ORIGINAL ARTICLE

Cardiovascular response during urodynamics in individuals with spinal cord injury

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Study design: Retrospective chart review.

Objectives: To establish the frequency and severity of autonomic dysreflexia (AD) during urodynamics among individuals with chronic spinal cord injury (SCI) and to investigate the possible effect of the number of years since SCI on the severity of AD.

Setting: SCI outpatient clinic.

Methods: A retrospective chart review was undertaken of individuals with SCI who were seen at an outpatient clinic and could potentially develop an episode of AD (T6 and above). Data regarding age, gender, urodynamic examination, lower urinary tract function, cardiovascular parameters and SCI were collected. In addition, information on signs and symptoms of AD were retrieved.

Results: A total of 76 individuals with SCI were examined with blood pressure (BP) monitoring. The majority had cervical SCI (79%). The mean age was 47.8 ± 13.9 years. The median duration after SCI was 51.5 months. During urodynamics, a total of 48 (63.2%) individuals showed an increase in systolic BP > 20 mm Hg, meeting the criteria for AD. Indicators for higher incidences of AD were cervical SCI, being > 2 years after SCI, the presence of detrusor sphincter dyssynergia (DSD) and low bladder compliance. AD was more severe in individuals with complete (American Spinal Cord Association (ASIA) impairment scale (AIS) A) injuries, worse with greater time after SCI.

Conclusion: Individuals with cervical SCI, DSD, poor bladder compliance or > 2 years after SCI were associated with a higher possibility of developing AD during urodynamics. Furthermore, AD was more severe in complete (AIS A) individuals and was exacerbated with time after injury.

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INTRODUCTION

Bladder dysfunctions, bowel dysfunctions and abnormal cardiovascular (CV) control contribute significantly to the poor quality of life of individuals after spinal cord injury (SCI), requiring both daily management and continuous medical care. Many individuals with SCI considered the improvement of bladder control, bowel control and the elimination of unpleasant episodes of autonomic dysreflexia (AD) among their priorities for improvement of quality of life.¹

It is well known that bladder control following SCI is frequently abnormal and requires many individuals to use catheterization for management.² Furthermore, it is recommended that all individuals with SCI undergo urodynamic evaluations in order to determine urinary bladder functionality and make decisions for future management.³ Urodynamic evaluation is critical for these individuals' bladder management and upper urinary tract damage prevention, but the procedure may elicit episodes of AD that could potentially be life threatening.⁴ In fact, stimulation of the urethra/prostate/internal sphincter region is likely to be a more potent stimulus of AD than just the filling of the bladder involved in urodynamics.⁵ AD is characterized by episodic hypertension and occurs in up to 90% of individuals with cervical and high thoracic SCI.⁶ If this condition is

misdiagnosed or poorly managed, the consequences can be devastating. Evidence from the literature suggests that episodes of AD may result in myocardial infarction,⁷ stroke⁸ or even death.^{8,9} The signs and symptoms experienced during AD can vary and include increased systolic and diastolic blood pressure (SBP and DBP, respectively), bradycardia or tachycardia, pounding headache, cutis anserina, anxiety, flushing and sweating above the neurological level of SCI, malaise and nausea.¹⁰

According to Curt *et al.*,¹¹ urodynamic examination can be regarded as an effective and a standardized diagnostic procedure for provoking an AD response. Linsenmeyer *et al.*¹² found urodynamic examination to be an excellent way to detect whether individuals with SCI are prone to asymptomatic AD. Previous studies revealed incidences of AD during urodynamics,^{11–16} but the diagnostic criteria varied among these studies. Some studies^{12,13} used maximal SBP and DBP as criteria, whereas others^{11,14–16} just used SBP change. The International Standards to document remaining Autonomic Function after Spinal Cord Injury (ISAFSCI)¹⁷ recommends the diagnostic criteria for AD as a SBP increase of > 20 mm Hg from baseline. Only two previous studies^{14,15} used the same criteria; however, the study by Huang *et al.*¹⁴ did not clarify SBP, DBP and heart rate (HR) changes in the AD

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subgroup but only demonstrated a change in a combination of these CV parameters in all individuals with and without AD. Therefore, it is difficult to obtain data for evaluation of the severity of AD in this study.

Giannantoni *et al.*¹³ compared the mean duration after SCI between individuals with and without AD and reported no relationship between the occurrence of AD and the time after SCI. However, this comparison did not provide direct CV parameter changes for different lengths of time after SCI.

The aim of the present study was to establish the frequency and severity of AD during urodynamics among individuals with chronic SCI at T6 and above (individuals susceptible to AD). We also examined the possible effect of time following SCI on the CV responses elicited by urodynamics. In addition, we analyzed the CV responses in relation to lower urinary tract (LUT) parameters included in ISAFSCI,¹⁷ as well as the urodynamics parameters according to the International Spinal Cord Injury Urodynamic Data Set.¹⁸

MATERIALS AND METHODS

Following study protocol approval by the Clinical Research Ethics Board, a retrospective chart review was undertaken of all SCI individuals above T6 who underwent urodynamic examination in conjunction with BP monitoring. The review lasted from January 2011 to December 2012.

Data collection

Data collected about each individual included age, gender, date of urodynamic examination, duration of SCI, neurological level of lesion and the American Spinal Cord Association (ASIA) Impairment Scale (AIS). These variables align with the International Spinal Cord Injury Core Data Set.¹⁹ CV parameters for BP and HR at baseline and during urodynamics were collected, as well as noted symptoms or signs of AD. In addition, all charts were specifically reviewed for antihypertensive medications.

During urodynamic procedures, individuals underwent continuous BP and HR monitoring (Dinamap 100, GE, Fairfield, CT, USA) recorded at intervals of 1 min starting from the position of individuals on the urodynamic table (baseline), during catheter insertion and during all stages of the urodynamic examination. The full printout of the CV parameters during the procedure was

stored in the patient's chart in addition to the following CV parameters documented on the urodynamic log: BP and HR at baseline, first sensation, leakage point, and for BP the overall maximum BP reached. Any symptoms or signs of AD were documented to distinguish silent and symptomatic AD.

According to the diagnostic criteria for AD in the ISAFSCI,¹⁷ individuals were divided into two subgroups: an AD subgroup (increase in SBP of >20 mm Hg) and a Non-AD subgroup (increase in SBP ≤20 mm Hg or a decrease in SBP). The CV parameters in the whole group, the AD subgroup and the Non-AD subgroup were analyzed, and comparisons were made between the AD and Non-AD subgroups.

Collection of LUT function data was collected in the Lower Urinary Tract, Bowel and Sexual Function Table, in accordance with the ISAFSCI.¹⁷ The variables for the bladder-emptying method originated from the definition in the International Spinal Cord Injury Lower Urinary Tract Function Basic Data Set.²⁰ Only the main emptying method was collected for the SCI individuals in our study. The urodynamic parameters aligned with the International Spinal Cord Injury Urodynamic Basic Data Set.¹⁸ To facilitate our reporting, we collapsed some items in these variables, that is, bladder sensation was recorded as present or absent, detrusor function as neurogenic detrusor overactivity (NDO) or non-NDO and urethral function as detrusor sphincter dyssynergia (DSD) or non-DSD. Bladder compliance described the relationship between the change in bladder volume and the change in detrusor pressure, with low bladder compliance defined as <10 ml per cm of water.

Urodynamic parameters were also collected during urodynamic evaluations (Aquarius TT, Laborie, Montreal, QC, Canada). Evaluations were carried out by the same group of registered nurses and urologist according to the principles set forth by the International Continence Society.²¹ The examination consisted of cystometry with warm water (37 °C) at a filling rate of 30 ml min⁻¹ through a 6-F double lumen catheter while the patients were supine. Abdominal pressure was measured with a 10-F intrarectal balloon catheter. Pelvic floor electromyography was recorded during cystometry with a bipolar wire electrode in the urethral sphincter. Filling was stopped when the patients reported sensation of fullness, at the moment of urine leakage or when bladder filling reached 500 ml.

Statistical analyses

Statistical analysis was conducted using SPSS 19.0 (IBM-SPSS, Chicago, IL, USA) as follows: the data of continuous variables are expressed as mean ± s.d. or median. Categorical variables are expressed as percentages and absolute frequencies. For continuous variables, statistical analyses were carried out using Student's *t*-test or analysis of variance if normal distribution was present. Otherwise Mann-Whitney *U*-test or Kruskal-Wallis *H*-test for nonparametric comparisons was used. A chi-square test was performed to compare categorical variables. Correlations of SBP and years after SCI were analyzed with the Spearman method. Significance level was set at *P* < 0.05.

RESULTS

General presentation of AD during urodynamics

A total of 76 individuals with SCI above T6 were examined with BP monitoring during urodynamics at a urology outpatient clinic from January 2011 to December 2012. The mean age was 47.8 ± 13.9 years. None of the individuals were on any continuous antihypertensive medications. However, all of them had standing order for management of episodes of AD that included either nifedipine or captopril on as needed basis. None of the SCI individuals took medication prior to the urodynamics. The majority individuals in the present study had cervical SCI (79%; 60/76), and because of poor hand function most of them used reflex triggering (40%; 24/60) or indwelling catheter (37%; 22/60) for bladder management (see Table 4). The median duration of injury was 51.5 months. The standardized demographic characteristics, neurological level of lesion and AIS of the study population are shown in Table 1. In the AD subgroup, SBP increased from 124.4 ± 20.4 to 176.0 ± 31.8 mm Hg, whereas in the Non-AD subgroup it increased from 121.0 ± 16.0 to 130.0 ± 17.3 mm Hg.

Table 1 Study population characteristics

Characteristics		
Age at examination (years)	47.8 ± 13.9	(19–80)
Duration since spinal cord lesion (months)	51.5	(2–532)
Gender		
Male	66	86.8%
Female	10	13.2%
Etiology		
Sports	11	14.5%
Assault	4	5.2%
Transport	37	48.7%
Fall	11	14.5%
Other traumatic cause	2	2.6%
Non-traumatic cause	11	14.5%
Neurological category		
C1–C8 AIS A	30	39.5%
C1–C8 AIS B–D	30	39.5%
T1–T6 AIS A	12	15.8%
T1–T6 AIS B–D	4	5.2%

Abbreviation: AIS, American Spinal Injury Association Impairment Scale.

The CV parameters for the whole group, the Non-AD subgroup and the AD subgroup are shown in Table 2. During urodynamic examination, 48 (63.2%) individuals experienced an SBP elevation > 20 mm Hg, which met the criteria for AD diagnosis. The highest BP recorded during urodynamics was 242/129 mm Hg. Among the AD subgroup, 28 (58.3%) individuals had symptoms that included headache, sweating and flushing, whereas the remaining (41.7%) had asymptomatic AD, also known as silent AD.^{22,23}

Level and severity of SCI and AD

Table 3 shows the comparison between incidence of AD and the average changes in SBP, DBP and HR by different injury levels (C1–C8 vs T1–T6), completeness of injury (AIS A vs AIS B–D) and duration after injury (<2 years vs >2 years). The incidence of AD was statistically significantly higher for individuals with cervical SCI and also those with >2 years after injury ($P=0.003$ and $P<0.001$, respectively). The SBP change was significantly larger in cervical than in thoracic SCI ($P=0.021$), whereas DBP and HR changes did not reveal statistically significant differences. If only comparing SBP changes in the AD subgroup, no significant difference was found between cervical and thoracic SCI. Both SBP and DBP changes

were significantly larger ($P<0.001$ and $P<0.001$, respectively) in individuals >2 years after SCI. There were no statistically significant changes, however, in HR. Interestingly, although no difference was found for incidence of AD in relation to injury completeness according to AIS grades, SBP change was significantly larger ($P=0.020$) and HR decreased more ($P=0.004$) in those with complete (AIS A) than in those with incomplete SCI. AIS A individuals with AD had a significantly larger increase in SBP than AIS B–D individuals with AD ($P=0.024$). The SBP increase in individuals >2 years after injury was significantly higher than in individuals <2 years after injury ($P=0.043$) in the AD subgroup. In addition, SBP change showed significantly positive correlations with years after injury in the whole group (Figure 1) and the AD subgroup (Figure 2).

LUT functions and AD

The divisions of the study population into subgroups by LUT function parameters are shown in Table 4. For AD incidence and changes in SBP, DBP and HR in the AD subgroup, no significant differences were found between individuals with or without awareness of the need to empty the bladder, between individuals with or without the ability to prevent leakage and among three different bladder-emptying methods.

The relationship between AD incidence, CV parameter changes and urodynamic parameters is shown in Table 5. Incidence of AD was higher in individuals with low bladder compliance and DSD ($P=0.027$ and $P=0.007$, respectively). SBP changes were likewise significantly larger in individuals with and without AD when the bladder compliance was low and DSD was present ($P=0.009$ and $P=0.007$, respectively). However, if only analyzing individuals who developed AD, no significant differences were found. Furthermore, there were no statistically significant differences between individuals with and without AD when comparing detrusor leak point pressure, maximum detrusor pressure, cystometric bladder capacity and postvoid residual volume. In addition, in the whole group and the AD subgroup, we found no correlation between SBP increase and bladder pressure or capacity.

DISCUSSION

Previous studies^{11,12} have established the use of urodynamic examination as an appropriate screening tool for AD. Our study further

Table 2 Cardiovascular parameters of the study population during urodynamics

Items	Whole group	Non-AD subgroup	AD subgroup
Number	76	28	48
SBP baseline (mm Hg)	120.7 ± 18.8	121.0 ± 16.0	120.4 ± 20.4
DBP baseline (mm Hg)	70.0 ± 12.8	70.3 ± 12.9	70.0 ± 12.9
HR baseline (b.p.m.)	69.3 ± 14.4	76.2 ± 13.0**	65.3 ± 13.7**
SBP maximal (mm Hg)	159.1 ± 35.3	130.0 ± 17.3***	176.0 ± 31.8***
DBP at SBP maximal (mm Hg)	84.4 ± 18.0	71.9 ± 13.5***	91.7 ± 16.3***
HR at SBP maximal (b.p.m.)	61.9 ± 13.2	69.4 ± 12.6***	57.5 ± 11.5***
SBP change (mm Hg)	38.4 ± 28.3	8.9 ± 8.5***	55.6 ± 20.5***
DBP change (mm Hg)	14.3 ± 15.2	1.5 ± 9.1***	21.8 ± 12.9***
HR change (b.p.m.)	-7.5 ± 10.1	-6.8 ± 9.4	-7.8 ± 10.5

Abbreviations: AD, autonomic dysreflexia; b.p.m., beats per minute; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure.
AD is defined as SBP increase > 20 mm Hg.

** $P<0.01$ and *** $P<0.001$ (comparison between non-AD and AD subgroups).

Table 3 Comparison of autonomic dysreflexia incidence and cardiovascular parameters during urodynamic investigation by injury characteristics

Items	N	Incidence of AD, % (n)	SBP change (mm Hg)		DBP change (mm Hg)		HR change (b.p.m.)	
			Whole group	AD subgroup	Whole group	AD subgroup	Whole group	AD subgroup
Injury level								
C1–C8	60	71.7 (43)**	42.6±29.5*	57.0±21.0	15.0±15.8	21.4±12.9	−6.2±8.6	−7.3±9.7
T1–T6	16	31.3 (5)**	22.7±15.7*	43.4±10.1	11.9±12.9	25.6±12.9	−12.0±13.8	−12.4±16.7
Completeness of injury								
AIS A	42	66.7 (28)	44.8±28.5*	60.8±20.5*	15.6±16.2	22.9±13.6	−9.9±9.7**	−9.1±9.0
AIS B–D	34	58.8 (20)	30.5±26.4*	48.3±18.4*	12.7±14.0	20.3±12.0	−4.4±9.8**	−6.0±12.4
Years after injury								
<2 years	31	38.7 (12)***	22.5±23.8***	46.8±18.7*	6.8±12.5***	17.2±9.9	−7.9±9.7	−10.3±12.6
>2 years	45	80.0 (36)***	49.4±26.0***	58.6±20.4*	19.5±14.8***	23.3±13.5	−7.1±10.4	−7.0±9.8

Abbreviations: AD, autonomic dysreflexia; AIS, American Spinal Injury Association Impairment Scale; b.p.m., beats per minute; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure.

* $P<0.05$, ** $P<0.01$ and *** $P<0.001$.

Figure 1 Scatter diagram shows the positive correlation ($r=0.543$, $P<0.001$) of SBP change with years following SCI. A duration of <1 year after injury was assigned as 0, between 1 and 2 years was assigned as 1 and so on.

Figure 2 Scatter diagram shows the positive correlation ($r=0.350$, $P=0.015$) of SBP change with years following SCI in individuals who developed autonomic dysreflexia. A duration of <1 year after injury was assigned as 0, between 1 and 2 years was assigned as 1 and so on.

supports that BP monitoring during urodynamics is highly recommended as an AD screening tool for individuals with SCI. In our study, 48 (63.2%) individuals showed SBP elevation by >20 mm Hg, indicating an onset of AD. Among them, 28 (58.3%) had symptoms, whereas the remaining 20 individuals could be categorized as having silent AD.^{22,23}

Previously, the incidence of silent AD during urodynamics was reported as 43–50%,^{12,24} which is similar to our finding. Hence, urodynamics could be considered as a screening tool for individuals with SCI prone to AD, especially for those whose AD is asymptomatic. In addition to urodynamics, bowel programs²² and sperm retrieval²³ also could elicit episodes of silent AD. Therefore, routine BP monitoring during these iatrogenic procedures is highly recommended.

When making comparisons between AD incidence and the neurological level of lesion, AD was seen more frequently in those with

cervical SCI, consistent with observations in previous studies.^{13,14} The SBP increase also revealed a larger increase in cervical SCI, in accordance with Huang *et al.*¹⁴; however, the SBP increase in individuals with AD demonstrated no significant difference between cervical and thoracic SCI, instead reflecting a similar severity of AD irrespective of the neurological level above T6.

Completeness of injury according to the AIS grade was also regarded as a contributing factor for the development of AD. Typically individuals with AIS A have more frequent and more severe bouts of AD.^{6,11} Previous studies,^{13,14} however, have not verified this hypothesis during urodynamics. In our study, although the incidence of AD did not show a statistically significant difference between complete (AIS A) and incomplete (AIS B–D) injuries, the SBP increase was larger and the HR decrease more pronounced in those with complete SCI. Although we only found a trend as a result of our study, it may be postulated that AD is more severe in those with complete SCI.

The correlation of AD frequency and severity with duration post-SCI is not well described. In an animal experiment, it was suggested that AD severity increased with time after injury.²⁵ However, in a study conducted by Giannantoni *et al.*,¹³ no correlation was found between AD and duration of SCI. In our study, the incidence of AD and change in SBP were both higher in individuals >2 years after SCI. Furthermore, we also found a positive correlation between SBP change and years after injury, further suggesting that AD worsens with time after SCI. The possible reason for the discrepancy between our and the previous study¹³ may be that the median duration after SCI exceeded 4 years in our study but only 2 years in the previous study.¹³

Three main topics of LUT function include awareness of the need to empty the bladder, ability to prevent leakage and bladder-emptying methods. In our study, no statistically significant differences were found between these LUT function parameters and either incidence of AD or CV parameter changes. One previous study¹³ likewise found that AD presence was unrelated to bladder management. Therefore, we can conclude that AD occurrence seems not to be influenced by bladder awareness, urinary incontinence and bladder-emptying methods.

In our study, AD incidence was statistically significantly higher in those individuals with DSD and low bladder compliance. The impact of urethral function and bladder compliance with respect to the development of AD remains controversial. The study by Giannantoni *et al.*¹³ showed no correlations between AD and incidence of DSD or low bladder compliance. However, Huang *et al.*¹⁴ revealed that SBP changes were significantly larger in individuals with DSD and severely impaired bladder compliance. Perkash²⁶ also found that SBP increase was significantly lower after transurethral modified sphincterotomy than before transurethral modified sphincterotomy, further supporting the relationship between AD and DSD. When comparing SBP changes in relation to DSD and low bladder compliance in the whole group, SBP changes were larger than those reported in a previous study by Huang *et al.*¹⁴ However, the results from the previous study¹⁴ were based on the combination of results from individuals with and without AD; thus they could not demonstrate a possible relationship to the severity of AD. Considering that SBP increased in the AD subgroup only, we found no significant differences regarding severity of the AD between individuals with and without DSD or between individuals with and without low bladder compliance. In our study, neither AD incidence nor SBP increase in AD individuals was significantly different between those with or without NDO. Correspondingly, Linsenmeyer *et al.*¹² reported that maximum detrusor pressure and bladder capacity were not statistically different between groups with

Table 4 Comparison of autonomic dysreflexia incidence and cardiovascular parameters during urodynamic investigation by lower urinary tract function from International Standards to document remaining Autonomic Function after Spinal Cord Injury (ISAFSCI)

Items	N	Incidence of AD, % (n)	SBP change (mm Hg)		DBP change (mm Hg)		HR change (b.p.m.)	
			Whole group	AD subgroup	Whole group	AD subgroup	Whole group	AD subgroup
Awareness of the need to empty the bladder								
Present	32	59.4 (19)	32.2±25.8	49.8±17.2	12.6±13.1	19.4±11.4	-5.6±9.0	-7.9±10.9
Absent	44	65.9 (29)	42.9±29.5	59.4±21.8	15.6±16.6	23.3±13.7	-8.8±10.7	-7.8±10.4
Ability to prevent leakage								
No	43	69.8 (30)	43.7±27.1	57.3±20.7	14.8±15.4	20.6±13.4	-9.5±11.3	-9.9±10.7
Yes	33	54.5 (18)	31.5±28.7	52.8±20.3	13.7±15.1	23.8±12.0	-4.8±7.6	-4.4±9.5
Bladder-emptying method								
Bladder reflex triggering	26	69.2 (18)	44.8±29.1	59.6±22.1	15.8±16.2	22.1±14.4	-6.7±7.4	-8.6±8.1
Intermittent catheterization	23	65.2 (15)	37.4±26.4	52.5±19.4	14.2±13.5	20.0±10.4	-9.7±13.7	-8.8±12.9
Indwelling catheter	27	55.6 (15)	33.2±28.9	53.9±20.1	13.0±16.0	23.2±13.9	-6.3±8.6	-5.9±10.9

Abbreviations: AD, autonomic dysreflexia; b.p.m., beats per minute; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure.

Table 5 Comparison of autonomic dysreflexia incidence and cardiovascular parameters during urodynamic investigation by urodynamic parameters from the International Spinal Cord Injury Urodynamic Basic Data Set

Items	N	Incidence of AD, % (n)	SBP change (mm Hg)		DBP change (mm Hg)		HR change (b.p.m.)	
			Whole group	AD subgroup	Whole group	AD subgroup	Whole group	AD subgroup
Bladder sensation								
Present	30	56.7 (17)	33.1±24.9	51.1±17.8	12.0±13.0	19.1±11.5	-6.2±9.1	-8.5±11.3
Absent	46	67.4 (31)	41.9±30.1	58.1±21.6	15.9±16.4	23.3±13.5	-8.2±10.7	-7.4±10.2
Detrusor function								
NDO	54	68.5 (37)	42.4±27.0	56.6±20.2	16.6±16.4*	23.6±13.7	-8.2±11.0	-7.7±11.0
Non-NDO	22	50.0 (11)	28.5±29.6	52.2±21.9	8.7±10.8*	15.6±6.7	-5.7±7.2	-8.3±9.1
Low bladder compliance								
Yes	50	72.0 (36)*	44.5±26.8**	56.9±20.8	17.9±14.7**	23.0±13.7	-7.9±11.1	-7.2±10.7
No	26	46.2 (12)*	26.7±27.9**	51.8±19.6	7.4±13.8**	18.3±9.6	-6.6±7.9	-9.8±10.3
Urethral function								
DSD	59	71.2 (42)**	42.8±28.1**	56.2±21.0	15.5±15.6	21.7±12.9	-7.7±9.2	-8.4±10.5
Non-DSD	17	35.3 (6)**	23.2±24.2**	51.2±17.4	10.4±13.3	22.5±13.6	-6.5±12.9	-3.5±10.8

Abbreviations: AD, autonomic dysreflexia; b.p.m., beats per minute; DBP, diastolic blood pressure; DSD, detrusor sphincter dyssynergia; HR, heart rate; NDO, neurogenic detrusor overactivity; SBP, systolic blood pressure.

* $P<0.05$ and ** $P<0.01$.

and without AD. However, their study emphasized that the increase in BP in individuals with uninhibited contractions was not caused by bladder distension itself but rather by bladder distension triggering an uninhibited bladder contraction. The relationship between AD and NDO needs further investigation.

Although our center has an established urodynamic protocol that includes urological procedure, CV monitoring and follow-up in case of AD development, we have to acknowledge a few possible limitations in the present study. We conducted a retrospective data collection, which is obviously a limiting factor of the study with respect to the collection of information on the developed symptoms of AD. Data presented in the study were collected from the records of the urodynamic logs that are typically made by nursing personnel during the procedure. In addition, we used maximal SBP change in

individuals who developed AD, which could only reveal the peak response in an episode of AD. We did not examine the time point when individuals exceeded the SBP increase threshold (that is, 20 mm Hg) that would represent the onset of an episode of AD nor did we calculate the duration of the episode of AD. Furthermore, presently there is no technology available at our center to combine and simultaneously illustrate the urodynamic logs and CV data. This point would need to be clarified in a further prospective study that utilizes more precise, continuous BP monitoring.

CONCLUSION

BP monitoring at 1-min intervals during urodynamic investigations is highly recommended to aid in the screening of AD, especially in cases of asymptomatic, silent AD. The results of the present study suggest

that individuals with cervical SCI, DSD, poor bladder compliance and >2 years after SCI are associated with a higher possibility of developing AD during urodynamic examinations. The episode of AD is more severe in individuals with complete (AIS A) SCI and is exacerbated with time after injury. Therefore, close monitoring and caution should be taken in individuals who present with these features.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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