Review

Evaluation Methods of Detrusor Sphincter Dyssynergia in Spinal Cord Injury Patients: A Literature Review

José Alexandre Pereira * and Thierry Debugne

Centre National de Rééducation Fonctionnelle et de Réadaptation, Rehazenter, Unité d’Évaluation Pelvi-Périnéale (UdEPP), rue André Vésale, 2674 Luxembourg, Luxembourg; debugne@eltrona.net
* Correspondence: jalexandrepereira@gmail.com

Abstract: Detrusor sphincter dyssynergia (DSD) is defined as an external urethral sphincter anomalous contraction concomitant to detrusor contraction during voiding, due to a neurological disease. It commonly occurs in suprasacral spinal cord-injured (SCI) patients and can be associated with autonomic dysreflexia. DSD generates risks to the urinary system and overall health; hence, it should be promptly diagnosed and managed. Bladder neck dyssynergia is a condition that should be integrated in DSD assessment. We reviewed the literature indexed in PubMed/Medline on the evaluation methods of DSD in SCI patients. Urodynamics is the mainstay evaluation method and has a prognostic value for the progression of upper urinary tract structural degradation and renal function decline. We found a lack of consensus on the optimal urodynamics configuration when evaluating DSD, especially in obtaining and measuring the signal from external urethral sphincter (EUS) activity. It appears that a combination of recordings of voiding cystourethrography and EUS electromyography, either with or without EUS pressure measurement, is the most accurate method available for evaluating DSD. While gathering articles, we came across an interesting approach in evaluating DSD in the past: urodynamics coupled with ultrasound imaging. Despite being considered valuable from a diagnostic standpoint by some prominent authors, it is no longer represented in the current literature. In addition to the instrumental diagnosis, health professionals should consider additional clinical features when evaluating and managing DSD in SCI patients, to design a customized plan to achieve the best compromise between quality of life and urinary system protection.

Keywords: spinal cord injury; detrusor sphincter dyssynergia; urodynamics; evaluation

1. Introduction

Detrusor sphincter dyssynergia (DSD) is defined as a detrusor contraction concurrent with an involuntarily contraction of the urethral and/or periurethral striated muscle [1]. The most recent International Continence Society (ICS) 2020 Standards [2] define DSD as a dyscoordination between detrusor and rhabdosphincter function during voiding due to a neurological abnormality (i.e., detrusor contraction synchronous with the contraction of the urethral and/or periurethral striated muscle). This is a feature of neurological bladder voiding disorders. DSD generally occurs due to a lesion above the sacral level and below the pons [3]. According to these standards [2], the classifications of DSD can be divided into two groups: intermittent (type 1), in patients with incomplete neurologic lesions; and continuous (type 2), which occurs more often in patients with complete lesions. In type 1 DSD (intermittent), there is a progressive increase in external urethral sphincter (EUS) contraction activity that peaks at maximal detrusor contraction, followed by sudden relaxation of the EUS as the detrusor pressure declines, allowing for urination. In type 2 DSD, there is a continuous EUS contraction throughout the entire detrusor contraction, resulting in a urinary obstruction or an inability to urinate (Figures 1 and 2). DSD occurs when there is a disruption of spinobulbar pathways between the pontine micturition complex and Onuf’s nucleus, which results in high urethral closure pressures during a detrusor contraction [4].
Although this is a straightforward definition, there are still some controversies on this topic:

(a) There were previous DSD classifications considering three groups by Blaivas [5] and three dysfunctions by Yalla [6], according to sphincter electromyographic (EMG) activity during urodynamics.

(b) In contrast with the above definition [2] that considers DSD as being striated urethral sphincter overactivity during voiding, detrusor–internal sphincter dyssynergia or bladder neck dyssynergia (BND) is a failure of the smooth muscle of the bladder neck and proximal urethra to relax during detrusor contraction in the voiding phase [4,6]. BND might have implications in the evaluation and management methods of DSD [7].

(c) DSD may also occur in non-neurological pathologies [8,9].
Figure 2. Urodynamics of type 2 (continuous) DSD according to ICS classification, where there is a continuous EUS contraction throughout the entire detrusor contraction. This case is better defined by type 2 according to the Blaivas et al. classification [5]: clonic EUS contractions in EMG channel (line arrows) and EUS pressure channel (red graph) interspersed through detrusor contractions (arrowheads), source: UdEPP Rehazenter database.

The prevalence of DSD in suprasacral spinal cord-injured (SCI) patients after the spinal shock phase is high [5], and ranges between 70 and 100% [8,10].

In clinical practice, a neurogenic bladder in SCI leading to high vesical pressures, such as any type of DSD, is associated with the risk of rapidly developing irreversible pathophysiological and structural modifications, such as bladder wall thickening and trabeculations, vesicoureteral reflux, uretero-hydronephrosis, in addition to infectious and lithiasis complications in the bladder, ureters, and kidneys leading to renal failure, and a risk of neoplasia [11–14]. Additionally, in SCI patients with lesions above T6, namely those with complete lesions, DSD is also associated with frequent episodes of autonomic dysreflexia [15].

Hence, DSD is prevalent in the SCI population, and is threatening to the urinary system and overall health status, which means that its diagnosis must be established as soon as possible. Although urodynamics is the cornerstone of DSD assessment, other aspects should also be evaluated in SCI patients. One may ask, should the clinician evaluating two different SCI patients with the same urodynamics criteria for DSD severity consider other clinical parameters to establish a follow-up and therapeutic intervention plan?

Different therapeutic interventions for DSD are discussed elsewhere in the literature. The treatment plan should be patient centered. EUS botulinum toxin injection and a bladder
drainage strategy, preferably with clean intermittent catheterization, are the mainstay when managing DSD in SCI patients. Other therapeutic options include oral drugs (alpha-blockers), EUS stents, and EUS sphincterotomy [4].

In this review, we aim to audit the literature, focusing on the evaluation methods of DSD in SCI patients, including urodynamics settings and the assessment of other clinical dimensions. The International Classification of Function and Disability and Health [16] provides the framework of reasoning.

2. Methods

We performed a review of the biomedical literature in PubMed/Medline database, according to the PRISMA checklist (Figure 3), applying the keywords: “detrusor sphincter dyssynergia”, “bladder sphincter dyssynergia”, “neurogenic bladder spinal cord”, “detrusor sphincter dyssynergia”, “dyssynergie vésico-sphinctérienne”, and filtered for articles with an abstract in English, French, Portuguese, and Spanish from 1976 to 2022.

Figure 3. Literature review according to PRISMA flow chart.
Employing the above-mentioned criteria, the search for “Detrusor sphincter dyssynergia” resulted in 851 heterogeneous results. Similarly, combining “neurogenic bladder” and “spinal cord” resulted in a broader sample of 1007 disparate papers. This led us to narrow the search, combining keywords as following: “spinal cord” and “detrusor sphincter dyssynergia”, thereby resulting in 295 articles. We further used cross-referencing to identify meaningful studies in this subject. The sampled articles were then sorted according to the following principles: describing at least one method for evaluating DSD, and with human clinical pertinence.

3. Results and Discussion

3.1. Urodynamics Evaluation of DSD in SCI Patients

Urodynamics investigation is the mainstay in evaluating neurogenic bladders, including DSD, in SCI patients. We should keep in mind that the presence of DSD criteria in the urodynamic testing of a patient with unknown spinal cord pathology should address further investigation of spinal cord involvement [9,17]. At the same time, the examiner should be aware that, during urodynamics, a neurologically intact subject may voluntarily contract the external sphincter during detrusor contractions [5].

3.1.1. Filling Cystometry/Pressure-Flow Study/Urethral Pressure

Cystometry evaluates the filling and storage phases of detrusor function by measuring changes in the intravesical pressure that occur with increases in bladder volume. The normal adult bladder capacity is around 400–750 mL, with bladder pressure not exceeding 15 cm H2O during the filling phase. During cystometry, the leak-point pressure (the pressure value at which voiding occurs) is also measured. Whenever this is higher than 40 cm H2O, which is common in DSD, it indicates a risk of subsequent renal damage [18,19]. Other abnormal cystometry findings in DSD patients include decreased bladder compliance, which is hazardous for the kidneys [18,19].

In the literature about DSD assessment in SCI subjects, we found a diversity of invasive urodynamic setups either with or without a pressure-flow study. While there is unanimity in the measuring method of intravesical pressure [2,20,21], the disagreement was due mainly to the different techniques employed to obtain and measure the signal to study EUS behavior, either with or without bladder neck involvement.

Indirect Assessment of EUS Activity

DSD cannot be diagnosed or evaluated via filling cystometry alone, without any trace of EUS activity either from image or EMG, as Versi et al. confirmed [22]. Nevertheless, Geirsson et al. [23] showed that, in 76 patients (56 men and 20 women) with suspected DSD, an ice water test during urodynamics could replace the burden of EUS EMG. In their study, the absence of leakage, despite a sustained reflex detrusor contraction, after a rapid instillation of 100 mL of sterile ice-water correlated with DSD, also defined by EUS EMG activity.

In an urodynamics study comprising filling cystometry and a pressure-flow study, without any direct recording(s) of EUS activity, Schaefer et al. [21] described that in the presence of a constant detrusor contractility, changes in outflow resistance will lead to changes in flow rate, which, in the absence of artifacts, may be an indication of DSD.

Voiding Cystourethrography (VCUG) and EUS EMG

VCUG [6], either with or without EUS EMG monitoring, is preconized by the 2020 ICS standards for the diagnosis of DSD [2]. Normal EUS EMG findings include an increment in the EMG activity of the EUS during bladder filling, secondary to an increased recruitment of motor units. Secondly, before voiding, and prior to detrusor contraction, diminished EMG activity in the EUS is expected. Conversely, in DSD, when a decrease in the EMG activity would be physiologically expected, there is an abnormal pattern of EUS EMG, with the markedly increased EMG activity of the EUS being a hallmark of DSD [18].
Blaivas et al., in 1981 [24], defined DSD as an increased EUS EMG activity during an involuntary detrusor contraction and, described DSD by VCUG as a dilated posterior urethra obstructed by the contracted EUS. Although Blaivas used and recommended VCUG in combination with EMG when studying DSD, recognizing an additional diagnostic value, he did not evaluate the relationship between the two.

Interestingly, while assessing DSD in SCI patients, some authors found some discordance of diagnostic value between VCUG and EUS EMG. This is intuitive, as De et al. [25] explained: in some patients who might present BND, the closed bladder neck on VCUG prevents the visualization of the EUS. The De et al. article summarizes the controversies on this topic very well, including the diversity of EUS EMG recording methods. They reviewed 49 urodynamics studies from patients diagnosed with DSD (gender distribution not mentioned): 10 patients with DSD criteria by VCUG lacked EMG abnormality; 11 patients with DSD by EMG had a closed bladder neck in VCUG result, and therefore did not have the criteria of DSD by VCUG. They found only 60% agreement (28 urodynamic studies) between wire needle EUS EMG and VCUG in diagnosing DSD. Thus, they suggested that a combination of EUS EMG and VCUG may identify more cases of DSD than either modality alone. Moreover, in two different studies, using skin patch EMG electrodes, Miller et al. [26] and Spettel et al. [27] also found disparate findings from VCUG coupled with EUS EMG versus EMG and VCUG used alone in identifying DSD. In addition, they suggested a combined used of EUS EMG monitoring and VCUG in urodynamics to avoid underdiagnosing DSD.

From a methodological standpoint, we did not find any research, for this literature review, comparing placement and/or type of EMG electrodes (skin patch/wire/concentric/coaxial needle) while monitoring EUS EMG in urodynamics.

**EUS Pressure Measurement**

The role of urethral pressure measurement and profilometry in the diagnosis of DSD is controversial and is considered by the ICS to be investigational [28]. In the literature, it is commonly used to appreciate DSD treatment outcome, such as in EUS botulinum toxin injection [29], where a decrease in EUS pressure is expected.

In our review, we found a lack of consensus concerning the use of this measure in invasive urodynamics while evaluating DSD patients.

Specifically for investigating DSD, recorded urethral pressure in the internal and external sphincter regions was used by Schurch et al. [7], and coupled with EMG recording in periurethral striated muscles by Yalla et al. [6]. Stoffel et al. routinely used urethral pressures as a complementary measurement for diagnosing DSD. [4].

In a series of 42 male suprasacral SCI patients, Bary et al. [30] found an add-value of intraurethral pressure measurement to characterize DSD, even in those patients who underwent sphincterotomy to treat DSD. They mentioned that, apparently, the combined recordings of detrusor pressure, EUS EMG, and VCUG, along with intraurethral dynamic pressure measurement, would be the best available method in assessing DSD in SCI patients. However, in the article by Suzuki et al. [31], out of 72 patients (36 men, 36 women) diagnosed with DSD using the VCUG and EUS EMG setting, only 6 patients were diagnosed with DSD when only EUS pressure was considered. Their cutoff for EUS pressure variation to diagnose DSD was defined as any increase, maintenance, or decrease < 10 cm·H₂O during the voiding phase. They concluded that the EUS sphincter pressure measurement alone is inaccurate and cannot replace the combined pelvic floor EMG and VCUG method to assess DSD. Conversely, in a more recent study, Corona et al. [32] described a protocol for using urethral pressure during urodynamics for identifying patients with DSD. In their retrospective analysis of a database of 72 patients (42 men, 30 women) diagnosed with SCI or multiple sclerosis and urodynamic evidence of DSD based in VCUG or EUS EMG findings, EMG alone diagnosed DSD in 79%, VCUG alone in 63%, and a rise in urethral pressure > 20 cm·H₂O as a single indicator of DSD occurred in 86%. The 20 cm·H₂O cutoff is relatively specific to DSD patients, since only 8.7% (2 of 23) of the control neuro-
genic bladder patients with detrusor overactivity without DSD had a urethral pressure amplitude > 20 cm H2O during detrusor contraction. This threshold of 20 cm H2O rise in urethral pressure is also defined by Stoffel et al. [4], who obtained similar outcomes in their series. The conflicting results on this topic [30–32], which could be explained by different methodologies and defined pressure cutoffs, claim the need for further investigation.

3.1.2. DSD and BND

Urodynamics with VCUG can evaluate BND [5–7]. Yalla et al. [6] considered that internal sphincter dysynergia alone in SCI patients is rarely seen. In Schurch et al.’s [7] research, 44 urodynamics studies from 34 out of spinal shock SCI patients (28 men, 6 women) with upper motor neuron bladders were evaluated. Interestingly they were able to investigate BND and DSD, since their urodynamics framework included pressure transducers in the bladder, bladder neck, and membranous/bulbar urethra. They found BND and DSD were both present in almost all patients with complete SCI above T12, and that paraplegics with incomplete lesions had DSD without BND. Furthermore, all tetraplegics, either complete or incomplete, presented with BND associated with autonomic dysreflexia. According to Schurch, active BND was independent of EUS action. BND would occur when there was a disruption of the inhibitory influence of the parasympathetic system on the sympathetic control in the bladder neck. These findings should raise questions when considering treatment options in patients with complete SCI above T12, where interventions aiming only the EUS might fail. Soler et al. [33] retrospectively studied the outcome predictors of EUS botulinum toxin injection as a therapeutic intervention in 99 adults male suprasacral SCI patients with DSD, and they determined that the presence of a BND in VCUG was a predictor of failure for this intervention.

3.1.3. Ultrasound and Urodynamics

In 1986, when diagnostic ultrasound technology was in its early stages, Perkash et al. used combined urodynamics and transrectal sonography, which they found instrumental in their understanding of neurogenic voiding dysfunction, as well as the role that DSD plays [34]. In our PubMed/Medline search, we found only three other articles, all dating back to the 1980s, related to the simultaneous use of urodynamics and transrectal ultrasound [35–37]. Shapeero et al. [36] explored the bladder neck and urethra functions of 32 men with suspected bladder neuromuscular dysfunction using transrectal sonography, urodynamic studies, and VCUG. There were 27 coupled transrectal voiding sonography and urodynamic studies with recordings of periurethral EMG, VCUG, and urethral pressure. Shabsigh et al. [37] performed 31 combined transrectal ultrasonographic and urodynamic studies in 24 suprasacral SCI male patients to study specifically DSD. A variety of urodynamic measurements, including bladder pressure, rectal pressure (obtained from the water-filled condom around the ultrasound probe), detrusor (subtraction) pressure, uroflow, and EUS EMG activity were recorded, and this technique was considered useful in evaluating DSD. Both authors [36,37] found a superiority in diagnostic accuracy of sonography when compared with VCUG, with an advantage/drawback trade-off favoring the ultrasound (an absence of irradiation exposure to the patient and examiner, the potential of imaging the periurethral and bladder soft tissue, and a longer duration of image acquisition). Given the paucity of research results found on urodynamics combined with ultrasound imaging techniques, whose technology has improved exponentially, we searched the literature for other possibilities in this field that might be of interest for the instrumental evaluation of DSD in SCI individuals. Contrast-enhanced voiding urosonography (ceVUS) is a well-established ultrasound method used in children for detecting and grading vesicoureteral reflux, as well as for urethral imaging [38,39]. Notwithstanding, since we did not find any publication on contrast-enhanced voiding urosonography coupled with urodynamics, it seems logical that, at least conceptually, this possibility merits dedicated research in evaluating DSD in SCI patients, especially when electronic pressure sensors will be widely available in urodynamics.
3.1.4. Uroflowmetry, Post Void Residual Volume (PVR) and Bladder Diary

While not specific to DSD, the measurement of the urinary flow rate in an SCI patient with DSD should confirm the presence of bladder outlet obstruction [40]. An intermittent or low flow and the presence of significant PVR in uroflowmetry in a SCI subject is highly suggestive of DSD [8]. In clinical practice, uroflowmetry or important PVR measured by ultrasound, indicating bladder outlet obstruction in an SCI patient, is a noninvasive procedure that should alert the clinician of the likelihood of DSD, fostering further urodynamics investigation. The same argument applies when there is evidence of urine retention in the data from a patient’s bladder or voiding diary, i.e., a daily record of the patient’s bladder functioning which provides an objective documentation of voiding pattern, sensation, volumes (including PVR), incontinence episodes, and events that might lead to an incontinent episode, or urine retention evidence [18]. PVR can also be used as an outcome to appreciate efficacy in DSD treatment [41,42].

3.2. Other Clinical Dimension in Evaluation of DSD in SCI Patients

3.2.1. Anamnesis

In SCI patients with DSD, anamnesis should ascertain comorbidities, past medical history, prior surgeries, bowel and sexual function, previous and present management of DSD, bladder emptying method, parenting desire, and factors implied in DSD management, such as prostate enlargement and post-obstetric urethral hypermobility [40,43]. Usual medication must be considered, with special attention paid to the anticholinergic burden, especially when dealing with older SCI patients presenting cognitive impairment either with or without glaucoma [19,44]. Clinicians should inquire for the availability of support, home and work circumstances, lifestyle factors, motivation for treatment, and risk for irritative conditions such as pressure ulcers. [43]. Special attention should be paid to clues of early clinical degradation, such as an aggravation of autonomic dysreflexia clinical pattern (episodes symptoms, duration, frequency, unknown trigger), recurrent urinary tract infections, and worsening signs of urinary retention. These should be kept in view in the therapeutic plan or while evaluating treatment outcomes [19,43]. Quality of life measures are common indicators of therapeutic success for DSD in SCI patients in the literature [41] and are encouraged to be used in clinical practice [43].

3.2.2. Physical Exam

SCI patients should have routine physical examination, including general neurologic examination, establishing SCI severity with a validated system such as the American Spinal Cord Injury (ASIA) score, (neurologic level and completeness of injury), verifying emergence from spinal shock by disclosure of the sacral metameric reflexes, which coincides with appearance of DSD, and searching for spasticity which is associated with DSD [8,43]. Physical exam should include a perineal examination, voluntary pelvic floor contractions, anal sphincter voluntary contraction and tone, sensation of the sacral dermatomes and testing the sacral reflexes (anocutaneous and respectively the bulbocavernous and bulboanal in male or the clitoridocavernous, and clitoridoanal in female patients). An evaluation of the prostate is also important in men. Hand function should also be appreciated, expressly to assess the patient’s ability to practice clean intermittent bladder self-catheterization as a voiding method whether indicated; for this purpose, the pencil and paper test could be used [45].

3.2.3. Complementary Diagnostic and Follow-Up

There are no one-size-fits-all surveillance workup protocols for these patients, but undoubtedly, a clinical frequent follow-up (annually for Corcos et al. [46]) is advised for this population of patients, and should include [18,19,43] the assessment of:
• renal function:
  o routine: plasma concentration of electrolytes, urea, creatinine (or cystatin C),
    24 h creatinine clearance.
  o optional or with special indication: kidney scintigraphy.
• upper and lower urinary tract structural changes:
  o routine: upper and lower tract transabdominal ultrasound examination with
    morphometric measures and PVR estimation, screening for lithiasis, bladder
    trabeculation, and diverticula.
  o optional or with special indication: VCUG, urethro-cystoscopy, transrectal ultra-
    sound for prostate assessment, long term screening of neoplasms.
• screening for lower urinary tract bacterial colonization. Asymptomatic bacteriuria in
  these population should not be treated with antibiotics.

3.2.4. Autonomic Dysreflexia and DSD

Autonomic dysreflexia is an abnormal autonomic reflex responding to nociceptive
stimuli below the level of injury, which develops in patients with high-level SCI (usually
above T6) and is commonly associated with DSD [7]. A remarkable rise in blood pressure
during an autonomic dysreflexia episode sometimes leads to serious complications, such
as intracranial hemorrhage and lethal arrhythmias [47,48]. Physicians should remove
the causes of the stimuli as soon as possible, and deal with the hypertensive crisis. When DSD
is suspected in a patient undergoing invasive urodynamics, an infusion debit of 20 mL/min
during cystometry is advised. Furthermore, symptoms and blood pressure should be
carefully monitored during examinations that require bladder filling (urodynamics [15],
cystoscopy [19]). In SCI with DSD, an aggravation of autonomic dysreflexia should prompt
for more DSD aggressive treatment [49].

4. Conclusions

In SCI patients, anamnesis, symptoms, and signs related to neurogenic bladder, in-
cluding DSD, may correlate poorly with urodynamics severity parameters. Still, careful
history taking, clinical presentation, and bladder diary data have valuable information
for urodynamics interpretation and should be coherent with urodynamics findings. More-
over, irritative conditions, such as pressure ulcers and anorectal problems, medication that
influences DSD, and autonomic dysreflexia manifestations should be considered when
analyzing urodynamics results. On the other hand, in SCI with DSD, urodynamics severity
parallels with progression to deterioration of the upper renal tract and kidneys and is the
basis of diagnosis and of the management plan in these patients.

Although this literature review sheds a light on the lack of consensus in the instrumen-
tal evaluation methods of DSD in SCI, which are a synonym of ongoing progress in this
discipline, it also highlights the valuable effort being realized in urodynamics standardiza-
tion. From our literature review, it emerges that urodynamics with coupled EUS EMG and
VCUG, either with or without EUS pressure measurement, adds accuracy in diagnosing
DSD in SCI individuals. In any case, since DSD is very prevalent in suprasacral SCI patients
out of spinal shock phase, clinicians should have a high suspicion of its diagnosis in that
context. When dealing with SCI patients with DSD, other clinical parameters, as well as
urodynamics, are worthy when tailoring the management and treatment strategy.

Finally, more important than distinguishing the type of DSD, clinicians taking care of
SCI patients must be aware of the evolutive natural history of DSD if left untreated, as well
as its menacing consequences. Similar to other forms of neurogenic bladder, the goal in
managing DSD in SCI patients is to define a follow-up and therapeutic intervention plans
conducive to attain the best compromise between, on the one hand, quality of life, and
social participation, and, on the other hand, protection of the urinary system.
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Abbreviations

BND Bladder Neck Dyssynergia
DSD Detrusor External Sphincter Dyssynergia
EMG Electromyography
EUS External Urethral Sphincter
ICS International Continence Society
PVR Post Void Residual Volume
SCI Spinal Cord Injury
VCUG Voiding cystourethrography

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