Research Article

Diastolic blood pressure changes during episodes of autonomic dysreflexia

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Objective: The current diagnostic criteria of autonomic dysreflexia (AD) is based solely on systolic blood pressure (SBP) increases from baseline without regard to changes in diastolic blood pressure (DBP). During urodynamics in persons with SCI at or above the sixth thoracic level (T6), we evaluated diastolic blood pressure (DBP) changes related with AD episodes.

Design: Retrospective review of blood pressures recorded during urodynamics.

Setting: Outpatient SCI urology program in a free standing rehabilitation center.

Participants: Persons with spinal cord injury at or above the T6 level.

Interventions: Urodynamic procedures performed between August 2018 to January 2019, as well as their prior testing for up to 10 years.

Outcome Measures: Systolic and diastolic blood pressures were recorded during the procedure and episodes of AD defined as SBP > 20 mmHg above baseline.

Results: Seventy individuals accounting for 282 urodynamic tests were reviewed. AD occurred in 43.3% (122/282) of all urodynamics tests. The mean maximum SBP and DBP increase from baseline for those with AD were 35.5 ± 10.9 mmHg and 19.0 ± 9.4 mmHg, respectively. There was a concomitant rise of DBP > 10 mmHg with a SBP rise of > 20 mmHg in 76.2% (93/122) of urodynamic tests. An elevation of DBP > 10 mmHg was recorded in 23.8% (38/160) of urodynamics that did not have AD by the SBP definition.

Conclusion: DBP increments of > 10 mmHg with concurrent SBP increases of > 20 mmHg occurs in the majority of AD episodes. Given the significance of cardiovascular complications in chronic SCI, further work is warranted to determine the significance of DBP elevations for defining AD.

Keywords: Autonomic dysreflexia, Diastolic blood pressure, Spinal cord injury, Urodynamics

Introduction

Autonomic dysreflexia (AD) is defined as a constellation of signs and/or symptoms occurring in persons with spinal cord injury (SCI) at or above ($\geq$) the T6 neurological level.¹ Any noxious or non-noxious cutaneous or visceral stimulus below the neurological level can lead to a reflex sympathetic activation and cause AD.^{1–3} The prevalence of AD in susceptible individuals (levels $\geq$ T6) is between 48% and 91%.^{4,5}

The definition of AD has changed over the last few decades. In 1997, the Autonomic Dysreflexia

Guideline Development Panel defined AD by systolic blood pressure (SBP) of 150 mmHg or above and/or diastolic blood pressure (DBP) of 100 mmHg in the absence of other clinical causes.⁶ In 2001, the Consortium for Spinal Cord Medicine Autonomic Dysreflexia Clinical Practice Guidelines defined AD as an increase in SBP of “20–40 mmHg above baseline for adults and more than 15–20 mmHg above baseline in adolescents”.⁷ In 2009, AD criteria were revised to a SBP increase $\geq$ 20 mmHg above baseline.⁸ Recently, the International Standards to document remaining Autonomic Function after SCI (ISAFSCI) defined AD as a “SBP increase of > 20 mmHg from baseline, with

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or without headache, flushing, piloerection, stuffy nose, sweating above the level of the neurological lesion, vasoconstriction below the level of the lesion, and dysrhythmias".¹

As such, the current definition for AD is based solely on SBP increases from baseline without regard to change in DBP.¹ DBP changes have been reported during AD, but there are no consistent data to inform adjusting the definition of AD for inclusion of increases of DBP changes. Significant DBP changes included increases of 10 or 20 mmHg, or 30%, from baseline in association with SBP increases.^{4,5,9-13} Increases in DBP to 90 or 100 mmHg have also been used to define AD in some studies.^{6,9,14} Increases in DBP of >20 mmHg were more closely correlated to symptoms of AD than increases in SBP changes in persons with SCI >T6,¹⁵ although the reasons for this are unclear and requires further research.

DBP plays an important role in the uninjured population as an important predictor of subsequent cardiovascular disease (CVD) including coronary heart disease and hypertension.¹⁶⁻¹⁹ For individuals with SCI, who are at increased risk for cardiovascular complications,²⁰⁻²² determining the change in DBP and its inclusion in defining AD may be extremely important to identify persons who may be at increased risk for CVD. The goals of this study were to document DBP changes during urodynamics to gain a better understanding of DBP changes during episodes of AD as determined by SBP.

Materials and methods

After approval by the Institutional Review Board, retrospective chart reviews were conducted for individuals who had consecutive urodynamic examinations from August 2018 to January 2019. Inclusion criteria consisted of a traumatic SCI, neurological level of injury $\geq$ T6, age 18 years and above, and duration of injury of at least 3 months. In individuals who met the inclusion criteria, up to 10 years of prior urodynamic testing were reviewed. AD was defined as SBP >20 mmHg from their baseline blood pressure according to the current definition of the ISAFSCI.¹ Data collected for each individual included age, sex, date of urodynamic examination, duration of injury from the most recent study, neurological level of injury, and the American Spinal Cord Injury Association (ASIA) Impairment Scale (AIS) according to International Standards for Neurological and Functional Classification of Spinal Cord Injury Patients.²³

All urodynamics were performed by the same urologist according to the standards of the International

Continence Society.²⁴ All studies were performed with individuals laying down in a lithotomy position. A double lumen catheter with continuous filling of room temperature isotonic saline at a fill rate of 60 ml/min was used for each urodynamics test. Baseline brachial blood pressures (BPs) were recorded with a manual sphygmomanometer before the procedure was initiated (five minutes after the individual was placed in the lithotomy position to prepare for the urodynamic study), at the beginning of the filling phase, and intermittently during the procedure to monitor for BP changes. Systolic and diastolic blood pressures were documented during each study; individual blood pressures, maximum SBP, and maximum DBPs were compared between those with and without AD according to the current diagnostic criteria for AD.¹¹

Bladder filling was stopped when any of the following occurred; person felt their bladder was full; the bladder filling reached the person's usual "catheterization volume", the person had involuntary bladder contractions visible on urodynamic testing, there was a steady rise in the bladder pressure due to poor bladder wall compliance (40–60 cmH₂O), or the individual began to develop symptoms of AD (headache, facial flushing, chills or sweating and or SBP rose >20 mmHg above their baseline).

Statistical analysis

Statistical analysis of the SBP and DBP changes was conducted using SPSS (version 21.0 IBM, Armonk, NY) as follows: the data of continuous variables were expressed as mean $\pm$ standard deviation. Categorical variables were expressed as percentages and absolute frequencies. For continuous variables, statistical analyses were carried out using t-tests if normal distributions were present. The Mann-Whitney U test was used for nonparametric comparisons. Statistical significance was defined as $P < 0.05$.

Results

Seventy people met the inclusion criteria during the study period and had up to 10 years of prior urodynamic testing reviewed. Fifty-nine participants had multiple tests (mean = 4.6 ± 2.5 tests with a range of 2–11). In total, 282 urodynamic tests were available for analysis. Demographic data of this sample is listed in Table 1. Average number of blood pressure readings during each procedure was 5.4 ± 2.5 readings (range 2–18).

AD (defined as SBP increase of >20 mmHg above baseline) occurred in 43.3% (122/282) of all urodynamics tests. Fifty-two of 70 individuals (74.3%) had AD during at least one of their tests over the study

Table 1 Study population characteristics (N = 70).

Characteristics	N = 70
Age – years (mean ± SD)	42.4 ± 14.8
Sex – % (N)	
Male	90% (63)
Female	10% (7)
Time since injury (years) (mean ± SD)	8.2 ± 8.2
<12 months	22.9% (16)
≥12 months	77.1% (54)
Level of injury – % (N)	
Cervical (C1–C8)	82.9% (58)
Thoracic (T1–T6)	17.1% (12)
AIS – % (N)	
A	55.7% (39)
B–D	44.3% (31)
Methods of bladder management – % (N)	
Intermittent catheterization	30% (21)
Foley catheter	24.3% (17)
Suprapubic catheter	35.7% (25)
Reflex voiding	10% (7)

Abbreviations: SD, standard deviation; C, cervical; T, thoracic; AIS, ASIA Impairment Scale.

period. Most individuals with more than one urodynamic test over the last 10-year period did not have AD on each test. Of the 59 individuals who underwent multiple tests over time, seven had AD in all tests, 38 had AD in at least one test but not in all, and 14 had no episodes of AD in any of the tests. Of the 11 individuals with only one test, seven had episodes of AD and four did not.

Blood pressure measurements are documented in Table 2. The mean maximum SBP and DBP increase from baseline for those with AD were 35.5 ±

Table 2 Blood pressure recordings of the study population during urodynamics.

BP measurements during Urodynamics	All cases (N = 282) (mean ± SD)	AD group (N = 122) (mean ± SD)	Non-AD group (N = 160) (mean ± SD)
SBP baseline (mmHg)	113.8 ± 12.8	111.2 ± 12.2	114.9 ± 13.1
SBP maximum (mmHg)	134.6 ± 18.6	147.7 ± 14.9*	124.7 ± 14.5*
SBP change (mmHg)	21.2 ± 15.3	35.5 ± 10.9*	10.3 ± 6.9*
DBP baseline (mmHg)	74.7 ± 10.3	74.0 ± 10.5	75.2 ± 10.1
DBP maximum (mmHg)	87.2 ± 11.3	93.1 ± 9.3*	82.7 ± 10.5*
DBP change (mmHg)	12.6 ± 9.8	19.0 ± 9.4*	7.7 ± 6.8*

Abbreviations: BP, blood pressure; AD, autonomic dysreflexia; DBP, diastolic blood pressure; SBP, systolic blood pressure; SD, standard deviation. Values are given as mean ± standard deviation. *P < 0.001 (comparison between non-AD and AD subgroups). Mann-Whitney U test used.

10.9 mmHg and 19.0 ± 9.4 mmHg, respectively as compared to the non-AD group (mean maximum SBP change was 10.3 ± 6.9 mmHg and mean maximum DBP change was 7.7 ± 6.8 mmHg). These differences were both significant (P < 0.001).

When AD was present, there was a concomitant rise of DBP >10 mmHg in 76.2% (93/122) of urodynamic tests (See Table 3). However, there was also an elevation of DBP >10 mmHg recorded during the procedure in 23.8% (38/160) of urodynamics that did not have AD by the SBP definition. In these cases, the mean maximum SBP change was only 13.0 ± 6.5 mmHg. There was a rise in DBP of ≥20 mmHg in 50% (61/122) of tests with AD, with only 5% (8/160) of tests without AD having this level of rise. Of note, 7.8% (22/122) of tests with AD had a SBP rise >30 mmHg with a concomitant rise of DBP ≥20 mmHg.

Discussion

The focus of this study was to determine the increase in DBP during episodes of AD as defined by the current diagnostic criteria of ISAFSCI¹ in persons with traumatic SCI ≥T6 neurological level. Our prevalence of AD in 43.3% of urodynamics tests is consistent with other studies of urodynamics, although different definitions of AD have previously been used including an increase of SBP >30 mmHg, DBP >20 mmHg, elevation of SBP/DBP >160/90 mmHg, or SBP >15 mmHg from baseline with a pulse rate below 60 beats.^{3–5,9,10,13–15,25–27} We identified a mean increase of the SBP and DBP of 35.5 and 19.0 mmHg, respectively from baseline in those who had AD by the current definition, and these results are also similar to prior studies.^{4,9,12,13,15}

The consideration of whether an increase in DBP could be an independent definition of AD from rise of SBP may be warranted. We found DBP rose >10 mmHg in the majority of tests (76.2%) that developed AD based upon an SBP rise of >20 mmHg.

Table 3 DBP changes during urodynamics based upon presence of AD (defined as a SBP >20 mmHg).

Changes in DBP	AD group (N = 122) % (N)	Non-AD group (N = 160) % (N)
DBP	85.3% (104)	43.1% (69)
≥10 mmHg		
DBP >10 mmHg	76.2% (93)	23.8% (38)
DBP ≥20 mmHg	50.0% (61)	5% (8)

Abbreviations: AD, autonomic dysreflexia; DBP, diastolic blood pressure; SBP, systolic blood pressure.

However, we also found a considerable number of cases (23.8%) having an isolated DBP increase of >10 mmHg without a rise of SBP of >20 mmHg. The 23.8% of cases in this study who had a DBP of >10 mmHg without a concomitant rise of SBP of >20 mmHg, could possibly represent undiagnosed and untreated AD episodes within this group. This is important, as a diagnosis based purely on a rise in DBP of >10 mmHg would have placed these individuals not previously categorized as dysreflexic, as now having AD. Further studies are needed to determine if isolated yet persistent DBP elevations above 10 mmHg without SBP rise above 20 mmHg is a significant change in persons with SCI. If this is the case, consideration for adding DBP parameters to the definition of AD may be warranted.

The effects of elevated DBP of >10 mmHg, even if isolated from significant SBP increases, may be clinically important given the increased incidence of CVD in persons with chronic SCI.^{20–22} Elevated DBP at any age in the uninjured individual is a marker of increased peripheral vascular resistance and an important parameter of CVD.^{16–18} Increased routine DBP measurements are the most important predictor of subsequent hypertension and cardiovascular risk in patients <50 years old.²¹ Additionally, DBP increases in 10 mmHg increments are known to be a more powerful predictor of cardiovascular risk than SBP.¹⁹ Therefore, elevated DBP, with or without a SBP increase, may be a potential contributing factor for CVD worthy of consideration in SCI. It is unclear if isolated and transient increases in DBP have the same negative long-term impact as sustained elevated DBP. However, given the frequency of AD in some patients with SCI, including during bowel programs^{28–30} and the many episodes of AD that are recorded throughout the day,^{31,32} these frequent isolated changes may indeed have an important impact.

Of note, some individuals who had multiple urodynamic tests reviewed over the years did not have episodes of AD on all tests. There were no patterns noted to the individuals who had AD at some tests and not on others. This shows the importance of scheduled follow up to determine if these individuals are maintaining appropriate BP with bladder filling over time.

Limitations of this study includes the retrospective nature of study, the manual and intermittent method of BP measurements, and the inability to correlate symptoms of AD with blood pressure changes. More frequent, or preferably continuous blood pressure measurement could have potentially captured additional brief episodes of AD and a greater range of blood pressure measurements.

Conclusion

The current definition of AD is based solely on SBP changes, without consideration of the change in DBP. Using the current ISAFSCI definition of AD (a rise in SBP >20 mmHg), a significant rise in DBP (>10 mmHg) was seen in the majority of subjects, although isolated elevations of DBP occurred occasionally without significant increases in SBP, and may be an important factor contributing to cardiovascular complications. Further work is warranted to determine the significance of isolated elevations in DBP particularly with regards to signs and symptoms of AD as well as overall cardiovascular health.

Disclaimer statements

Contributors None.

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Conflict of interest There are no conflicts of interest to declare.

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