Cureus
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Open Access Original Article

Factors Associated With Autonomic Dysreflexia in Spinal Cord Injury Patients Receiving Urodynamics Testing

Review began 10/26/2026
Review ended 11/15/2026
Published 11/18/2026

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DOI: 10.7759/cureus.119860

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Abstract

Background and objective

Autonomic dysreflexia (AD) is a potentially life-threatening complication that can occur during urodynamic testing in patients with spinal cord injury (SCI). We sought to determine the incidence of AD during urodynamics and evaluate factors associated with its occurrence in a tertiary-care SCI cohort.

Materials and methods

We conducted a retrospective cohort study of patients with SCI undergoing urodynamic testing at a tertiary referral hospital between February 2020 and December 2024. AD was defined as clinician-documented symptoms or a blood pressure rise prompting cessation of the study. Candidate variables included age, gender, spinal level, injury chronicity, American Spinal Injury Association (ASIA) Impairment Scale (AIS) grade, bladder management, and baseline bladder capacity. Associations with AD were assessed using univariable and multivariable binomial logistic regression, with results reported as odds ratios (OR) and 95% confidence intervals (CI). Significance was defined as $p < 0.05$.

Results

Of the 338 patients identified, 205 met the inclusion criteria. The incidence of AD was 16.6% (34/205). On multivariable analysis, factors independently associated with AD included spinal level at or above the sixth thoracic (T6) spinal segment (adjusted OR: 15.73, 95% CI: 1.80-137.46, $p = 0.013$), indwelling catheter use (adjusted OR: 15.65, 95% CI: 1.56-156.98, $p = 0.019$), and medium bladder capacity 200-400 mL relative to large capacity (adjusted OR: 5.34, 95% CI: 1.35-21.22, $p = 0.017$). Acute injury (< 300 days) was associated with reduced odds of AD relative to chronic injury (adjusted OR: 0.13, 95% CI: 0.03-0.47, $p = 0.002$). Age, gender, and AIS completeness were not significantly associated with AD.

Conclusions

Spinal level, injury chronicity, catheter management, and medium bladder capacity were independently associated with AD during urodynamics in patients with SCI. Clinicians should remain particularly vigilant and prepared for AD in patients with these risk factors.

Categories: Urology, Orthopedics
Keywords: autonomic dysreflexia, neurogenic bladder dysfunction, risk factors , spinal cord injury, urodynamic studies

Introduction

Spinal cord injury (SCI) affects an estimated 250,000 to 500,000 people worldwide annually [1]. Autonomic dysreflexia (AD) is a potentially life-threatening condition characterised by episodic hypertension in individuals with SCI at or above the sixth thoracic (T6) spinal segment. It is typically triggered by noxious or non-noxious stimuli below the level of injury. The International Standards to document remaining Autonomic Function after Spinal Cord Injury (ISAFSCI) define AD as an increase in systolic blood pressure of more than 20 mmHg above baseline, with or without accompanying symptoms [2]. If unrecognised or inadequately managed, AD can result in serious complications, including seizures, stroke, and death [3]. Urodynamic investigation is a mainstay of lower urinary tract assessment in patients with SCI; however, bladder filling during this procedure is a recognised trigger of AD [4].

Predictors of AD during urodynamic testing remain inconsistently characterised. A recent systematic review reported considerable heterogeneity in the reported incidence and predictors of AD, partly attributable to variations in diagnostic definitions and monitoring methods across studies [5]. The primary objective of this study was to determine the incidence of clinically documented AD during video urodynamic testing in patients with SCI at a single tertiary referral centre. The secondary objective was to evaluate the associations

between demographic, neurological, and urological factors and the occurrence of AD.

Materials And Methods

Study design and setting

This was a retrospective, single-centre cohort study at a tertiary referral hospital (Sydney, Australia), evaluating patients with SCI who underwent video urodynamic (VUD) studies between February 2020 and December 2024.

Participants

Patients with SCI who attended for urodynamic testing during the study period were identified from the hospital's electronic patient record system. Of the 338 patients identified, 130 were excluded because of missing data in one or more predictor variables, leaving 208 patients eligible for complete-case analysis. Missing data reflected inconsistent documentation in the clinical record. Patients who underwent more than one urodynamic study within the audit period were identified using their patient identifier numbers. Where more than one episode existed, only the first episode within the study period was retained, which led to the exclusion of a further three episodes and a final analytic cohort of 205 patients.

Urodynamic technique and monitoring

VUD studies were performed with the patient supine or semi-recumbent. Filling cystometry used a 6-8 Fr double-lumen transurethral bladder catheter and an 8-10 Fr rectal catheter to measure abdominal pressure. The bladder was filled with sterile 0.9% saline at room temperature, at 10-50 mL/min individualised to the patient. Intravesical and abdominal pressures were measured simultaneously, and detrusor pressure was calculated as intravesical minus abdominal pressure. Bladder capacity was recorded as the volume at the end of filling, which was also stopped if AD occurred. A baseline blood pressure was recorded before filling; blood pressure was not monitored continuously, and any further measurements were operator-dependent. If AD occurred, the study was stopped, and continuous blood pressure monitoring was applied. One patient whose symptoms did not settle was transferred to the emergency department.

Outcome

The primary outcome was the occurrence of AD, defined as either symptoms of AD or a clinically significant rise in blood pressure prompting cessation of the study, as documented in the clinical urodynamics appointment note. There was no standardised blood pressure threshold for stopping the study. This decision was made at the discretion of the assessing clinician.

Predictor variables

The following predictor variables were extracted: age, gender, level of spinal cord injury, chronicity of injury, American Spinal Injury Association (ASIA) Impairment Scale (AIS) grade, bladder management (catheter status), and baseline bladder capacity. Chronicity of injury was grouped as acute (< 300 days) or chronic (> 300 days), per the European Multicentre Study about Spinal Cord Injury (EMSCI) definition [6]. Spinal level was determined per the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) [7], and grouped as above or below T6, reflecting the clinically established threshold for disruption of splanchnic sympathetic outflow [3]. AIS grade was determined per ISNCSCI criteria [7] and grouped as motor complete (AIS A-B) or motor incomplete (AIS C-D), consistent with prior studies of AD [4].

AIS A denotes a complete injury, with no sacral (S4-S5) motor or sensory function preserved; B, sensory but not motor function preserved below the neurological level, including the sacral segments; C, motor function preserved below the neurological level, with more than half of key muscles graded less than 3 (active movement against gravity); and D, motor function preserved below the neurological level, with at least half of key muscles graded 3 or more [8]. As the four-level and two-level groupings are collinear, only the two-level grouping was entered into the regression model. Bladder management was grouped as indwelling catheter (urethral or suprapubic, bypassing normal bladder filling and stretch cycles) or non-indwelling management (intermittent catheterisation or spontaneous/reflex voiding, both preserving cyclical bladder filling). Bladder capacity was grouped as small (< 200 mL), medium (200-400 mL), or large (> 400 mL), approximating the International Continence Society's reference ranges for bladder sensation during filling cystometry [9].

Statistical analysis

Continuous variables are reported as mean (standard deviation (SD) and categorical variables as n (%). Groups were compared using the independent samples Student's t-test for continuous variables and the chi-square test for categorical variables. Factors associated with AD were assessed using binomial logistic regression, with results reported as unadjusted (univariable) and adjusted (multivariable) odds ratios (OR) with 95% confidence intervals (CI). Reference categories were as follows: female sex, chronic injury, spinal level below T6, AIS C-D, intermittent catheterisation/no catheter, and large bladder capacity. Candidate

variables were selected based on prior published literature and clinical relevance and entered together into the multivariable model. With 34 AD events, the analysis was considered exploratory. Statistical significance was defined as $p < 0.05$. All analyses were performed using Jamovi (Version 2.6.45).

Ethical considerations

This study was conducted as a registered quality improvement project (registered July 14, 2024) with the Royal North Shore Hospital Patient Safety and Quality Unit. Formal ethical risk assessment confirmed no ethical risks requiring Human Research Ethics Committee review, and the requirement for individual patient consent was waived given the retrospective, non-interventional use of routinely collected clinical data.

Results

Participant flow

Of the 338 patients with SCI who underwent urodynamic testing at Royal North Shore Hospital between February 2020 and December 2024, 133 were excluded: 130 due to missing data in one or more predictor variables, and a further three for undergoing more than one urodynamic study within the study period. This yielded a final analytic cohort of 205 patients (Figure *1*). AD occurred in 14 of the 130 patients excluded for missing data (10.8%), compared with 34 of the 205 analysed (16.6%) ($p = 0.15$).

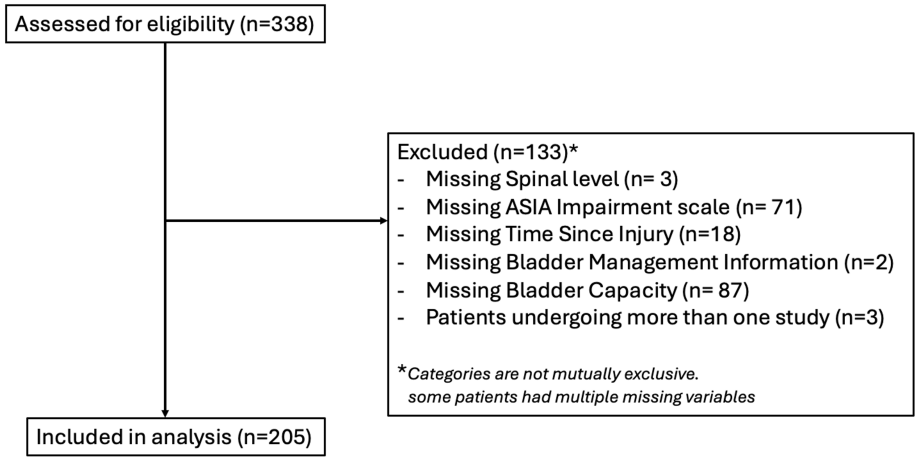


FIGURE 1: Participant flow diagram

ASIA: American Spinal Injury Association

Baseline characteristics

The overall incidence of AD during urodynamic testing was 16.6% (34/205). Baseline characteristics, stratified by AD status, are presented in Table *1*. Mean age was similar between groups (58 years, SD: 16) in the AD group vs 60 years (SD: 18) in the non-AD group) and was not significantly associated with AD. The cohort was predominantly male (157/205, 77%). A higher proportion of males was observed in the AD group (88%) than in the non-AD group (74%) ($p = 0.079$). Acute versus chronic injury status, spinal level, bladder management, and bladder capacity all differed significantly between the AD and non-AD groups (all $p < 0.05$). AIS grade and AIS completeness (motor complete (A-B) vs motor incomplete (C-D)) showed a non-significant trend toward association with AD ($p = 0.058$ and $p = 0.071$, respectively).

Variable	Total cohort (N = 205)	AD group (n = 34)	Non-AD group (n = 171)	Test statistic	P-value
Age, years, mean (±SD)	60 (±17)	58 (±16)	60 (±18)	T(203)=-0.63	0.532
Gender, n (%)				$\chi^2(1) = 3.09$	0.079
Male	157 (77)	30 (88)	127 (74)		
Female	48 (23)	4 (12)	44 (26)		
Acute vs chronic SCI, n (%)				$\chi^2(1) = 20.23$	< 0.001
Acute (< 300 days)	173 (84)	20 (59)	153 (89)		
Chronic (> 300 days)	32 (16)	14 (41)	18 (11)		
Spinal level, n (%)				$\chi^2(1) = 15.98$	< 0.001
T6 and above	139 (68)	33 (97)	106 (62)		
Below T6	66 (32)	1 (3)	65 (38)		
ASIA Impairment Scale (AIS) grade, n (%)				$\chi^2(3) = 7.50$	0.058
AIS A	47 (23)	13 (38)	34 (20)		
AIS B	39 (19)	6 (18)	33 (19)		
AIS C	57 (28)	10 (29)	47 (27)		
AIS D	62 (30)	5 (15)	57 (33)		
Complete vs incomplete SCI, n (%)				$\chi^2(1) = 3.25$	0.071
AIS A-B (complete)	86 (42)	19 (56)	67 (39)		
AIS C-D (incomplete)	119 (58)	15 (44)	104 (61)		
Bladder management, n (%)				$\chi^2(1) = 11.85$	< 0.001
Indwelling catheter (urethral catheter/SPC)	150 (73)	33 (97)	117 (68)		
Intermittent catheterisation/none	55 (27)	1(3)	54 (32)		
Bladder capacity, n (%)				$\chi^2(2) = 19.48$	< 0.001
< 200 mL (small)	41 (20)	14 (41)	27 (16)		
200-400 mL (medium)	84 (41)	17 (50)	67 (39)		
> 400 mL (large)	80 (39)	3 (9)	77 (45)		

TABLE 1: Baseline demographic and clinical characteristics of the study cohort, stratified by AD status

Continuous variables were compared using Student's t-test, and categorical variables were compared using the chi-square test

AD: autonomic dysreflexia; SD: standard deviation; SCI: spinal cord injury; ASIA: American Spinal Injury Association; SPC: suprapubic catheter

Factors associated with autonomic dysreflexia

Unadjusted and adjusted associations between candidate predictors and AD, derived from binomial logistic regression, are presented in Table *2*. Spinal level was strongly associated with AD. Patients with a lesion at or above T6 had substantially higher odds of AD than those with a lesion below T6 on both univariable (unadjusted OR: 20.24, 95% CI: 2.70-151.41, p = 0.003) and multivariable analysis (adjusted OR: 15.73, 95% CI: 1.80-137.46, p = 0.013). Chronicity of injury was also significantly associated with AD. Patients with acute SCI (< 300 days) had markedly lower odds of AD than those with chronic injury (> 300 days), both unadjusted (OR: 0.17, 95% CI: 0.07-0.39, p < 0.001) and after adjustment (adjusted OR: 0.13, 95% CI: 0.03-

0.47, p = 0.002).

Variable	Unadjusted OR (95% CI)	Univariable p-value	Adjusted OR (95% CI)	Multivariable p-value
Age, years, mean	0.993 (0.973-1.01)	0.530	0.985 (0.958-1.014)	0.302
Gender				
Male	2.598 (0.867-7.792)	0.088	2.248 (0.627-8.059)	0.214
Female	Reference		Reference	
Acute vs chronic SCI				
Acute (< 300 days)	0.168 (0.073-0.389)	<0.001	0.127 (0.034-0.471)	0.002
Chronic (> 300 days)	Reference		Reference	
Spinal level				
T6 and above	20.236 (2.704-151.412)	0.003	15.733 (1.801-137.458)	0.013
Below T6	Reference		Reference	
Complete vs incomplete SCI				
AIS A-B (complete)	1.966 (0.935-4.135)	0.075	2.092 (0.796-5.501)	0.134
AIS C-D (incomplete)	Reference		Reference	
Bladder management				
Indwelling catheter (urethral catheter/SPC)	15.231 (2.030 - 114.261)	0.008	15.654 (1.561-156.976)	0.019
Intermittent catheterisation/none	Reference		Reference	
Bladder capacity				
< 200 mL (small)	13.309 (3.549 - 49.907)	<0.001	3.353 (0.627-17.930)	0.157
200-400 mL (medium)	6.512 (1.828 - 23.197)	0.004	5.342 (1.345-21.216)	0.017
> 400 mL (large)	Reference		Reference	

TABLE 2: Univariable and multivariable binomial logistic regression analysis of predictors of AD

The regression analysis included 205 patients, of whom 34 had AD

AD: autonomic dysreflexia; OR: odds ratio; CI: confidence interval; SCI: spinal cord injury; ASIA: American Spinal Injury Association; SPC: suprapubic catheter

Bladder management was independently associated with AD. Indwelling catheter use (urethral or suprapubic) carried significantly higher odds of AD than intermittent catheterisation or no catheter, on both univariable (unadjusted OR: 15.23, 95% CI: 2.03-114.26, p = 0.008) and multivariable analysis (adjusted OR: 15.65, 95% CI: 1.56-156.98, p = 0.019). Baseline bladder capacity was associated with AD. Medium bladder capacity (200-400 mL) was associated with significantly higher odds of AD relative to large capacity (> 400 mL) on both univariable (unadjusted OR: 6.51, 95% CI: 1.83-23.20, p = 0.004) and multivariable analysis (adjusted OR: 5.34, 95% CI: 1.35-21.22, p = 0.017). Small bladder capacity (< 200 mL) was significantly associated with AD on univariable analysis (unadjusted OR: 13.31, 95% CI: 3.55-49.91, p < 0.001) but did not retain statistical significance after adjustment (adjusted OR: 3.35, 95% CI: 0.63-17.93, p = 0.157). Age, gender, and AIS completeness (motor complete (A-B) vs motor incomplete (C-D)) were not significantly associated with AD on either univariable or multivariable analysis (all p > 0.05, Table *2*).

Discussion

In this retrospective, single-centre cohort of 205 patients with SCI undergoing urodynamic testing, we found a relatively low incidence of AD of 16.6% (34/205). Factors independently associated with AD on

multivariable analysis included spinal injury level at or above T6, chronic (versus acute) injury, indwelling catheter use, and medium (200-400 mL) bladder capacity relative to large capacity. Given the potentially life-threatening complications of AD, including stroke, seizures, and cardiac arrhythmia [3], identifying high-risk patients is important to guide safe clinical practice and inform local care. AD in this study was identified from either symptoms or a clinically significant blood pressure rise, documented by the assessing clinician at clinical discretion rather than against a standardised threshold. This differs from the ISAFSCI definition, which defines AD as a systolic blood pressure rise of > 20 mmHg from baseline irrespective of symptoms [2].

Studies using continuous cardiovascular monitoring have reported considerably higher AD incidences than our own (16.6%), ranging from 63.2% to 73% [10,11]. Kirshblum et al., using frequent intermittent manual blood pressure checks rather than continuous monitoring, similarly reported a higher incidence of 43.3% [12]. This discrepancy is likely explained by 'silent' or asymptomatic AD, blood pressure elevations meeting diagnostic criteria without symptoms, which a recent systematic review found to affect a substantial proportion of AD episodes [5], reported in 43.75% by one continuous-monitoring study [13]. Whether silent AD carries the same risk as symptomatic AD remains unclear [14]. Our symptom-based approach therefore likely underestimates the true incidence of AD in this cohort.

Spinal injury level at or above T6 was the strongest factor associated with AD in our cohort, with increased odds on both univariable (unadjusted OR: 20.24, 95% CI: 2.70-151.41, p = 0.003) and multivariable analysis (adjusted OR: 15.73, 95% CI: 1.80-137.46, p = 0.013). This is consistent with a recent systematic review reporting a level-dependent gradient of adjusted odds, from 16.2 at C1-C4 down to 2.6 at T4-T6, relative to injuries below T6 [5]. This reflects the underlying neuroanatomy. Splanchnic sympathetic outflow arises from T5-T12, so higher lesions disconnect more supraspinal inhibitory control, permitting an increasingly unopposed sympathetic reflex to stimuli below the injury level, such as bladder distension [3]. Only one of 66 patients with a lesion below T6 developed AD (1.5%), consistent with other symptom-based studies such as Koyuncu et al. (1.9%) [15] and Huang et al. (15.4%) [16].

Chronicity of injury was also strongly associated with AD in our cohort. Patients with acute injury (< 300 days) had markedly lower odds of AD than those with chronic injury (> 300 days), both unadjusted (OR: 0.17, 95% CI: 0.07-0.39, p < 0.001) and adjusted (OR: 0.13, 95% CI: 0.03-0.47, p = 0.002). This is broadly consistent with previous findings linking greater time since injury to AD. Liu et al., 2016 [10] identified being ⩾ 2 years post-SCI as an indicator of higher AD incidence, while Liu et al., 2013 [17] found similarly greater blood pressure change beyond two years post-SCI. AD is uncommon in the initial weeks after high-level SCI, a period of depressed sympathetic activity termed spinal shock, with most cases manifesting three to six months post-injury as spinal sympathetic circuitry reorganises into a hyperexcitable state [3]. This may explain the lower odds of AD among our acute-injury patients, many still within this early window.

Bladder management was independently associated with AD. Indwelling catheter use (urethral or suprapubic) carried markedly higher odds of AD than intermittent catheterisation or no catheter, on both univariable (unadjusted OR: 15.23, 95% CI: 2.03-114.26, p = 0.008) and multivariable analysis (adjusted OR: 15.65, 95% CI: 1.56-156.98, p = 0.019). This finding contrasts with Vırseda-Chamorro et al., 2017, who found catheter use was, if anything, less frequent among AD patients on univariable analysis (16% vs 39%, p=0.024), not persisting after adjustment [18]. A possible explanation is bladder capacity: chronic indwelling catheterisation bypasses normal filling and stretch cycles and is associated with poorer bladder compliance [19], a parameter related to capacity, itself associated with AD. Catheter type may also reflect case-mix, since indwelling catheters are preferentially used in more severe bladder dysfunction. The discrepancy with Vırseda-Chamorro et al. may reflect differing catheterisation practice between centres [18]. The wide confidence intervals indicate substantial uncertainty in the size of this association.

Medium bladder capacity was associated with AD after adjustment, but small capacity was not. Medium bladder capacity (200-400 mL) was associated with significantly higher odds of AD relative to large capacity (> 400 mL) on both univariable (unadjusted OR: 6.51, 95% CI: 1.83-23.20, p = 0.004) and multivariable analysis (adjusted OR: 5.34, 95% CI: 1.35-21.22, p = 0.017). Small bladder capacity (< 200 mL) was significantly associated with AD on univariable analysis (unadjusted OR: 13.31, 95% CI: 3.55-49.91, p < 0.001) but did not retain significance after adjustment (adjusted OR: 3.35, 95% CI: 0.63-17.93, p = 0.157), likely reflecting small subgroup numbers. This contrasts with several previous studies finding no association between capacity and AD [18,20], though reduced bladder compliance, a related parameter, has more consistently been linked to AD [10].

Compliance and capacity are not independent. The International Continence Society defines compliance using cystometric capacity as one of two measurement points [21], meaning a stiffer bladder reaches a given pressure, and therefore its recorded capacity, at a smaller volume. It is therefore plausible that our capacity variable partly reflects this phenomenon rather than a wholly independent factor. Capacity was also recorded as the volume at the end of filling, and filling was stopped when AD occurred; AD may therefore have shortened filling and lowered recorded capacity, creating or inflating this association. Whether the association is genuine warrants replication in a larger, prospective cohort with capacity measured independently of AD.

Age, gender, and AIS completeness (motor complete (A-B) vs motor Incomplete (C-D)) were not significantly associated with AD on either univariable or multivariable analysis (all $p > 0.05$). This is consistent with the majority of the literature, where a recent systematic review [5] concluded that completeness does not predict AD, citing Huang et al., 2011 (39.6% vs 34.7%, $p > 0.05$) [16] and Walter et al., 2018 (adjusted OR: 1.1, $p = 0.657$)(4). Evidence on age is more mixed. Giannantoni et al., 1998 [20] and Walter et al., 2015 [11] found no significant age difference, consistent with our null result. Walter et al., 2018 [4] found a small but statistically significant difference (AD patients older), and Vırseda-Chamorro et al., 2017 found the opposite, with age under 45 an independent predictor [18]. This disagreement suggests age is not consistently associated with AD. Gender was rarely examined in the literature, with studies often restricted to a single sex, so our null finding is unremarkable.

Limitations

This study has several limitations. First, as a retrospective design, causality cannot be established despite multivariable adjustment, and residual confounding cannot be excluded. Second, as a single-centre study, our findings may reflect local practice patterns, for example around catheter selection or bladder capacity thresholds, limiting generalisability to other settings. Third, our reliance on clinician-documented AD identification, without a standardised blood pressure threshold, likely underestimates true incidence and introduces inter-operator variability relative to continuous, objective monitoring. Patients with higher lesions may also have been monitored more closely, introducing potential detection bias. Fourth, with only 34 AD events across seven variables (eight model parameters, about four events per parameter), our model is at risk of overfitting, and several estimates had wide confidence intervals. Findings should be considered exploratory and hypothesis-generating rather than definitive.

Fifth, capacity was recorded at the end of filling, which was stopped when AD occurred, so AD may have artificially reduced recorded capacity. Sixth, compliance, detrusor overactivity, detrusor pressure, filling rate, and medications were not included in the model, and sensitivity analyses using other definitions of chronicity were not performed. Finally, 130 of 338 patients (38%) were excluded due to missing data, reflecting variable documentation in the clinical record. AD rates were similar in those excluded and those analysed (10.8% vs 16.6%, $p = 0.15$), although selection bias cannot be excluded.

Conclusions

In this retrospective cohort of patients with SCI undergoing urodynamic testing, AD occurred in 16.6% of patients. Despite the limitations discussed, spinal injury level at or above T6, chronic injury, indwelling catheter use, and medium bladder capacity were independently associated with AD in this exploratory analysis. These findings may help clinicians anticipate patients at greatest risk of AD during urodynamic testing, supporting clinical vigilance and preparedness to manage this complication. They also add to the existing evidence base on factors associated with AD and may help inform local practice around bladder management. Future studies using a standardised definition of AD are needed to enable pooling of data across studies and more precisely define factors associated with AD, and to determine whether our bladder management and capacity findings replicate using continuous cardiovascular monitoring.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Patrick J. Benc

Acquisition, analysis, or interpretation of data: Patrick J. Benc

Drafting of the manuscript: Patrick J. Benc

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Royal North Shore Hospital Medical Services Patient Safety and Quality Unit, on Behalf of Northern Sydney Local Health District (NSLHD) issued approval NA. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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