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Clinical Aspects and Risk Factors of Low Compliance Bladder

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To determine the prevalence of low compliance bladder and its effects on the upper urinary tract, 431 persons with neurogenic bladder have been evaluated over the past 3 years. Among them, 34 persons (7.9%) had low compliance bladder. Thirty-two persons who had lower motor neuron type neurogenic bladder served as controls. Bladder capacity (280 ml vs. 420 ml; $P < 0.05$) and creatinine clearance rate (53 ml/min vs. 83 ml/min; $P < 0.05$) of the low compliance bladder group were significantly lower than those of controls. The chance of urinary tract infection was greater and the post-injury duration was longer in the low compliance group, in spite that there was no statistical difference between them. In contrast to the previous studies, the incidence of high cord injury individuals with low compliance bladder was higher than expected. Eight patients (32% of group 1) with low compliance bladder had upper urinary tract changes, while none of lower motor neuron group did ($P<0.05$). The ice water test could not predict the detrusor response in the low compliance bladder group (false positive rate: 73%) as in the regular patients with neurogenic bladder.

We concluded that all measures should be tried to avoid the occurrence of low compliance bladder and ice water test seemed to be not appropriate for prediction of the detrusor reflex in patients with low compliance bladder. (J Rehab Med Assoc ROC 1997; 25(1): 41-49)

Key words: compliance, lower motor neuron, ice water test, neurogenic bladder

INTRODUCTION

Patients with neurogenic bladder have long been known to be at risk for damage to the upper urinary tract [1]. This complication is still a common cause of morbidity and mortality of such patients, although there have been some recent progress in the management of neurogenic bladder dysfunction, including clean intermittent self-catheterization (CIC), bladder augmentation and artificial urinary sphincter [2-5]. Risk factors of damage to upper urinary tract consist of impaired bladder emptying, high bladder pressure, increased outflow resistance from sphincter dyssynergia or a fixed urethral resistance, bladder deformity, vesicoureteral reflux (VU reflux) and low compliance bladder [6-8].

Compliance as a parameter of bladder function has been noted recently. McGuire et al described the development of low vesical compliance that places the upper urinary tract at increased risk [6]. Hackler and associates also found that 64% of spinal cord injury (SCI)

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patients with low compliance bladder had hydronephrosis, and 46% of them had VU reflux [8]. Similar clinical observations were made here, creating a desire for further understanding of low compliance bladder.

Ice water test, introduced by Ernest Bors, has been used to detect the autonomous reflex of urinary bladder for a long time [9-10]. Although this test had high sensitivity and specificity in evaluation of detrusor reflex in patients with neurogenic bladder, its accuracy of predicting detrusor reflex in patients with low compliance bladder has not been evaluated before and doubted by some clinical observation [11].

The aim of this study was to determine the prevalence, urodynamic characteristics, clinical manifes-tations and possible risk factors of low compliance bladder. We also attempted to evaluate the prediction power of ice water test in detecting the detrusor activity in patients with low compliance bladder.

MATERIALS AND METHOD

Subjects

We reviewed the results of urodynamic study of 431 patients with neurogenic bladder who had been admitted to this Department or referred from other Departments from September, 1991 to June, 1994. Among them, 66 patients with detrusor areflexia, but no history of over-distended bladder, were enrolled in this study. The reason to exclude patients with history of over-distended bladder was that this kind of bladder dysfunction reflected transient bladder status after some episode of overdistension or spinal shock. This dysfunction could not manifest the last and steady state of ones' bladder. The 66 patients were divided into two groups, low compliance bladder group and lower motor neuron type neurogenic bladder group, according to the results of urodynamic study (Table 1, Fig. 1, and Fig. 2). Of these 66 subjects, 34 subjects (7.9%) had low compliance bladder and 32 subjects (7.4%) had lower motor neuron type neurogenic bladder. Fourteen patients (7 with low compliance bladder and 7 with lower motor neuron type neurogenic bladder) were excluded later due to absence of abdominal pressure tracing during examination.

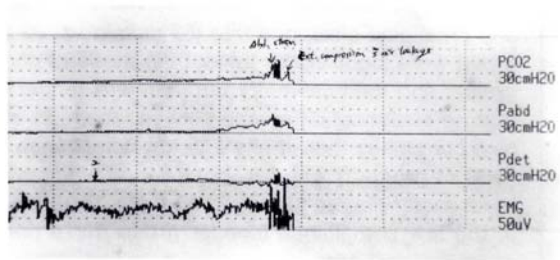


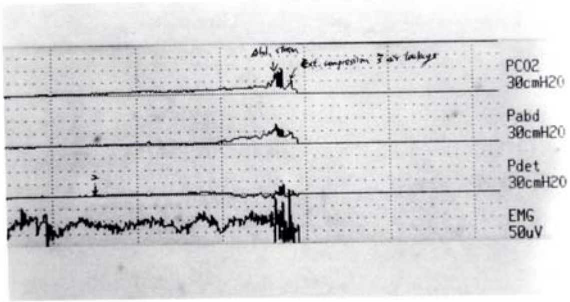
Fig. 1. This is a urodynamic result of low compliance bladder. 50 ml/min CO_2 gas was infused into the bladder via 14F indwelling catheter. Pressure curve of detrusor was somewhat linear in shape, and the detrusor pressure at the point of 100 ml bladder volume was 31 cm-H_2O (greater than 5 cm- H_2O at 100 ml bladder capacity)

Another 9 patients (2 with low compliance bladder and 7

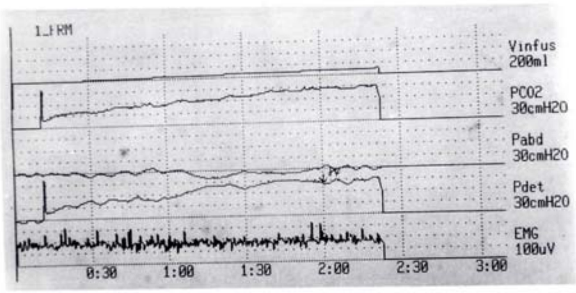
Table 1. Urodynamic characteristics of low compliance bladder and lower motor neuron type neurogenic bladder

	Detrusor pressure at 100 cc bladder volume	Detrusor pressure response before supersensitivity test	Supersensitivity test
Low compliance bladder	> 5 cm-H_2O	no prominent detrusor response	Negative
LMN bladder	<5 cm-H_2O, near 0, or 0 through the whole examination course	no prominent detrusor response	Positive

LMN : lower motor neuron type neurogenic bladder; Supersensitivity test : positive - after subcutaneous injection of bethanecol (dose : 0.035 mg/kg), detrusor pressure is 15 cm-H_2O higher than that before bethanecol injection at 150 cc bladder volume[12], negative : the elevation of detrusor pressure less than 15 cm-H_2O after subcutaneous injection of bethanecol



(a)



(b)

Fig. 2. This is a urodynamic result of lower motor neuron type neurogenic bladder. 100 ml/min CO_2 gas was infused into the bladder via 14F indwelling catheter. (a) There was no detrusor response through the entire examination course before the bethanecol supersensitivity test. (b) Detrusor response appeared after subcutaneous injection of bethanecol.

with lower motor neuron type neurogenic bladder) were excluded for incomplete clinical history. Finally, 43 patients, 25 cases with low compliance bladder (Group 1) and 18 cases with lower motor neuron type neurogenic bladder (Group 2), were studied.

Among these individuals with low compliance bladder, underlying diseases included SCI, cerebral vascular accident (CVA), cervical cancer treated with radical hysterectomy, L5-S1 herniated disc, Parkinson's disease and multiple sclerosis. The underlying diseases of patients in group 2 included SCI and L5-S1 herniated disc (Table 2). The neurological level of SCI was defined according to the criteria of The American Spinal Injury Association [12].

Clinical information

The subjects underwent a series of interventions, including history taking, physical examination, neurological examination, blood chemistry study, urinary analysis, urine culture, creatinine clearance rate (CCr), imaging studies (voiding cystourethrography and excretory urography), and cystometric examination. The frequency of symptomatic urinary tract infection (UTI) in the past three years was recorded. The diagnosis of symptomatic UTI included positive urine culture ($>10^5$ colony counts per ml urine) and any one of the following symptoms which were defined by Stover [13] : fever, leukocytes in the urine generated by the mucosal lining, hematuria, onset of urinary incontinence, autonomic hyperreflexia, cloudy urine with increased odor, discomfort or pain over the kidney or bladder or during micturition, malaise, lethargy, sense of unease, increased spasticity and leukocytosis.

Ice water test

Twenty-seven of 43 patients received the ice water test which was performed within three days before cystometric examination as part of our evaluation. Ninety milliliters of 0°C sterile saline was infused into the bladder via 14 F decuffed indwelling catheter first and any response within 1 minute after infusion was observed. If the catheter was expelled or water leaked along the catheter within 1 minute after infusion, the responses were graded as 3＋and 2＋ respectively. If no response happened 1 minute after infusion, another 210 ml of 0°C sterile saline was introduced into the bladder, and observed for another 5 minutes. Any change mentioned above as 1＋ and no response was － [10-11].

Urodynamic study

DANTEC UD5500 was used to evaluate bladder condition. The bladder of all subjects was filled with CO_2 gas via a 14 F indwelling catheter at 50 or 100 ml/min until air leakage happened or patients felt uncomfortably full. Bladder capacity was determined by air leakage, uncomfortable complaint without detrusor contraction or when 500 ml of sterile saline had been infused. Compliance (change in volume divided by change in pressure , $\triangle V/\triangle P$) was calculated at the point of 100 cc

Table 2. Subjects information

	Group 1	Group 2
No.	25	18
Female	11	7
Male	14	11
Age (years old)	48±20 (8~86)	42±20 (15~78)
Duration after injury (months)	52±55 (1~192)	42±64 (1~204)
Causes		
CVA	2	0
SCI	18	16
C4~C6	2	0
T1~T12	10	0
L1~L5	4	12
S1~S5	0	4
Cauda Equina Syndrome	2	0
Cervical cancer	2	0
Multiple sclerosis	1	1
Parkinson's disease	1	0
L5-S1 herniated disc	1	1
Voiding methods		
Cystostomy	5	0
Indwelling catheter	2	0
Self intermittent catheterization	3	0
Crede's maneuver	8	7
Abdominal strain	3	8
Spontaneous	2	1
Suprapubic tapping	2	0
Unknown	0	2
CCr (ml/min)	53±19*	83±27*
Sphincter pressure (cm-H2O)	49±23	44±16
Bladder capacity (ml)	280±140*	420±110*
Frequency of UTI (times/person)	1.2±1.9	0.4±0.6

Group 1 : patients with low compliance bladder, Group 2 : patients with lower motor neuron type neurogenic bladder, CVA : cerebral vascular accident, SCI : spinal cord injury, *: $P<0.05$

bladder volume. The diagnostic criteria of low compliance bladder used are listed below : (1) compliance of 20 or less at 100 cc volume (in other words, the pressure had to be 5 cm-H2O or more at 100 cc volume) and, (2) more or less linear bladder pressure curve, thereby maintaining low compliance at higher volume (Fig. 1) [9]. Lower motor neuron type neurogenic bladder was diagnosed when the detrusor did not contract during procedure or after infusion of 500 ml of sterile saline, but contracted at 150 ml bladder volume after subcutaneous bethanecol (Urecholine®, dose: 0.035 mg/kg) supersensitivity test (Fig. 2) [14]. Age, duration after injury, frequency of symptomatic UTI and results of intervention, including CCr, bladder capacity, and sphincter pressure were analyzed by Student's t-test. The incidence between low compliance bladder and instrumentation and changes of upper urinary tract were analyzed by chi-square test.

RESULTS

There were no significant differences in average age and duration after injury between patients with low compliance bladder and those with lower motor neuron type neurogenic bladder. (Table 2).

Renal function and frequency of symptomatic UTI

The CCr value (53±19 ml/min) in low compliance group (Group 1) was significantly lower than that (83±27 ml/min) in the lower motor neuron type neurogenic bladder (Group 2). The frequency of UTI rate (1.2±1.9 times/person) in group 1 had no significant difference from that (0.4±0.6 times/person) in group 2 (Table 2).

Ratio and duration of instrumentation

The frequency of instrumentation, including cystostomy and indwelling catheter in group 1 was 28% and zero in group 2 (P < 0.01). The average duration of instrumentation was 46±60 months.

Imaging studies

Eight patients (32%) with low compliance bladder had abnormalities in upper urinary tract, while there was no morphological changes in patients with lower motor neuron type neurogenic bladder. In these eight patients, four had dilated lower ureter or hydronephrosis (16%), and four had VU reflux (16%). The result of the chi-square test revealed that the development of upper urinary tract changes occurred significantly more often in patients with low compliance bladder and less in patients with lower motor neuron type neurogenic bladder (P<0.05). Voiding methods were different in these eight patients : one had received long term indwelling catheter, three had cystostomy, two performed self-intermittent catheteriza-tion program and the other two used abdominal strain, or Crede's maneuver to void.

Eight patients with upper tract changes had significant lower CCr (50±18 ml/min vs. 83±27 ml/min), smaller bladder capacity (271±138 ml vs. 420±110 ml) and higher frequency of symptomatic UTI (1.6±2.3 times/person vs. 0.4±0.6) than patients in group 2 (P<0.05). The duration after injury in patients with upper urinary tract changes tended to be longer than that for patients without changes (72±57 months vs. 42±64 months). They also had significant higher instrumentation rate (50%) than those without changes in group 2 (0%) (P<0.05).

Urodynamic findings

The average compliance in group 1 was 7.1±4.0 ml/cm-H_2O at the point of 100 cc bladder volume. No definite compliance data was available in group 2 owing to the zero pressure (or almost zero) at 100 cc bladder volume. The average bladder capacity in group 1 was 280±140 ml which was significantly lower than that of group 2. In contrast to bladder capacity, there was no significant difference of maximal urethral sphincter pressure between them. (Table 2).

Ice water test

Fifteen patients in group 1 and 12 patients in group 2 received ice water test.. The false positive rate (73%) in group 1 was higher than that (20%) of group 2 (Table 3).

DISCUSSION

The ratio of a change in bladder volume to the associated change in pressure determines bladder compliance. However, there is no clear-cut data that differentiate normal from low compliance bladder.

Table 3. Results of ice water test

	Positive	Negative	Negative Predictive Value	False positive rate
Group 1	11	4	27%	73%
Group 2	1	11	91%	9%

Positive : result of ice water test was positive (1+~3+)
Negative : no response to ice water test

Abrams believed that a bladder pressure at 3.3 cm- H_2O or less at 100 ml volume, i.e. compliance greater than 30.3 ml/cm- H_2O would represent normal compliance [15]. McGuire stated that bladder pressure should not exceed 6 cm- H_2O before detrusor contraction [16]. Gotoh proposed that a bladder compliance of 10 ml/cm-H_2O as the lower limit of the normal range [17]. To assure that a patient had a low compliance bladder, compliance of 20 ml/cm- H_2O or less at 100 ml bladder volume was considered as low compliance bladder in our study. In other words, the pressure had to be 5 cm- H_2O or more at 100ml bladder volume [8].

Mechanisms to develop low compliance bladder

According to previous studies, almost all SCI patients with low compliance bladder dysfunction had injury level at the sacral cord level [6,8,18,19]. In contrast to previous studies, almost all our SCI patients with low compliance bladder had suprasacral cord lesions. We postulated that patients with higher cord lesion had more severe spastic bladder, which then induced more hypertrophied smooth muscle and resulted in smaller bladder capacity after a longer period of time. Finally, low compliance bladder developed.

The percentage of instrumentation was also significantly higher in patients with low compliance bladder than those with lower motor neuron type neurogenic bladder. Patients who received instrumentation emptied their bladders more frequently, so bladder capacity became smaller and smaller due to no chance to distend bladder. Instrumentation might contribute partly to the development of low compliance bladder.

Chronic urinary retention and high frequency of UTI are common causes for inducing fibrosis of bladder smooth muscle [20,21]. Stott and Abrams found an increased connective tissue amount in spina bifida patients who had low compliance bladder. They also mentioned the strong correlation between the amount of connective tissue and bladder compliance according to the results of histologic and cystometric examination [21]. The findings might support the theory that low compliance bladder may develop secondary to fibrosis and smooth muscle hypertrophy, but further study is necessary. However, our study could not find the relationship between the occurrence of low compliance bladder dysfunction and frequency of symptomatic UTI. The reason was probably due to the underestimation of the frequency of symptomatic UTI, because patients did not visit doctor every time when they had problems.

The other hypothesis for low compliance bladder is parasympathetic decentralization [6,18,19]. Parasympathetic neural injury can reverse the usual β-adrenergic receptor response (smooth muscle relaxation) to α-adrenergic effect (smooth muscle contraction) [22]. Ghoniem and his colleagues demonstrated increased collagen as well as smooth muscle hyperplasia and hypertrophy in dogs after bilateral sacral decentralization [20]. In our study, The development of low compliance bladder dysfunction in two patients with radical hysterectomies for cervical cancer, two patients with cauda equina syndrome, and one patient with L5-S1 herniated disc could probably be explained by parasympathetic decentralization.

Upper urinary tract changes

Stott and Abrams noted that 40% of the spina bifida patients with low compliance bladder had upper urinary tract changes [20]. McGuire et al detected reflux in 15 of 22 (68%) patients with low compliance bladder and Hackler detected reflux in 39 of 84 (46%) renal units of those who had similar bladder dysfunction [6,8]. In this series, 8 of 25 patients (32%) with low compliance bladder had upper urinary tract changes and 4 of 25 (16%) had VU reflux in comparison with absence of morphological changes in patients with lower motor neuron group. Belman described the frequency of symptomatic UTI might relate to the upper urinary tract changes [23]. The frequency of symptomatic UTI did not differ significantly between our two groups in this study. We found those with upper urinary tract changes in group 1 had higher frequency of symptomatic UTI than those without upper urinary tract changes in group 2. Thus, low bladder compliance and frequency of symptomatic UTI was considered to be common causes of upper urinary tract changes.

In the study of Styles et al, patients without dilated upper urinary tract had higher glomerular filtration rate (92.8 ± 20 ml/min/1.73m^2) than that (40.9 ± 23 ml/min/1.73m^2) of patients with dilated upper tract [21]. CCr is a helpful and convenient tool to evaluate renal function clinically, so CCr was adopted instead of glomerular filtration rate to evaluate renal function. The findings (50±18 ml/min versus 83±27 ml/min) were compatible with the results of Styles et al [24]. VU reflux, which may happen under the conditions of small bladder capacity and higher vesical outlet pressure, was supposed to cause functional deterioration and morphological changes in upper urinary tract [6]. UTI may induce further deterioration of upper urinary tract, but results of the study could not prove the assumption. Further detailed evaluation of this problem is necessary. Patients with low bladder compliance may develop VU reflux and UTI easily, so their renal function is also impaired easily.

To avoid further renal deterioration, adequate emptying to maintain low intravesical pressure is necessary. Eight patients with upper tract changes used different methods to empty their bladders. One patient with long term indwelling catheter, and two patients with cystostomy immediately after injury, had upper tract changes. Instrumentation, as our previous discussion seemed to be a factor associated with low bladder compliance, so bladder training with CIC program to empty bladder is recommended.

Ice water test

Fall et al. discovered that there were cold receptors in human urinary bladder. Ice water test induced detrusor response by stimulation of the cold receptors and the stimulation was transmitted to conus medullaris via C fiber. He also found that the test could differentiate the upper from lower motor neuron type neurogenic bladder dysfunction [25]. The ice water test, modified by Balmaseda et al, has long been a convenient way to evaluate detrusor reflex at bedside.[10] This clinical tool had high sensitivity (96%) ,high specificity (79%), and high positive predictive rate (89%). False positive rate was 21% in the same study. Three of four patients who revealed false positive results had low compliance bladder [11]. Fifteen patients with low compliance bladder underwent this test in the past three years, and the false positive rate reached as high as 73%. It was considered that the average bladder capacity in this kind of patient was smaller than 300 ml, so the false positive result could be explained as a kind of overflow incontinence.

In conclusion, fibrosis, hypertrophy of bladder smooth muscle, and parasympathetic decentralization may cause low compliance bladder dysfunction. All of the above can happen easily on patients with suprasacral cord lesion instead of sacral cord lesion. Instrumentation may also contribute to the development of low compliance bladder dysfunction. Patients with low compliance bladder dysfunction have greater chance of renal impairment. Urinary tract infection may further deteriorate renal function. Since this is not a prospective study, more evidence is necessary. CIC program or other bladder training instead of long-term instrumentation to maintain bladder capacity, adequate bladder emptying and reduce the frequency of urinary tract infection were recommended. The chance to develop low compliance bladder will probably be reduced after adequate bladder management. Ice water test as a helpful tool to evaluate detrusor reflex at bedside is not appropriate for this kind of neurogenic bladder dysfunction.

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彈性不良膀胱的臨床意義及危險因子

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為瞭解彈性不良膀胱(low compliance bladder)的盛行率，及其對上泌尿道的影響，我們在過去 3 年中對 431 位病人進行尿動力學檢查。34 位(7.9%)具彈性不良膀胱病變的病人為實驗組，32 位具下運動神經元神經性膀胱(lower motor neuron type neurogenic bladder)病變的病人作為控制組。實驗組病人的容積(280ml vs. 420ml; P<0.05)及肌肝酸廓清率(53ml vs. 83ml; P<0.05)均較控制組低，並具有統計上的意義。實驗組病人尿道感染機會較高，且脊髓損傷後的時間也較長，但並未達到統計上的意義。與以前一些研究不同的是，脊髓損傷病人中以高位損傷患者出現彈性不良膀胱的比率較高。8 位(32%)彈性不良膀胱的病人併有上泌尿道病變，與控制組比較，有統計上的意義(P<0.05)。運用冰水測試來預測彈性不良膀胱病人逼尿肌反應的偽陽性比率為 73%，故不宜用來預測此類病人的逼尿肌反應。

我們建議應利用各種方法來避免彈性不良膀胱的發生，而冰水測試不宜用來預測彈性不良膀胱病人的逼尿肌反應。（中華復健醫誌 1997; 25(1): 41 - 49）

關鍵字：彈性(compliance)，下運動神經元(lower motor neuron)，冰水測試 (ice water test)，神經性膀胱(neurogenic bladder)

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