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REVIEW ARTICLE

SYSTEMATIC REVIEW OF URODYNAMIC EVALUATION IN PATIENTS AFTER SPINAL CORD INJURY

BADANIE URODYNAMICZE U PACJENTÓW PO URAZIE RDZENIA KRĘGOWEGO – ARTYKUŁ PRZEGLĄDOWY

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ABSTRACT

Introduction

The world-widely acknowledged method of diagnosing dysfunctions in the lower urinary tract is urodynamic study (UDS), however many of patients with adult neurogenic lower urinary tract dysfunction (ANLUTD) have not undergone this test or have been examined a couple of years after the spinal cord injury (SCI). Recent studies provide evidence of significance UDS in precise diagnosis and monitoring of ANLUTD.

Aim

The aim of this article is to analyze the value of UDS in the management of neurogenic bladder in patients after.

Material and methods

Research was performed on the databases Pubmed and Web of Science.

Results

Out of 2012 articles found by performing the above research procedure, 9 matched the inclusions criteria and were analyzed.

Discussion

One study showed significant differences in those groups regarding maximum cystometric capacity and volume at first involuntary contraction. Other authors proved significant differences in bladder function among groups with different C and L level of injuries. In follow up patients with maximum cystometric (MCC) capacity < 200 ml experienced significantly more often ($p = 0.019$) UUT deterioration than those with MCC ≥ 200 ml. In the study with annual UDS, 47.9% of the patients needed at least one type of intervention (in 82.6% of cases – urological interventions) basing on their UDS. None of those patients complained of new urological symptoms since their previous.

Conclusions

UDS should be performed as a standard examination in patients after SCI. Regular follow up UDS should be performed for prevention UUT deterioration.

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STRESZCZENIE

Wstęp

Szeroko uznaną metodą diagnostyki dysfunkcji dolnych dróg moczowych jest badanie urodynamiczne, jednakże niewielu pacjentów jest poddawanych temu badaniu lub następuje to po latach od urazu rdzenia kręgowego. Badania z ostatnich lat dostarczają dowodów na szczególne znaczenie badania urodynamicznego w szczegółowej diagnostyce i monitorowaniu pęcherza neurogennego.

Cel

Analiza znaczenia badania urodynamicznego w monitorowaniu i terapii pęcherza neurogennego.

Materiał i metody

Badanie zostało wykonane przy użyciu baz Pubmed i Web of Science.

Wyniki

Z 2012 artykułów otrzymanych za pomocą powyższej metody zakwalifikowano 9 zgodnie z kryteriami włączającymi.

Dyskusja

Jedno z badań wykazało istotne różnice pomiędzy grupami z różnymi poziomami uszkodzenia rdzenia kręgowego w maksymalnej objętości pęcherza moczowego. Inni autorzy wykazali istotne różnice w funkcji pęcherza wśród pacjentów z różnym poziomem uszkodzenia w obrębie C i L rdzenia kręgowego. W badaniu „follow-up" pacjenci z maksymalną objętością pęcherza < 200 ml znacząco częściej (p = 0.019) doświadczali pogorszenia funkcji górnych dróg moczowych niż pacjenci ≥ 200 ml. Coroczne badanie urodynamiczne wykazało, że 47.9% pacjentów wymaga podjęcia interwencji medycznej (w 82.6% przypadków – interwencji urologa). Żaden z pacjentów nie zgłaszał wówczas żadnych objawów.

Wnioski

Badanie urodynamiczne powinno być standardowym badaniem u pacjentów po urazie rdzenia kręgowego. Regularny „follow-up" zapobiega pogorszeniu funkcji górnych dróg moczowych.

Słowa kluczowe: uraz rdzenia kręgowego, badanie urodynamiczne, pęcherz neurogenny.

Introduction

Classification of SCI

World widely used scale for standardizing and for detailed documentation of spinal cord injury is American Spinal Injury Association (ASIA) Impairment Scale. Determination of completeness, incompleteness, and level of injury plays an important prognostic role and has practical clinical usefulness. The assessment is based on a myotomal-based motor examination, dermatomal based sensory examination, and an anorectal examination. The biggest limitation of this method is its subjectiveness (1).

Adult Neurogenic Lower Urinary Tract Dysfunction after SCI

The process of voiding is controlled by the nervous system in a quite complicated manner.

Physiologically it works in the coordination of certain areas of the brain, spinal cord, peripheral nerves, and many neurotransmitters. Disruption (especially multiple) at any of these levels may result in a mixed picture of the adult neurogenic lower urinary tract dysfunction ANLUTD (2–4).

Clinical manifestation in regards to the level of injury

Suprapontine lesion (lesion above the pons) interrupts the detrusor contractility. There is a reflex contracion of the detrusor wih impaired cerebral regulation and central inhibition and usualyy synergistic voiding/bladder emptying. Clinically urinary frequency, urgency without incontinence can be observed (2–4).

In lesion in the pons or under (pontine or suprasacral lesion) the main manifestation is destrusor overactivity (DO) with incontinence, and with or without destrusor-urethral sphincter dyssynergia (DSD) "high pressure" bladder and post-void residual (PVR) (2–4).

Sacral Spinal Cord Lesion (SSCL) results in acontractile detrusor with decreased bladder compliance and also with the weak sphincter activity. Bladder sensation may be decreased [2].

The above mentioned definitions are consistent with terminology reported by Gajewski *et al.,* and International Continence Society, published in 2017 (4). Therefore publications before 2017 may not include new terminology.

Urodynamic Study

Urodynamic study (UDS) is a gold standard in the assessment of lower urinary tract (LUT) function (5). Often disorders of LUT have a functional nature. Studies show that treatment based only on a patient's symptoms is insufficient. Evaluation of function and dynamics of the LUT is a necessity to determine the pathology and can be revealed during UDS (6).

Patient can be in a supine position or upright position. Urologist introduces a catheter through the urethra into the bladder and fills it with usually saline 0.9% heated to room temperature. Sensation stops when the patient expresses a strong need to void. The patient is constantly in verbal contact with the urologist. During the UDS urologist is attempting to provoke the reflexes and present the symptoms.

Following parameters are measured: bladder-filling sensation, bladder capacity, detrusor compliance, detrusor stability, intravesical pressure, urethra sensation, ability to initiate the micturition, micturition control (continence ability), residual and micturated volume. Detrusor compliance is defined by the ratio of volume change (ΔV) to the exerted on the bladder wall pressure (Δp), in ml/cm H_2O/ (7,8).

SCI can be complete or incomplete (with different urological manifestations). It is impossible sometimes to predict LUT outcomes relying only on neurological lesion. Thus UDS plays an important role in bladder management after SCI. The main goal is to plan a therapy that prevents further complications like deterioration of the function of the upper urinary tract, prevention of infections and efficient bladder emptying (9).

The limitations of the UDS are urinary tract infections (UTI) caused by the examination (10, 11). Some authors exclude patients with urinary tract stones, foreign bodies, symptomatic UTI or any urinary tract dysfunctions from their studies with UDS (9, 12). Those conditions may interfere with UDS, but no studies focused on this subject were conducted.

Aim

Aim of this article is to analyze the value of UDS in the management of neurogenic bladder in patients after SCI. A systematic review of the literature was performed.

Materials and methods

The study was registered in Clinical Trials (number: NCT04231474).

Inclusions criteria

The inclusion criteria were: studies conducted on human adults (over 18 years), the studies group consisted of at least 70 patients after SCI and with ANLUTD, who underwent UDS, articles published after 2013.

Search strategy

Our research was performed on the databases PubMed and Web of Science. Keywords used by the implemented research strategy were "spinal cord injury" AND "urodynamic" OR "spinal cord injury" AND "urodynamic evaluation" OR "spinal cord injury" AND "urodynamic testing" OR "spinal cord injury" AND "urodynamic study".

Results and discussion

Studies included

Out of 2012 articles found by performing the above research procedure, nine matched the inclusions criteria and were analyzed. The PRISMA flow diagram is illustrated in Figure 1.

Groups description

The number of patients included in the study was in a range from 70 to 246. There was a disproportion in each study in women to men ratio, however, p value was either not given or > 0.05. The results of UDS were not differentiated in regards to completeness or incompleteness of SCI. Detailed characteristics of groups are summarized in Table 1. Risk of bias and quality assessment was performed using Newcastle-Ottawa Scale (Table 2).

Urodynamic study in the assessment of outcomes after SCI

As mentioned above, completeness or incompleteness of lesion is determined subjectively based on neurological examination. The simplicity of this method may seem attractive, but not always perfectly explains differences in clinical and urodynamic manifestations in patients, who were classified to the same group of injury. Those differences inspired some authors to investigate the urological

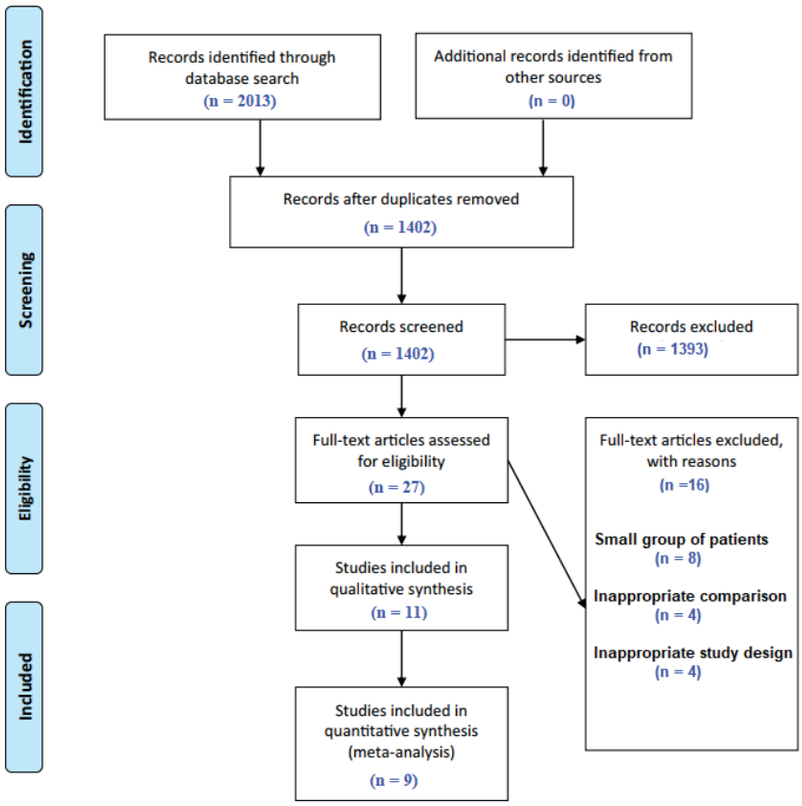

Figure 1. PRISMA flow diagram (n-number of samples).

Table 1. Summary of the included studies.

No.	Study	Population									Description	Outcomes p < 0.05	Duration	Conclusion
		N	Level of traumatic SCI			ASIA		Sex		Age				
								Female	Male					
1	**Suha *et al.***		L1–L2	L3–S5		A	B + C + D							
	[7] (2015)	121	74	47		51	70	29	92	34 (SD =13)	Bladder-filling sensation Detrusor overactivity Detrusor hypocompliance Storage disorder Emptying disorder	Detrusor hypocompliance Micturated urine (ml) Anticholinergic drug prescription Alpha-blocker drug prescription Bladder-emptying method on admission		Differences between upper lumbar and lower lumbar–sacral SCI patients in respect of neurogenic bladder features and treatment options.
2	**Agrawal *et al.***		C	Th	L	S								
	[9] (2015)	70	35	16	14	5	39	31			Urodynamic findings in spinal cord injury at each level Bladder compliance Leak point pressure	Bladder compliance Leak point pressure	>3 months	Bladder function differs according to the level of injury.
3	**Kooshesh *et al.***		C	Th	L	S								
	[14] (2018)	112	27 C1–Th12 69	58 L1–S5 28	41	4	13	12	31	86	35 (SD = 12)	Type of detrusor function Bladder compliance Storage capacity Emptying ability External urethral sphincter function First desire to void Voided urine volume (ml) Residual urine volume (ml)	non significant		There is an association between detrusor muscle function and the level of the spinal cord injury. However, there is no exact relationship between the level and the completeness of SCI with the urodynamic evaluation characteristics.
4	**Sayılır *et al.***		C1-C5	C6-C8										
	[12] (2013)	90	51	39		50	40	8	82	30 (SD = 12)	Bladder-filling sensation Detrusor overactivity frequency Storage disorder frequency Emptying disorder frequency Residual urine volume (ml) Anticholinergic drugs Alpha-blocker drugs	Detrusor overactivity frequency Residual urine (ml) Anticholinergic drugs Alpha-blocker drugs Prescribed emptying method	> 6 months	There are differences in the upper and lower SCI cases in terms of neurogenic bladder characteristics and therapeutic approaches.
5	***Zhang et al.***		C	Th	L						Prescribed emptying method			
	[15] (2014)	112	34	51	27		72	40	21	91	18–60 years	Bladder compliance, DSD, detrusor sphincter Dyssynergia, Maximum cystometric capacity	Bladder compliance Maximum cystometric capacity	2 years	Urodynamic parameters with high detrusor pressure also were dangerous signals of UUT deterioration.

Table 1. (cont.) Summary of the included studies.

No.	Study	Population										Description	Outcomes p < 0.05	Duration	Conclusion
		N	Level of traumatic SCI				ASIA		Sex		Age				
									Female	Male					
6	**Schöps *et al.***		C	Th	L	S									
	[16] (2015)	246	54	138	47	7	116	127	55	191	> 18 years	Comparison of the latest and earliest UDS	Maximum cystometric capacity, Compliance, mL/cmH2O Detrusor overactivity Detrusor sphincter dyssynergia	5 years	NLUTD due to SCI (mean duration of SCI 17 years) had urodynamic findings within the safe limits
7	**Welk *et al.***		C	Th	L		AGD comorbidity score,% 0–11 (lower)	≥ 12 (high)							
	[17] (2016)	1551	37	43	20		77	23	407	1144	33–63	Frequency of UDS after SCI in follow up	Age of patients > 65 years high comorbidity quadriplegia	5 years	Guideline recommendation do not find their application in clinical practice
8	**Linsenmeyer *et al.***		C1-T6	T7-T11	T12-S2										
	[19] (2013)	96	73	13	10		73	23	16	80	18–80	Percentage of patients who required medical intervention based on UDS	47,9% of patients required at least one type of medical intervention	5 months	Annual UDS is an important tool in modification neurogenic bladder management
9	**Garcia *et al.***														
	[13] (2020)	194					51	143	71	123		Maximum cystometric capacity Volume at first involuntary contracion Bladder compliance Maximum pressure of the detrusor Detrusor leak poin pressure Residual urine volume (ml)	Maximum cystometric capacity Volume at first involuntary contracion	4 years	Urodynamic differences in patients with complete and incomplete SCI

Legend: ASIA – American spinal injury association, C – cervical DSD – detrusor sphincter dyssynergia, L – lumbar, S – sacral SCI – spinal cord injury, Th – thoracical, UDS – urodynamic study, UUT – upper urinary tract.

outcomes in patients after SCI with the use of objective methods like UDS.

Garcia *et al.* (13) conducted a study on 51 patients with complete (ASIA A) and 143 patients with incomplete (ASIA B-E) SCI. In the study showed differences in those groups regarding maximum cystometric capacity and volume at first involuntary contraction.

Agrawal and Joshi (9) wanted to find a correlation between the level of SCI and bladder functions. They analyzed results of UDS of 35 patients with cervical-, 16 with thoracic-, 14 with lumbar- and 5 with sacral SCI. Analyzed data didn't provide any significant findings, possibly due to a small number of patients in each group. However, 72.30% of patients with suprasacral cord lesions had high detrusor leak point pressure, 27 out of 35 with cervical SCI had hypocompliant bladder that manifested mainly as detrusor overactivity or DESD. Detrusor areflexia is mainly associated with lower motor neuron injury (below the conus medullaris), however in this study 9.2% patients with suprasacral injuries demonstrated detrusor areflexia (whereas 81.5% had detrusor hyperreflexia, and 9.2% had normal bladders).

Those findings are partially consisted with results of Kooshesh *et al.* (14) who had not found any significant relationship between the level of SCI and urodynamic parameters at first. They compared the groups of 66 patients with suprasacral, 28 with sacral and 19 with both suprasacral and sacral lesion. Eventually,

Table 2. Risk of Bias and quality assessment of studies using Newcastle-Ottawa Quality Assessment Scale.

Study	Selection				Comparability	Outcome			Total
	Representativeness of the exposed cohort	Selection of the non exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow up of cohorts	
Suha *et al.* [7] (2015)	*	0	*	0	**	*	0	0	*****(5)
Agrawal *et al.* [9] (2015)	*	0	*	0	*	*	0	0	**** (4)
Kooshesh *et al.* [14] (2018)	*	0	*	0	**	*	0	0	*****(5)
Sayılır *et al.* [12] (2013)	*	0	*	0	**	*	0	0	*****(5)
Zhang *et al.* [15] (2014)	*	0	*	*	**	*	*	0	*******(7)
Schöps *et al.* [16] (2016)	*	0	*	*	**	*	*	0	*******(7)
Welk *et al.* [17] (2016)	*	0	*	0	**	*	*	0	******(6)
Linsenmeyer *et al.* [19] (2013)	*	0	*	*	**	*	0	0	******(6)
Garcia *et al.* [13] (2020)	*	0	*	0	**	*	0	0	*****(5)

in their calculation, they compared only 2 first groups and found a significant relationship between the level of injury and type of detrusor function, which was described as overactive, underactiveor normal (p = 0.019). In their study hypocompliant bladder was found more often in patients with suprasacral lesions.

The following authors decided for even more narrow group of patients than previous, but still, they obtained some relevant differences. Saylir *et al.* (12) conducted a study on 90 patients (82 male, 8 female) with cervical SCI and divided them into 2 groups with upper (C1-C5) and lower (C6-C8) injury. They compared parameters of UDS in both groups and found significant differences in bladder-filling sensation (p = 0.000), detrusor overactivity frequency (p = 0.048) that occurred more often in upper cervical SCI patients and residual urine (p = 0.036). Patients with lower cervical SCI had higher residual urine volume. Those findings may implicate the need for different bladder management in terms of continence and risk of infections.

A similar study, but in regards to lumbar SCI have conducted Suha *et al.* (7). This study also revealed important differences in a seemingly identical group of patients. Patients were divided into two groups – upper (L1-L2, n = 74) and lower (L3-S1, n = 47) lumbar SCI. There was a significant relationship between the level of lumbar SCI and detrusor hypocompliance (p = 0.021) that was more frequent in the upper lumbar SCI group and micturated urine (0.015).

Urodynamic study in monitoring

One of the causes of death of patients after SCI used to be kidney failure, as a result of high intravesical pressure and vesicoureteral reflux. Although this condition is no longer as fatal as in previous decades, high bladder pressure still contributes to high morbidity among SCI patients. However, it is important to say that European Association of Urology

Guidelines on Neuro-Urology do not clearly indicate the frequency of follow-up in patients after SCI.

UDS is an essential tool, that assesses risk factors and predicts upper urinary tract (UUT) deterioration. In a prospective study with a mean follow-up of 2 years, Zhang and Liao (15) found that urodynamic parametrs are significantly correlated with UUT in patients with SCI. Patients with maximum cystometric (MCC) capacity < 200 ml experienced significantly more often ($p = 0.019$) UUT deterioration than those with MCC ≥ 200 ml. Similarly, deterioration of UUT was more frequent in patients with higher maximal detrusor pressure (≥ 40 cm H_2O) – 55.4%, than in those with lower maximal detrusor pressure (< 40 cm H_2O) – 36.8% ($p = 0.063$), but the most significant correlation was found in case of bladder compliance ($p = 0.004$). Hypocompliant bladder was found in 55.2% of patients with UUT deterioration.

Another prospective study of Schöps *et al.* (16) compared the earliest and the latest available UDS of 246 patients with SCI (mean [SD] duration of SCI 17 years). The authors based treatment strategy on urodynamic findings, as they assumed that only urodynamic evaluation is reliable to prevent UUT deterioration. Indeed, during 6 years of study, modifications in the therapy were necessary. Eventually, according to latest available urodynamic investigations, the mean bladder compliance (95 ml/cm H_2O) was higher than in the earliest ones (55 ml/cm H_2O, $p < 0.001$), also there was a decrease in the number of patients with DESD ($p = 0.001$). On the other hand, the number of patients with detrusor overactivity increased from 59 individuals to 130 in the latest available UDS ($p < 0.001$) and also increase in patients with incontinence was found.

Although the importance of UDS in diagnosing the bladder dysfunctions is widely acknowledged, the "every-day" clinical practice does not reflect those ideals. Canadian study of Welk *et al.* (17) reports that from the group of patients with SCI (n = 1551) patients who had at least one urodynamic study after 1 year of follow-up was 631 (41%), after 2 years – 712 patients (53%), after 3 years – 662 (57%). UDS were significantly less often performed in patients over 65 years old ($p < 0.01$), quadriplegia ($p < 0.01$) and those with a higher level of co-morbidity. Authors suspect that this may be due to factors like patient preference and compliance, limited access to medical care or a more individualized approach to SCI patients assessment. What is more, Musco *et al.* (18) in their systematic review also highlight the role of urodynamics in the management of adult neurogenic lower urinary tract dysfunction (ANLUTD) and similarly stress the need of standardization that would improve outcomes of neuro-urological patients.

Interventions based on urodynamic study

In contrast to results of the study of Welk (17), 3 years earlier in American research of Todd and Linsenmeyer (19) UDS had a great impact on decision-making in treatment of patients with SCI. The study was conducted on 80 male and 16 female who had to have been injured for at least 2 years. The patients underwent annual UDS and 47.9% of them needed at least one type of intervention (in 82.6% of cases – urological interventions) basing on their UDS. What is important, none of those patients complained of new urological symptoms since their previous UDS. In the study of Welk (17) 53% patients after traumatic SCI had at least one UDS, 80% had at least one renal imaging study after 2 years of follow-up. This shows that there is relevant group of patients, who may stay underdiagnosed and needs some intervention. Similarly, Schöps *et al.* (16) also acknowledged the importance of modification of a therapy based on UDS. Their study shows that in the time between the earliest and the latest UDS the number of patients who took any neuro-urological medication increased. Also the number of botulin toxin A injections into the detrusor increased from 12% to 33% and pararell decrease of antimuscarinic medication. None

of the above mentioned studies included clear information about the percentage of loss in follow-up, what can introduce bias.

Patients after SCI have different manifestations of adult neurogenic lower urinary tract dysfunction (ANLUTD), which can be presented in UDS and require different bladder management strategies (7, 9, 12, 14) however, in practice those strategies depend also on inevitable factors like personal motivation, availability medical care, sex, help of a caregiver, financial situation of the patients (19, 20).

Conclusions

The number of publications regarding the role of UDS in management of adult neurogenic lower urinary tract dysfunction (ANLUTD) after SCI and conducted on a large group of patients are limited. There is very little amount of studies with a high quality follow-up. But those published in the last few years provide strong evidence that USD is an essential tool in planning NLUTD management. Unpredictable results of different types of injuries require objective methods of study in diagnosing urological outcomes in SCI patients. Therefore the UDS should be performed as a standard examination in patients after SCI. All of them need therapy adjusted to their condition and needs, which also may change with the pass of time and implementing some modifications can be a necessity. Regular follow up UDS should be performed for prevention UUT deterioration. However, available literature provide very modest evidence of sufficient frequency of follow-up. There is a need for randomized controlled trials.

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