Contemporary diagnostic methods of the urinary system in patients after spinal injury with subsequent neurological deficits: Diagnostics of the lower urinary tract

Współczesne metody oceny układu wydalniczego u osób po urazie kręgosłupa powikłanym zaburzeniami neurologicznymi – diagnostyka dolnych dróg moczowych

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Key words
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Abstract
Introduction: Spinal injury with neurological deficit usually results in a neurogenic bladder disorder. The problem may range from total lack of micturition during the spinal shock phase to various forms of detrusor-sphincter dyssynergia. Typical consequences include increased intra-vesical pressure, inability to effectively empty the bladder, increased risk of vesico-ureteral reflux, infection, bladder or kidney stones, neoplastic complications within the urinary tract and renal failure. Proper diagnostics of urinary tract function and morphology enables choosing adequate bladder emptying strategy, early diagnosis and effective treatment of urinary complications in patients after spinal injury with neurological deficit.
Study purpose: Presentation of contemporary methods of functional, imaging and endoscopic diagnostic tests of the lower urinary tract in patients with spinal injury with neurological deficit. We discuss clinical value and accuracy of particular diagnostic methods in prevention and monitoring of the therapy of urinary complications.
Study form: Literature review.
Conclusions: Although urodynamic studies serve as the principal tool among the modern methods of the lower urinary tract function assessment, simple functional tests such as measurement of residual urine volume measurement or cystometrogram may be helpful in clinical practice, particularly during the early post-traumatic phase. Ultrasonographic examination is the first choice imaging study. Clinical validity of screening cystoscopy in spinal injury with neurological deficit patients remains doubtful, but this procedure is of unquestionable value in cases with haematuria.

Słowa kluczowe:
Kręgosłup, uraz, powikłania, diagnostyka, pęcherz neurogenny, dolne drogi moczowe

Streszczenie
Wstęp: Uraz kręgosłupa powikłany zaburzeniami neurologicznymi (UKPZN) jest przyczyną neurogennej dysfunkcji opróżniania pęcherza moczowego. Zaburzenie może mieć formę od całkowitego braku odruchu mikcji w fazie szoku rdzeniowego do różnych form dyssynergii wypieraczowo-zwieraczowej. Typowymi konsekwencjami jest zwiększenie ciśnienia w pęcherzu moczowym, niemożność całkowitego opróżnienia w czasie mikcji, wzrost ryzyka refuksu, infekcji, kamicy, nowotworów dróg moczowych, niewydolności nerek. Właściwa diagnostyka funkcji i morfologii układu wydalniczego umożliwia wybór najlepszej strategii opróżniania pęcherza, daje szansę na wczesne rozpoznanie i skuteczne leczenie powikłań.
Cel pracy: przedstawienie klasycznych i współczesnych metod oceny czynnościowej, obrazowych oraz endoskopowych dolnych dróg moczowych z omówieniem ich przydatności klinicznej w profilaktyce i monitorowaniu leczenia schorzeń układu moczowego po UKPZN w kontekście patofizjologii zmian.
Forma pracy: przegląd literatury
Wyniki i wnioski: Chociaż podstawą nowoczesnej czynnościowej oceny dróg moczowych po UKPZN jest badanie urodynamiczne, nie można kwestionować wartości prostych testów funkcjonalnych takich jak pomiar objętości zalegającej czy cystometrogram przydatne zwłaszcza we wczesnym okresie po urazie. Podstawowym badaniem obrazowym dolnych dróg moczowych jest ultrasonografia. Istnieją kontrowersje w kwestii przydatności przesiewowej cystoskopii u osób po UKPZN, jednak badanie to wydaje się mieć istotne znaczenie u osób z hematurią.

Authors' contribution: A – project of the study, work; B – collection of the data, information; C – statistical analysis; D – data interpretation; E – preparation of the manuscript; F – literature query; G – obtaining funds

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INTRODUCTION

Not as long time ago as 30 years, urinary tract complications were the leading cause of death of persons during the late stage after spinal cord injury[1]. Currently, diseases of the excretory system are on the 10th place of death causes accounting for 4.4% of all deaths in this group of patients[2]. This significant reduction in mortality was due to availability of modern, broad diagnostic tools of the urinary tract that enabled introduction of effective methods of maintenance of urinary outflow, prevention and treatment of complications.

Spinal injury with neurological consequences (SINC) is a cause of functional and – secondarily – structural pathology within the urinary tract. Damage to innervation of the muscles responsible for urinary collection and emptying of the urinary bladder, dysfunction of the centres controlling micturition, as well as lesion of afferent nerve fibres supplying the urinary tract lead to detrusor-sphincter dyssynergia (DSD), which involves contractions of the external and/or internal sphincter during the activity of the detrusor, which results in an increase in urinary tract pressure, inability to empty the bladder, occurrence of vesico-ureteral reflux. This increases the risk of infection, lithiasis and irreversible damage to the structure and function of the urinary tract. The neurogenic pathology can superimpose on the SINC-independent disturbances of the urinary tract, such as prostate hypertrophy, exertion-associated incontinence or inborn defects. Commonly used methods of urine elimination, such as permanent catheterisation, can induce severe complications. High incidence of urinary tract infections, cystolithiasis (29%), trauma and stenoses of the urethra (14%) in patients with SINC (Ruutu[3]) is – in major – considered a iatrogenic effect resulting from prolonged maintaining of the Foley catheter in the urinary bladder during the early phase of treatment. Urinary bladder catheterisation also constitutes one of the causes of an increased risk of urinary bladder cancer in post-SINC patients that is 16-28-fold higher than that in healthy persons[4].

AIM OF THE STUDY

The aim of the present work is presentation of contemporary and classical methods of functional and morphological diagnostic evaluation of the lower urinary tract (the urethra and the urinary bladder) in a person with SINC in the context of pathophysiology of urinary disturbances.

PATHOPHYSIOLOGY OF THE LOWER URINARY TRACT IN SINC

The detrusor of the urinary bladder receives efferent parasympathetic innervation via the pelvic nerves from the centre localised within the grey matter of the sacral spinal cord at the S2-S4 level. Acetylcholine is the neurotransmitter of the post-ganglionic fibres. Stimulation of the sacral parasympathetic centre induces contraction of the detrusor muscle.

The sphincter and the internal detrusor are supplied with descending sympathetic fibres via the hypogastric nerves. These fibres conduct impulses generated within the centre located in the segments Th11-L2. Adrenergic stimulation of the beta-receptors mainly located within the wall of the urinary bladder results in relaxation of the detrusor, while stimulation of the alpha-receptors of the internal sphincter induces its contraction. The external sphincter receives somatic innervation via the pudendal nerve from the segments S1-S4. Association of the external sphincter with the autonomic system has not been elucidated; it seems that the external sphincter, apart from the somatic innervation, is supplied with sympathetic and parasympathetic fibres[5]. The external sphincter is under control of the cerebral cortex, whereas the remaining musculature of the lower urinary tract is under control of supraspinal centres regulating the autonomic tone and other controlling centres, such as the Barrington centre, located in the anterior part of the pons, stimulating micturition[6]. The most important afferent fibres activated by the tension of the urinary bladder wall run with the pelvic nerves to the sacral centre.

The form of a disturbance of bladder emptying resulting from nervous system lesions depends on the localisation of the lesion:

- Lesions above the pons usually induce hyperreflexia of the detrusor without signs of DSD. These disturbances can, however, be complex because of the overlap of a sub-vesical obstruction, cognitive dysfunction, and the effects of pharmacotherapy.
- Spinal cord lesions proximal to the sacral centres of the spinal cord induce abolition of detrusor contractions during the phase of spinal shock. Usually, return of the vesical reflexes can be seen following return of the reflex function of the skeletal muscles[5]. In patients with a lesion above the sacral segment, signs of hyperreflexia with DSD usually develop. Episodes of urinary incontinence and simultaneous contraction of the sphincter and the detrusor are observed[7]. When intra-vesical pressure increases, aggravation of spasticity may be observed. In patients with spinal cord lesion above Th6, signs of autonomic dysreflexia become evident. Although spontaneous micturition returns approximately in the 12th week following SINC[8], cases of increasing detrusor hyperreflexia have been observed as late as 22 months after a trauma[9]. If neurological deficit is not complete, those disturbances can have a different form[5].
- Lesion of the sacral segment of the spinal cord can elicit areflexia of the detrusor with concomitant formation of a stretching-compliant bladder, where no contraction is possible. The small difference among the location of the nucleus of the pudendal nerve and the centres supplying the detrusor can augment (e.g. in cases of damage to the micturition centre with concomitant sparing of the proximally located source of the innervation of the external sphincter) the tendency to formation of an excessively stretched, flaccid urinary bladder[5].

- Peripheral lesions can induce a destruction of both the afferent and the efferent innervation of the lower urinary tract. A stretched, contraction-incapable urinary bladder can occur both as a result of reduced parasympathetic impulses reaching the bladder and the lack of reception of signals conveying the information about the tone of the urinary bladder wall[5,7].

OVERVIEW OF DIAGNOSTIC STUDIES

To evaluate the function of the urinary tract, clinical tests are performed, part of which can be conducted as bedside tests, without special equipment, while other tests require complicated diagnostic devices.

Measurement of post-void urinary residual volume

Measurement of post-void urinary residual volume (URV) is one of the simplest tests evaluating the efficacy of the bladder emptying phase. The test is useful for the assessment of indications for periodic catheterisation and the assessment of the effectiveness of applied pharmacotherapy. The test can be performed by means of catheter placement or using the ultrasound examination

Catheterisation, although enables obtaining the urine directly from the bladder, e.g. for general urine analysis or microbiological study, can be a source of patient's discomfort and anxiety, urethral trauma; it is also a time- and material-consuming procedure. It was demonstrated that 14-30% of URV measurements performed by urology nurses by means of bladder catheterisation are associated with an error of 76-85 ml on average[10].

In the western countries, ultrasound URV measurement (USG-URV) is a routine procedure with diagnostic yield of 94%, sensitivity of 97% and specificity of 91%[11]. It was demonstrated that USG-URV routinely performed in patients requiring an URV assessment in hospitals, outpatient clinics and nursing houses is associated with time-saving, sparing medical materials and reduces the risk of catheterisation-related complications[12,13]. Usefulness of USG-URV in children deserves special attention. Ultrasound examination is also helpful in supra-pubic puncture, in identifying intra-vesical pathology such as concrements and tumours. Thickness of the urinary bladder wall, a parameter indirectly indicating presence of a sub-vesical urine outflow obstruction, can be assessed[12,14].

URV assessment is useful in the monitoring of formation of automatic micturition reflex and in verifying the effectiveness of bladder emptying method used by the patient. The measurement allows distinguishing a group of patients requiring detailed diagnostics of structural and functional disturbances of the urinary tract[12].

Measurement of URV is an important part of periodic catheterisation, the currently recommended strategy of urinary bladder emptying in patients with impaired micturition reflex[15]. Post-micturition urinary retention indicates an increased risk of urinary tract infection. Residual volume of over 300 ml is associated with a risk of vesico-ureteral reflux and hydronephrosis[12]. If post-micturition urine volume is lower than 50 ml (or even - according to many authors - lower than 200 ml), termination of intermittent catheterisation is recommended[5,12,15,16]. Drawing too strict conclusions based on the measurement of post-micturition volume can be problematic, especially in the elderly, in whom physiological post-micturition retention of about 100-150 ml may be present[5].

Normal result of URV measurement does not necessarily indicate the lack of significant disturbances in urinary outflow. Compensatory detrusor hypertrophy accompanying prostate hypertrophy or DSD, as well as bladder emptying using Valsalva method or Crede procedure can serve as examples. Falsely high values obtained in URV measurements may result from a delay in the measurement following micturition.

Bedside cystometrogram

It is a screening test aiming at assessment of urinary bladder volume, of sensation of filled bladder, determining presence of reflex detrusor contraction. Cystometrogram may provide an answer to a question, whether the patient is still at the phase of spinal shock. The testing involves filling of the bladder through a Foley catheter with water delivered from a 60-ml syringe connected to a manometer followed by observation of intra-vesical pressure. The test is quite sensitive, however, of low specificity. Difficulty in determining whether small rises in pressure depend on detrusor muscle contraction or fluctuations of the intra-abdominal pressure constitutes one of limitations of cystometrogram usefulness. Administration of ice-cold water into the bladder (the baloon of the Foley catheter must be emptied) is a variant of the method, which, when the patient is not at the spinal shock phase, induces abrupt detrusor muscle contraction that pushes the catheter out with water[5,17].

Urodynamic study

Urodynamic study involves recording of objective (hydraulic, electrophysiological) and subjective parameters (sensation) during filling of the urinary bladder and micturition. The study provides information on disturbances of urinary bladder filling and emptying phases. In patients with SINC at higher levels, monitoring of blood pressure may be important because of possible occurrence of autonomic dysreflexia.

Components of the urodynamic study include:

- Cystometry – assessment of urinary bladder function by means of measurement of intra-vesical fluid pressure and volume during filling, collection and micturition. Single-channel measurement with assessment of the intra-vesical pressure or multi-channel assessment, with additional measurement of the intra-abdominal pressure using sensors placed in the vagina or the rectum, can be used. In post-SINC patients, it is especially important, as it enables differentiation of the internal and external pressures affecting the urinary bladder, as well as an indirect calculation of the

pressure actually resulting from detrusor contraction.

- Uroflowmetry – measurement of urine outflow rate.
- Assessment of intra-urethral pressure (static).
- Determination of leak point pressure (LPP), that is the pressure exerted by the abdominal muscles, at which the resistance produced by the sphincter muscle of bladder neck during the phase, when the patient does not intend to urinate, is overcome. Usually, to determine LPP, the patient is asked to perform Valsalva manoeuvre or to cough. Normally, LPP should not exceed 40 cmH_2O. In contrast to the above-mentioned intra-urethral pressure profile, LPP provides information on urethral function during a dynamic situation associated with micturition.
- Evaluation of sphincter activity during detrusor contraction[7].

Evaluation of the filling phase is conducted during fluid infusion into the bladder and enables assessment of sensation, volume, bladder wall compliance and the so-called bladder stability (observation, whether detrusor contractions occur during urine collection)[18]. Normally, sensation of fluid volume should not occur earlier than after the bladder has been filled with 100-200 ml of fluid. Sensation of a full bladder is usually perceived following infusion of 300-400 ml, while sensation of urgency should occur when there is 400-500 ml of fluid in the bladder. Analysis of the above results should take into account individual variability of bladder volume. When a healthy bladder is full and its wall has normal compliance, intra-vesical pressure should not exceed 15 cmH_2O [5].

Evaluation of the emptying phase is conducted during micturition initiated following examiner's command or as a result of spontaneous detrusor contractions. During this phase, maximum micturition-related intra-vesical pressure, intra-urethral pressure, intra-abdominal pressure and – indirectly – pressure produced by the detrusor can be measured. Normal ranges depend on gender and should not exceed 30 cmH_2O in males[16].

During uroflowmetry, urine peak flow rate (Qmax) is measured. The result is usually reported in millilitres per second. Time period between micturition initiation and the time when Qmax has been reached can also be measured[19]. Qmax should not be lower than 10 ml/s, while typical Qmax range is 15-20 ml/s. Measurements of flow rate are reliable when baseline fluid volume in the bladder exceeds 150 ml[12,20,21]. Normal plot of the intra-vesical volume during micturition is characterised by symmetrical rising and falling phases.

Assessment of the emptying phase also involves measurement of volume of the excreted urine, post-micturition intra-vesical volume as well as evaluation of bioelectrical activity of the sphincter[22]. During micturition phase, the sphincter should remain inactive; rises in intra-abdominal pressure should not occur.

Urodynamic evaluation can be valuable even during the phase, when spontaneous micturition has not yet been restored following SINC[5]. Sphincter spasticity may be so intense that micturition at given detrusor contractions is not possible[20]. There is general agreement that urodynamic study should be performed every year or at least every second year in case of persistent neurogenic disturbances of the urinary tract, especially when 10 years have passed following SINC, because of the risk of development of a status with high pressures in the urinary tract, associated e.g. with urolithiasis[5,16,20].

To determine presence of detrusor hypersensitivity, urodynamic study is sometimes performed following administration of sympathomimetics (betanechol, carbachol). The study can be falsely positive in case of mental stress or urinary tract infection[23]. Urodynamic study is most valuable for the assessment of the urinary tract function during a period of 3 to 6 months following SINC.

Video-urodynamic study

Video-urodynamic evaluation is a combination of urodynamic study and urography using video-recording coupled with fluoroscopy. During the slow bladder filling phase, volume-pressure relationships in the bladder are registered. Bladder filling and emptying is radiographically monitored. The study enables assessment of detrusor activity, observation of features of DSD, of sub-vesical obstruction, or vesico-ureteral reflux[24]. Drawbacks of the method include exposure to radiation, cost and necessity to use special devices. Clinical usefulness of a complete video-urodynamic study is sometimes criticised[25], therefore, video-cystometry is the most frequently applied video-urodynamic technique[26].

Urodynamic study is sometimes performed with simultaneous ultrasonographic evaluation of the lower urinary tract using a trans-rectal head. USG visualisation helps in precise placement of the electrodes, allows real-time observation of preservation of the bladder neck, which enables detection of DSD signs as well as it allows determining presence of local deformations such as urethral and vesical diverticuli and focal changes of the urinary bladder or the prostate. Ultrasonography does not allow observation of ureteral reflux signs[27,28].

Voiding cystourethrography

Voiding cystourethrography (VC) is a radiological study of the urinary bladder and the urethra during micturition, following administration of a marker into the bladder. During VC, a contrast agent can be introduced into the bladder and a series of X-rays can be performed during micturition or an isotopic marker can be used and imaging perfoemd using a gamma-camera. Imaging in the lateral and oblique projection is helpful in differentiating causes of effort-related and neurogenic incontinence[29]. VC is a sensitive test to diagnose vesico-ureteral reflux. Other abnormalities observed during VC in post-SINC patients include prostate hypertrophy, urethral diverticuli and stenoses, as well as post-micturition urostasis[30].

Sensitivity of VC in diagnosing urethral diverticuli is 66.7%[31]. Special urethrography with increased

intra-urethral pressure, also called two-baloon urethrography, is a variant of VC. This technique enables elimination of falsely negative errors of the classical VC[31].

Ultrasonographic evaluation

Trans-abdominal, perineal, trans-rectal, trans-vaginal ultrasonography (USG) performed in classical and 3D sequences[32] is a valuable non-invasive method of imaging the structures of the fundus of the pelvis, urinary bladder and urethra. Concrements within the urinary tract, diverticuli and urethral and vesical tumours[33,34], prostate hypertrophy and deformations of the pelvic fundus causing effort-associated urinary incontinence[35] can be detected using this method[33,34]. Perineal USG allows assessing thickiness and morphology of the urinary bladder wall. Enhanced bladder trabeculation and wall thickness greater than 5 mm indicate detrusor hyperactivity[36] resulting from neurogenic disturbances or a change secondary to a sub-vesical obstruction.

Ultrasonographic examination should be performed in every patient with neurogenic bladder dysfunction at least once a year. Such study should be performed when the bladder is filled – to assess possible presence of concrements in the urinary tract, and after micturition – for spontaneous assessment of urine retention in the urinary bladder.

Magnetic resonance imaging

The fact that this study outweighs ultrasonography and radiographic studies in sensitivity and specificity of urethral diverticuli detection[37] is a prerequisite justifying performing MRI when a pathology typical for SINC is suspected. Moreover, MRI enables more precise determination of the morphology of diverticulum.

Endocscopic studies of the lower urinary tract

Endoscopy of the urinary tract allows obtaining a direct picture of the urethra and the urinary bladder as well as it enables performance of more and more therapeutic procedures. Using cystoscopy, diverticuli, tumours, concrements, post-inflammation scars, signs of enhanced trabeculation of the urinary bladder, urethral pathology can be detected. Cystoscopy can prove the only test enabling visualisation of small stones in the bladder or foreign bodies such as pubic hair getting into the bladder during catheterisation[38,39].

Indications for cystoscopy include haematuria, recurrent urinary tract infections, especially with bacteria facilitating urolithiasis (*Proteus mirabilis)*, urostasis or incontinence, or status after Foley catheter removal after a period of 4-6 weeks[5]. Because of the significant risk of bladder cancer in patients after SINC and the possibility of course of the disease without typical signs such as haematuria[40,41], regular conduction of cystoscopic examination in persons with SINC of over 10-year duration is recommended[5]. According to Yang, cystoscopy is not a useful screening tool for detection of urinary bladder cancer in post-SINC patients regularly undergoing catheterisation for 10 years or smoking and undergoing catheterisation for 5 years[42]. Navon et al.[43] state that yearly screening cystoscopy performed in post-SINC patients with haematuria allow detecting of bladder cancer at earlier stages and prolong life expectancy. Duldulao et al.[44] concluded that cystoscopy is not essential in the diagnosis of bladder tumours in patients without haematuria[44].

Endoscopic examination of the urethra enables functional observation of the bladder neck and manometric measurements at rest, at voluntary contraction of the sphincter, during Valsalva manoeuvre. Robertson described a technique of dynamic urethroscopy used for the assessment of urinary incontinence[45]. The study proved to be of low precision in persons with effort-related incontinence showing sensitivity of about 62%, predictive value of 74.6% and specificity of 79.1%. Dynamic urethroscopy is of low clinical value in detecting excessive detrusor activity and has a sensitivity of 24.6%[18].

Transient haematuria is a typical complication of cystoscopy; it should subside after three subsequent sets of micturition. Rare, but possible complications include sepsis, bleeding from a cancerous change, bladder perforation. Rectal perforation was described in males, whose urethra is longer and more curved, frequently narrowed by the prostate[47].

In persons with vesical dyssynergia, spastic sphincter, partial incision of the sphincter can be performed using cystoscopy.

Cytologic urine examination

Long-term maintenance of Foley catheter in the bladder, frequently used in post-SINC patients, increases the incidence of inflammatory changes in the bladder mucosa, papillary and polyps-like changes, widespread cystitis glandularis and follicular cystitis and of dysplastic changes of urinary bladder mucosa[38]. Because of the risk of bladder cancer that is several-fold greater in post-SINC patients[12,40,41], microscopic evaluation of urine sediment for presence of metaplastic cells is highly important.

CONCLUSIONS

Although urodynamic study is the principle method of modern functional urinary tract evaluation in post-SINC patients, the value of simple functional tests such as measurement of post-micturition volume or cystometrogram, useful especially during the early post-traumatic period, should not be underestimated. Ultrasonography is the principal imaging study of the lower urinary tract. There are controversies as to screening usefulness of cystoscopy in post-SINC patients; however, this study seems to be of significant importance in patients with haematuria.

Patients with signs of neurogenic urinary bladder should receive prevention care involving periodic performance of USG examinations, endoscopy and urodynamic studies dur-

ing the period of time between the 6th and the 12th month following occurrence of trauma.

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