



Weakness of the Pelvic Floor Muscle and Bladder Neck Is Predicted by a Slight Rise in Abdominal Pressure During Bladder Filling: A Video Urodynamic Study in Children

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Purpose: To investigate the significance of slowly rising abdominal pressure (SRAP), which is often observed in nonneurogenic children during bladder filling in video urodynamic studies (VUDS).

Methods: The records of patients who underwent VUDS from July 2011 to June 2013 were reviewed. SRAP was defined as a rising curve over 5 cm H₂O from the baseline abdominal pressure during the filling phase in VUDS. Bladder descent was defined when the base of the bladder was below the upper line of the pubic symphysis. An open bladder neck was defined as the opening of the bladder neck during the filling phase.

Results: Of the 488 patients, 285 were male patients. The mean age at VUDS was 3.7 years (range, 0.2–17.6 years). The VUDS findings were as follows: SRAP, 20.7% (101 of 488); descending bladder, 14.8% (72 of 488); and bladder neck opening, 4.3% (21 of 488). Of the 72 patients with a descending bladder, 84.7% had SRAP. A significant difference in the presence of SRAP was found between the descending bladder and the normal bladder ($P < 0.001$). Of the 101 patients with SRAP, 40 (39.6%) did not have a descending bladder. Of the 40 patients, 14 (35.0%) had a bladder neck opening, which was a high incidence compared with the 4.3% in all subjects ($P < 0.001$).

Conclusions: SRAP was associated with a descending bladder or a bladder neck opening, suggesting that SRAP is a compensatory response to urinary incontinence. SRAP may also predict decreased function of the bladder neck or pelvic floor muscle.

Keywords: Urodynamics; Pelvic Floor; Urinary Bladder; Urology; Child

- **Research Ethics:** The Institutional Review Board of Yonsei University of College of Medicine approved our study protocol (approval number: 4-2014-0470).
- **Conflict of Interest:** No potential conflict of interest relevant to this article was reported.

INTRODUCTION

A slight rise in abdominal pressure (SRAP) during filling cystometry is often observed in children. Irregular wave-like abdominal pressures (Pabd) have also been observed in neurogenic bladders with impacted rectums [1]. Unlike these uneven

pressure alterations, the authors also found a gradual and slight increase in Pabd during cystometry. However, the significance and interpretation of SRAP are still unknown.

An increase in Pabd was thought to be a consequence of a posterior positional change in the bladder filling due to decreased pelvic floor support in myelomeningocele (MMC) [2].

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However, because that study only evaluated patients with MMC, it is difficult to apply its significance in relation to increases in Pabd to that of SRAP in nonneurogenic children. Evaluating the function of pelvic floor support by visual inspection and digital rectal examination is another limitation. Therefore, the significance and interpretation of SRAP in nonneurogenic bladder need to be evaluated.

In addition, bladder descent and open bladder neck were observed on radiological evaluations in patients with urinary incontinence [3-5]. However, urinary incontinence not caused by detrusor overactivity is known as a symptom of decreased pelvic floor support. Video urodynamic study (VUDS) is particularly useful when anatomic structure and function are assessed [6]. Thus, the purpose of this study was to investigate the significance of SRAP during the filling phase by analyzing VUDSs.

MATERIALS AND METHODS

Subjects

From July 2011 to June 2013, we retrospectively reviewed the consecutive medical records of 1,108 patients who underwent VUDS. We excluded patients with neurological abnormalities such as MMC, lipomyelomeningocele, and spinal cord injury, and those with anatomical abnormalities such as posterior urethral valves, anterior urethral valves, and ureterocele. We included 488 cases in this study. The 488 subjects had either refractory overactive bladder (OAB) or vesicoureteral reflux. With the parents', guardians', and/or patients' consent, those with refractory OAB underwent VUDS to diagnose the etiology. Those with vesicoureteral reflux underwent VUDS instead of voiding cystourethrography for postsurgery follow-up examination.

Video Urodynamic Study

Invasive urodynamic investigations during the filling and emptying phases were performed according to the International Children's Continence Society's standardizations [7]. We used 6-Fr double-lumen catheters for the urethra and 12-Fr fluid-filled balloon catheters for the rectum. After insertion of the urethral catheter, the residual urine volume was assessed. A saline solution was warmed to body temperature and mixed with a contrast medium for infusion at filling rates of 5%–10% of a known or predicted capacity. The expected bladder capacity was estimated by using the following formula (in mL): $[30 + (\text{age in years} \times 30)]$. For infants, the following formula was used (in mL): $(7 \times \text{weight in kilogram})$ [8]. Patients had a bowel

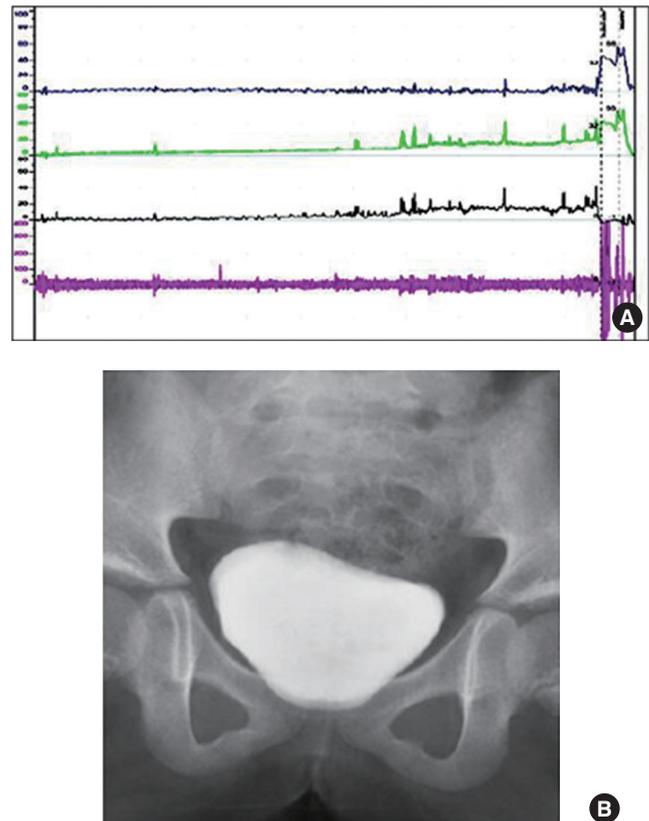


Fig. 1. Video urodynamic study of an 8.4-year-old girl. She complained of urinary urgency and urge incontinence. (A) Cystometric graph showing a slight rise in abdominal pressure. The first line represents the detrusor pressure; the second line, the vesical pressure; and the third line, the abdominal pressure. The black solid line shows the start of voiding. (B) Fluoroscopic image showing bladder descent.

clean-out before the VUDS.

The VUDS was performed at a dedicated unit, on a fluoroscopy table. The patients were in the supine position and were not under anesthesia during the examination. They were repositioned temporarily when the oblique position was needed. The bladder was viewed on fluoroscopy before and during filling, and during and after voiding.

Definitions of Terminology

SRAP was defined as the gradual rising curve over 5 cm H₂O from the initial Pabd during the filling phase (Figs. 1A, 2A). When the patient moved or cried, we took the line of each base of the Pabd. Bladder descent was defined when the base of the bladder was below the superior margin of the pubic symphysis on fluoroscopy [9] (Fig. 1B). An open bladder neck was defined

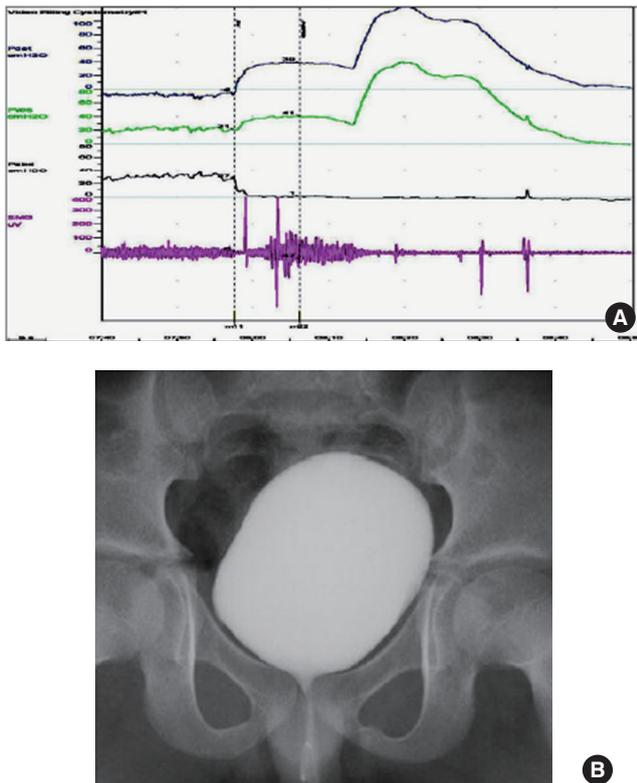


Fig. 2. Video urodynamic study of a 6.2-year-old-boy. He complained of urinary urgency and urge incontinence. (A) Cystometric graph showing a slight rise in abdominal pressure. The first line represents the detrusor pressure; the second line, the vesical pressure; and the third line, the abdominal pressure. The black solid line shows the start of voiding. The graph was expanded to show the front and rear of the start of voiding. (B) Fluoroscopic image showing open bladder neck when idiopathic detrusor overactivity did not occur.

as an opening of the bladder neck during the filling phase on fluoroscopy without idiopathic detrusor overactivity (Fig. 2B). The relationship between SRAP on cystometry and the phenomenon on fluoroscopy was analyzed. OAB was defined as having an urgency with or without urinary incontinence.

Statistical Analysis

IBM SPSS ver. 18.0 (IBM Co., Armonk, NY, USA) was used for the statistical analysis. Independent-sample t-test, and chi-square analysis, including the Fisher exact test and linear-by-linear association, were performed. A P-value less than 0.05 was considered statistically significant.

Good Clinical Practice Protocol

The Institutional Review Board of Yonsei University of College

Table 1. Patient characteristics (n = 488)

Characteristic	SRAP (n = 101)	NAP (n = 387)	P-value
Sex			< 0.001
Male	38 (37.6)	247 (63.8)	
Female	63 (62.4)	140 (36.2)	
Age (yr)	6.74 ± 3.34	2.89 ± 2.40	< 0.001
Bladder descent			< 0.001
Yes	61 (60.4)	11 (2.8)	
No	40 (39.6)	376 (97.2)	
Bladder neck			< 0.001
Open	14 (13.9)	7 (1.8)	
Close	87 (86.1)	380 (98.2)	

Values are presented as number (%) or mean ± standard deviation. SRAP, slight rise in abdominal pressure; NAP, no rise in abdominal pressure.

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RESULTS

Of the 488 patients, 203 (41.6%) were females and 285 (58.4%) were males. Their ages ranged from 0.2 to 17.6 years (mean, 3.7 years). The VUDS findings were as follows: SRAP, 101 patients (20.7%); bladder descent, 72 (14.8%); and open bladder neck, 21 (4.3%) (Table 1).

Of the 101 patients with SRAP, 63 (62.4%) were females and 38 (37.6%) were males. A significant difference in the presence of SRAP was observed between the sexes ($P < 0.001$). Of the 72 patients with a descent bladder, 48 were females (66.7%) and 24 were males (33.3%). The presence of a descent bladder also showed a significant difference between the sexes ($P < 0.001$). The female patients tended to have a SRAP and descending bladder more than the male patients. However, the incidence of an open bladder neck did not differ between the sexes ($P = 0.50$).

The age range of the subjects with a SRAP was 0.9–17.6 years (mean, 6.74 ± 3.34 years). The age range of the subjects with no rise in their Pabd was 0.2–16.6 years (mean, 2.89 ± 2.40 years), and this difference was significant ($P < 0.001$). Two subjects aged < 2 years had a SRAP, and another two subjects aged < 2 years had a descending bladder (Table 2).

Of the 72 patients with a bladder descent, 61 (84.7%) had SRAP. A significant difference in the presence of SRAP was observed between the patients with a bladder descent and those with normally positioned bladders ($P < 0.001$). Of the 101 patients with a SRAP, 40 did not have a bladder descent. Of the 40

Table 2. Age-related characteristic depending on classification of videourodynamic study findings

Variable	No. (%)	Age (yr), mean ± SD	P-value
Abdominal pressure			< 0.001
SRAP	101 (20.7)	6.74 ± 3.34	
NAP	387 (79.3)	2.89 ± 2.40	
Bladder descent			< 0.001
Yes	72 (14.8)	6.38 ± 3.55	
No	416 (85.2)	3.22 ± 2.69	
Opened bladder neck			< 0.001
Yes	21 (4.3)	6.67 ± 2.56	
No	467 (95.7)	3.55 ± 3.00	

SD, standard deviation; SRAP, slight rise in abdominal pressure; NAP, no rise in abdominal pressure.

subjects, 14 (35.0%) had an open bladder neck. This percentage was high compared with the 4.3% of the total subjects. A significant difference in the presence of SRAP was found between an open bladder neck and a closed bladder neck ($P < 0.001$).

To evaluate the clinical outcomes of the patients with SRAP, we analyzed the characteristics of SRAP according to the presence of OAB (Table 3). Of the 488 patients, 181 were able to complete the questionnaire about voiding and defecation symptoms. Of the 181 patients, 120 were females. The age range was 2.4–17.6 years (mean, 6.6 years). Of the 139 patients with OAB symptoms, 77 (55.4%) had SRAP. In particular, of the OAB patients without involuntary detrusor contraction (IDC), 55 (84.6%) had SRAP. A significant difference was observed between the OAB symptoms and the presence of IDC in 98 patients without SRAP ($P < 0.001$). However, no significant difference was observed in 83 patients with SRAP ($P = 1.00$).

DISCUSSION

A regular gradual rise in vesical pressure (Pves) and Pabd without a change in detrusor pressure (Pdet) was observed on cystometry in children. Low compliance showing a gradual rise in the Pdet and Pves was not observed. SRAP showed a gradual rise before voiding and differed from the phenomenon caused by rectal contraction [1]. However, the significance of SRAP on cystometry in children is unknown. In the cystometry of children with MMC, SRAP occurrence was caused by bladder filling in the decreased pelvic floor support group [2]. Confirming the function of the pelvic floor support by visual examination alone was difficult. However, Gundogdu et al. [2] determined decreased pelvic floor support by performing rectal digital ex-

Table 3. Characteristic of SRAP depending on OAB symptoms

OAB	Total	SRAP	NAP
Yes (n = 139)			
IDC			
Yes	74 (53.2)	22 (29.7)	52 (70.3)
No	65 (46.8)	55 (84.6)	10 (15.4)
Total	139 (100)	77 (55.4)	62 (44.6)
No (n = 42)			
IDC			
Yes	11 (26.2)	1 (9.1)	10 (90.9)
No	31 (73.8)	5 (16.1)	26 (83.9)
Total	42 (100)	6 (14.3)	36 (85.7)

Values are presented as number (%).

SRAP, slight rise in abdominal pressure; OAB, overactive bladder; NAP, no rise in abdominal pressure; IDC, involuntary detrusor contraction.

amination alone and in nonneurogenic bladders, although a decreased rectal tone confirmed by digital rectal examination was rare, SRAP was often observed. Therefore, the significance and interpretation of SRAP needs to be studied further.

Some theories relating to the maintenance of continence suggest that a supporting structure to resist the downward pressure was essential to preserve continence [10–12]. For example, according to Hammock hypothesis, when intra-abdominal pressure increases during a cough or the Valsalva maneuver, the urethra is compressed against the supporting structures, which acts like a backboard and prevents loss of urine. When the supporting structures fail, rotational descent of the bladder neck and proximal urethra can occur. However, if this supporting layer establishes its stability, continence may still be preserved [10]. The supporting structures (i.e., the pelvic floor support) presented in Hammock theory include the levator ani muscle complex, arcus tendineus fascia pelvis, endopelvic fascia, and pubocervical fascia.

Kuo [9] found that in patients with stress urinary incontinence, the mean bladder neck descent was significantly reduced during stress compared with that at rest. After pelvic floor muscle training, the bladder neck elevation was significantly greater than at baseline [9]. Thus, pelvic floor muscle training can cause stability of the rotational descent surrounding the bladder neck and proximal urethra. On the other hand, if the pelvic floor support is weak, rotational descent surrounding the bladder neck and proximal urethra may occur.

In this study, SRAP during the filling phase was significantly associated with weak pelvic floor support (i.e., bladder descent and an open bladder neck). The authors detected that SRAP can compensate for urinary incontinence. Of the OAB patients

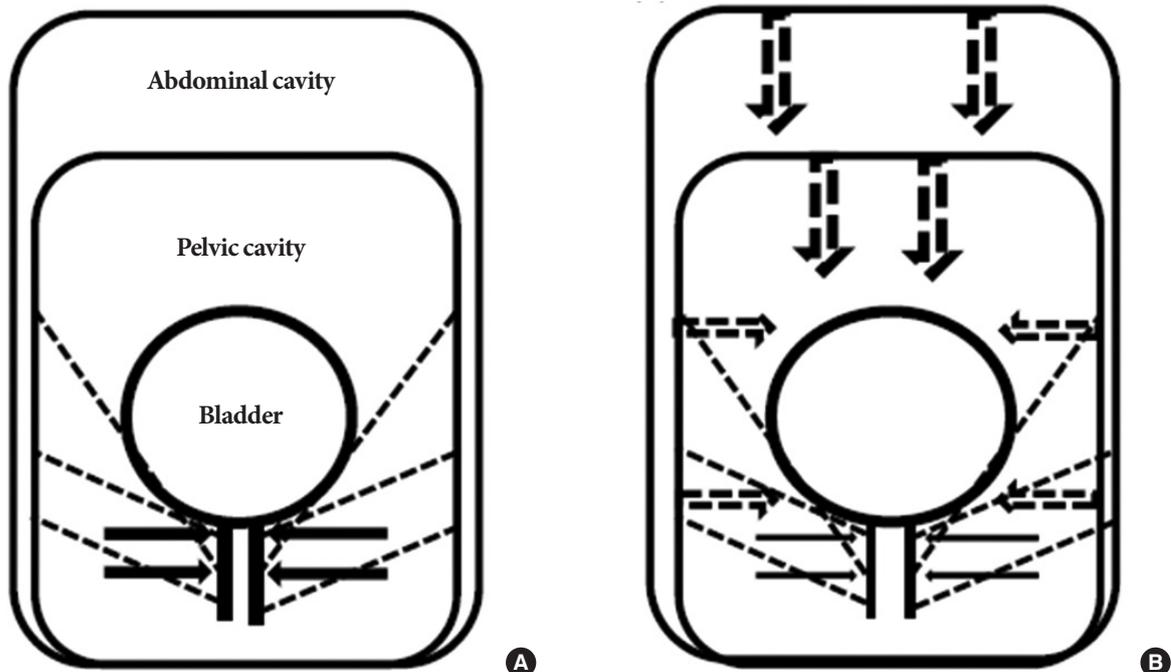


Fig. 3. Analogy demonstrating the compensation for decreased pelvic floor support in order to resist the downward pressure. (A) Under normal pelvic floor support (thick unbroken arrows), the reservoir function of the bladder is maintained by well-functioning sphincter and abdominal muscle relax. (B) Under weak pelvic floor support (thin unbroken arrows), the weak sphincter function is compensated by the increasing tension (thin double broken arrows) of the circumferential muscles, fasciae, and ligaments connecting to the pelvic floor (thin dotted line). This process manifests as tightness of the pelvic floor and a slight rise in abdominal pressure.

without IDC, 84.6% had SRAP. This result suggests that decreased pelvic floor muscle function represented by SRAP may cause pediatric OAB, aside from IDC. The evidence for this hypothesis is evident in the feature of SRAP in this study, which differs from that in the MMC group. In the MMC group, when the bladder was emptied and the recording was continued, Pabd gradually reached the initial value. However, although the features of SRAP in both studies were similar during the filling phase, they differed after the filling phase. The black dotted line on Fig. 1 represents the amount of time that the subject was permitted to void. After the subject was allowed to void, the Pabd immediately reached its initial value, and the urine stream started simultaneously. The interpretation that SRAP was a consequence of a posterior positional change in neurogenic bladders cannot be applied to nonneurogenic bladders. If the interpretation of SRAP in the MMC group was applied to this study during the voiding phase, the Pabd should gradually reach the initial value. However, in this study, the Pabd sharply decreased.

Based on the differences in the features of SRAP, we found that SRAP was a compensatory response to the decreased pel-

vic floor support in order to resist the downward pressure. A child with decreased pelvic floor support could not contract the sphincter effectively. Therefore, electromyography could not be performed when patients withhold urination. These patients may pull circumferential muscles and fascia-connected pelvic floor support, including the pubourethral ligament and pubococcygeus muscle, to tighten the pelvic floor support (Fig. 3). For example, to quote the integral theory [11], a weak pubourethral ligament causes the sling of the proximal urethra in the pubococcygeus muscle to soften. Then, the urethra opens. To prevent incontinence occurring as a result of that phenomenon, patients may try to tighten the pubourethral ligament involuntarily. Thus, the force that pull inwardly the whole abdominal wall above the pubis is needed to tighten the pubourethral ligament. We think that the action of pulling like the force make occur SRAP. In other words, SRAP occurs when children learn these compensatory mechanisms. Therefore, intra-abdominal pressure gradually increases during the filling phase and then decreases to the initial value immediately after the voiding phase starts. In this study, two subjects aged <2 years had SRAP. The current guideline for toilet training suggests that

most healthy children are developmentally ready to begin toilet training between the ages of 18–24 months [13,14]. Yang et al. [15] suggest that early toilet training for urine was associated with early attainment of both daytime and nighttime urinary continence. A prospective study suggested that initiating toilet training after 24 months is associated with problems in attaining and maintaining bladder control [16]. In addition, this study on toilet training suggested that the age for initiating toilet training is approximately 2 years. Therefore, we think that the difference in the presence of SRAP between the ages was significant because when children learn bladder control, SRAP occurs owing to the aforementioned compensatory mechanisms.

The retrospective nature of this study is a limitation. However, this study contains valuable analysis because it is the first study on SRAP in children with nonneurogenic bladders. We think that a further study on the relationship between SRAP and the voiding symptoms needs to be conducted to confirm the significance of SRAP. In addition, a study on the spontaneous results of SRAP should be performed to interpret SRAP more clearly. Thus, we plan to conduct further studies by using abdominal electromyography after performing VUDS to prove the phenomenon of SRAP. In addition, we plan to study the changes in OAB symptoms after pelvic floor muscle training in these patients.

In conclusion, SRAP is an obvious phenomenon in children with weak pelvic floor support (i.e., bladder descent and an open bladder neck), suggesting that SRAP is a compensatory factor for urinary incontinence. Therefore, this study suggests that SRAP may help predict decreased bladder neck and pelvic floor muscle functions.

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