Taiwanese Journal of Obstetrics & Gynecology 54 (2015) 709–715

Contents lists available at ScienceDirect

Taiwanese Journal of Obstetrics & Gynecology

journal homepage: www.tjog-online.com

Original Article

Monitoring bladder compliance using end filling detrusor pressure: Clinical results and related factors

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A R T I C L E I N F O

Article history:
Accepted 7 May 2015

Keywords:
low compliance bladder
lower urinary tract symptoms
urinary bladder
urodynamics

A B S T R A C T

Objective: To assess the clinical significance of low compliance bladder (LCB) in women with lower urinary tract symptoms.
Materials and Methods: Medical records of 1490 women undergoing videourodynamic studies (VUSs) were reviewed. Comprehensive medical histories, physical examinations, bladder diaries, and results of multichannel VUS were analyzed. This study adopted an end filling detrusor pressure (EFP) greater than 20 cmH_2O to define LCB.
Results: Among the study patients ($n = 1490$), 9.1% were diagnosed with LCB using a cutoff value of 17.5 cmH_2O, which had a sensitivity and specificity of 89% and 92.7%, respectively. Results of multivariate analysis indicated that age ($p = 0.005$), maximum cystometric capacity (MCC; $p = 0.002$), detrusor overactivity (DO; $p = 0.001$), pelvic organ prolapse (POP; $p = 0.018$), recurrent urinary tract infection ($p = 0.001$), and radical abdominal hysterectomy (RAH; $p < 0.001$) as independent prognostic factors. Furthermore, our study results indicate that the MCC, urinary tract infection, and a history of RAH have a positive correlation with LCB, whereas, age, POP, and DO have a negative correlation with LCB.
Conclusion: Our idea using EFP ($\geq$17.5 cmH_2O) for screening women with LCB is feasible for clinical use.

Introduction

The functions of urinary bladder are not only storage of urine and emptying but at a higher level, also maintaining the relatively low intravesical pressure [1]. An increase in intravesical pressure, for whatever reason, is universally accepted to be a major factor in disorders of compliance and as clinical experience has demonstrated increased intravesical pressure plays a major role in deterioration of the upper urinary tract and the appearance of voiding disorders with severe repercussion on quality of life [2].

Bladder compliance, which describes the relationship between change in bladder volume and change in detrusor pressure ($\Delta V/\Delta P$) [3], is generally regarded as a measure of bladder dispensability and the key determinant of the upper urinary tract deterioration in clinical interpretation. Decrease of the compliance may be seen in some pathological conditions such as infection or fibrosis (e.g., radiation, Foley indwelling, obstructive uropathy, or neurogenic bladder). At present, this is no golden standard to diagnose low compliance bladder (LCB) in women and this is the primary reason for conducting this study. The normal range for bladder compliance in adults has not yet been validated and previous reports suggested it to be above 12.5–40.0 mL/cmH_2O [4,5]. Bladder compliance below this range is usually considered to indicate LCB. However, in clinical practice, physicians are unable to read the bladder compliance data from the screen while performing urodynamic studies, and thus have to wait until the end of the study to investigate the data which are printed out in sheets. Fortunately, the end filling detrusor pressure (EFP) could be a potential alternative in this regard, which is easier to measure and does appear on cystometry more readily. Therefore, this study adopted an EFP greater than 20 cmH_2O, a cutoff commonly used in clinical practice, to define LCB [6].

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http://dx.doi.org/10.1016/j.tjog.2015.10.003
1028-4559/

A previous report [7] proposed that LCB was correlated with the presence of neurological conditions, and thus the goal of this study was to investigate the clinical significance of LCB. For this purpose, we collected and compared the correlation between patients' clinical data and the results of videourodynamic studies (VUSs).

Materials and methods

Study design

A retrospective analysis was performed in 1490 women who had received VUS to evaluate the cause of lower urinary tract symptoms (LUTSs) between January 2005 and December 2010. All the clinical data and VUS results were recorded in a prospective setting using the same protocol. The main indications for VUS included women with voiding dysfunction [8], urinary incontinence [for women who failed to respond to conservative treatment (e.g., medications, physiotherapy)], pelvic organ prolapse (POP; greater than Stage II of the POP-Q system [9]), recurrent urinary tract infection (RUTI), and neurogenic bladder. We defined RUTI as follows: either three or more symptomatic UTI episodes in the past year or two such episodes in the past 6 months [10]. Neurogenic bladder, which refers to dysfunction of the bladder due to disease of the central nervous system or peripheral nerves, in our patients most likely referred to women with diabetes mellitus (DM), a history of cerebrovascular accident, or spine surgery or radical abdominal hysterectomy (RAH).

The Institutional Review Board of Chang-Gung Memorial Hospital approved the chart evaluation of this retrospective study. In brief, the study protocol is as follows: First, all patients underwent a face-to-face structured interview that included questions related to their age, parity, medical illness, and previous surgery. Drug history was also obtained to exclude the cause that may aggravate the symptoms. Physical examination included height, weight, and pelvic examination to detect the presence of POP.

Digital examination and pinprick test were performed to assess the S2–S4 dermatome. Patients with abnormal neurological sign such as Babinski sign during pelvic examination or unsteady gait were assessed for the underlying diseases. All women in the study group had baseline assessment including urinalysis, postvoid residual (PVR) checked by an ultrasonic bladder scan (BVI 3000; Diagnostic Ultrasound Corporation, Bothell, WA, USA), and a bladder diary.

Second, in all cases only one physician (LHT) performed the VUS throughout the study period using the same protocol (UD-2000; Medical Measurement System, Enschede, The Netherlands), which complied with the guidelines of the International Continence Society (ICS) [1], and all the terms used in this study followed the ICS guidelines. A 4-Fr double lumen catheter (Medical Measurement Systems) was inserted into the bladder and a 10-Fr rectal catheter (Medtronic, Skovlunde, Denmark) was inserted into the rectum. VUS was performed according to the standard protocol. Data on VUS included uroflowmetry [maximum free flow rate, voided volume (VV1), and PVR], filling cystometry [first desire, maximum cystometric capacity (MCC), and EFP], and voiding cystometry [maximum flow rate (Q_{max}), detrusor pressure at maximum flow (VP), and voided volume (VV2)].

Uroflowmetry, filling, and voiding cystometry were performed using a Dantec Menuet (Dantec Medical A/S, Skovlunde, Denmark) multichannel urodynamic machine in combination with a C-arm imaging system (GE OEC 9800). All data were recorded and analyzed using the Dantec Menuet (Dantec Medical A/S) multichannel urodynamic machine.

Statistical analysis

Values were presented as mean ± standard deviation. All variables were tested for normal distribution using the Kolmogorov–Smirnov test. The Student *t* test was used to compare the means of continuous variables and normally distributed data; otherwise, the Mann–Whitney *U* test was used. Categorical data were tested using the Chi-square test on the variables that evaluated differences between groups as appropriate. The risk factors for LCB were assessed by univariate analysis initially. The statistically significant ($p < 0.05$) variables obtained by the univariate analysis were used for multivariate analysis. Multivariate analysis was performed by multiple logistic regression applied based on forward data elimination. Calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test (C statistic). Discrimination was assessed using the area under a receiver operating characteristic curve (AUROC). Areas under two AUROC curves were compared by a nonparametric approach. Finally, the cutoff point was calculated by acquiring the best Youden index (sensitivity + specificity − 1) [11], which is a global measure of a test performance used for the evaluation of overall discriminative power of a diagnostic procedure and for comparison of this test with other tests. All statistical tests were two-tailed and data were analyzed using SPSS 19.0 for Windows software (SPSS, Inc., Chicago, IL, USA). A value of $p < 0.05$ was considered significant.

Results

Patient characteristics

Of the 1490 VUS performed consecutively, 136 women [9.1% (mean age 56; mean parity 3)] diagnosed as a case of LCB based on our definition (i.e., EFP > 20 cmH_2O) were chosen for further analysis. Among the study patients ($n = 1490$), 939 (63%) were postmenopausal women. The main indications for VUS included women with voiding dysfunctions (385, 25.8%), urinary incontinence (374, 25.1%), POP (275, 18.5%), RUTI (171, 11.5%), and neurogenic bladder (285, 19.1%). Table 1 presents patients' demographic data and the clinical characteristics of LCB. Women in the LCB group seemed to have higher residual urine (168 mL vs. 104 mL, $p < 0.001$) and higher prevalence of RUTI (22.3% vs. 11.5%, $p < 0.001$). They were also more likely to have received the intermittent catheterization program (ICP) (12.5% vs. 10.4%, $p < 0.001$); besides, the incidence of vesicoureteral reflux (VUR) was also higher in this group (12.2% vs. 9.7%, $p < 0.001$).

The risk factors for LCB were assessed by univariate analysis initially. Using multivariate analysis, the following were identified as prognostic factors with a statistical significance (Table 2): age ($p = 0.005$), MCC ($p = 0.002$), EFP ($p = 0.028$), detrusor overactivity (DO; $p = 0.001$), POP ($p = 0.018$), RUTI ($p = 0.001$), and RAH ($p < 0.001$). Furthermore, we found that MCC, EFP, RUTI, and RAH have a positive correlation with the LCB, whereas age, POP, and DO have a negative correlation with the LCB.

The logarithm of odds of LCB is as follows: $1.094 - 0.018 \times \text{age} + 0.001 \times \text{MCC} + 0.003 \times \text{EFP} + 0.471 \times \text{RUTI} - 0.475 \times \text{DO} + 1.144 \times \text{RAH} + 0.599 \times \text{POP}$

Calibration and discrimination for illness scoring systems

The illness scoring systems (ISSs) can be used to compare groups of patients in research trials or predict mortality and prognosis for individuals and groups. The ISS can also measure physiological variables derived from logistic regression from large demographic data sets as in our study. The ISSs provide calibrated and validated data, high level of discrimination, and can also indicate prognosis

Table 1
Demographic data and clinical characteristics of all study patients and those in the LCB group.

	All patients ($n = 1490$)	LCB ($n = 136$)	p
Age (y)	60.39 ± 12.47	56.01 ± 14.36	0.001
Body height (cm)	154.78 ± 7.59	154.23 ± 5.49	0.55
Body weight (kg)	56.36 ± 12.15	56.88 ± 8.30	0.001
Parity	3.07 ± 1.54	3.48 ± 1.88	0.146
Maximum flow rate (mL/s)	19.45 ± 8.24	15.3 ± 8.09	0.001
VV1 (mL)	330.75 ± 87.52	265.99 ± 160.63	0.701
PVR (mL)	104.29 ± 130.66	167.91 ± 195.81	<0.001
First desire (mL)	226.06 ± 17.26	409.98 ± 211.14	<0.001
MCC (mL)	433.51 ± 43.22	530.69 ± 215.19	<0.001
EFP (cmH_2O)	15.02 ± 7.54	48.67 ± 95.58	<0.001
VP (cmH_2O)	37.51 ± 11.28	47.70 ± 27.00	<0.001
Q_{max} (mL/s)	17.39 ± 7.11	13.27 ± 9.00	<0.001
VV2 (mL)	369.99 ± 115.43	359.66 ± 210.98	<0.001
POP	19.2%	4.0%	<0.001
RUTI	11.5%	22.3%	<0.001
ICP	10.4%	12.5%	<0.001
VUR	9.7%	12.2%	<0.001
DM	35.1%	11.0%	0.108
RAH	19.5%	11.3%	<0.001

Data presented as mean ± standard deviation or percentages.
DM = diabetes mellitus; EFP = end filling detrusor pressure; ICP = intermittent catheterization program; LCB = low compliance bladder; MCC = maximum cystometric capacity; POP = pelvic organ prolapse; PVR = postvoid residual; Q_{max} = maximum flow rate; RAH = radical abdominal hysterectomy; RUTI = recurrent urinary tract infection; VP = detrusor pressure at maximum flow; VUR = vesicoureteral reflux; VV1 = voided volume of uroflowmetry; VV2 = voided volume of voiding cystometry.

and risk. The Hosmer–Lemeshow Chi-square statistic was used for measuring the overall goodness-of-fit for predicting LCB risk and the AUROC was used to assess the calibration and discrimination. Table 3 and Figures 1 and 2 present the analytical results, which indicate that age ($p = 0.002$), MCC ($p < 0.001$), EFP ($p < 0.001$), RUTI ($p < 0.001$), POP ($p < 0.001$), DO ($p < 0.001$), and RAH ($p < 0.001$) were strongly correlated with LCB risk. The results are presented in two figures because it is not possible to show all predictors in one figure: Figure 1 shows the discrimination power of age, POP, and DO, which are negative predictors of LCB; Figure 2 shows the discrimination power of MCC, EFP, RUTI, and RAH, which are positive predictors of LCB. Negative predictors will cause the ROC curve to lie under the diagonal line (line of no-discrimination) [12] and these are considered as poor predictors (but in fact, they could be good predictors as "negative predictors"). However, the output of a consistently poor predictor could simply be inverted to obtain a good predictor, and therefore in case of factors with negative predicting powers, simply inverting their decisions leads to a new predictive method, which are mirrors according to the line of no-discrimination and this mirrored method simply reverses the

Table 2
The logistic regression for LCB risk factor prediction.

Parameter	Beta coefficient	Standard error	Odds ratios (95% CI)	p
Univariate logistic regression				
Age (y)	−0.026	0.008	0.957 (0.960–0.989)	0.001
Body weight (cm)	−0.039	0.012	0.962 (0.939–0.985)	0.001
Maximum flow rate (mL/s)	−0.055	0.018	0.946 (0.914–0.980)	0.002
PVR (mL)	0.005	0.001	1.005 (1.003–1.006)	<0.001
MCC (mL)	0.002	0.001	1.002 (1.001–1.003)	< 0.001
EFP (cmH_2O)	0.082	0.009	1.086 (1.066–1.105)	<0.001
VP (cmH_2O)	0.019	0.005	1.109 (1.010–1.028)	<0.001
First desire (mL)	0.004	0.001	1.004 (1.002–1.005)	<0.001
Q_{max} (mL/s)	−0.071	0.016	0.931 (0.903–0.960)	<0.001
POP	−1.509	0.303	0.221 (0.122–0.401)	<0.001
RUTI	1.886	0.224	6.592 (4.248–10.228)	<0.001
ICP	2.118	0.300	8.315 (4.623–14.955)	<0.001
VUR	1.486	0.261	4.420 (2.652–7.368)	<0.001
DO	−1.268	0.218	0.281 (0.184–0.431)	<0.001
RAH	3.867	0.483	47.802 (18.546–123.211)	<0.001
HTN	−0.563	0.213	0.569 (0.375–0.864)	0.008
Multivariate logistic regression				
Age (y)	−0.051	0.018	0.950 (0.917–0.985)	0.005
MCC (mL)	0.003	0.001	1.003 (1.001–1.006)	0.002
EFP (cmH_2O)	0.006	0.003	1.006 (1.001–1.012)	0.028
POP	−1.410	0.599	0.244 (0.076–0.789)	0.018
RUTI	1.569	0.471	4.802 (1.907–12.095)	0.001
DO	−1.616	0.475	0.199 (0.078–0.504)	0.001
RAH	4.467	1.144	87.112 (9.251–820.282)	0.000
Constant	−0.095	1.094	0.909	0.930

CI = confidence interval; DO = detrusor overactivity; EFP = end filling detrusor pressure; ICP = intermittent catheterization program; LCB = low compliance bladder; MCC = maximum cystometric capacity; POP = pelvic organ prolapse; PVR = postvoid residual; RAH = radical abdominal hysterectomy; RUTI = recurrent urinary tract infection; VP = detrusor pressure at maximum flow; VUR = vesicoureteral reflux.

Table 3
Assessment of the predictive value of each measurement, sensitivity, specificity, and overall correctness of prediction.

Possible risk factor of LCB	Calibration			Discrimination		
	Hosmer–Lemeshow Chi square	*df*	*p*	AUROC ±SE	95% CI	*p*
POP	0.00	0	<0.001	0.619 ± 0.026	0.568–0.671	<0.001
RUTI	0.00	0	<0.001	0.700 ± 0.028	0.645–0.756	<0.001
DO	0.00	0	<0.001	0.651 ± 0.027	0.597–0.704	<0.001
RAH	0.00	0	<0.001	0.695 ± 0.030	0.637–0.754	<0.001
Age	5.442	8	0.709	0.592 ± 0.029	0.535–0.650	0.002
EFP	88.621	8	<0.001	0.960 ± 0.009	0.942–0.979	<0.001
MCC	5.683	0	0.683	0.647 ± 0.028	0.593–0.701	<0.001

AUROC = area under a receiver operating characteristic curve; CI = confidence interval; DO = detrusor overactivity; EFP = end filling detrusor pressure; LCB = low compliance bladder; MCC = maximum cystometric capacity; POP = pelvic organ prolapse; RAH = radical abdominal hysterectomy; RUTI = recurrent urinary tract infection; SE = standard error.

predictions. The mirror results of age, POP, and DO (Figure 1) allow us to compare discrimination powers between them with factors listed in Figure 2.

EFP, calibration for EFP (Hosmer–Lemeshow Chi-square = 88.621; $p < 0.001$), had the best predictive power. The AUROC curve confirmed the superior discrimination of the EFP compared with other factors. To assess the predictive value, sensitivity, specificity, and overall correctness of prediction, the Youden index was calculated and the EFP was found to have the best Youden index and the highest overall correctness of prediction (Table 4). Table 4 shows the discrimination powers between age, MCC, and EFP. The reason we listed these three factors is because only continuous variables are effective predicting factors. The cutoff points obtained are then analyzed by SPSS. According to the cutoff point, when a woman has EFP greater than 17.5 cmH_2O, she tends to develop LCB with a sensitivity and specificity of 89% and 92.7%, respectively.

Discussion

We diagnosed 136 women with LCB using our definition and our study indicated that age, MCC, DO, POP, RUTI, and RAH as independent prognostic factors; in addition, our study results show that using EFP for screening women with LCB is feasible for clinical use. According to the cutoff point, when a woman has EFP greater than 17.5 cmH_2O, she tends to develop LCB with a sensitivity and specificity of 89% and 92.7%, respectively.

We chose EFP instead of bladder compliance ($\Delta V/\Delta P$) because we felt that this may be more practical for clinical use to define LCB as it can be directly seen on the screen [6,13]. LCB may be caused by

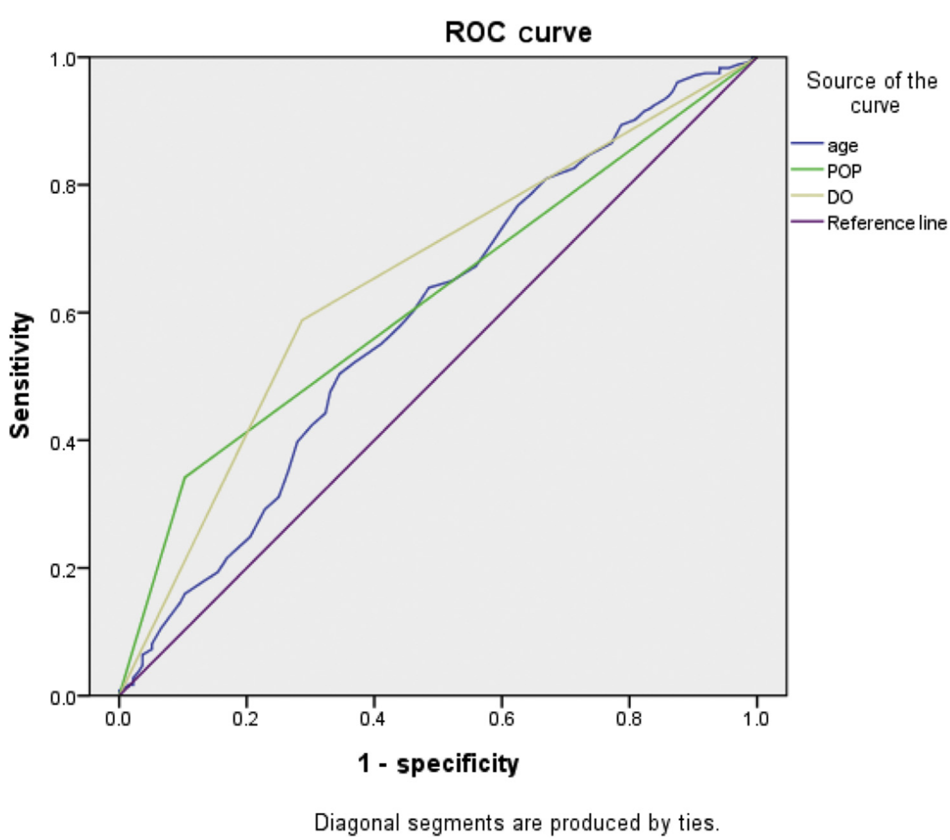

Figure 1. Area under a receiver operating characteristic curve showing the discrimination power of age, POP, and DO, which are negative predictors of low compliance bladder. DO = detrusor overactivity; POP = pelvic organ prolapse; ROC = receiver operating characteristic curve.

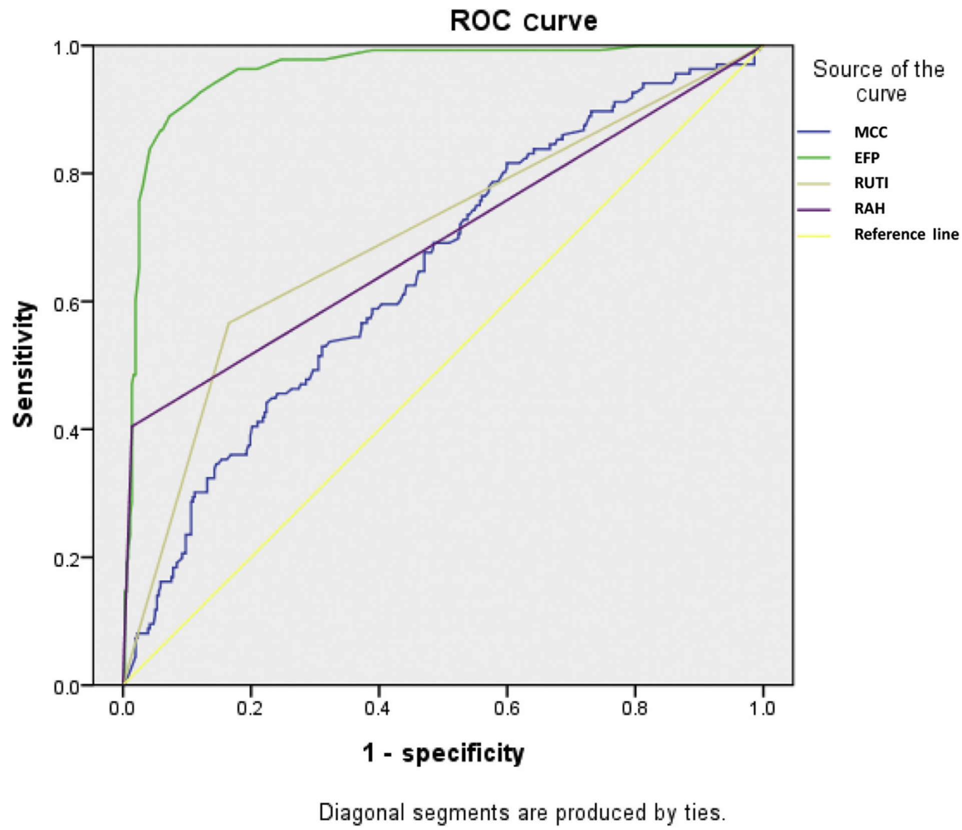

Figure 2. Area under a receiver operating characteristic curve showing the discrimination power of MCC, EFP, RUTI, and RAH, which are positive predictors of low compliance bladder. EFP = end filling detrusor pressure; MCC = maximum cystometric capacity; RAH = radical abdominal hysterectomy; RUTI = recurrent urinary tract infection.

decreased elastic and viscoelastic properties of the bladder wall or muscle tone change [14], or both. It is not surprising that EFP increases in women with LCB, which can be attributed to the decreasing dispensability of the bladder. Data for bladder compliance in urology are sparse and even less in urogynecology [4,5,7]. The most recent study on this issue was conducted by Cho et al in 2009 [7]. The criterion they used for LCB was 10 mL/cmH_2O and LCB was diagnosed in 170 (3.4%) cases (76 males and 94 females) in their study. They also found that LCB was correlated with the presence of neurological conditions and a history of pelvic irradiation or radical prostatectomy. The incidence of VUR in their study was 1.93% (1.7–2.4%) in female patients. By contrast, our study focuses on women with LUTS and the incidence of VUR was found to be higher (9.7%). This rate was even higher in patients in the LCB group (12.2%). We found that age, MCC, EFP, DO, POP, RUTI, and RAH were strongly correlated with the risk of LCB and a cutoff value was obtained for clinical implication. Harris et al [5] reported their experience concerning bladder compliance in neurologically intact women and their data showed that 95% of neurologically intact women have bladder compliance greater than 40 mL/cm; but, if we use the current concept (MCC of 400–600 mL) [15], then the EFP will range from 10 (400/40) cmH_2O to 12.5 (600/40) cmH_2O. However, their data did not offer much clinical information about LCB. Because LCB might have an impact on quality of life and in particular may cause upper urinary tract damage, we wanted to find a clinically useful tool to delineate LCB using objective data. We also wanted to find out a cutoff value of EFP to offer clinicians a valuable tool to assess LCB. However, we could not find sufficient studies discussing about the relationship between EFP and LCB. Recently, Gray [16] defined the concept of bladder wall compliance, discussed various methods of measuring or assessing compliance, and reviewed its clinical relevance. Based on existing evidence, Gray [16] noted that low bladder wall compliance is attributable to increased detrusor muscle tone during bladder filling or changes in the viscoelastic properties of the bladder wall that impede the ability of the bladder wall to stretch. The author also indicated that low bladder wall compliance is clinically relevant because of its potential to produce upper urinary tract damage, and there is an increased risk of febrile urinary tract infections, hydronephrosis, VUR, renal scarring, compromised urinary tract function, and urinary incontinence because of its direct influence on the bladder outlet. In addition, low bladder wall compliance is associated with a

Table 4
Assessment of the discrimination power between age, MCC and EFP.

Predictive factors of LCB	Cutoff point	Youden index	Sensitivity (%)	Specificity (%)	Overall correctness (%)
Age	61.5	0.159	50.4	65.4	47.7
MCC	503.5	0.218	52.9	68.9	65.44
EFP	17.5 [a]	0.817	89.0	92.7	88.97

EFP = end filling detrusor pressure; LCB = low compliance bladder; MCC = maximum cystometric capacity.
[a] Value giving the best Youden index.

variety of clinically relevant disorders, including neurogenic bladder dysfunction, pelvic irradiation, interstitial cystitis, and likely, in our case, RAH.

Our study also indicates that RAH ($p < 0.001$) is a prognostic factor (positive predictor) with a statistical significance for LCB. The possible impact on bladder function may be, during RAH, interruption of pelvic nerves and fascial structures in the anterior, posterior, and lateral parametrium, which eventually leads to various degrees of bladder dysfunction [17]. In a recent review, Plotti et al [17] reported the overall incidence of urodynamic bladder dysfunctions to be 72%; in particular, the incidence rates of detrusor dysfunctions (with high or low compliance), mixed urinary incontinence, and stress urinary incontinence were reported to be 42%, 24.5%, and 40%, respectively. Concerning detrusor dysfunctions, the studies reviewed by Plotti et al [17] reported a high incidence of DO (34%) associated with low compliance. Besides, their review also indicated a decrease in the maximal urethral closure pressure between the preoperative analysis and postoperative analysis. They also tried to explain the reasons for various bladder dysfunctions after RAH, which included impaired urethral pressure (possibly related to the damage of the pelvic plexus and pudendal nerves with loss of periurethral zone) [18], high incidence of DO, and urinary stress incontinence (the loss of sympathetic alpha-adrenergic stimulation due to surgical damage, which may have an excitatory effect on parasympathetic transmission to the detrusor muscle during urine storage and lead to permanent relaxation of the bladder neck and the proximal urethra) [19].

Our study indicates that RUTI ($p = 0.001$) is a prognostic factor (positive predictor) with a statistical significance for LCB, which means that if a woman gets more UTI, bladder compliance will get worse. In our study, women in the LCB group had higher prevalence of UTI (22.3% vs. 11.5%, $p < 0.001$) among the whole study group and we believe that this is due to the synergistic effect of UTI and LCB. UTI in itself will increase intravesical pressure [20] and by damaging the urothelium or bladder lining, the viscoelastic properties of the bladder, based on its composition of smooth muscle, collagen, and elastin, could be impaired. The bladder eventually losses the ability to store urine during normal bladder filling, leading to reduced bladder compliance. In addition, UTI weakens the urethrovesical junction, predisposing to reflux [21].

Our study indicates that MCC ($p = 0.002$) is a prognostic factor (positive predictor) with a statistical significance for LCB, which means that as the bladder capacity increases, bladder compliance decreases and this is in contrast to our thinking because, based on clinical observations, the bladder compliance should remain stable during the filling phase for most women and LCB was diagnosed in women with low-capacity bladder. MCC reflects the volume at which a patient with normal bladder sensation can no longer delay voiding, indicating that the bladder capacity has reached its maximum and that normal voiding needs to be initiated. In this study, based on ICS guidelines, MCC was defined as the volume at which the patient felt a strong urge to void and/or voided. For patients who did not experience an urge to void, we just stopped bladder filling at a bladder volume of 1000 mL. An interesting study by Purohit et al [22] tried to describe the pathophysiology, differential diagnosis, and urodynamic findings in patients with a large capacity bladder (MCC $\geq$ 700 mL). A total of 56 men and 44 women with a bladder capacity of 700–5013 mL were studied. LCB was found in eight patients (8%), although the sex of these patients was not indicated. The authors found that patients with LCB had a higher P_{detmax} than those with normal compliance and there were no differences in Q_{max}, $P_{det}Q_{max}$, PVR, or MCC between the two patient groups. Five patients with LCB had bladder diverticula but only one had hydronephrosis. By contrast, in our study, LCB was found in 136 (9.1%) patients and our study data suggested that women with LCB had a higher P_{detmax}, MCC, PVR, and lower Q_{max} than those with normal compliance. One article discussed urodynamic findings in chronic renal failure patients [23] and found that the mean detrusor compliance and detrusor capacity significantly decreased as the disease progressed.

Our study indicates the presence of POP ($p = 0.018$) as a prognostic factor (negative predictor) with a statistical significance for LCB, meaning that the more the POP, the lesser the chance of LCB. However, we could not find any article that addressed the relation between POP and LCB. Most published articles on urodynamic findings in women with POP mainly focused on preoperative/postoperative comparisons and only a few of them discussed the relation between urodynamic findings and POP. A recent study conducted by Serati et al [8] offered valuable information regarding this issue. The authors found that POP quantification stages and baseline data were poorly correlated with final urodynamic findings; in addition, both urinary stress incontinence and overactive bladder were independently associated with each urodynamic studies (UDS) diagnosis, including DO, urodynamic stress incontinence (USI), and mixed urinary incontinence (USI plus DO). However, the authors recommended that urodynamic study plays a key role in preoperative counseling of women scheduled for pelvic reconstructive procedures to reveal particular conditions, such as occult USI or in patients in whom DO represents the underlining condition of overactive bladder. Araki et al [24] also reported that the presence of DO was a good predictor of postoperative persistence of urgency and urge urinary incontinence in women with POP; in addition, poor detrusor contractility was reported as the best predictor of large PVR occurrence [24].

Our study results indicate that age ($p = 0.005$) is a prognostic factor (negative predictor) with a statistical significance for LCB, indicating that older women are significantly less likely to have LCB, and this again is in contrast to our thinking. The pathophysiological change of aging is a broad-spectrum issue and aging is associated with declining function in almost every physiological system. In the urinary system, LUTSs are more frequent among elderly individuals, and urodynamic studies demonstrate the relationship between aging and reduced bladder capacity, uninhibited contractions, decreased urinary flow rate, and increased PVR volume [25]. Several mechanisms including collagen deposition [26], loss of acetylcholinesterase-positive nerve terminals [27], detrusor fibrosis, and impaired contractility have been proposed in this regard. Although many clinical studies agree that aging has an impact on LCB, it is hard to understand whether the pathogenesis is mainly caused only by aging or any other underlying disease (such as DM or others causing neuropathies involving micturition reflex).

Our study results indicate that the presence of DO ($p = 0.001$) is a prognostic factor (negative predictor) with a statistical significance for LCB, meaning women with DO are significantly less likely to have LCB. However, we could not find any article that addressed the relation between DO and LCB because some physicians might treat both of these conditions using the same antimuscarinic agents. In women with DO, the bladder may experience generalized, nerve-mediated excitation of the detrusor or a combination of spontaneous excitation within smooth muscle and an enhanced prolongation to excite the bladder wall [28], which shows up involuntary contractions in the cystometric findings. Theoretically, in women with DO, involuntary contractions are more likely or earlier to occur during filling because of the prolongation of bladder wall excitation, and thus the patient can no longer delay micturition. Some studies have demonstrated the inverse relationship between severity of bladder overactivity and bladder capacity [29]. MCC is widely regarded as an important tool to judge the severity of the DO [30], but it is not recognized as a tool for DO predictions so far.

Despite these encouraging results, this study has some limitations. This is a retrospective study from a single tertiary medical center, and therefore it may not have much persuasiveness in generalization, and a selection bias associated with a hospital-based study may exist. The actual association between LCB and predictive factors is yet to be fully understood. However, all of the clinical data and VUS results in this study were recorded in a prospective setting with a uniform protocol using a real-time electronic data recording system. In addition, because our study focused on women with LCB, only 136 patients with voiding difficulty and prolapse, rather than a general group which had baseline urodynamics, were chosen among those who required VUS ($n = 1490$). Thus, future studies should recruit additional patients to present more powerful results.

In conclusion, we investigated the clinical significance of LCB in women with LUTS and tried to use EFP as a tool to predict and distinguish women who might develop LCB. Our study results indicate that EFP can be used as a screening tool and we even identified a cutoff point for EFP (17.5 cmH_2O). Nevertheless, the data presented do not establish the precise cause nor the incidence and these results are very preliminary, and therefore further studies are needed to substantiate the clinical utility of these methods.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

L-HT and J-YL wrote the paper; J-YL and Y-HL developed analytical tools, J-YL and C-CL performed data analysis and wrote the paper; W-CH and S-JL validated the results; and L-HT supervised the project.

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