

ORIGINAL ARTICLE

RELATIONSHIP BETWEEN URODYNAMIC PARAMETERS AND LEVEL OF SPINAL CORD INJURY

BADANIE ZALEŻNOŚCI MIĘDZY PARAMETRAMI BADANIA URODYNAMICZNEGO A POZIOMEM USZKODZENIA RDZENIA KRĘGOWEGO

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ABSTRACT

Introduction

Low back pain and comorbid afflictions influence negatively on the quality of life, postural control and gait. Facet joint syndrome is one of the causes of low back pain. Cryoablation is a minimal invasive percutaneous technique for zygapophysial joint syndrome.

Aim

The aim of the study was to investigate the effectiveness of the cryoablation in patients with chronic low back pain on pain, disability and spatiotemporal gait parameters in the course of facet joint syndrome.

Material and methods

The study included 19 patients (13 women, 7 men) with chronic low back and facet arthropathic changes in MRI, and with failure in conservative treatment. The evaluation was performed before and with one-month follow-up after cryoablation and included pain assessment (Numeric Rating Scale), the evaluation of functional state and disability (Revised Oswestry Low Back Pain Disability Index, Roland-Morris Disability Questionnaire) and an analysis of spatiotemporal gait parameters (treadmill).

Results

A significant improvement in pain, functioning and spatiotemporal gait parameters such as distance and the number of steps were found.

Conclusions

Cryoablation is an effective method for pain reduction in facet joint syndrome, which improves functioning and gait. Cryoanalgesia is a safe procedure for the treatment of low back pain related to facet joint syndrome if earlier conservative management failed.

Keywords: cryoablation, low back pain, functional assessment, gait.

STRESZCZENIE

Wstęp

Diagnostyka pęcherza neurogennego bazuje często w praktyce na subiektywnym badaniu neurologicznym, natomiast jego wyniki nie oddają faktycznego stanu i funkcji pęcherza

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moczowego. Na tej podstawie rozpoznanie pęcherza neurogennego może być mało precyzyjne i utrudnić w przyszłości dostosowanie odpowiedniej terapii dla pacjenta z danym poziomem uszkodzenia rdzenia kręgowego. Badanie urodynamiczne ujawnia różnice między poszczególnymi poziomami uszkodzenia rdzenia kręgowego.

Cel

Określenie różnic w parametrach badania urodynamicznego wśród grup pacjentów z różnymi poziomami uszkodzenia rdzenia kręgowego.

Materiały i metody

Analiza retrospektywna parametrów badań urodynamicznych: czucie cewki moczowej, czucie pęcherza moczowego, podatność wypieracza, maksymalna pojemność pęcherza moczowego, ciśnienie wypieracza pęcherza moczowego, nietrzymanie moczu, trudność w rozpoczęciu mikcji. Dokonano analizy statystycznej wyników 54 pacjentów z niekompletnym urazem rdzenia kręgowego hospitalizowanych na Oddziale Rehabilitacji Neurologicznej w latach 2010–2018.

Wyniki

Pacjenci z szyjnym uszkodzeniem rdzenia kręgowego wykazywali gorszą podatność pęcherza moczowego niż w grupie z uszkodzeniem na poziomie lędźwiowym ($p < 0,001$). Czucie cewki moczowej było znacząco częściej zachowane u pacjentów po lędźwiowym niż po szyjnym urazie rdzenia kręgowego ($p < 0,001$).

Wnioski

Poziom uszkodzenia rdzenia kręgowego istotnie wpływa na funkcje pęcherza moczowego. Badanie urodynamiczne powinno stanowić istotne narzędzie w codziennej praktyce diagnostyki i terapii pęcherza neurogennego.

Słowa kluczowe: uraz rdzenia kręgowego, pęcherz neurogenny, podatność wypieracza, badanie urodynamiczne, czucie cewki moczowej.

Introduction

The diagnosis of adult neurogenic lower urinary tract dysfunction (ANLUTD) is commonly based on ASIA (American Spinal Injury Association) Impairment Scale, which is neurological, subjective examination (Roberts *et al.*, 2017). Clinical findings might not correlate with the specific bladder dysfunction (Schurch *et al.*, 2003). Thus the clinical-based diagnosis of ANLUTD may not meet the needs of patient condition, which requires a dedicated therapy. One of the essential elements of micturition after SCI is to determine the cystometric capacity and bladder dysfunction.

Because of the this fact, we wanted to investigate if there is a relationship between the level of SCI and the parameters of urodynamic

study. To study this problem, we analyzed the results of the urodynamic study of patients, who were divided into 3 groups, according to their level of SCI: cervical, thoracic and lumbar. The parameters of interest were: urethral sensation, intravesical pressure, bladder compliance, detrusor overactivity, bladder sensation, maximum cystometric capacity, presence of hesitancy and incontinence. Statistical analysis of those parameters in regards to the level of SCI may bring new light on the ANLUTD in patients after SCI and would lead to new conclusions about its management. In contrast, other authors, who investigated the urodynamic patterns after SCI, did not provide information about

urethral sensation. In light of current findings, this information might be useful in the near future in applying new therapy based on electrical stimulation of urethra in order to provoke micturition on demand [3]. Similarly, in other publications are some information about residual volume of urine after micturition, but no information about maximum cystometric capacity after SCI, which is important in monitoring of deterioration in the anatomy of the bladder (for instance stretching due to bladder overflow). Additionally, other authors focus their research on a certain level of injury (i.e. only on cervical or lumbar) or divide patients in more specific groups (suprasacral C1-T12 or sacral L1-S5).

Aim of the study

The aim of the study is to investigate the relationship between the level of SCI and the urodynamic parameters. This article puts a light on urethral sensation and maximum cystometric capacity, in patients after SCI, which were mostly neglected by other authors till now. However, those two parameters might play a great role in monitoring and management of adult neurogenic lower urinary tract dysfunction.

Methods

Retrospective study, which analyzed 100 medical histories of patients who were admitted to the Neurological Rehabilitation Ward of the Rehabilitation Clinic in the Orthopedic-Rehabilitation Hospital in Poznan in years 2010–2018. Approval for the study was granted by the Medical Bioethics Committee by the Poznan University of Medical Sciences, nr 111/19. All patients considered for the study underwent routine testing: blood counts, urinalysis, urine culture, and sensitivity.

Inclusion criteria were: incomplete SCI, complete medical records, the results of the urodynamic study (conducted by the same urologist) by admission, urine culture test by admission.

Exclusion criteria were: patients with the complete spinal cord injury (because of a small group) without urodynamic study in medical documentation, without urine culture test, with bladder stones, foreign bodies, symptomatic urinary tract infection or other pathologies of the urinary tract, which may interfere with urodynamic study.

Eventually, 54 patients were enrolled in the study (12 women, 42 men). The incompleteness and level of SCI were diagnosed based on MRI, which was performed directly after the injury in Neurosurgery Ward or Trauma Center and neurological and neurophysiological examination with respective ASIA score. Urodynamic study were performed in a range of 55.4 to 133.8 days after the injury depending on the patient's condition. The statistical analysis of medical records of 54 patients with SCI (cervical – 18, thoracic – 21, lumbar – 15) has been made. Characteristics of the group were summarized in Table 1.

Urodynamic study

All data were obtained using the MMS Alfa 4T by the same urologist with use of an 8 Charr catheter. Cystometry was conducted with sterile 0.9% saline solution at room temperature. Filling was stopped when patients experienced strong need to void, continuous leakage occurred or intravesical pressure was 40 cm H₂O. Urethral sensation and the bladder-filling sensation was classified as preserved, partially preserved or absent. Bladder compliance was classified as normal or low. During urodynamic study following parameters were analyzed: urethral sensation, intravesical pressure, bladder compliance, detrusor overactivity, bladder sensation, maximum cystometric capacity presence of hesitancy and urinary incontinence.

Statistical analysis

All statistical analyses were performed with the use of Statistica software version 13.1 (StatSoft, Poland). Continuous variables were presented as mean values, standard

deviations, and median. The normality distribution was studied with the Shapiro-Wilk test. The nonparametric Kruskal-Wallis test was used to analyze differences between groups. Categorical variables were presented as an absolute number and relative frequencies. Chi-square test was used to test the differences. P-values less than 0.05 were considered statistically significant.

thoracic SCI (ThSCI) ($p=0.371$), but there is a significant difference between the groups CSCI together with ThSCI and lumbar SCI (LSCI) ($p<0.001$). Only 3 of 15 patients with LSCI have absent urethral sensation in comparison with group CSCI, where 12 of 18 patients and group ThSCI where 18 from 21 patients have absent urethral sensation.

Table 1. Demographic and clinical features of the patients.

	Total	C	Th	L	p
Number of patients	54	18	21	15	
Sex					
Men	42	15	18	9	0.147
Women	12	3	3	6	
Age (years)					
Average		42.3	50.4	39.3	0.148
Median		38.5	56	20	
Standard Deviation		11.5	19.5	26.9	
Barthel scale					
Average		0.8	3.3	7.6	0.148
Median		1	3	7	
Standard Deviation		0.4	1.7	3	
Time from injury to hospitalization (days)					
Average		145.2	27.3	95.6	0.148
Median		73.5	21	90	
Standard Deviation		190.5	17	84.7	
Time from injury to urodynamic evaluation (days)					
Average		129.2	55.4	133.8	0.148
Median		156	40	126	
Standard Deviation		78.2	40.2	80.4	
Duration of hospitalization (days)					
Average		106.4	87.5	37	< 0.001
Median		112	95	35	
Standard Deviation		13	24.3	10.7	
American Spinal Injury Impairment Scale					
A					0.999
B					
C					
D					

* Bold p values show significance.

Results

We summarized the results of the study in Table 2. The study was registered in Clinical Trials (number: NCT04231474).

Urethral sensation

We have found significant relationship between the level of SCI and urethral sensation ($p < 0.001$). Additional analyses showed that there are no significant differences between groups with cervical SCI (CSCI) and

Bladder compliance

The CSCI patients had the worse outcomes in regards to bladder compliance, indeed 50% of them have hypocompliant bladder, whereas in groups ThSCI and LSCI those percentages are 14.3% and 0% respectively.

Maximum cystometric capacity,

The average capacity of CSCI, ThSCI, and LSCI were 349.9 ml, 306.4 ml and 258.2 ml respectively. Statistical analysis revealed

Table 2. Comparison of urodynamic outcomes and treatment options in patients with cervical, thoracic and lumbar spinal cord injury.

	Total	C	Th	L	p
Urethra sensation					
preserved	9	0	0	9	
reduced	12	6	3	3	< 0.001
absent	33	12	18	3	
Intravesical pressure					
normal	9	3	3	3	
low	45	15	18	12	0.902
Bladder compliance					
high	42	9	18	15	
reduced	12	9	3	0	< 0.001
Detrusor overactivity					
no	28	9	13	6	
yes	26	9	8	9	0.423
Bladder sensation					
preserved	12	3	3	6	
reduced	12	6	3	3	0.177
absent	30	9	15	6	
Maximum cystometric capacity					
Average		349.9	306.4	258.2	
Median		322.5	300	172	0.028
Standard deviation		71.7	105.1	170.2	
Incontinence					
present		9	9	12	
absent		9	12	3	0.073
Voluntarily initiated micturition					
present		3	5	3	
absent		15	16	12	0.858
Catheterization					
Indwelling	46	18	16	12	
Intermittent	0	0	0	0	0.091
No catheterization	8	0	5	3	
Omnic prescription¹	27	9	6	12	0.01
Vesicare prescription¹	15	6	6	3	0.692

*Bold p values show significance. ¹prescribed after the urodynamic evaluation.

a significant difference between the groups ($p = 0.033$).

Incontinence

Although the p level = 0.073 it is worth noticing that half of the CSCI patients can control micturition and do not have incontinence in contrast with LSCI group, where able are only 20% of patients.

Hesitancy

Over 75% of patients in all groups are not able to initiate micturition.

Other parameters

There was no significant relationship between the level of SCI and intravesical pressure, detrusor overactivity, bladder sensation, hesitancy and incontinence.

Discussion

In our study we analyzed only those patients with C-L level of injury, thus DSD and spastic bladder would be expected in those patients. Our clinical experience with patients after SCI shows that it is not always possible to predict the manifestation of adult neurogenic lower urinary tract dysfunction (ANLUTD) after SCI basing solely on neurological investigation. This is due to different quantitative and qualitative character of dysfunction in regards to the level of injury. In the study of Sayilir *et al.* (2013), there were significant differences between the groups of patients with C1-C5 and C6-C8 level of injury. Study of Agrawal *et al.* (2015) also has presented differences in detrusor activity and presence of DSD among groups of patients with C, Th, L and S level of injury. None of the authors explained

the neurophysiology those phenomena, however, their findings have application in every-day practice, for instance in selection of proper urological treatment. This has motivated us to find relationships between the maximum cystometric capacity, bladder compliance, and the level of injury in cervical, thoracic and lumbar parts of the spine. Our results indicate the different characteristics of overactive detrusor and DSD in patients with upper motor neuron lesion on different levels of injury, what until now, was rarely described in the literature.

Bladder compliance

Bladder compliance is defined by the ratio of volume change (ΔV) to the change in detrusor pressure (ΔP_{det}) $c = \frac{\Delta V}{\Delta P_{det}}$. Bladder compliance is accepted as normal with detrusor pressure $\geq 20 \frac{\text{ml}}{\text{cm H}_2\text{O}}$ and bladder compliance can be described as low, when detrusor pressure is $< 20 \frac{\text{ml}}{\text{cm H}_2\text{O}}$ [7, 20]. The bladder filling process, during the urodynamic study, in groups Th and L proceeded smoothly and unperturbed, which means that the bladders of those patients distended during bladder filling under low pressure (high bladder compliance). On the contrary in group C, the bladder walls extended under high pressure, thus reduced bladder compliance was identified. Suha *et al.* [14] in their study on 121 patients with lumbar SCI found that 75.2% of patients had bladder with low compliance, but our findings do not match with their results. This can be explained by the differences in completeness of injury among patients. In study of Suha 45.9% of patients had complete SCI, whereas in our study those patients were excluded from research. In our study, 50% of patients with CSCI had low values of bladder compliance, while in the study of Sayilir *et al.* (2013) 76.5% of patients with upper CSCI (C1-C5) and 79.5% with lower CSCI (C6-C8) had hypocompliant bladder (however the difference was not statistically significant $p = 0.733$).

Maximum cystometric capacity

There was a significant relationship between the level of injury and maximum cystometric capacity, (MCC) ($p = 0.033$). The highest mean MCC was found in groups CSCI. The median value of maximum cystometric capacity, was the lowest in LSCI group ($V = 258.2 \text{ ml}$). A possible explanation for that can be the fact that with absent or decreased bladder sensation (common in C group) patients are not able to report the need for bladder-emptying during and bladder walls are overstretched, what results in high maximum cystometric capacity. On the contrary, groups with preserved bladder sensation can earlier report the need to void and thus can avoid excessive stretching of the bladder wall (Samson and Cardenas 2007). The initiation of the bladder training (its autonomic function), in the acute phase of injury, is based on periodically closed outlet of the catheter. The aim is the regulation of stored urine volume in the bladder and consequently maximum cystometric capacity, bladder compliance and detrusor activity. This allows to prepare the patient for micturition in acceptable for him conditions. The opening of the catheter and bladder emptying in this phase of patient-care depends on the patient's request (sensation of full bladder) or occurrence of vegetative symptoms preceding micturition (sweating, increase in blood pressure), which is characteristic for hyperreflexic bladder with DSD (upper motor neuron injury). The next stage of bladder training in clinical practice of Intensive Care Department of Orthopedic-Rehabilitation Hospital in Poznan is removal of the catheter and maintenance of micturition reflexes which depend on bladder sensation. However in some patients (Table 2) bladder sensation was absent. Due to this fact in those patients bladder training was unsuccessful. Our study shows that in group with cervical level of injury the patients have relatively high maximum cystometric capacity in comparison to other groups. This is a novelty and was not previously described in literature.

Urethral sensation

Another parameter, where a significant difference between the groups was found, is urethral sensation, which was mostly absent in patients with cervical level of injury. This observation was not described in previous articles of other authors who have investigated this subject. In our study, in group LSCI, 80% of patients had at least partially preserved urethral sensation, but only 20% of patients from the LSCI group can voluntarily initiate micturition. This suggests that patients with LSCI might have better chances in initiating micturition with the help of electrical stimulation, because of a mostly preserved function of afferent pudendal nerves. Bladder emptying and hesitancy is an everyday challenge, which has to face many patients after SCI. The method for bladder emptying is catheterization, which often inconvenient and causes complications (Nicole 2014, Zhang and Liao 2014). A desirable solution for this situation would be provoking micturition on demand when the patient would find it convenient and socially acceptable. At first, it may seem like a futuristic and unavailable option, but recent studies of some authors presented modest evidence of new possibilities of bladder management after SCI. To provoke sustained bladder contraction and micturition on-demand Yoo *et al.* (2011) stimulated with electrical impulses distal and proximal urethra in patients with SCI. Although the study was conducted on 7 participants, in 6 of those patients Yoo *et al.* evoked bladder contractions, monitored in urodynamic study. A similar study conducted by Woock *et al.* (2008), who have proven on an animal model, that by preserved urethral sensation, electrical stimulation of urethra allows at least partial bladder control. In their study, provoked bladder contractions in cats with dissected spinal cord have been achieved by electrical stimulation of urethra. McGee *et al.* (2017) conducted a study on 13 human males and 4 human females after suprasacral SCI. During urodynamic study, by the

electrical stimulation of proximal and distal urethra, they evoked bladder activation mediated by pudendal and pelvic afferents. Continuing studies in this subject may contribute to independency of SCI patients from catheterization and provocation of micturition on demand. Yet it is known that the density of the innervation in the bladder neck and proximal urethra and their proper function influence storage and voiding reflexes (Fowler *et al.*, 2008, AlSaleh *et al.*, 2018).

Catheterization

In the long-term management, clean intermittent catheterization (CIC) is preferable to indwelling Foley catheterization (IFC), as the second one leads more often to urinary tract infection (Karsenty and Cortos 2006) or upper urinary tract deterioration (Zhang and Liao 2014). The choice of the type of catheterization as bladder management depends on the sex, level of injury and thus maneuver abilities, costs, availability of catheters, personal motivation and potential complications (Karsenty and Corsos 2006). In the study comparing effects of these two types of catheterization of Suha *et al.*, 86.7% of patients with lumbar SCI experience emptying disorders ($p = 0.326$), but indwelling catheterization was prescribed to only 27.2% of patients (Suha and Ersotz 2015). In contrast, the range of percentage of patients who use IFC is from 2.9%–24% (Karsenty and Corsos 2006, Yildiz *et al.* 2014). In our study none of the patients used CIC, but only IFC if it was recommended. Reasons for this state remain unclear, possibly it is due to differences in costs of those bladder managements, experience or motivation of the patients. However, no analysis of this problem was conducted.

Limitations

One of the factors, which could influence the results is different time between the SCI incident and urodynamic study (Table 1). It is commonly acknowledged that stabilization

of neurological conditions after SCI occurs six months after the injury (Denis et al., 2018), but in case of our study it was not always possible due to patients' condition. Also the low number of patients and enrollment only patients with incomplete SCI is a significant limitation.

Conclusions

Bladder compliance: Bladder compliance was significantly higher in ThSCI and LSCI groups than in CSCI. **Urethral sensation:** In patients with preserved and partially preserved urethral sensation and also with hesitancy, it should be considered to conduct a study with application of electrical stimulation of the urethra to provoke micturition. **Maximum cystometric capacity:** Significant relationship between the maximum cystometric capacity and the level of SCI was found. Possible explanation for this result are differences in bladder sensation between the groups. Follow-up urodynamic study would deliver more information about the condition of adult neurogenic lower urinary tract dysfunction in patients after rehabilitation.

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