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# The Pathophysiology of Large Capacity Bladder

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**Purpose:** We describe the pathophysiology, differential diagnosis and urodynamic findings in patients with a large capacity bladder.

**Materials and Methods:** This was a retrospective, observational study of 100 consecutive patients with voiding dysfunction and a cystometric bladder capacity of greater than 700 ml. Clinical data, cystometric bladder capacity and other urodynamic findings were evaluated. Bladder outlet obstruction and impaired detrusor contractility were defined by the Schaefer nomogram in men and the Blaivas-Groutz nomogram in women.

**Results:** A total of 56 men and 44 women 36 to 97 years old (median age 75, mean 71.2) with a bladder capacity of 700 to 5,013 ml (median 931, mean 1,091) were studied. The primary pathophysiological diagnoses were bladder outlet obstruction in 48% of cases, impaired detrusor contractility in 11%, absent detrusor contractility in 24% and normal detrusor pressure/uroflow study in 17%. Bladder outlet obstruction was attributable to anatomical obstruction in 34% of patients, acquired voiding dysfunction in 11% and detrusor-external sphincter dyssynergia in 3%. In patients with detrusor contractions the initial contraction occurred at a median of 1,000 ml (mean 1,154, range 86 to 5,000). Associated diagnoses in men included benign prostatic enlargement in 52% and neurological disease in 14%, and in women they were pelvic organ prolapse in 27%, stress incontinence in 18% and neurological disorders in 9%.

**Conclusions:** The etiology of large capacity bladder is multifactorial and often a potentially remediable underlying condition exists. A large capacity bladder may be accompanied by bladder outlet obstruction, impaired or absent detrusor contractions, or normal detrusor pressure/uroflow studies. When detrusor contractions are present, they usually occur only at large bladder volumes. Therefore, it is important during cystometry to fill the bladder until capacity is achieved.

*Key Words: bladder; muscle, smooth; urination disorders; urinary bladder neck obstruction*

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A large capacity bladder is often discovered during the routine evaluation of LUTS. Although healthy volunteers can have LCB,<sup>1</sup> when the condition is accompanied by LUTS, the clinician is faced with the problem of having to determine what role, if any, that LCB has in the genesis of those symptoms. For example, some patients present in urinary retention with LCB and it is important to determine whether the etiology is impaired or absent detrusor contractility, bladder outlet obstruction or a combination of the 2 conditions. Other patients have stress incontinence or pelvic organ prolapse and they are incidentally found to have LCB, raising concerns about the risk of voiding dysfunction after corrective surgery.

There are few studies of the etiology and pathophysiology of LCB. We evaluated the pathophysiology, urodynamic findings and differential diagnoses of LCB.

## MATERIALS AND METHODS

This was a retrospective, observational study of 100 consecutive patients referred to a tertiary urology center who underwent urodynamic testing because of persistent LUTS and who had a cystometric bladder capacity of greater than 700 ml. Patients with a history of augmentation cystoplasty or

neobladder were excluded. If the patient underwent more than 1 urodynamic study, data from the first study was used. During this catchment period 2,900 videourodynamic studies were completed and approximately 200 patients (7%) had a bladder capacity of greater than 700 ml. Of these 200 patients 100 consecutive patients were analyzed.

All patients completed a 24-hour bladder diary and underwent uroflowmetry, estimation of PVR by ultrasound, videourodynamics and cystoscopy. Patients with urethral obstruction and/or low compliance underwent renal ultrasound.

Videourodynamics were performed with the patient seated using a 7Fr dual lumen vesical catheter and a 9Fr rectal balloon catheter at a medium filling rate with radiographic contrast medium as the infusant. Bladder capacity was defined as the volume at which the patient felt a strong urge to void and/or voided voluntarily or involuntarily. In patients who did not experience an urge to void bladder capacity was defined as the volume at which the patient felt comfortably full. If a patient felt comfortably full during cystometry at a bladder volume of less than MVV on the bladder diary, filling was stopped, the patient was distracted and filling then continued until the patient became comfortably full again. PVR was measured by subtracting voided volume from the amount instilled after emptying the patient bladder.

The data extracted were age, sex, clinical diagnosis, MVV, PVR, cystometric bladder capacity, bladder volume at first detrusor contraction, Q<sub>max</sub>, P<sub>det</sub>Q<sub>max</sub>, P<sub>det</sub>max and bladder compliance. Bladder compliance was denoted as normal—above 20 ml/cm H<sub>2</sub>O and low—below 20 ml/cm H<sub>2</sub>O

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based on data in women<sup>2</sup> because to our knowledge there are no studies to date describing normal values in men.

Pdet/uroflow studies were categorized as normal, impaired detrusor contractility or bladder outlet obstruction based on the Schaefer nomogram in men.<sup>3</sup> In women the Blaivas-Groutz nomogram<sup>4</sup> was used and impaired contractility was defined by a Pdetmax of less than 20 cm H<sub>2</sub>O with a Qmax of less than 12 ml per second. The chart of each patient was examined to ensure that inclusion and exclusion criteria were adhered to and associated diagnoses such as diabetes mellitus were recorded. Patient characteristics and urodynamic data are presented as the median and mean with the SD. Other results are presented as percents.

The mean, median and SD were calculated for each patient parameter with  $p < 0.05$  considered statistically significant. Statistical analysis was done using Student's t test and Spearman's rho correlation coefficient.

**RESULTS**

The 100 patients consisted of 56 men and 44 women 36 to 97 years old (median age 75, mean 71). Bladder capacity was 700 to 5,013 ml (mean 1,091, median 931). Overall 76% of patients were able to generate a detrusor contraction during the urodynamic study. In these patients the detrusor contraction occurred at a median volume of 1,000 ml (mean 1,154, range 86 to 5,000). Of the patients 23 (23%) had low PVR (less than 100 ml). Tables 1 to 3 list urodynamic findings, urodynamic diagnoses and clinical diagnoses, respectively.

Low bladder compliance was found in 8 patients. Patients with low bladder compliance had a higher Pdetmax than those with normal compliance (157 vs 38 ml/cm H<sub>2</sub>O,  $p = 0.0009$ ). There were no differences in Qmax (13 vs 5 ml per second,  $p = 0.062$ ), PdetQmax (35.3 vs 35.1 cm H<sub>2</sub>O,  $p = 0.99$ ), PVR (706 vs 574 ml,  $p = 0.56$ ) or bladder capacity (902 vs 1,107 ml,  $p = 0.33$ ). Five patients (63%) with low bladder compliance had bladder diverticula but only 1 (13%) had hydronephrosis. Figures 1 to 3 show examples of urodynamic tracings demonstrating impaired detrusor contractility and urethral obstruction.

Renal ultrasound, computerized tomography or excretory urography results were available in 56 patients, of whom 4 men had bilateral hydronephrosis and 1 woman had an atrophic left kidney of unknown etiology. She had an acontractile detrusor and a remote history of lumbar sympathectomy. Two of the 4 men with hydronephrosis had severe obstruction (Schaefer grade VI), 1 had Schaefer grade IV obstruction and 1 had impaired detrusor contractility, in addition to a bladder diverticulum. One patient with obstruction also had low bladder compliance.

A total of 15 patients (15%) had large bladder diverticula, of whom 9 had impaired or absent detrusor contractility and

	Mean ± SD	Median	Range
Bladder capacity (ml)	1,090.9 ± 571.1	931	700-5,013
Vol at first detrusor contraction (ml)	1,154.3 ± 827.0	1,000	86-5,000
Qmax (ml/sec)	6.0 ± 10.7	2.7	0-23.3
PVR (ml)	585.1 ± 606.6	450	0-4,150
PdetQmax (cm H <sub>2</sub> O)	35.1 ± 28.9	26.4	0-138
Pdetmax (cm H <sub>2</sub> O)	47.0 ± 93.0	31	0-870
MVV (ml)	369.0 ± 204.0	360	0-900

	%
Bladder outlet obstruction	48
Impaired detrusor contractility	11
Absent detrusor contractility	24
Normal pressure flow study	17
Detrusor overactivity	4
Open bladder neck at rest	3
Low bladder compliance	8
Total value is more than 100% because some patients had more than 1 finding.	

6 had bladder outlet obstruction. Five of the 15 patients (33%) with bladder diverticula had low bladder compliance.

A total of 81 patients showed detrusor contractions and/or uroflow, which were plotted on the Schaefer and Blaivas-Groutz nomograms (figs. 4 and 5, respectively). Of the 37 female patients 30 (81%) had mild obstruction, 2 (5%) had moderate obstruction and 5 (13%) had no obstruction. Of these women 16 had impaired detrusor contractility. Based on the Schaefer nomogram 15 of the 44 male patients (34%) had obstruction (grades III-V), 17 (39%) had no or equivocal obstruction (grades 0-II) and 12 (27%) had impaired or absent detrusor contractility (fig. 4).

We used Spearman's rho correlation coefficient to analyze the relationship between cystometric capacity, voiding diary and office uroflow findings. There was no correlation between bladder capacity and MVV in voiding diaries ( $\rho = -0.04$ ,  $p = 0.77$ , fig. 6). There was a significant correlation between bladder capacity and voided volume at the office and PVR ( $\rho = 0.49$ ,  $p < 0.001$ , fig. 6). There was a significant inverse but relatively small correlation between bladder capacity and the number of voids in voiding diaries ( $\rho = -0.29$ ,  $p = 0.028$ , fig. 7).

Associated diagnoses in men were benign prostatic enlargement in 52% and neurological disease in 14%, and in women they were pelvic organ prolapse in 27%, stress incontinence in 18% and neurological disorders in 9%. In men and women diabetes mellitus was only seen in 5% of patients and large bladder diverticula were noted in 15%. No patient in our series had a bladder stone on cystoscopy.

**DISCUSSION**

In the current study bladder capacity was 700 ml to greater than 5 l. Common sense dictates that, if a bladder holds more than 5 l, there must be something terribly wrong with it and that bladder would not likely contract well. Despite

	%
Prostate/bladder neck obstruction	27
Normal studies	17
Neurological disease	17
Pelvic organ prolapse	12
Acquired voiding dysfunction	11
Intrinsic sphincter deficiency/sphincteric incontinence	10
Iatrogenic urethral obstruction	7
Diabetes mellitus	5
Prostate cancer	4
Detrusor-external sphincter dyssynergia	3
Total value is more than 100% because some patients had more than 1 finding.	

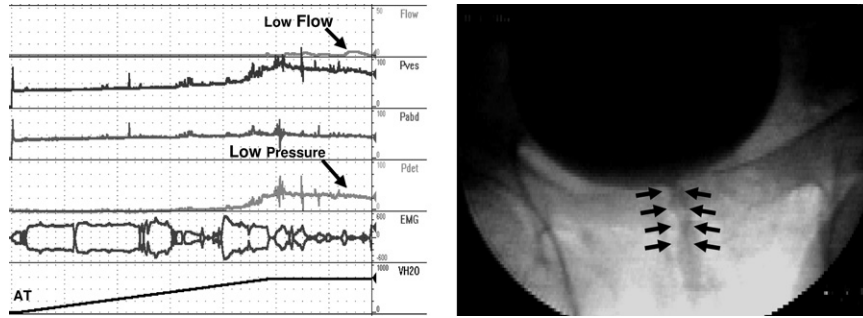


FIG. 1. LCB and impaired detrusor contractility in 58-year-old man (AT) evaluated because of urinary frequency, urgency, occasional urge incontinence, hesitancy and weak stream. Left, urodynamic study shows first filling sensation at 272 ml, first desire to void at 491 ml, severe desire to void at 620 ml, bladder capacity 710 ml, Qmax 6 ml per second, PdetQmax 28 cm H<sub>2</sub>O and Pdetmax 41 cm H<sub>2</sub>O. Right, x-ray at Qmax shows narrowed bladder neck and prostatic urethra (arrows). Reproduced with permission from one of us (JGB).

this inherent logic the man with the 5 l bladder had a strong, sustained detrusor contraction (fig. 3). Also, in fact, 76% of these patients generated a detrusor contraction during the urodynamic evaluation and at least 48% had urethral obstruction, which is a potentially correctable condition. The bladder volume at which detrusor contraction occurred was 86 to 5,000 ml (median 931).

The clinical ramifications of this finding are important. Many of these patients were labeled as having neurogenic bladder by the referring physicians because the bladder did not contract during the original urodynamic study. On re-

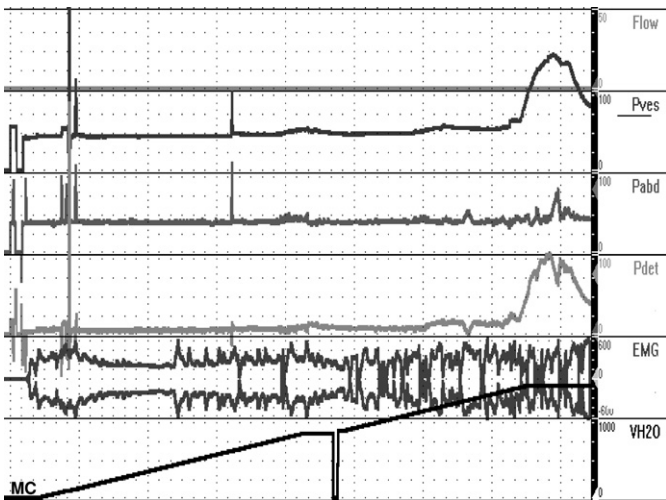


FIG. 2. LCB and primary bladder neck obstruction in 31-year-old man (MC) who was on twice daily intermittent catheterization for about 2 years after he was found to have renal failure with creatinine 7 mg/dl during evaluation of sudden onset pedal edema. At first he was treated with indwelling catheter and then with intermittent catheterization 4 or 5 times daily. He had been found to have PVR as high as several l. He underwent serial urodynamics and cystoscopy, and was told that “there is no blockage” but those studies stopped bladder filling at 600 to 1,000 ml. Voiding cystourethrography and cystoscopy revealed bladder neck obstruction and patient underwent transurethral prostate resection. Five years later patient voided 4 or 5 times daily and denied any symptoms. Qmax was 34 ml per second, voided volume was 436 ml, PVR was 24 ml, creatinine was stable at 2.4 mg/dl and creatinine clearance was 54 ml per minute. Urodynamic tracing demonstrates Schaefer grade 6 urethral obstruction. During bladder filling patient was repeatedly asked to try to void after infused volume was about 750 ml but he had no urge to void. Finally, at bladder volume of about 1,400 ml he had voluntary detrusor contraction. Pdet was 100 cm H<sub>2</sub>O but Qmax was too low to be detected by flowmeter. This corresponds to Schaefer grade 6 obstruction.

peat studies at our laboratory the bladder contracted. A review of the original tracings showed that bladder filling was arbitrarily discontinued at a bladder volume of 600 to 1,000 ml, which is the volume of most infusion containers. These findings indicate that during cystometry it is imperative to continue bladder filling until bladder capacity is attained. Failure to do so might result in many patients being treated with catheterization despite having remediable conditions, such as prostatic obstruction or pelvic organ prolapse.

LCB has also been referred to as lazy bladder in adults<sup>5</sup> and primary megalocystis in children.<sup>6</sup> However, there appears to be no consensus about the range of normal bladder capacity or what represents large capacity because of considerable overlap between normal and abnormal conditions. Bladder capacity has proved difficult to standardize because it varies widely even among healthy young adults. Values of 300 to 1,000 ml have been documented by frequency volume charts.<sup>7,8</sup> In the current series an otherwise normal patient with polyuria had a bladder capacity of 1,200 ml and yet voided to completion with normal voiding mechanics. LCB has also been described in elderly women, which is thought to be due to social constraints that favor infrequent voiding.<sup>9</sup>

The method by which bladder capacity is assessed may affect reported values. The International Continence Society Standardization Committee defines 3 bladder capacities, including 1) MVV (functional bladder capacity), 2) cystometric bladder capacity and 3) anesthetic bladder capacity.<sup>10</sup> There is some disagreement about how these values correlate with each other.<sup>11</sup> Gender does not appear to have a role in determining normative values.<sup>1</sup>

The etiology as well as the physiological and clinical consequences of LCB are also poorly understood. On 1 hand, it is well documented that bladder outlet obstruction,<sup>12</sup> neurogenic bladder,<sup>6</sup> diabetes mellitus<sup>13</sup> and acquired voiding dysfunction (Hinman’s syndrome)<sup>14</sup> may lead to detrusor decompensation and LCB. All of these conditions contributed to LCB in the current series (table 3). On the other hand, 17% of our patients with LCB were considered to be otherwise normal. They denied voiding symptoms and voided to completion with normal voiding dynamics. To our knowledge it is not known whether with time detrusor dysfunction will develop in these patients.

The deleterious effects of urethral obstruction have been extensively studied in animal models. Bladder outlet obstruction initially causes detrusor smooth muscle hypertro-



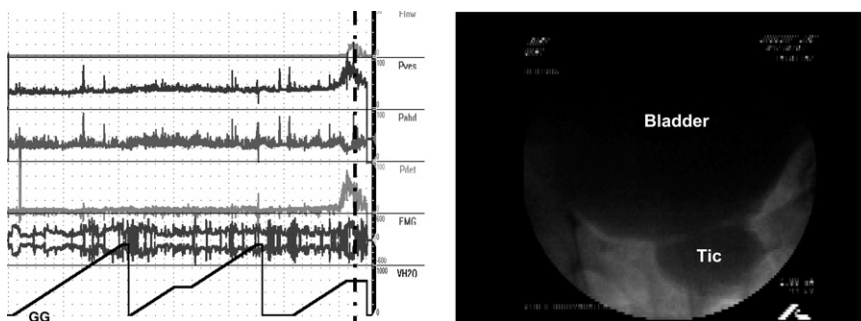


FIG. 3. Huge bladder capacity in 59-year-old man (GG) in urinary retention with greater than 5 l after uneventful percutaneous placement of coronary artery stents. He had noticed weak stream for decades but denied other symptoms. Left, videourodynamic study revealed multiple large bladder diverticula and Schaefer grade 2 voiding. PdetQmax was 50 cm H<sub>2</sub>O and Qmax was 12 ml per second. He underwent bladder diverticulectomy and transurethral prostate resection. At 1-year followup he was asymptomatic with Qmax 29 ml per second, voided volume 387 ml and PVR 134 ml. Right, x-ray during voiding at first glance appeared to show dilated prostatic urethra. In fact, urethra is obscured by large bladder diverticulum (Tic) that was discovered at surgery, and extended behind and below prostate.

phy and hyperplasia but eventually ischemia sets in, contractility decreases, bladder emptying is impaired and bladder capacity increases.<sup>12</sup>

It has been also been postulated that ischemia may be a primary factor in the genesis of detrusor dysfunction and, hence, LCB. Studies in healthy volunteers have shown that, as bladder volume and pressure increase with filling, blood flow increases but at capacity the blood flow substantially decreases.<sup>15</sup> Rats with severe iatrogenic outflow obstruction demonstrate decreased blood flow and impaired detrusor contractility.<sup>16</sup> Furthermore, in bladder outlet obstruction animal models ischemia and subsequent hypoxia have been shown to be a major pathway for causing LCB.<sup>17</sup>

Mirone et al suggested that mechanical tension on the detrusor due to high bladder volume is thought to activate stretch receptors in the bladder, which may impact long-term bladder remodeling, resulting in LCB.<sup>18</sup> It is unclear why only some patients with LCB undergo these cellular changes. It may involve the altered sensitivity of afferent C fibers, which can increase functional bladder capacity.<sup>19</sup> The 11% of patients with acquired voiding dysfunction in the current series probably show conscious or unconscious inhi-

bition of the normal response to bladder filling, ie they override the stimulus to void.

Although the classic study of diabetic cystopathy concluded that diabetes mellitus causes LCB,<sup>13</sup> no clinical evidence of this was seen in our study. The incidence of diabetes in patients with LCB was not significantly different from that in the general population in our study. This may have been due to the early detection and successful treatment of diabetes, which for other diabetic neuropathies has been shown to have a protective effect.<sup>20</sup>

The potential consequences of LCB include recurrent infection, bladder stones, hydronephrosis and renal damage. However, it is not well documented that bladder volume alone causes these morbidities. Rather, increased voiding pressure and low bladder compliance may have a more profound effect. In our study only 4 patients (7.1%) who underwent imaging had hydronephrosis, which is much too small a number to enable any meaningful conclusions.

The shortcomings of this study are inherent in its retrospective observational design. For each patient the urodynamic study represents a single snapshot at 1 point in time. There are no meaningful data on progression or even

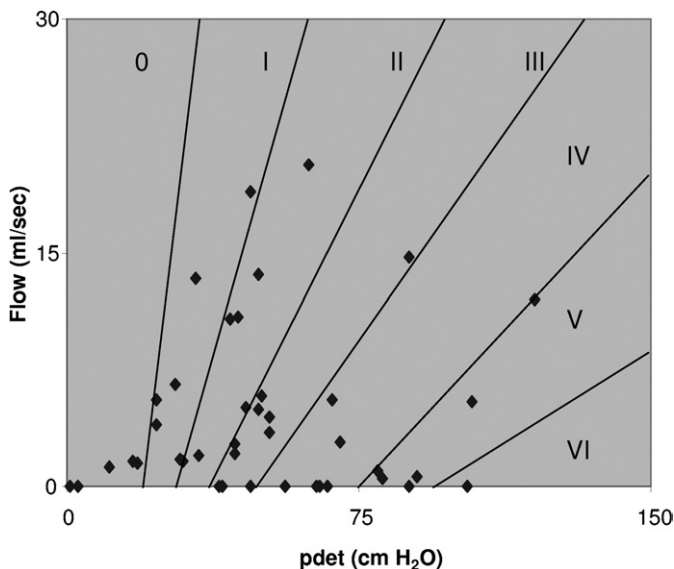


FIG. 4. Schaefer nomogram. Uroflow studies could not be performed in 6 men. Roman numerals indicate obstruction grade.

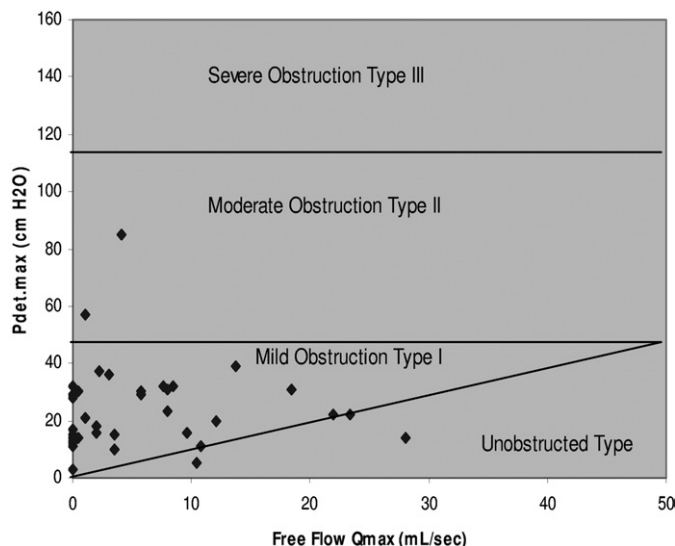


FIG. 5. Blaivas-Groutz nomogram. Uroflow studies could not be performed in 7 women. Pdet.max, Pdetmax.

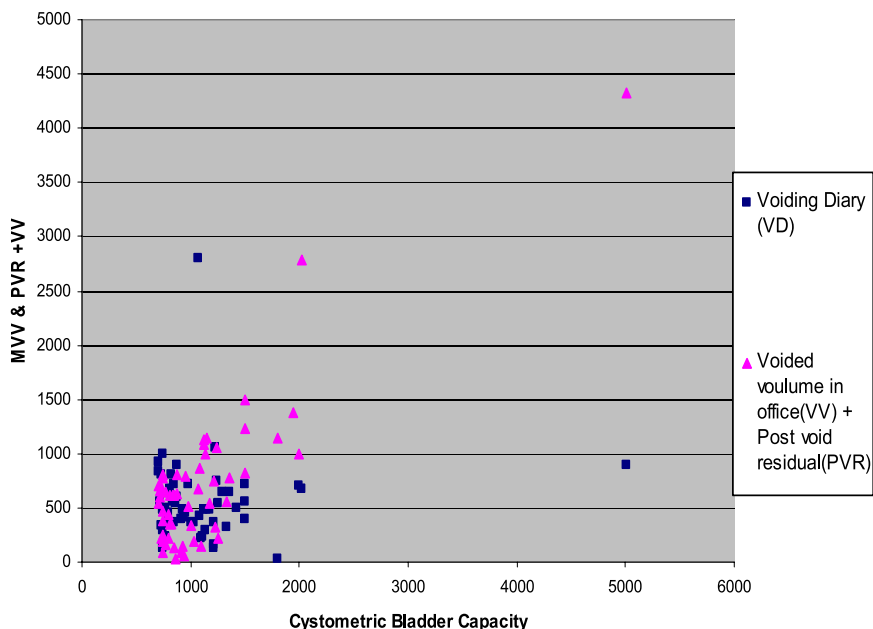


FIG. 6. Cystometric capacity vs MVV on voiding diary and PVR plus voided volume (VV) at office

on the pathological condition that actually caused LCB. Furthermore, for each of the underlying pathological conditions there is no denominator, so that it is not possible to determine how often a particular condition, such as prostatic obstruction or pelvic organ prolapse, is accompanied by LCB or whether those conditions actually cause LCB.

**CONCLUSIONS**

The etiology of LCB is multifactorial and in 17% of our patients it was accompanied by normal voiding dynamics, as measured by pressure flow nomograms. The most common associated conditions were urethral obstruction in 48% of patients, followed by impaired detrusor contractility in 24% and absent detrusor contractions in 11%. In these patients detrusor contractions may occur only at large bladder volume, so that it is important during cystometry to fill the bladder until capacity is attained.

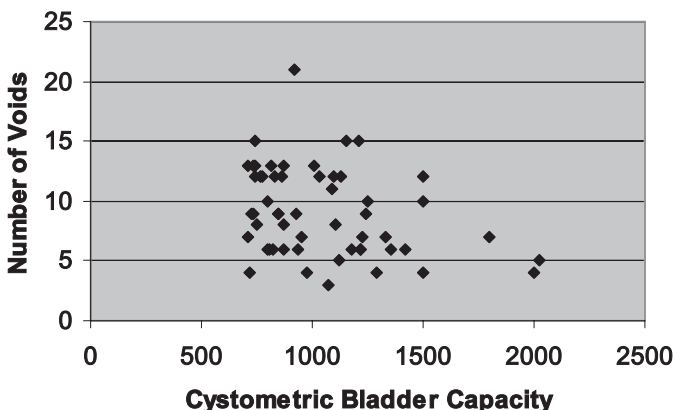


FIG. 7. Cystometric capacity vs number of voids

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Abbreviations and Acronyms	
EMG	= electromyography
LCB	= large capacity bladder
LUTS	= lower urinary tract symptoms
MVV	= maximum voided volume
Pabd	= abdominal pressure
Pdet	= detrusor pressure
Pdetmax	= maximum Pdet
PdetQmax	= Pdet at Qmax
Pves	= vesical pressure
PVR	= post-void residual urine
Qmax	= maximum flow rate
VH20	= volume infused

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