However, from a different point of view, relieving bladder outlet obstruction could alleviating worsening of bladder remodeling and could resulted in long-term storage symptom improvement after prostate surgery. Thus, using the institutional laser prostatectomy database, including photoselective vaporization of the prostate (PVP) and holmium laser enucleation of the prostate (HoLEP), we assessed the effects of bladder compliance on the long-term functional outcomes after laser prostatectomy in patients with BPH, with a focus on storage symptoms.

MATERIALS AND METHODS

1. Patient cohort

From January 2008 to March 2014, a total of 1,985 patients with BPH who underwent laser prostatectomy at two university hospitals were initially included. Among these patients, PVP was performed in 836 patients, and HoLEP was performed in 1,149 patients. After excluding 377 patients with incomplete data about bladder compliance prior to surgery, 1,608 patients were finally included in the analysis. Medical records of these patients were retrospectively reviewed using database of our institute from 2018 to 2020. Data were fully anonymized before accessed them. This study was approved and the consent was waived due to its retrospective design by the Institutional Review Board of SNU-SMG Boramae Medical Center (30-2018-49). In addition, all methods were performed in accordance with relevant guidelines and regulations by including statement in the methods section to this effect.

2. Surgical procedures

Surgical treatment was performed in patients with LUTS that did not sufficiently improved after medical treatments or patients who wanted to be surgically treated, after sufficient consideration regarding patient, clinical characteristics and clinicians' preference. n general, three urologic surgeons (JSP, SJO, HS) who were experts on laser prostatectomy performed these surgeries. Two experts (JSP, SJO) performed HoLEP and one expert (HS) performed PVP. Surgical methods were selected after careful considerations of patient characteristics, surgeon's familiarity and expertise.

3. Preoperative and postoperative patient evaluation

In these patients, validated Korean version of International Prostate Symptom Score (IPSS) questionnaires were acquired preoperatively [18]. Prostate volume measurement using trans-rectal ultrasonography, serum prostate specific antigen (PSA) level examination, and uroflowmetry with post-voided residual urine were also performed prior to surgery. In addition, UDS was routinely performed before the surgery. At postoperative 1, 12, and 36 months, IPSS questionnaires and uroflowmetry with post-void residual urine were evaluated. Serum PSA level and prostate volume were measured at postoperative 6 months.

4. Definitions

Bladder compliance was calculated using parameters derived from UDS by normalizing the bladder volume change to the change in detrusor pressure during that change in bladder volume [15]. In the current study, we divided bladder compliance into 3 groups as follows: <12.5, 12.5–25, ≥25 mL/cmH_2O [19-21]. In this study, the functional outcomes measured at postoperative 1, 12, and 36 months were defined as short-term, mid-term, and long-term functional outcomes, respectively. At 1, 12, and 36 months after surgery, 1,029 (64.0%), 513 (31.9%), and 357 (22.2%) patients were followed-up, respectively. The variables associated with long-term functional outcomes were analyzed and demonstrated.

5. Statistical analysis

Patient characteristics were presented and compared according to bladder compliance using the mean±standard deviation (SD) for continuous variables and a frequency table for categorical variables. Preoperative and postoperative data of IPSS questionnaires and uroflowmetry with post-voided residual urine were presented and compared according to bladder compliance. In addition, the changes in these parameters were demonstrated and compared. The percent changes in PSA level and prostate volume were also calculated and demonstrated according to bladder compliance. We calculated absolute changes and relative changes of IPSS total, voiding sub, and storage sub-score at postoperative 1 month, 12 months and 36 months. A multivariable linear regression analysis was performed to determine the impacts of decreased bladder compliance on long-term functional changes after adjusting other variables, including age, body mass index, prostate volume, surgical methods, UDS-related variables (detrusor overactivity, first desire to void, maximum flow rate, and post-void residual urine) and IPSS related variables. For multivariable analysis, a backward elimination method was used for analysis. The impact of decreased bladder compliance in the HoLEP and PVP groups was separately assessed using multivariable analysis for the differences in the effects of decreased bladder compliance on functional outcomes according to surgical methods. All statistical comparisons were performed using IBM SPSS Statistics, Version 27 (IBM SPSS, Armonk, NY, USA). A p-value of less than 0.05 was considered statistically significant.

RESULTS

Among 1,608 patients, bladder compliance was <12.5 mL/cmH_2O in 50 patients (3.1%), and 12.5–25 mL/cmH_2O in 232 patients (14.4%) (Table 1). Bladder compliance decreased as age increased (72.9 *vs.* 68.9 *vs.* 68.4 y, p<0.001) and body mass index decreased (22.9 *vs.* 23.6 *vs.* 24.1 kg/m^2, p=0.002). The IPSS total score (22.3 *vs.* 19.5 *vs.* 19.0, p=0.018) and storage sub-score (9.0 *vs.* 8.2 *vs.* 7.5, p=0.002), and quality of life (QoL) index (4.7 *vs.* 4.2 *vs.* 4.1, p=0.001) increased as bladder compliance decreased, although the voiding sub-score was equivalent regardless of bladder compliance. PVP was more frequently performed in patients with decreased bladder compliance compared to HoLEP. At postoperative 6 months, the percent decrease in PSA (p=0.854) and prostate volume (p=0.755) were similar regardless of bladder compliance (Supplement Table 1).

At postoperative 1, 12, and 36 months, IPSS total, voiding sub-score, and storage sub-score, respectively, were equivalent according to bladder compliance, although the preoperative IPSS total and storage sub-score were significantly different (Supplement Table 2). In addition, the peak flow rate also showed no difference at postoperative 1, 12, and 36 months according to bladder compliance. However, bladder voiding efficiency (BVE) was significantly higher in men with bladder compliance >25 mL/cmH_2O than decreased bladder compliance at postoperative 36 months, although there was no difference in BVE at postoperative 1 and 12 months. Absolute decreases in IPSS total score were significantly higher in patients with bladder compliance <12.5 mL/cmH_2O at postoperative 36 months (-13.7 *vs.* -7.6 *vs.* -7.4, p=0.036) (Table 2, 3). Although decreases in voiding sub-score were equivalent regardless of bladder compliance, decreases in storage sub-score at postoperative 12 months (-3.9 *vs.* -3.3 *vs.* -2.5, p=0.041) and 36 months (-5.3 *vs.* -2.9 *vs.* -2.3, p=0.005) were significantly higher in patients with bladder compliance <12.5 mL/cmH_2O than in the other groups. In addition,

Table 1. Baseline characteristics according to bladder compliance

Variable	Bladder compliance (mL/cmH$_2$O)			p-value
	<12.5	12.5–25	≥25	
No. of patients	50 (3.1)	232 (14.4)	1,326 (82.5)	
Age, y	72.9±6.9	68.9±8.0	68.4±8.0	<0.001
BMI, kg/m^2	22.9±3.1	23.6±3.1	24.1±2.9	0.002
Hypertension	21 (42.0)	97 (41.8)	576 (43.4)	0.886
Diabetes	8 (16.0)	31 (13.4)	235 (17.7)	0.260
Neurologic disease	2 (4.0)	10 (4.3)	65 (4.9)	0.895
Cerebrovascular disease	0 (0.0)	13 (5.6)	51 (3.8)	0.155
PSA, ng/mL	6.5±7.2	5.4±8.2	4.0±5.7	0.001
Prostate volume, mL	76.3±47.0	60.3±33.1	57.5±29.2	<0.001
IPSS questionnaires				
Total score	22.3±8.2	19.5±8.1	19.0±8.0	0.018
Voiding sub-score	13.3±5.3	11.4±5.3	11.5±5.4	0.089
Storage sub-score	9.0±3.9	8.2±3.7	7.5±3.5	0.002
QoL Index	4.7±1.0	4.2±1.3	4.1±1.2	0.001
Qmax, mL/s	7.0±3.6	8.5±3.9	10.6±6.8	<0.001
BVE, %	53.4±33.3	69.2±26.0	73.8±23.6	<0.001
Bladder Outlet Obstruction Index	54.0±39.2	47.9±36.8	33.6±25.7	<0.001
Bladder Contractility Index	95.6±32.6	99.3±40.4	93.9±27.4	0.091
Detrusor overactivity	25 (50.0)	91 (39.2)	395 (29.8)	<0.001
Max. bladder capacity, mL	282.3±111.6	339.2±102.9	391.8±113.4	<0.001
Operative methods				<0.001
PVP	31 (62.0)	113 (48.7)	387 (29.2)	
HoLEP	19 (38.0)	119 (51.3)	939 (70.8)	

Values are presented as number (%) or mean±standard deviation.
BVE: bladder voiding efficiency, BMI: body mass index, HoLEP: holmium laser enucleation of the prostate, IPSS: International Prostate Symptom Score, PSA: prostate specific antigen, PVP: photoselective vaporization of the prostate, QoL: quality of life.

Table 2. Changes in subjective parameters after laser prostatectomy (absolute changes)

Variable		Postoperative (mo)		
		1	12	36
IPSS total (mL/cmH$_2$O)	<12.5	-9.8±9.1	-12.9±9.3	-13.7±8.1
	12.5–25	-7.6±9.7	-9.8±9.1	-7.6±10.2
	≥25	-7.1±9.1	-8.5±8.8	-7.4±8.7
	p-value	0.253	0.050	0.036
IPSS-voiding (mL/cmH$_2$O)	<12.5	-7.3±6.0	-9.0±6.3	-8.1±5.2
	12.5–25	-6.5±6.7	-6.4±6.8	-4.9±7.0
	≥25	-6.2±6.4	-6.0±6.2	-5.1±6.1
	p-value	0.612	0.103	0.164
IPSS-storage (mL/cmH$_2$O)	<12.5	-2.5±4.3	-3.9±3.77	-5.3±3.1
	12.5–25	-1.1±4.3	-3.3±3.9	-2.9±4.1
	≥25	-1.0±4.1	-2.5±3.6	-2.3±3.6
	p-value	0.114	0.041	0.005

IPSS: International Prostate Symptom Score.

Table 3. Changes in subjective parameters after laser prostatectomy (relative changes)

Variable		Postoperative (mo)		
		1	12	36
IPSS total (mL/cmH_2O)	<12.5	-37.1±41.5	-44.0±95.7	-60.5±30.0
	12.5–25	-28.6±65.7	-37.1±78.1	-32.6±51.9
	≥25	-27.6±61.5	-38.4±59.7	-29.0±119.2
	p-value	0.702	0.911	0.128
IPSS-voiding (mL/cmH_2O)	<12.5	-52.3±37.0	-57.8±28.9	-61.1±31.8
	12.5–25	-47.7±61.5	-29.7±53.9	-30.4±76.4
	≥25	-40.5±89.7	-23.9±49.6	-29.0±119.2
	p-value	0.534	0.684	0.555
IPSS-storage (mL/cmH_2O)	<12.5	-22.6±43.5	-53.0±28.9	-57.9±29.1
	12.5–25	7.9±92.7	-29.2±53.7	-27.7±53.9
	≥25	4.9±80.7	-25.3±66.2	-27.6±61.0
	p-value	0.179	0.170	0.034

IPSS: International Prostate Symptom Score.

Table 4. Variables associated with long-term functional changes after laser prostatectomy

Variable	IPSS total score			IPSS voiding sub-score			IPSS storage sub-score		
	B	95% CI	p-value	B	95% CI	p-value	B	95% CI	p-value
Prostate volume (continuous)	-0.043	-0.074 to -0.013	0.006	-0.028	-0.049 to -0.007	0.009			
Surgical methods (HoLEP *vs.* PVP)	-2.529	-4.273 to -0.786	0.005	-2.113	-3.319 to -0.908	0.001	-0.886	-1.614 to -0.159	0.017
Bladder compliance (<12.5 *vs.* ≥12.5 mL/cmH_2O)							-3.301	-5.830 to -0.772	0.011
First desire to void	0.013	0.001 to 0.025	0.029	0.015	0.007 to 0.023	<0.001			
Residual urine				-0.006	-0.010 to -0.001	0.021			
IPSS total score (continuous)	-0.635	-0.748 to -0.522	<0.001						
IPSS voiding sub-score (continuous)				-0.663	-0.776 to -0.551	<0.001			
IPSS storage sub-score (continuous)							-0.556	-0.664 to -0.449	<0.001

HoLEP: holmium laser enucleation of the prostate, IPSS: International Prostate Symptom Score, PVP: photoselective vaporization of the prostate.

at 36 months after surgery relative changes in storage symptom was also superior in patients with bladder compliance <12.5 mL/cmH_2O compared to other groups.

On the multivariable analysis, bladder compliance <12.5 mL/cmH_2O (B=-3.301, p=0.011), in addition to preoperative IPSS storage sub-score and surgical methods, was significantly associated with decreases in the IPSS storage sub-score at postoperative 36 months (Table 4) although decreased bladder compliance was not significantly associated with changes in IPSS total and voiding sub-score after adjusting other variables. On additional analysis based on the surgical methods, there was no difference in storage sub-score decrements according to treatment methods (PVP *vs.* HoLEP) at 1-month (1.1 *vs.* 1.0, p=0.575), 1- (2.5 *vs.* 2.8, p=0.326) and 3-year after surgery (2.3 *vs.* 2.8, p=0.269) although decreases in voiding sub-score was superior after HoLEP, except for 1-month after surgery. In addition, bladder compliance, regardless of the surgical methods, was associated with decreases in storage score, although statistical significance was not achieved in patients who underwent HoLEP (Table 5).

DISCUSSION

A considerable proportion of patients with BPH

Table 5. Impacts of bladder compliance (<12.5 *vs.* ≥12.5 mL/cmH_2O) on long-term functional changes according to surgical methods (adjusted by prostate volume IPSS score)

Variable	IPSS total score			IPSS voiding sub-score			IPSS storage sub-score		
	B	95% CI	p-value	B	95% CI	p-value	B	95% CI	p-value
PVP	1.724	-0.600 to 8.925	0.086	2.180	-1.049 to 5.408	0.185	2.112	0.168 to 4.057	0.033
HoLEP	10.17	-1.431 to 21.780	0.085	6.030	-1.874 to 13.930	0.134	4.302	-0.632 to 9.236	0.080

HoLEP: holmium laser enucleation of the prostate, IPSS: International Prostate Symptom Score, PVP: photoselective vaporization of the prostate.

ultimately undergo surgical treatment for BPH and, recently, laser prostatectomy has been increasingly selected [1,2,22]. However, even though surgical treatment for BPH has been performed, a recent study reported that about a half of patients with BPH are still treated with medication due to the persistent LUTS [6]. In this regard, current clinical guidelines recommend a number of preoperative examinations [23]. However, even though these examinations are performed, it is not easy to accurately predict the postoperative symptomatic improvement, and some novel parameters for predicting improvements in postoperative storage symptoms after laser surgery are needed due to the impairment of storage symptoms after laser prostatectomy. As mentioned above, bladder compliance, which related to severe storage symptoms, has been regarded as results of bladder remodeling and a marker of decompensation [17]. In the current study, we evaluated the role of bladder compliance on the predicting the postoperative functional changes after laser prostatectomy, especially focused on the storage symptom changes.

In the previous study, the bladder compliance has been reported to decrease as men age [24], which is consistent with the findings of the current study. In that study, about 1 out of 5 patients showed decreased bladder compliance regardless of its severity, and about 1 out of 33 patients showed bladder compliance <12.5 mL/cmH_2O among patients with BPH who opted for laser surgery. In these men with bladder compliance <12.5 mL/cmH_2O, preoperative subjective symptoms, especially storage symptoms, were impaired compared to men with bladder compliance >25 mL/cmH_2O. which is in accordance with previous study. These relations might come from increased detrusor overactivity in men with poor bladder compliance [25]. Although decreased compliance could be related with the neurogenic bladder, in the current study, the prevalence of neurological or cerebrovascular diseases was not associated with bladder compliance, which might be due to the exclusion of patients with moderate to severe neurogenic bladders who were generally regarded as not optimal candidates for BPH surgery. In addition, in this study, bladder compliance was negatively associated with prostate volume or bladder outlet obstruction, in accordance with a previous study [26,27]. A previous study also suggested that BPH-induced decreased bladder compliance could be due to collagen deposition in the bladder smooth muscle fiber [28].

The findings of the study suggest that as preoperative bladder compliance decreased, more improvements in storage symptom could be expected at long-term follow-up. However, interestingly, storage symptom was similarly improved regardless of the degree of bladder compliance at the short-term follow-up. Relief from of BPH seemed to be helpful for improving storage symptoms induced by decreased bladder compliance, although at least a few years are needed to realize these improvements, which was consistent with a previous study [29]. This could also be supported by another previous study demonstrating that restoration of bladder compliance was not significantly observed at 6 months after surgery [30]. These findings might be related to the elimination of collagen deposition in the bladder smooth muscle fiber after resolving bladder outlet obstruction; however, this hypothesis needs to be validated in a future study. In addition, based on the results of the current study, clinicians could be more interested in the laser surgery for BPH in men with severe storage symptoms and decreased bladder compliance. However, because storage symptom was similarly improved regardless of the bladder compliance at short term follow-up, the clinicians should be careful for offering laser surgery in these patients with decreased bladder compliance by expecting immediate improvement in storage symptoms. In other words, clinicians should not avoid laser surgery in men with severe lower urinary symptoms because of the low bladder compliance, because storage symptoms might be alleviated with the time. One concern was that the effects of bladder compliance on functional outcomes might be not equivalent according to surgical methods. Based on the current study, HoLEP seemed to be superior compared to PVP regarding long-term voiding and storage symptom improvements, which might come from large removal of the prostate. However, the differences in storage sub-score outcomes according to surgical methods seemed to be minimized compared to voiding sub-score. In other words, compared to voiding sub-score, impacts of laser prostatectomy on long-term storage functional outcomes according to bladder compliance seemed to be similar regardless of surgical methods.

In addition, based on this study, bladder compliance <12.5 mL/cmH_2O was thought to be a reliable and reasonable cut-off value for predicting long-term functional outcomes after laser prostatectomy. This was because bladder compliance with 12.5–25 mL/cmH_2O showed similar improvements for subjective symptoms compared to the bladder compliance ≥25 mL/cmH_2O. Although several cut-off values for bladder compliance have been suggested [19,20], none of these cut-off values have been validated in patients with BPH who underwent laser prostatectomy. Furthermore, the results of the current study need to be validated in a future study with a larger number of patients and longer follow-up duration.

There were several limitations in the current study in addition to its retrospective design. For the first, the current study included patients who performed PVP and HoLEP as a single study population for the analysis although these two techniques have different tissue removal technique and different proportion of tissue removal. Although the current study aimed to assess the effects of bladder compliance on the long-term functional outcomes after laser prostatectomy, the future studies are needed to elucidate the similarities and differences between two techniques in the view of effects of bladder compliance on long-term functional outcomes. However, in order to overcome this limitation, we performed additional analysis according to surgical methods and these results would help to increase the reliability of the results of this study. In addition, due to the long study period, the selection of the surgical methods may have changed, and this may affect the results of the current study. In addition, a relatively high drop-out rate through the long-term follow-up after surgery may have inadvertently created a selection bias, which could result in the compromise the strength of the results of the current study. However, the results of the current study could be useful for clinicians to properly predict and explain surgical outcomes, especially in men with decreased bladder compliance.

CONCLUSIONS

In conclusions, in patients with preoperative bladder compliance <12.5 mL/cmH_2O, storage symptoms could be further improved at 36 months after laser prostatectomy compared to others. Thus, laser prostatectomy could be a considerable treatment option for patients with severely decreased bladder compliance. In addition, bladder compliance <12.5 mL/cmH_2O seemed to be a reliable cut-off value for predicting superior improvements in long-term storage symptoms after laser prostatectomy.

Conflict of Interest

The authors have nothing to disclose.

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None.

Author Contribution

Conceptualization: SY, MCC. Data curation: SY, HJ. Formal analysis: SY. Investigation: SY. Methodology: SY, MCC. Resources: HS, SJO, JSP. Supervision: HS, SJO, JSP. Writing – original draft: SY. Writing – review & editing: MCC.

Data Sharing Statement

The data analyzed for this study have been deposited in HARVARD Dataverse and are available at https://doi.org/10.7910/DVN/ZESEYD.

Supplementary Materials

Supplementary materials can be found *via* https://doi.org/10.5534/wjmh.220081.

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