

Six-month Postoperative Urodynamic  
Score: A Potential Predictor of  
Long-Term Bladder Function after  
Detethering for Lipomyelomeningocele

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Directed by Professor Sang Won Han

The Master's Thesis  
submitted to the Department of Medicine,  
the Graduate School of Yonsei University  
in partial fulfillment of the requirements for the degree  
of Master of Medical Science

Sang Woon Kim

December 2013

This certifies that the Master's Thesis of

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December 2013

## ACKNOWLEDGEMENTS

First of all, I would like to thank my thesis supervisor, Prof. Sang Won Han as my mentor who has been most supportive to me finishing my Master's thesis. His advice and guidance have always been great encouragement for me.

I also appreciate Prof. Dong Seok Kim, Prof. Hyun Woo Kim who gave me expert advice. I thank Prof. Jang Hwan Kim for his bright ideas and encouragement and all members of our department for their assistance and supports.

And I thank my family, my parents and brother from the bottom of my heart for great their support and love being with me always.

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## ABSTRACT

### Six-month Postoperative Urodynamic Score: A Potential Predictor of Long-Term Bladder Function after Detethering for Lipomyelomeningocele

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#### **Purpose**

An increasing number of asymptomatic children are diagnosed with occult spinal dysraphism, raising the question of their optimal management. The urologic outcomes after detethering operation in patients with lipomeningomyelocele(LMMC) are controversial because of the absence of objective tools for evaluating urodynamic results. We evaluated the changes of urodynamic parameters after detethering operation based on previously introduced urodynamic score system.

#### **Patients and Method**

From January 2005 to March 2011, 148 patients with LMMC underwent detethering surgery in our hospital; of these, 44 who had preoperative and postoperative UD data and a minimum follow-up period of 2 years were included in this study. Patients were excluded if they had prior anorectal surgery or impaired bladder function requiring clean intermittent catheterization. All included patients underwent video UD



study preoperatively and within 6 months after surgery.

### **Results**

The mean age at operation was 38 months and mean follow-up duration was 57.25 months. The total UD score at 6 months postoperatively was higher than preoperatively (5.61 vs. 4.43,  $p=0.033$ ) and remained at a similar value during follow-up. The 16 patients who required no treatment at last follow-up had a significantly lower 6-month postoperative total UD score than patients with urologic symptoms requiring treatment (2.88 vs. 7.18,  $p<0.001$ ). The difference in UD scores between these two groups became more prominent over time. The total UD score at 6-month follow-up accurately predicted the presence of urologic symptoms at last follow up by regression analysis (hazard ratio, 16.484; 95% confidence interval, 1.814-149.802;  $p=0.013$ ).

### **Conclusion**

Six-month postoperative UD scores accurately predicted the presence of urologic symptoms during long-term follow-up and may be an important predictor of long-term urologic outcomes after detethering surgery.

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Key words : Urodynamics, Lipomeningomyelocele, Detethering

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## **I. INTRODUCTION**

Tethered cord syndrome is a neurologic disorder caused by abnormal fixation of the spinal cord that results in traction of the spinal cord during development<sup>1</sup>. It can lead to various neurologic symptoms, including weakness, gait disturbances, pain, and urologic dysfunction. Lipomyelomeningocele (LMMC) is the most common cause of primary tethered cord syndrome.

The natural history of LMMC includes a high likelihood of progression. Although no neurologic deficit may be evident at birth, lower extremity pain and motor dysfunction often become manifest during early infancy and puberty, when rapid lengthening of the spinal cord occurs. The symptoms caused by spinal cord injury include not only motor and sensory impairment of the lower extremities, but also dysfunction of the gastrointestinal and lower urinary tracts<sup>2-4</sup>.

Although there are several reports on the urologic outcomes of detethering the results are controversial<sup>5-7</sup>. Moreover, few studies have

evaluated changes in urodynamic parameters after detethering<sup>7-9</sup>. Since LMMC is usually diagnosed at an early age, the evaluation of specific symptoms associated with LMMC is difficult. Urodynamic (UD) studies are an objective tool for evaluating the urologic function of individuals with LMMC<sup>10</sup>. Because of difficulties in interpreting UD results, Meyrat et al<sup>11</sup> introduced a multi-parameter UD scoring system. In the current study, we assessed whether this UD scoring system is an accurate reflection of urologic symptoms and evaluated urologic function during long-term follow-up after detethering surgery for patients with LMMC.

## **II. MATERIALS AND METHODS**

### **1. Patients Selection**

From January 2005 to March 2011, 148 patients underwent primary detethering surgery at our hospital. Of these, 17 patients were excluded due to the lack of preoperative or postoperative UD study. Children with other than LMMC including myelomeningocele were excluded. 26 patients who had anorectal surgery for a congenital anomaly, including an imperforate anus or a cloacal anomaly, were also excluded. 33 patients without long-term follow up UD study (at least 2 years) were excluded. Totally, 44 patients with pathologically confirmed LMMC were included in this study.

### **2. Urodynamic Study Score**

We used the UD scoring system previously described by Meyrat et al<sup>11</sup>. This system is composed of four parameters: bladder volume, bladder compliance, detrusor activity, and vesicosphincter synergy. Each parameter is graded by the degree of deviation from normal.

Bladder volume was measured when the child began to urinate or demonstrated discomfort suggesting the need to urinate. The volume was expressed on a scale of 0 to 5, based on the percentage of the normal value for the child's age. Grade 0 signified a normal bladder volume, whereas 5 represented a bladder volume less than 20% of normal.

Bladder compliance was calculated by dividing the incremental change in bladder volume by the incremental change in intravesical pressure. It was graded on a scale of 0 to 4, with Grade 0 representing normal compliance and Grade 4 signifying a compliance of less than 10 mL/cmH<sub>2</sub>O.

Bladder contraction was defined as an increase in detrusor pressure of more than 2 cmH<sub>2</sub>O above the resting value, and a high amplitude contraction (HAC) was defined as an increase in detrusor pressure of more than 15 cmH<sub>2</sub>O. Detrusor activity was graded from 0 to 5 based on the frequency and the force of detrusor contractions during the entire bladder filling phase.

Vesicosphincteric synergy was graded from 0 to 3, where Grade 0 referred to synergic sphincter action during voiding and Grade 3 signified continuous dyssynergia, with crescendo-decrescendo activity of the external sphincter together with detrusor activity.

The scores for these four parameters were summed to generate the total score, ranging from a lowest possible score of 0 to a maximum possible score of 17. The scores (total and for each parameter) before and after surgery were compared. A UD score ranging 0 to 4 was suggested as normal and UD scorer of 5 to 6 should raise the question of an underlying urological disorder. UD score above 6 was regarded as abnormal<sup>11</sup>.

### **3. Clinical Symptoms**

Clinical symptoms were reviewed to evaluate clinical status of the patients. Information on urinary frequency, incontinence, febrile urinary tract infections, and other voiding problems were obtained by interviewing the parents.

### **4. Statistical Analysis**

Data are expressed as mean  $\pm$  standard deviation (SD). Variables and UD

scores of the two groups were compared using unpaired Student t-tests. Paired Student t-tests were used to compare the UD scores at different time points. A p value <0.05 was considered statistically significant. All statistical analyses were performed with statistical package SPSSP for Windows (Version 20, SPSS, Chicago, IL)

### **5. Good Clinical Practice Protocols**

The study was performed in accordance with all applicable laws and regulations, good clinical practices, and ethical principles as described in the Declaration of Helsinki. The Institutional Review Board of our hospital approved the study protocol (Approval number: 4-2013-0521).

### III. RESULTS

Of the 44 patients included in this study, 18 were male and 26 were female (Table 1). The mean age at operation was 38.0 months (range, 2-384 months) and the mean follow-up duration was 57.3 months (range, 26-200). In 30 patients, the diagnosis of LMMC was made during the first year of life.

Of the 17 patients with preoperative symptoms (including clubfoot, urinary incontinence, weakness of lower extremities, and constipation), 15 had urologic symptoms requiring treatment during long-term follow-up. Two children with UD scores of 5 and 10 at the last follow-up video UD study underwent repeat surgery for re-tethering of the spinal cord at 3 and 4 years, respectively, after the primary detethering procedure.

**Table 1. Preoperative patient characteristics**

	No. of Pts (%)
Diagnosis	
Thickened filum terminale	7
Lumbar lesion	24
Lumbosacral lesion	13
Sex	
M	18 (40.9%)
F	26 (59.1%)
Symptomatic patients (%)	17 (38.6%)
Urologic	13 (29.5%)
Musculoskeletal	13 (29.5%)
Age at operation (months)	38.00±77.22 (range 2 to 384)
Mean follow up duration (months)	57.25±20.65 (range 26 to 100)

The mean preoperative total UD score was 4.43 for the entire group of patients (range, 0-13) (Table 2). The mean total UD score at 6 months postoperatively increased to 5.61 (range, 0-12), which was significantly higher than the preoperative score ( $p=0.033$ ). The detrusor activity score was significantly higher at the 6-month follow-up than preoperatively ( $p=0.008$ ), but the other parameters did not change significantly. At the last follow-up, the mean total UD and detrusor activity scores remained higher than preoperatively ( $p=0.026$  and  $p=0.031$ , respectively). The bladder compliance score at last follow-up was also higher than preoperatively, but the difference did not achieve statistical significance ( $p=0.06$ ).

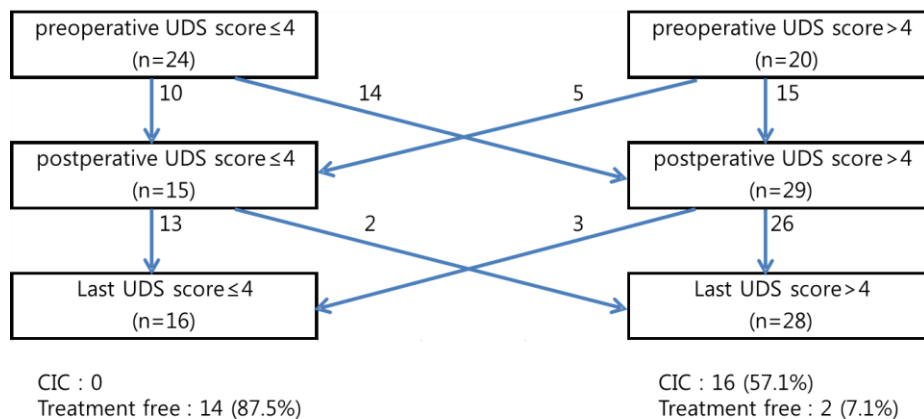


**Table 2. Comparison of urodynamic scores before and after detethering operation**

	Preop	Postop 6month	Last follow up
Bladder volume	0.84±1.28	0.82±1.30	1.16±1.38
P value		0.901(vs preop)	0.095(vs preop) 0.083 (vs 6mon)
Detrusor contraction	1.95±1.95	2.95±1.92	2.86±2.26
P value		0.008(vs preop)*	0.031(vs preop)* 0.795(vs 6mon)
Vesicosphincteric synergy	0.86±1.05	1.02±1.17	0.68±1.18
P value		0.391(vs preop)	0.430(vs preop) 0.038(vs 6mon)
Compliance	0.77±0.44	0.82±1.48	1.30±1.77
P value		0.839(vs preop)	0.060(vs preop) 0.057(vs 6mon)
Total UDS score	4.43±3.57	5.61±2.71	6.00±4.012
P value		0.033(vs preop)*	0.026(vs preop)* 0.438(vs 6mon)

The patients also analyzed based on a preoperative total UD score of 4 or less versus a score greater than 4 (Figure 1). Of the 24 patients with a preoperative total UD score  $\leq 4$ , 10 patients (41.7%) maintained a total UD score  $\leq 4$  at 6 months after detethering surgery and 14 (58.3%) showed an increase in total UD score to  $>4$ . Of the 20 patients with a preoperative total UD score over 4, 15 (75%) had a total UD score of  $>4$

or more at 6 months after detethering, whereas five (25%) showed a reduction in the total UD score to  $\leq 4$ . However, the total score for each patient was relatively consistent between the 6-month postoperative and the last follow-up.



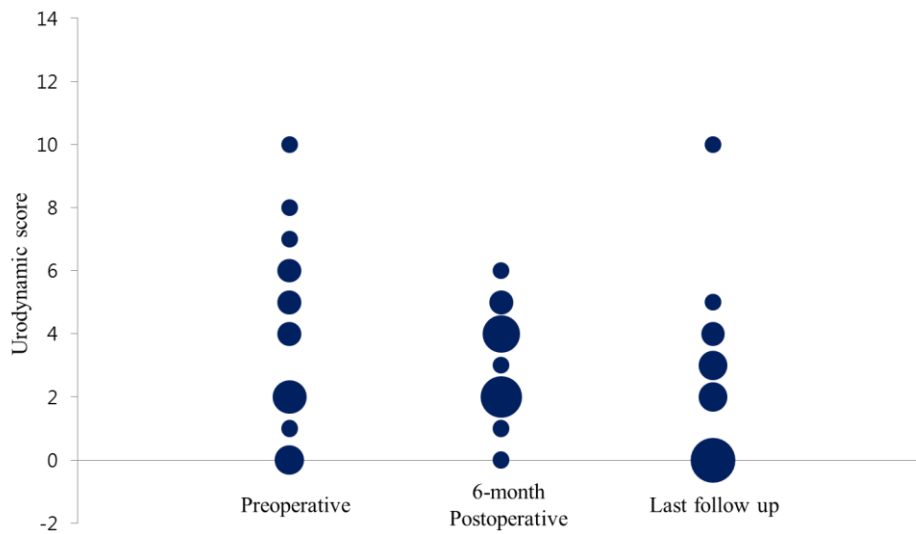
**Figure 1. Changes in urodynamic study scores after detethering for patients with a preoperative score of 4 or less and those with a preoperative score greater than 4.**

Sixteen patients had no urinary symptoms and did not require further intervention or treatment at last follow-up; these patients were assigned to the treatment-free group and were compared with 28 patients presenting urologic symptoms including urinary urgency, incontinence, straining and others which required further treatment (Table 3).

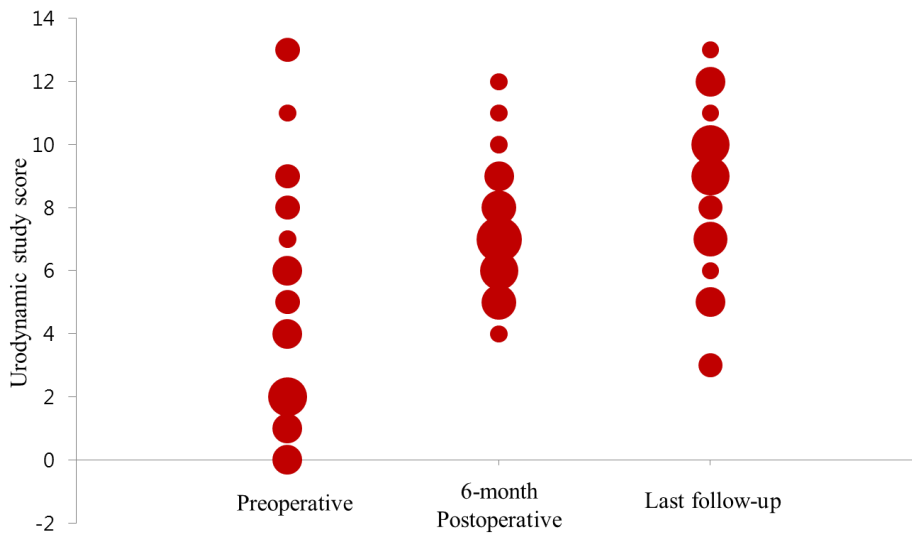
**Table 3. Comparison of urodynamic scores between non treatment and treatment group during follow up period**

	Treatment-free(n=16)	Treatment(v=28)	p value
Age at operation (months)	12.38±21.50	52.64±92.88	0.036*
Sex (M : F)	4:12	14:14	0.125
Presence of Preop Symptom (%)	2 (12.5%)	15 (53.6%)	0.010*
Follow up periods (months)	52.06±20.31	60.21±20.62	0.212
Preop UDS total	3.50±2.88	4.96±3.85	0.193
Bladder volume	0.56±0.96	1.00±1.41	0.231
Detrusor contraction	1.69±1.92	2.11±1.99	0.499
Vesicosphincteric synergy	0.81±1.11	0.89±1.03	0.810
Compliance	0.44±1.21	0.96±1.64	0.232
Postop 6month UDS	2.88±1.46	7.18±1.89	<0.001*
Bladder volume	0.69±1.25	0.89±1.34	0.620
Detrusor contraction	1.25±1.24	3.93±1.51	<0.001*
Vesicosphincteric synergy	0.63±0.89	1.25±1.27	0.062
Compliance	0.31±0.79	1.11±1.71	0.042*
Last UDS	2.25±2.72	8.29±2.73	<0.001*
Bladder volume	0.56±0.96	1.50±1.48	0.015*
Detrusor contraction	1.25±2.02	3.93±1.70	<0.001*
Vesicosphincteric synergy	0.25±0.68	0.93±1.33	0.031*
Compliance	0.19±0.75	1.93±1.88	<0.001*

The preoperative UD scores did not differ between the treatment and treatment-free groups; however, the mean age at the time of operation and the percentage of patients with preoperative symptoms were both higher in the treatment group. The total UD score and detrusor activity and bladder compliance scores at 6 months postoperatively were significantly higher in the treatment group (Table 3, Figure 2). Among the parameter scores, detrusor activity showed the greatest difference between groups. The differences in UD scores between the two groups were greatest at the last follow-up.



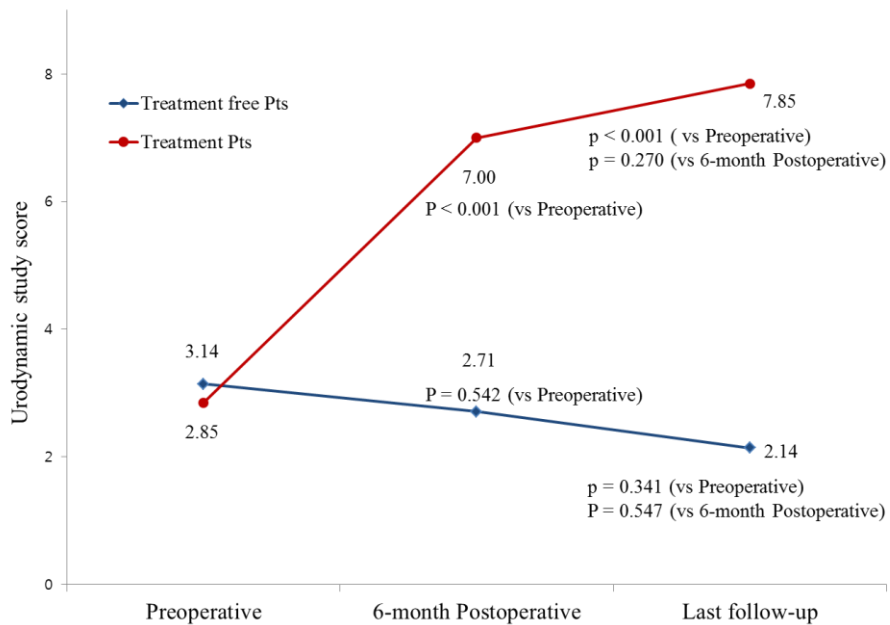
### 1) Treatment-free group



### 1) Treatment group

**Figure 2. Distribution of total urodynamic (UD) scores preoperatively and during follow-up**

Of 27 preoperatively asymptomatic patients, 14 showed favorable urologic outcome requiring no treatment at last follow up, and 13 presented urologic symptoms requiring treatment. The mean age at the time of operation was not different between two groups (6.50 vs. 4.85 months,  $p=0.483$ ). The preoperative UD scores between two groups were not different; however, the 6-month postoperative UD scores in the treatment group were significantly increased, whereas they were relatively stable in treatment-free group (Figure 3).



**Figure 3. Changes in total urodynamic (UD) scores during follow-up in preoperatively asymptomatic patients**

Sixteen patients with deterioration of the total UD score during long-term follow-up required CIC. The preoperative and 6-month postoperative total UD score were significantly worse in the CIC group (6.19 vs. 3.43,  $p = 0.030$ ; 7.56 vs. 4.50,  $p < 0.001$ , respectively) and the differences between the two groups became more significant with longer follow up time (9.50 vs. 4.14,  $p < 0.001$ ), particularly for detrusor activity and compliance (4.19 vs. 2.25,  $p < 0.001$ ; 3.00 vs. 0.32, respectively,  $p < 0.001$ ). Univariate regression analysis revealed that a higher total UD score at 6-month follow-up was associated with a higher likelihood of urinary symptoms at last follow up (hazard ratio, 16.484; 95% confidence interval, 1.814-149.802;  $p = 0.013$ ). The cut-off point of total UD score for predicting urinary symptoms at long-term follow-up was approximately 4.5 (sensitivity, 0.929; specificity, 0.875).

#### **IV. DISCUSSION**

The urologic outcomes of detethering surgery are difficult to characterize because most patients with LMMC are diagnosed at younger than 1 year of age and the clinical manifestations are often not obvious. Although UD study is considered the most objective method of detecting neuro-urologic dysfunction related to LMMC, the results of UD after detethering in patients with LMMC are difficult to interpret because of inconsistencies in UD parameters between examinations and problems related to integrating these parameters. As long-term outcomes have important clinical implications, a valid scoring system integrating the results of multiple UD parameters is necessary to objectively document outcomes.

Early UD scoring systems did not undergo external validation to verify their effectiveness<sup>12,13</sup>. The UD scoring system used in this study was developed by Meyrat et al<sup>11</sup>. It has been reported to be useful for monitoring children with LMMC<sup>14</sup> and improved scores after detethering surgery have been documented in 86% and 55% of patients who were preoperatively asymptomatic and symptomatic, respectively. However, it is difficult to define how these scores relate to improvement or deterioration of function because the clinical implications of score changes have not been established.

Several investigators have reported improved UD parameters after detethering surgery<sup>15,16</sup>. On the contrary, a recent study demonstrated that none of preoperative studies including UD study correlated with the clinical urologic outcome after detethering surgery<sup>8</sup>. Our results also suggested that preoperative UD study is not correlated with the long-term



urologic outcome. This lack of correlation between preoperative and postoperative UD results may be attributed to difficulties in performing UD study and interpreting the results in infants. Furthermore, except for retethering of cord, symptomatic deterioration after detethering has been reported in several reports, although the time to deterioration vary<sup>17</sup>. To our knowledge, it is unclear whether postoperative urological deterioration during long-term follow up is because of underlying myelodysplasia or neurological injury including some vascular damage during surgery.

However, patients with favorable urologic outcome at long-term follow up, defined as the absence of urologic symptoms requiring treatment or intervention, exhibited slightly lower UD scores at 6 months after detethering and further improvement was seen with subsequent follow-up. In contrast, patients with unfavorable urologic outcome had higher UD scores at 6 months postoperatively, which tended to increase over time. These results are in agreement with previous study reporting that the long-term outcome of preoperatively symptomatic patients depended on immediately postoperative functional results<sup>18</sup> and also suggest that the 6-month postoperative UD score could be a significant predictive factor for long-term urologic outcomes.

In a previous report, total UD scores of 4 or less were considered normal, scores of 5 to 6 were considered uncertain, and scores of 7 or higher were considered abnormal<sup>11</sup>. In our study, patients with total UD scores of 4 or less exhibited favorable urologic function at last follow up, whereas most patients with scores of 5 or higher had urologic symptoms requiring treatment. Based on receiver operating characteristics (ROC) analysis,

the total UD score at long-term follow-up accurately reflected the presence of clinical symptoms, and the cut-off point was approximately 4.5 (AUC 0.925).

It has been suggested that abnormal preoperative musculoskeletal symptoms and lipomatous dysraphism, rather than abnormal preoperative UD findings, are correlated with urological problems after tethered cord release<sup>8</sup>. Tseng et al demonstrated that age less than 2 years and lipomas of the filum terminale were prognostic factors for improved symptoms in patients with symptomatic spina bifida occulta<sup>19</sup>. Nevertheless, a definitive prognostic factor for predicting long-term urologic outcome has not yet been established. In accordance with previous reports, patients in our current study with preoperative symptoms showed unfavorable urologic outcomes at long-term follow-up: of the 17 patients with preoperative symptoms, 15 required treatment postoperatively and 11 required CIC. An older age at the time of surgery was also a preoperative factor predictive of an unfavorable urologic outcome (the need for urologic treatment) during long-term follow-up. In addition, patients with increased preoperative UD score tended to present deteriorated urologic function requiring CIC. Patients diagnosed with filum terminale had slightly better long-term urologic outcomes after detethering: three required treatment and four were treatment-free. However, the significance of this is uncertain because of the small number of patients with filum terminale in this study.

The surgical indication of detethering surgery in asymptomatic patients is controversial. Traditionally, detethering has been performed only when upper motor neuron symptoms become evident because of the possibility

of nerve damage and other risks associated with performing this surgery in infants<sup>20-22</sup>. However, Keating et al<sup>23</sup> reported that neonates or infants (mean age, 8.7 months) were more likely to revert to normal urodynamic findings (6 of 10 patients) than older children (mean age, 11.7 years; 3 of 11 patients) and other studies have supported the safety of detethering surgery in infants<sup>18,24</sup>. The practice at our institution is to perform detethering surgery before overt evidence of a neurologic disorder to prevent neurologic deterioration. Most children younger than 12 months are not continent, prohibiting the detection of neurologic dysfunction based on urologic symptoms alone; if one waits until neuro-urologic symptoms become evident, undetected neurologic damage may progress while the children appear to be asymptomatic. This study cannot determine the value of detethering surgery in asymptomatic patients since we don't have a control group. However, 8 of 27 (29.6%) preoperatively asymptomatic patients presented UD score >4 in preoperative UD studies. These results imply that undetected neuro-urologic dysfunction might exist in asymptomatic patients although the clinical implication is unknown.

One limitation of this study was the difficulty of grading vesicosphincteric synergy because the UD results were reviewed retrospectively. Electromyography is not sensitive enough to detect all sphincteric contractions during the filling phase in small children and many children will voluntarily contract their perineal musculature when voiding with a catheter in place or under stressful situations<sup>13</sup>. Another limitation was the insufficient and heterogeneous follow-up period. However, considering that almost all urologic deterioration occurring

after detethering surgery was seen within the 60-month follow up period<sup>18</sup>, we think our data is quite reasonable.

## **V. CONCLUSION**

This study is an initial attempt to validate the Meyrat UD scoring system and provides a comprehensive evaluation of the course of urologic function after detethering surgery. UD scores were closely associated with urologic symptoms on long-term follow-up and UD score at 6 months after detethering surgery may be an important predictor of long-term urologic outcome.

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ABSTRACT (IN KOREAN)

수술 후 6개월에 시행하는 요류역동학 점수; 지방척수수막류  
탈견인 수술 후 장기적인 방광 기능의 예측인자

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소아에서 무증상의 잠재 척추 과열증으로 진단되는 환자들이 늘어감에 따라 그들에 이에 대한 최선의 치료에 대한 논의가 중요해지고 있다. 지방척수수막류 환자에서 탈견인 수술 후 추적 검사의 대표적 방법인 요류역동학 검사를 통합적으로 해석하는 객관적인 지표가 없기 때문에 수술 후 비뇨기과적 결과에 대해 논란이 있다. 이에 탈견인 수술 후 요역동학적 검사의 변화를 이전에 소개되었던 요역동학 검사 점수 시스템을 이용하여 알아보하고자 한다.

2005년 1월부터 2011년 3월까지 총 148명의 환자가 지방척수수막류로 본원 신경외과에서 탈견인 수술을 시행받았다. 그 중 수술 전과 후 본원에서 요역동학 검사를 시행받았던 44명의 환자를 대상으로 하였다. 최소 추적 관찰 기간은 2년 이상으로 하였으며 항문, 직장의 기형으로 수술을 받은 환자는

제외하였다. 탈견인 수술 전 이미 방광기능의 저하를 보였던 환자를 제외하였으며 탈견인 수술 후 6개월 내에 술 후 검사를 시행하였다.

요역동학 검사 점수 체계는 방광 용적, 유순도, 배뇨근 활동성, 방광괄약근 조화의 4개 지표로 구성이 되어 있다. 탈견인 수술 직후 시행한 요역동학 검사에서 다른 지표들은 큰 변화를 보이지 않았으나 배뇨근 활동성의 평균 점수는 상승했으며( $1.95 \pm 1.95$  vs  $2.95 \pm 1.92$ ,  $p=0.008$ ) 총 점수 또한 상승하였다 ( $4.43 \pm 3.57$  vs  $5.61 \pm 2.71$ ,  $p=0.033$ ). 장기 추적 관찰하여 현재 치료를 요하지 않는 환자(16명)들은 수술 후 6개월 내에 시행한 요역동학 검사 점수가 치료를 요하는 환자들에 비하여 유의미하게 낮았으며 ( $2.88 \pm 1.46$  vs  $7.18 \pm 1.89$ ,  $p<0.001$ ) 이 차이는 시간이 경과함에 따라 더 확연해졌다. 회귀 분석을 시행하였을 때 요역동학 검사 점수 체계는 환자의 비뇨기과적 증상 유무를 비교적 정확하게 예측하였다( $HR=1.992$ ;  $95\% CI=1.353-2.933$ ,  $p<0.001$ ). 결론적으로 기존에 소개되었던 요역동학 검사 점수 체계는 탈견인 수술 후 환자의 비뇨기과적 증상 유무를 잘 예측할 수 있었으며, 수술 후 6개월 내에 시행하는 요역동학 검사의 결과가 장기적인 비뇨기과적 결과를 예측하는 데에 도움이 되었다.

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핵심되는 말 : 요역동학 검사, 지방척수수막류, 탈견인