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REVIEW

Iatrogenic urological triggers of autonomic dysreflexia: a systematic review

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Study design: This is a systematic review.

Objective: The objective of this study was to review the literature on iatrogenic urological triggers of autonomic dysreflexia (AD).

Setting: This study was conducted in an international setting.

Methods: A systematic review was conducted from PubMed search using AD/ autonomic hyperreflexia and spinal cord injury (SCI). Studies selected for review involved iatrogenic urological triggers of AD in individuals with SCI, including original articles, previous practice guidelines, case reports and literature reviews. Studies that did not report AD or blood pressure (BP) assessments during urological procedures were excluded.

Results: Forty studies were included for analysis and categorized into four groups: (1) urodynamics and cystometry; (2) cystoscopy and transurethral litholapaxy; (3) extracorporeal shock-wave lithotripsy (ESWL); and (4) other procedures. During urodynamics, the incidence of AD ranged from 36.7% to 77.8%. The symptomatic rate ranged from 50% to 65%, with AD symptoms seen predominantly in cervical SCI patients. The studies imply no consensus regarding the relationship between AD, neurogenic detrusor overactivity and detrusor sphincter dyssynergia. Without anesthesia, the majority of individuals develop AD during cystoscopy, transurethral litholapaxy and ESWL. The effectiveness of different anesthesia methods relies on blocking the nociceptive signals from the lower urinary tract (LUT) below the level of the neurological lesion. Other iatrogenic urological triggers were commonly associated with bladder filling.

Conclusion: The LUT triggers of episodes of AD are often associated with iatrogenic urological procedures. AD was more prevalent in cervical SCI than in thoracic SCI. To detect this potential life-threatening complication following cervical and high thoracic SCI, routine BP monitoring during urological procedures is highly recommended.

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INTRODUCTION

Autonomic dysreflexia (AD) is a potential life-threatening condition, and it is considered a clinical emergency[1,2] characterized by a constellation of signs and/or symptoms in response to a noxious or non-noxious stimuli originating below the level of the neurological lesion in individuals with spinal cord lesions at or above T6.[3,4] During AD, systolic arterial blood pressure (BP) may increase to 300 mm Hg and may, without immediate treatment, result in seizure, intracranial hemorrhage, myocardial infarction or death.[5–11]

A sudden and massive increase in systolic and diastolic BP (SBP and DBP, respectively) in response to noxious or non-noxious stimuli below the level of injury is a defining criterion for AD.[12] Bradycardia frequently accompanies episodes of AD and typically occurs as a result of baroreceptor-mediated increase in vagal activity above the neurological level owing to increased arterial BP; however, tachycardia is also documented in individuals suffering from AD.[13] During an episode of AD, individuals frequently experience the following signs and symptoms: pounding headache, goose bumps (cutis anserine), anxiety, flushing, sweating above the neurological level of lesion, malaise and nausea.[14] Despite this typical presentation of AD with objective signs

and subjective complaints, a variety of studies[15–19] have recognized a condition referred to as 'silent AD', which includes a significant increase in BP in the absence of other objective signs and subjective complaints.

The International Standards for Neurological Classification of Spinal Cord Injury evaluates sensation and voluntary motor strength, ignoring the role of the autonomic nervous system (ANS). To address impairments to the ANS, the International Standards to Document Remaining Autonomic Function after Spinal Cord Injury (ISAFSCI) was developed.[3,4] One of its more extensive topics was AD, which is defined as an increase in $SBP > 20$ mm Hg above baseline, with or without headache, flushing, piloerection, stuffy nose, sweating above the level of the neurological lesion, vasoconstriction below the level of the lesion or dysrhythmias.

In most cases (75–90%),[2,20,21] AD is triggered by events located in the lower urinary tract (LUT). Triggering of AD in the LUT happens in the course of living with a neurogenic bladder, such as indwelling catheter obstruction, malposition of the catheter tip, overfilling of the drainage bag, allowing the bladder to excessively distend between intermittent catheterizations and LUT infection. The cause is

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sometimes iatrogenic if, for example, the AD occurs during cystoscopy, cystometry, cystography, electroejaculation, penile vibration,[15] urodynamic evaluation and extracorporeal shock-wave lithotripsy (ESWL).[12] As sexual procedures related to AD were already reviewed,[22] the aim of this study was to review the literature on the iatrogenic urological triggers of AD.

MATERIALS AND METHODS

A systematic literature review from PubMed was conducted on all English-language studies that provided scientific evidence for iatrogenic urological triggers of AD following spinal cord injury (SCI). The keywords used during the search were population search terms that included 'paraplegia', 'tetraplegia', 'quadriplegia', 'spinal cord inj*', 'spinal cord dys*(function)', 'spinal cord dis*' and 'spinal cord lesion', as well as 'autonomic dysreflexia' or 'autonomic hyperreflexia'. Studies published between 1956 and 2014 were included into the search. The studies were assessed by two independent reviewers on the basis of each study abstract, which had to mention urological procedures and resultant AD or BP elevation. The selected studies included original articles, practice guidelines, case reports and literature reviews pertaining to iatrogenic urological triggers of AD. Studies with no data on AD or changes in BP during urological assessments were excluded. When the abstracts indicated relevance, authors retrieved the full-text articles, reviewed them and reached a consensus opinion.

RESULTS

The search yielded 691 articles. Articles that did not mention a urological procedure and AD were removed from the sample, because they did not include iatrogenic urological triggers of AD. This resulted in a total of 40 articles from which data were extracted for the current review. The included articles were divided into four groups according to the urological procedure: (1) urodynamics and cystometry ($n = 21$); (2) cystoscopy and transurethral litholapaxy ($n = 12$); (3) ESWL ($n = 6$); and (4) other procedures ($n = 2$). The 'other procedures' were voiding cystourethrography, loopography and micturition trial. One study involved both urodynamic investigation and cystoscopy.

Incidence of AD during iatrogenic urological procedures

The incidence of AD during urodynamics, cystoscopy and ESWL is shown in Table 1. The incidence of AD during urodynamics varied[15–17,21,23–26] ranging from 36.7% to 77.8%. This variation was influenced primarily by the neurological level and severity of the SCI. One study[27] reported the incidences for individuals with American Spinal Injury Association Impairment Scale (AIS) A and B to be 15.9% and 21.4%, respectively. However, this study involved individuals with SCI from C4 to T12. As the majority of AD would occur in SCI individuals injured at or above T6, the lower AD incidence in T7 to T12 group would lead to the lower overall incidence, that is, underestimating the incidence rate. It is traditionally expected that essentially all AD cases occur in individuals with injury at or above the T6 spinal. However, a few cases reported in the literature showed that episodes of AD could occur with SCI as low as L1.[24] It has to be understood that in all of these studies only the level of motor and sensory injuries was evaluated, without comment on the level of autonomic injury. As the more recent literature evidence suggests, the level of motor/sensory injury could differ with autonomic injury within the spinal cord.[28] Unfortunately, this same study did not report the incidence above T6 separately. Alderson et al.[29] revealed that 21 out of the 45 (47%) individuals with SCI developed AD during transurethral surgery; however, the authors did not mention the percentage of individuals injured above T6. In comparison, Snow et al.[30] reported a 70% incidence of AD during cystoscopy in individuals injured at or above T6 and no incidence for individuals with neurological lesions below T7. The incidence of AD during ESWL seems to be lower than that during urodynamics and cystoscopy, as a single study performed by Stowe et al.[31] reported that 9 out of the 40 (23%) individuals injured at or above T8 developed AD during the ESWL procedure.

Urodynamics and cystometry

Urodynamic investigation is considered the most common iatrogenic trigger of AD. Numerous investigators (Table 2) use urodynamics as a screening tool for AD. Giannantoni et al.[15] revealed that all patients with a lesion above T6 had significant BP elevation during

Table 1 The incidence of autonomic dysreflexia during iatrogenic urological procedures

First author, year (reference), country	Overall (above T6)	Level of injury			Completeness of injury	
		Cervical	Thoracic at or above T6	Below T6	Complete	Incomplete
Urodynamics						
Lindan, 1980,[21] USA	48% (103/213)	60% (86/143)	20% (17/87)	NA	NA	NA
Linsenmeyer, 1996,[16] USA	78% (35/45)	79% (31/39)	67% (4/6)	NA	NA	NA
Curt, 1997,[17] Switzerland	42% (13/31)	59% (13/22)	0% (0/9)	NA	50% (10/20)	27% (3/11)
Chancellor, 1998,[23] USA	57% (16/28)	NA	NA	NA	NA	NA
Giannantoni, 1998,[15] Italy	42% (20/48)	54% (13/24)	29% (7/24)	NA	44% (4/9)	41% (16/39)
Huang, 2011,[24] Taiwan	43% (40/94)	45% (38/85)	22% (2/9)	15%(4/26)	40% (19/48)	35% (25/72)
Huang, 2013,[25] Taiwan	42% (42/101)	NA	NA	NA	NA	NA
Sayılır, 2013,[26] Turkey	56% (50/90)	56% (50/90)	NA	NA	NA	NA
Cystoscopy						
Alderson, 1976,[29] UK	NA	79% (19/24)	10% (2/21)	NA	NA	
Snow, 1978,[30] USA	70% (40/57)	80% (33/41)	44% (7/16)	0% (0/45)	NA	NA
ESWL						
Stowe, 1989,[31] USA	23% (9/40)	21% (6/28)	25% (3/12)[a]	0% (0/12)	NA	NA

Abbreviations: ESWL, extracorporeal shock-wave lithotripsy; NA, not available.
[a]Thoracic at or above T8.

Table 2 Urodynamics and cystometry

First author, year [reference], country	Methodology	Results
Perkash, 1979,[36] USA	Total sample size: $N=53$ with DSD Intervention: (1) cystomanometry; (2) BP monitoring.	(1) High correlation among BP increase, level of injury and severity of DSD (2) In tetraplegia, SBP increases $\geqslant 40$ mm Hg and DBP increases $\geqslant 20$ mm Hg were significant to suspect DSD. (3) In paraplegia below T5, SBP increases $\geqslant 20$ mm Hg and DBP increases $\geqslant 10$ mm Hg were significant to suspect DSD.
Lindan, 1980,[21] USA	Total sample size: $N=213$, complete SCI, at or above T6 (180 under cystometry) Intervention: (1) cystometry; (2) BP was recorded during bladder filling, AD was defined as SBP and DBP rise by >10 mm Hg.	(1) 48% of the patients at risk developed AD. (2) More prevalent in patients with cervical lesions. (3) Majority exhibited signs and symptoms of AD by 6 months postinjury, and 92% by the end of the first year.
Lindan, 1985,[39] USA	Total sample size: $N=12$, cervical SCI Intervention: (1) cystometry; (2) BP at every 50-ml increments of CO_2, AD was defined as BP rise to $\geqslant 140/90$ mm Hg or exhibition of symptoms.	(1) Regular daily dosage with phenoxybenzamine or nifedipine will not prevent AD. (2) Nifedipine, 10 mg orally, is indicated for the treatment of acute AD. (3) Nifedipine, 10 mg sublingually or orally, can be given prophylactically to abort AD.
Barton, 1986,[43] USA	Total sample size: $N=16$, above T6, history of AD and DSD Intervention: (1) cystometry; (2) BP monitorning before and after TUS.	(1) Before TUS, 12 patients (75%) had evidence of AD. (2) After TUS, significant decrease in BP. Frequency and magnitude of AD can be diminished significantly by TUS.
Thyberg, 1992,[32] Sweden	Total sample size: $N=12$, cervical or high thoracic SCI with reflex bladder Intervention: (1) cystometry; (2) BP was measured every 30 s.	(1) SBP (20–60 mm Hg) and DBP (15–55 mm Hg) elevation in each cystometry. (2) The maximum BP always occurred during the emptying phase and in close relation to the peak Pdet.
Krum, 1992,[33] Australia	Total sample size: $N=23$, 9 patients above T5, 7 below T5 and 7 without SCI. Intervention: (1) bladder distension by slow bladder filling; (2) ECG HR, BP and vasoactive hormone levels were measured at baseline and during filling; AD was defined as SBP rise $\geqslant 30$ mm Hg or DBP rise $\geqslant 20$ mm Hg, associated with sweating, headache or flushing.	(1) SBP increased significantly by 56 mm Hg (48%) and DBP increased by 22 mm Hg (47%) in high spinal lesion; the rise in BP was associated with a significant fall in HR. (2) SBP, DBP and HR did not change significantly in low spinal lesion or normal control group.
Thyberg, 1994,[40] Sweden	Total sample size: $N=10$, cervical or high thoracic SCI with reflex bladder. Intervention: (1) cystometries; (2) BP was measured every 30 s before and after administration of 10 mg nifedipine sublingually.	(1) Before administration, SBP varied from 113 mm Hg to 147 mm Hg, and DBP varied from 76 to 110 mm Hg during cystometry. (2) After administration, SBP varied from 99 to 118 mm Hg, and DBP varied from 67 to 83 mm Hg during cystometry. (3) Nifedipine has a prophylactic effect.
Ricottone, 1995,[37] USA	Total sample size: $N=12$, complete, cervical SCI, with DSD Intervention: (1) urodynamics; (2) Before and after TUS with symptom monitoring.	(1) Before TUS, all demonstrate DSD and associated AD symptom with bladder filling. (2) Following initial TUS, nine experienced cessation of AD. (3) Most required repeat procedures for long-term resolution.
Linsenmeyer, 1996,[16] USA	Total sample size: $N=45$, complete, above T6 Intervention: (1) urodynamics; (2) Simultaneous BP and AD symptoms monitoring; AD was defined as SBP $\geqslant 160$ mm Hg or DBP $\geqslant 90$ mm Hg.	(1) 35 patients had AD (77.8%). (2) 15 patients had silent AD (43%). (3) Before voiding, no difference in SBP between with and without hypertension (117 vs 110 mm Hg, $P=0.28$). (4) During UDC, SBP was significantly higher in the hypertensive group (169 mm Hg) vs the normotensive group (131 mm Hg) ($P<0.000$ l). (5) No difference in BP between symptomatic and silent AD before and during UDC. (6) No correlation of AD with duration of injury, bladder management, maximum voiding pressures or bladder capacity. (7) No correlation of symptoms with duration of injury, maximum voiding pressures or bladder capacity.
Perkash, 1997,[38] USA	Total sample size: $N=26$, 21 tetraplegia, 5 high paraplegia with DSD Intervention: (1) urodynamics; (2) BP monitoring before and after TUS.	(1) Before TUS, SBP rise was 32.4 ± 16.3 mm Hg, and DBP rise was 14.3 ± 9.3 mm Hg. (2) Following TUS, SBP rise was 15.5 ± 0.1 mm Hg, and DBP rise was 7.3 ± 8.6 mm Hg ($P=0.001$). (3) High correlation exists between the magnitude of BP response, level of injury and severity of DSD.
Schurch, 1997,[35] Switzerland	Total sample size: $N=17$, above T6 Intervention: (1) urodynamics; (2) MAP changes analyzing during bladder filling, isometric bladder contraction and voiding.	(1) In nine with UDC, MAP increased progressively during bladder contraction until reaching MBP and continued elevation during voiding. (2) In two with DSD, maximal MAP occurred at or before MBP.
Curt, 1997,[17] Switzerland	Total sample size: $N=31$, 22 tetraplegia (11 complete, 11 incomplete), 9 paraplegia above T6 (complete). Intervention: (1) urodynamics; (2) BP and HR continuously monitoring. AD was defined as SBP rise $\geqslant 30$ mm Hg or DBP rise $\geqslant 20$ mm Hg associated with sweating, headache or flushing.	(1) 13 (59%) (10 complete, 3 incomplete) of 22 tetraplegic patients and 0 paraplegic patient presented signs of AD. (2) 8 (62%) of 13 patients complained of symptoms of AD. (3) During urodynamics, SBP increased from 115 ± 17 to 155 ± 32 mm Hg, and DBP increased from 64 ± 13 to 82 ± 16 mm Hg ($P<0.001$); HR reduced from 59 ± 6 to 53 ± 10 b.p.m. ($P<0.01$). (4) Signs of AD were induced by bladder distension and were related mainly to hyperreflexive bladder contractions and DSD.

Table 2 (Continued)

First author, year [reference], country	Methodology	Results
Chancellor, 1998,[23] USA	Total sample size: $N=32$, suprasacral SCI with detrusor hyperreflexia Intervention: (1) urodynamics and ice-water test. (2) AD was defined as SBP increase $\geqslant 50$ mm Hg within 3 min of ice-water instillation	(1) 16 (57%) of 28 with lesions above T7 diagnosed as AD. (2) 72% had a positive ice-water test.
Giannantoni, 1998,[15] Italy	Total sample size: $N=48$, 23 cervical, 25 thoracic above T6. 39 AIS A, 9 incomplete SCI. Intervention: (1) urodynamics; (2) SBP, DBP and PR were recorded before filling CMG and monitored every 2 min and at the beginning of each UDC. AD was defined as $BP \geqslant 100$ mm Hg.	(1) 20 (41.6%) showed AD during urodynamics. (2) In AD patients, SBP increased from 112.1 ± 16.3 to 167.5 ± 24.0 mm Hg during cystometry. (3) 13 (65%) of 20 showed AD symptoms. (4) AD was more frequent in cervical patients. (5) No correlation of AD with sex ratio, age, disease duration, completeness of lesion, incidence of NDO and DSD.
Lee, 2003,[41] Korea	Total sample size: $N=8$, male, cervical SCI Intervention: (1) cystometry with and without DPN stimulation; (2) BP and Pdet monitoring; AD was defined as SBP increase $\geqslant 40$ mm Hg.	(1) SBP increased from 122.7 ± 13.2 to 149.1 ± 15.2 mm Hg, and DBP increased from 73.1 ± 5.3 to 89.7 ± 8.9 mm Hg during the first contraction ($P<0.01$). (2) SBP and DBP increased as Pdet increased in all cases. (3) SBP and DBP during the first contraction decreased to 131.4 ± 9.9 and 79.9 ± 6.6 mm Hg, respectively, by electric stimulation, lower than without ($P<0.01$). (4) DPN stimulation decreased the increased BP in AD.
Rapidi, 2008,[27] Greece	Total sample size: $N=154$, 126 AIS A, 28 AIS B. Intervention: (1) urodynamics and retrograde cystography; (2) AD documented either during urodynamics or by episodes needing medical intervention.	(1) UDC usually combined AD in patients above T6. (2) 20 (15.9%) with AIS A and 6 (21.4%) with AIS B documented AD. (3) In patients with tetraplegia, 13 (39.4%) of 33 with AIS A and 6 (30%) of 20 with AIS B documented AD.
Huang, 2011,[24] Taiwan	Total sample size: $N=120$, suprasacral SCI, 94 above T6, 48 complete. Intervention: (1) urodynamics with cystourethrometry and concentric needle electrodes; (2) BP and PR were measured before the examination, during bladder filling and after the examination. AD was defined as an SBP increase of $\geqslant 20$ mm Hg.	(1) AD incidence rate was 36.7% in suprasacral SCI, 42.6% above T6 and 15.4% below T6. (2) AD was most frequent and severe in cervical injury. (3) No correlation of BP changes with completeness of injury. (4) No relationship between BP changes and maximal intravesical pressure, maximal urethral pressure, bladder capacity, detrusor overactivity and urine leakage. (5) BP increase was more significant in DSD or low bladder compliance.
Huang, 2013,[25] Taiwan	Total sample size: $N=101$, above T6 Intervention: (1) urodynamics; (2) BP, PR and AD symptoms were recorded before, every 2 min during and after the examination. AD was defined as SBP increase of $\geqslant 20$ mm Hg.	(1) AD prevalence was 41.7% (42/101). (2) 21 silent AD (50%). (3) The symptomatic group was significantly younger than the silent group (40.1 ± 11.7 vs 49.1 ± 10.4 years). (4) No difference in injury duration, injury level and completeness of injury between the two groups. (5) Symptomatic group showed more significant DBP increments (29.5 ± 9.4 vs 21.7 ± 7.9 mm Hg). (6) No difference in maximal SBP/DBP, SBP increment, maximal urethral pressure, bladder stiffness and chance of continuous DSD between the two groups.
Liu, 2013,[34] Canada	Total sample size: $N=21$, above T6 with AD Intervention: (1) urodynamics; (2) Resting BP and HR were recorded before starting the urodynamic examination. AD was defined as SBP increase of $\geqslant 20$ mm Hg.	(1) SBP increase was more pronounced in individuals with >2 years post-SCI (58.4 ± 21.0 mm Hg) than with <2 years post-SCI (38.6 ± 18.0 mm Hg) ($P=0.047$). (2) No difference between symptomatic and asymptomatic individuals (52.9 ± 22.1 vs 51.1 ± 22.5 mm Hg, $P=0.860$). (3) No difference between SCI complete and incomplete individuals (54.4 ± 21.5 vs 46.6 ± 23.0 mm Hg, $P=0.454$). (4) No correlation ($r=0.354$, $P=0.116$) between maximal detrusor pressure and changes in SBP.
Sayılır, 2013,[26] Turkey	Total sample size: $N=90$ with cervical SCI Intervention: (1) urodynamics; (2) AD was defined as $SBP>140$ mm Hg or 20–40 mm Hg increase in adults and 15 mm Hg increase in children.	(1) 50 of 90 (56%) individuals developed AD. (2) No significant difference was found regarding the frequencies of AD between C1–C5 and C6–C8 groups.
Faaborg, 2014,[44] Denmark	Total sample size: $N=8$ with SCI (AIS A) at or above T6 Intervention: (1) filling cystometry in comparison with transanal irrigation and digital evacuation; (2) AD was defined as an acute rise in SBP of >30 mm Hg above baseline.	(1) SBP increased from 125 (106–149) mm Hg at baseline to 200 (179–220) mm Hg at maximum stimulation. (2) SBP increased less during transanal irrigation (36 mm Hg, range 30–63) than during digital evacuation (57 mm Hg, range 41–75; $P<0.05$) or filling cystometry (61 mm Hg, range 55–100; $P<0.02$). (3) Median 'time at risk', defined as $SBP>150\%$ of baseline, was 4 min (range 2–7) during filling cystometry.

Abbreviations: AD, autonomic dysreflexia; AIS, American Spinal Injury Association Impairment Scale; BP, blood pressure; b.p.m., beats per minute; CMG, cystometrogram; DBP, diastolic BP; DPN, dorsal penile nerve; DSD, detrusor sphincter dyssynergia; ECG, electrocardiogram; HR, heart rate; MAP, mean arterial pressure; MBP, maximal bladder pressure; NDO, neurogenic detrusor overactivity; Pdet, detrusor pressure; PR, pulse rate; SBP, systolic BP; SCI, spinal cord injury; TUS, transurethral sphincterotomy; UDC, uninhibited detrusor contraction.

urodynamics compared with baseline. Linsenmeyer et al.[16] found urodynamics as an excellent tool in detecting both symptomatic and silent AD in men with SCI above T6 who were at an increased risk for AD. Curt et al.[17] determined urodynamic examination as an effective and standardized diagnostic procedure for provoking signs of AD. In their study, only half of the patients who showed signs of AD during urodynamic examination presented with clinical symptoms of AD.

AD during urodynamics was a result of the bladder distending during the procedure, although symptoms were not always prevalent. The rate of symptomatic AD in the four relevant studies[15–17,25] ranged from 50% to 65%. All individuals involved in these studies were injured at or above T6. Two of the studies[16,25] compared BP changes and potential factors associated with AD. Linsenmeyer et al.[16] found that those without symptoms had BP elevations similar to those with symptoms. The SBP before voiding in symptomatic AD and silent AD was 114 and 122 mm Hg, respectively, whereas during voiding SBP was 170 and 167 mm Hg, respectively. There was no correlation of symptoms with the duration of SCI, maximum voiding pressure or bladder capacity. Huang et al.[25] demonstrated that SBP in symptomatic AD increased from 115.5 ± 16.5 to 168.4 ± 32.7 mm Hg and from 116.9 ± 10.3 to 159.1 ± 13.9 mm Hg in silent AD, whereas DBP in symptomatic AD increased from 76.5 ± 14.4 to 104.7 ± 16.3 mm Hg and from 76.3 ± 7.5 to 98.1 ± 10.1 mm Hg in silent AD. These results were statistically significant for the DBP changes only. In addition, they found that the silent AD group was significantly older than the symptomatic AD group (49.4 vs 40.1 years, respectively).

According to the diagnostic criteria in ISAFSCI,[3,4] the primary characteristic of AD includes a minimum SBP increase of 20 mm Hg from baseline. Previous studies[15–17,24,32,33] demonstrated such an increase in BP during urodynamics. Thyberg et al.[32] found that SBP increased from 20 to 60 mm Hg and DBP increased from 15 to 55 mm Hg during cystometry. Krum et al.[33] revealed that SBP and DBP increased significantly in individuals with SCI above T5 with a significant decrease in HR, whereas these cardiovascular parameters did not change significantly in SCI individuals with neurologic lesions below T5 or in a normal control group. Giannantoni et al.[15] indicated that BP increase in the AD group was higher than that in the non-AD group (SBP 167.5 ± 24.0 mm Hg vs 121.6 ± 13.4, $P < 0.01$; DBP 101.8 ± 8.8 mm Hg vs 77.0 ± 10.3, $P < 0.01$). Huang et al.[24] compared the difference in BP changes between SCI individuals and healthy controls during urodynamic investigation and showed SBP change in individuals with SCI to be significantly higher than in controls (16.6 ± 22.5 vs 9.7 ± 10.6 mm Hg, $P < 0.05$), although these DBP and heart rate changes were not statistically significant.

As previously mentioned, several factors could influence the development of AD, including neurological characteristics (level, completeness and duration of injury), bladder management and neurogenic detrusor overactivity, detrusor sphincter dyssynergia (DSD), bladder compliance and bladder capacity, as found during urodynamic investigation. Among neurological characteristics, neurological level, completeness of SCI and duration of SCI are commonly investigated. Three studies[15,21,24] demonstrated that AD was more prevalent in cervical SCI than in thoracic SCI and BP increased more for those with cervical lesions.[24] However, no significant difference was found regarding the frequencies of AD between C1–C5 and C6–C8 groups.[26] Giannantoni et al.[15] found no correlation of AD to gender, age, disease duration or completeness of SCI. Huang et al.[24] similarly showed no correlation of BP changes in relation to completeness of injury. Linsenmeyer et al.[16] found no correlation of AD with the duration of SCI. However, Liu et al.[34] revealed that the severity of AD increased with time after SCI, as SBP increases were more pronounced in individuals with SCI for > 2 years than in those with SCI < 2 years.

Although bladder management is an important issue related to LUT function, Linsenmeyer et al.[16] reported that there was no correlation between AD development and various bladder management methods. From urodynamic observation, detrusor function, urethral function and bladder compliance can be obtained, all of which were compared with AD in several studies. However, inconsistencies existed among studies. Giannantoni et al.[15] found no difference in incidence of neurogenic detrusor overactivity and DSD, low compliance, uninhibited contraction amplitude and bladder capacity between SCI individuals with and without AD. Schurch et al.[35] reported that in SCI individuals with UDC the mean arterial pressure increased progressively during bladder contraction until reaching maximal bladder pressure and remained elevated during voiding. Huang et al.[24] reported no relationship between BP changes and maximal bladder pressure, bladder capacity, neurogenic detrusor overactivity or urine leakage. In the same study, however, BP increase was significantly higher in SCI individuals with both DSD and low bladder compliance than in those without. Perkash[36] proposed that BP rise could be considered an indicator of DSD and that SBP increases ⩾ 40 mm Hg and DBP increases ⩾ 20 mm Hg were significant enough to suspect DSD in individuals with tetraplegia. Two studies[37,38] further supported the same relationship between AD and DSD.

Some studies investigated the methods of mitigation of AD through, for instance, pharmacology therapy, electrical stimulation and surgery. Lindan et al.[39] used phenoxybenzamine (α-receptor blocker) and nifedipine (calcium channel blocker), whereas Thyberg et al.[40] used nifedipine only in their study for the prevention of AD. Both studies reported nifedipine as having a prophylactic effect in aborting AD symptoms. Lindan et al.[39] also suggested nifedipine as a possibility for the treatment of acute AD, but neither nifedipine nor phenoxybenzamine in regular daily dosage could prevent AD. Lee et al.[41] performed cystometry with and without dorsal penile nerve stimulation and revealed that dorsal penile nerve stimulation could decrease the BP elevation in AD probably by suppressing detrusor contraction.[42] Several studies[37,38,43] investigated the BP change after transurethral sphincterotomy, which could further strengthen the relationship between AD and DSD, which cause bladder distension. Barton et al.[43] found that the frequency and magnitude of AD could be diminished significantly after transurethral sphincterotomy. Ricottone et al.[37] reported that 9 out of the 12 individuals experienced cessation of AD following initial transurethral sphincterotomy, but most required repeat procedures for long-term resolution. Perkash[38] demonstrated that BP rises were transitory and not associated with significant symptoms of AD.

In addition, increase in SBP was used to compare the severity of AD response between urodynamics and cystoscopy, as well as urodynamics and bowel evacuation procedures such as transanal irrigation and digital evacuation. Liu et al.[34] reported that during cystoscopy SCI individuals developed greater changes in SBP than urodynamics (67.1 ± 33.8 vs 51.8 ± 21.8 mm Hg), indicating that stimulation of the urethra/prostate/internal sphincter region probably is a more potent stimulus of AD than just the filling of the bladder. Faaborg et al.[44] showed that SBP increased less during transanal irrigation (36 mm Hg, range 30–63) than during digital evacuation (57 mm Hg, range 41–75) or filling cystometry (61 mm Hg, range 55–100)—the SBP response between digital evacuation and filling cystometry was insignificant.

Among the described studies, the diagnostic criteria of AD varied. Most studies[17,21,23–25,33,34,41,44] used BP changes as the criteria, whereas some studies[15,16,39] used maximal BP as the criteria. One study[26] used both of these indicators. In the studies using SBP changes, the criteria varied from 10 to 50 mm Hg, whereas only three studies[24,25,34] published after 2009 used 20 mm Hg as the criteria, consistent with the ISAFSCI guidelines. Thus the use of the criteria from ISAFSCI should be encouraged in the future to make comparisons between studies easier.

Cystoscopy and transurethral litholapaxy

In addition to bladder distension, cystoscopy and transurethral litholapaxy also involve instrumentation into the urethra and bladder. Some studies (Table 3) reported AD during these procedures. Chancellor et al.[45] revealed that flexible cystoscopy could decrease the risk of triggering AD. In their study, only 6 of the 39 patients with previous episodes of AD became hypertensive during cystoscopy. Vespasiani et al.[46] reported that 3 out of the 17 individuals presented signs and symptoms of AD during ballistic lithotripter. Liu et al.[34] reported that the severity of AD increased with time following SCI, as demonstrated by a more pronounced SBP increase in individuals with SCI for >2 years compared with those with SCI for <2 years. In addition, no difference in SBP increase was found between symptomatic AD and asymptomatic AD individuals, as well as between complete and incomplete individuals during cystoscopy.

Table 3 Cystoscopy and transurethral litholapaxy

First author, year (reference), country	Methodology	Results
Braddom, 1969,[49] USA	Total sample size: $N=7$. Intervention: (1) a single oral dose of mecamylamine hydrochloride (2.5 mg) before cystometry; (2) BP, HR monitoring.	(1) Reduced increase in BP in five out of the seven participants. (2) Reduced or stopped sweating in three of the four participants. (3) Stopped headache in one participant.
Alderson, 1976,[29] UK	Total sample size: $N=45$, 24 cervical SCI. Intervention: (1) transurethral surgery with intravenous induction followed by inhalational anesthesia; (2) BP, HR monitoring.	(1) In 21 individuals, SBP rose above preoperative readings. In all, 19 of them had cervical SCI, 1 at T4 and 1 at T6. (2) Maximal rise of SBP was 40 mm Hg, no case with SBP rise >160 mm Hg. (3) Halothane anesthesia was useful in the control of hypertension from AD during transurethral surgery.
Snow, 1978,[30] USA	Total sample size: $N=102$, 57 above T7. Intervention: (1) cystoscopy; (2) AD was defined as SBP increase $\geqslant 40$ mm Hg.	(1) 40 (70%) of the 57 above T7 presented signs and symptoms of AD. No AD was seen below T7. (2) SBP increase ranged between 40 to 120 mm Hg, HR decrease ranged between 40 to 60 b.p.m. (3) Slow intravenous trimethaphan administration, 10–50 mg for severe hypertension.
Dykstra, 1987,[47] USA	Total sample size: $N=7$, cervical SCI Intervention: (1) cystoscopy; (2) AD signs and symptoms monitoring.	(1) Nifedipine 10 mg sublingually, alleviated AD. (2) Nifedipine 10 mg orally, 30 min before cystoscopy, prevented AD..
Baraka, 1989,[51] Lebanon	Total sample size: $N=1$, C6 Intervention: (1) cystoscopy; (2) Meperidine 100 mg diluted in 10 ml saline was injected in the epidural space at L3–L4 level.	(1) BP stabilized at 125/70–140/80 mm Hg throughout the surgical procedure. (2) Epidural meperidine prevented AD.
Chancellor, 1993,[45] USA	Total sample size: $N=69$. Intervention: (1) cystoscopy; (2) AD signs and symptoms monitoring.	(1) Only 6 of the 39 patients with previous episodes of AD became hypertensive. (2) Flexible cystoscopy causes minimal stimulation leading to the development of AD.
Vespasiani, 1996,[46] Italy	Total sample size: $N=17$. Intervention: (1) ballistic lithotripter; (2) AD signs and symptoms monitoring.	(1) Three individuals presented signs and symptoms of AD.
Vaidyanathan, 1996,[48] UK	Total sample size: $N=2$, C5 AIS A and C3 AIS A. Intervention: (1) cystoscopy; (2) BP monitoring.	(1) As cystoscopy was inserted in the urethra, penile erection occurred and BP rose to 200/110 mm Hg, HR decreased to 50 b.p.m. (2) Intravenous salbutamol, in a dose of 10 μg, produced immediate and persistent penile detumescence and BP decrease.
Yoo, 2008,[52] Korea	Total sample size: $N=28$, complete SCI. Intervention: (1) transurethral litholapaxy; (2) BP, HR monitoring, bispectral index and plasma concentrations of catecholamines and arginine vasopressin.	(1) SBP increased significantly by 67 ± 33 mm Hg, whereas HR decreased by 13 ± 8 b.p.m. (2) 9 (32%) SBP $\geqslant 180$ mm Hg received additional sevoflurane to treat hypertension. (3) The end-tidal concentrations of sevoflurane to prevent AD were EC50 of 3.12% and EC95 of 3.83%.
Yoo, 2011,[53] Korea	Total sample size: $N=96$, complete. Intervention: (1) transurethral litholapaxy; (2) BP, HR monitoring, bispectral index and plasma concentrations of catecholamines. AD was defined as SBP increase of $>20–40$ mm Hg.	(1) 82 (85.4%) of the 96 patients developed AD. (2) The end-tidal concentrations of sevoflurane to prevent AD were reduced to 2.6% and 2.2% in the groups receiving 1 and 3 ng ml^{-1} remifentanil, respectively, in comparison with 3.1% (2.9–3.3%) in the control.
Vaidyanathan, 2012,[50] UK	Total sample size: $N=3$, tetraplegia. Intervention: (1) cystoscopy and transurethral litholapaxy; (2) AD signs and symptoms monitoring.	(1) Without anesthesia, BP increased to $>200/110$ mm Hg during cystoscopy. (2) Subarachnoid block prevents occurrence of AD.
Liu, 2013,[34] Canada	Total sample size: $N=21$, above T6 with AD. Intervention: (1) cystoscopy in comparison with urodynamics; (2) Resting BP and HR were recorded before starting the cystoscopic examination. AD was defined as SBP increase of $\geqslant 20$ mm Hg.	(1) SBP increase was more pronounced in individuals with >2 years post-SCI (80.0 ± 32.2 mm Hg) than with <2 years post-SCI (41.4 ± 20.4 mm Hg) ($P=0.010$). (2) No difference between symptomatic and asymptomatic individuals (68.8 ± 39.6 vs 65.6 ± 29.6 mm Hg, $P=0.837$). (3) No difference between SCI complete and incomplete individuals (66.4 ± 31.6 vs 68.6 ± 40.7 mm Hg, $P=0.895$). (4) There was statistically more increase ($P=0.039$) in SBP during cystoscopy (67.1 ± 33.8 mm Hg) in comparison with urodynamics (51.8 ± 21.8 mm Hg).

Abbreviations: AD, autonomic dysreflexia; AIS, American Spinal Injury Asssociation Impairment Scale; BP, blood pressure; b.p.m., beats per minute; SBP, systolic blood pressure; HR, heart rate; EC50, 50% effective dose; EC95, 95% effective dose; SCI, spinal cord injury.

The pharmacological management of AD during cystoscopy has been examined. Dykstra et al.[47] found nifedipine 10 mg sublingually to be effective in alleviating AD symptoms, and when administered orally 30 min before cystoscopy, it could prevent AD altogether. Vaidyanathan et al.[48] found that intravenous salbutamol could produce penile detumescence and BP decrease when the insertion of a cystoscopy into the urethra caused penile erection, BP rise and heart rate decrease. Braddom and Johnson[49] also reported that a single oral dose (2.5 mg) of mecamylamine (ganglionic blocker) reduced the increase in BP during cystoscopy in five out of the seven participants with SCI. It also was effective in reducing or completely preventing sweating due to AD in 80% of participants.

A few studies revealed the relationship of anesthesia and AD during cystoscopy. Vaidyanathan et al.[50] reported a BP increase to >200/110 mm Hg in tetraplegic individuals without anesthesia. When cystoscopy was conducted again under subarachnoid block, the BP was stable during the procedure, thus demonstrating subarachnoid block as an effective method in preventing the occurrence of AD. Baraka et al.[51] suggested that epidural meperidine could prevent AD. Alderson et al.[29] used halothane anesthesia, and although 21 individuals experienced an elevation in SBP, the severity was mild and the maximal SBP change was 40 mm Hg, with no single elevation reaching levels >160 mm Hg. Yoo et al.[52] reported that SBP increased significantly (67 ± 33 mm Hg) and heart rate decreased (13 ± 8 b.p.m.) during transurethral litholapaxy. Afterward, they performed their study under general anesthesia in order to avoid AD. They used sevoflurane to prevent AD and found that the sevoflurane concentration required to block AD in 50% of the patients was $3.12 \pm 0.29\%$. The end-tidal concentrations of sevoflurane for the blockage of AD in 95% of the patients by logistic analyses were 3.83%. In another study,[53] remifentanil was administered with sevoflurane to individuals who developed AD and demonstrated that concentrations of 1 and 3 ng ml^{-1} remifentanil would reduce the amount of sevoflurane required to prevent AD in SCI patients undergoing transurethral litholapaxy by 16% and 29%, respectively.

Extracorporeal shock-wave lithotripsy

ESWL is a noninvasive method for treating patients with renal and urethral calculi, but for individuals with SCI, ESWL is like any other surgical procedure that may cause sufficient stimulation of somatic and/or visceral afferents in the area of the kidney to trigger an AD response. Several studies (Table 4) have assessed the use of anesthesia in preventing AD during ESWL. Kabalin et al.[54] reported that without anesthesia 19 out of the 20 individuals developed AD during ESWL. In another study conducted by Robert et al.[55] using piezoelectric ESWL, only 3 out of the 11 individuals received sedation and yet no episodes of AD occurred in any individuals. Stowe et al.[31] reported that 6 out of the 22 cervical SCI patients with spinal anesthesia developed AD. Spirnak et al.[56] reported that two out of five tetraplegic individuals developed significant intraoperative hypertension during ESWL. However, a study by Chen et al.[57] revealed that all individuals had SBP increases >20 mm Hg during ESWL intraoperatively, independent of sedation, spinal anesthesia or no anesthesia. They used trimethaphan, sodium nitroprusside and hydralazine to reduce BP. Burnstein et al.[58] demonstrated that nifedipine could be given to both acute AD and before the procedure in order to prevent AD.

Other iatrogenic urological triggers

In addition to urodynamics, cystoscopy and ESWL, other iatrogenic urological triggers, including voiding cystourethrography, loopography and trial of micturition, have been reported (Table 5). Barbaric et al.[59] reported two individuals with BP elevation during cystourethrography and loopography, respectively. Vaidyanathan et al.[60] found that two individuals developed AD during micturition trial 2–3 h after the removal of the urethral catheter. In fact, the nature of these triggers is still related to bladder distension. Vaidyanathan et al.[60] also used nifedipine 10 mg sublingually to treat the AD.

DISCUSSION

Although AD has been reported during various urological procedures, there are still issues requiring clarification. The incidence reported by

Table 4 Extracorporeal shock-wave lithotripsy (ESWL)

First author, year (reference), country	Methodology	Results
Spirnak, 1988,[56] USA	Total sample size: $N=5$, tetraplegia. Intervention: (1) ESWL with local field block or no anesthesia; (2) AD signs and symptoms monitoring.	(1) Two developed significant intraoperative hypertension. (2) IV hydralazine effective in decreasing BP.
Chen, 1989,[57] USA	Total sample size: $N=9$, tetraplegia. Intervention: (1) ESWL with IV sedation, spinal anesthesia or no anesthesia; (2) AD signs and symptoms monitoring.	(1) BP rose from 106/63 to 171/104 mm Hg intraoperatively and 154/103 initially at recovery room. (2) Anesthesia, monitoring and sedation (AMS) with treatment of hypertensive episodes to be adequate and safe for ESWL.
Stowe, 1989,[31] USA	Total sample size: $N=52$, complete, 28 cervical, 24 thoracic/lumbar. Intervention: (1) ESWL with general or regional anesthesia; (2) AD signs and symptoms monitoring.	(1) 9 of 52 developed AD with BP $198 \pm 11/112 \pm 6$ mm Hg. (2) 6 of 22 cervical injury patients with spinal anesthesia developed AD. (3) 3 of 24 with thoracic/lumbar injury developed AD.
Burnstein, 1992,[58] USA	Total sample size: $N=1$. Intervention: (1) ESWL; (2) AD signs and symptoms monitoring.	(1) Nifedipine could successfully treat AD. (2) Nifedipine could prophylactically prevent AD.
Kabalin, 1993,[54] USA	Total sample size: $N=20$. Intervention: (1) ESWL without anesthesia; (2) AD signs and symptoms monitoring.	(1) All but 1 with T12 level experienced AD with SBP increase by 44 mm Hg and DBP increase by 24 mm Hg, HR decrease by 22 b.p.m. (2) AD was successfully treated with sublingual nifedipine.
Robert, 1995,[55] France	Total sample size: $N=15$, 8 cervical, 6 thoracic, 1 lumbar. Intervention: (1) Piezoelectric ESWL; (2) AD signs and symptoms monitoring.	(1) No episodes of AD and, in particular, of hypertension during the sessions.

Abbreviations: AD, autonomic dysreflexia; BP, blood pressure; b.p.m., beats per minute; DBP, diastolic BP; ESWL, extracorporeal shock-wave lithotripsy; HR, heart rate; IV, intravenous; SBP, systolic BP.

Table 5 Other iatrogenic urological triggers

First author, year (reference), country	Methodology	Results
Barbaric, 1976,[59] USA	Total sample size: $N=2$, C2 and C4. Intervention: (1) voiding cystourethrography and loopography; (2) AD signs and symptoms monitoring.	(1) BP from 100/70 to 210/100 mm Hg, PR changed from 75 to 60 b.p.m. during cystourethrography. (2) BP from 100/70 to 190/100 mm Hg. PR decreased from 72 to 65 b.p.m. during loopography.
Vaidyanathan, 2003,[60] UK	Total sample size: $N=7$, cervical SCI. Intervention: (1) trial of micturition; (2) AD signs and symptoms monitoring.	(1) Two developed severe AD. (2) BP rose from 78/48 to 165/80 mm Hg in one individual after 2-h trail. (3) The maximal BP was 204/80 mm Hg after 2–3 h trail, nifedipine 10 mg sublingually was given and BP decreased to 137/67 mm Hg.

Abbreviations: AD, autonomic dysreflexia; BP, blood pressure; b.p.m., beats per minute; PR, pulse rate; SCI, spinal cord injury.

Huang et al.[24] as 36.7% was based on all suprasacral SCI lesions. The majority of AD occurs in SCI individuals injured at or above T6 spinal cord level. If we only calculate the AD incidence in individuals with SCI at or above T6 in their study, the rate would be 43%, and only 15% of patients with lesions below T6 developed AD. It is obvious that individuals with higher lesions will have higher incidences of AD. Thus, when all levels of SCI are taken together, a lower overall incidence rate of AD will be the result. Linsenmeyer et al.[16] reported the incidence in their study as high as 77.8%, with all patients having complete SCI. Individuals with complete SCI have more frequent and more severe AD.[1] Thus, if only individuals with complete SCI are included in a study as being representative of the AD incidence in a subgroup, the rate of AD would naturally be inflated compared with a group including both complete and incomplete SCI because the AD incidence in individuals with incomplete SCI is lower than that with complete SCI. Therefore, when reporting incidence of AD during urological procedures, it would be preferable to divide SCI individuals by the levels of their injury in cervical, high thoracic (above T6) and lower (below T6) lesion groups. Furthermore, information on the autonomic completeness of injury should be provided along with the AIS grade in future studies when reporting AD incidence.[61]

According to ISAFSCI,[3,4] AD is defined as an SBP change with or without symptoms. Thus symptoms are not necessary components of AD. The rate of symptomatic AD during urodynamics varied from 50% to 65%.[15–17,25] In addition, the consistency of this rate is higher than that of AD incidence rates during urodynamics (36.7–77.8%). However, only two studies[16,25] have explored the association of factors between symptomatic AD and silent AD. Linsenmeyer et al.[16] found that there was no correlation of symptoms of AD with duration of SCI, whereas Huang et al.[25] reported that aging decreases AD symptoms and the magnitude of DBP elevation. Therefore, this area requires further investigation. These data further emphasize the importance and necessity of continuous monitoring of arterial BP as a standard of practice during urodynamics in order to detect and initiate appropriate management for episodes of silent AD.

During urodynamics, several studies[15–17,24,32,33] have investigated the cardiovascular parameter changes between individuals with and without SCI and between SCI individuals with and without AD. When reporting BP outcomes, some studies compared baseline BP and maximal BP, whereas others compared the BP changes. It is recommended to use BP changes as the primary outcome measure of AD owing to the fact that normal resting arterial BP in individuals with cervical and high thoracic SCI is approximately 15–20 mm Hg lower than in able-bodied individuals,[62] and thus elevated BP due to episodes of AD may not always be obvious.

When comparing factors with potential influence on AD, such as SCI characteristics, LUT function or urodynamic parameters, the data included in the studies vary. As a consequence, it is difficult to compare the results. The purpose of the development of the ISAFSCI is to standardize the data collection and reporting of autonomic function in individuals after SCI. It is therefore recommended to use the items from this standard when collecting data. From the ISAFSCI, the three items that compose LUT function are awareness of the need to empty the bladder (sensation), ability to prevent leakage (continence) and bladder-emptying method. The classification and definition of bladder-emptying methods should be referenced to the International SCI LUT Function Basic Data Set.[63] The urodynamic parameters established in the ISAFSCI are all derived from the International SCI Urodynamic Basic Data Set,[64] which includes bladder sensation during filling cystometry, detrusor function, compliance during filing cystometry, urethral function during voiding, detrusor leak point pressure, maximum detrusor pressure, cystometric bladder capacity and postvoid residual volume. In addition to these LUT functions and urodynamic parameters, items pertaining to SCI characteristics are equally important and consist of age, gender, neurological level, completeness and duration of SCI. The latter information is likewise recommended to be reported in a standardized way.[65] Furthermore, urodynamics or simple cystometry are useful methods to evaluate the effectiveness of interventions used to prevent AD. Of the studies reviewed, the majority were preintervention–postintervention comparisons or were of limited sample size ($n=8$–26).[37–41,43,44] In an effort to increase evidence-based practice in this area, it is suggested in future studies to perform randomized controlled trials with an appropriate sample size and include cervical/thoracic, complete/incomplete SCI individuals. Although a variety of medications were used in the treatment of hypertension or during a hypertensive crisis, nifedipine in particular was shown to be the most effective during urodynamics,[39] cystoscopy[47] and ESWL[58] both for relief of acute AD and for the prevention of AD. The assessments of other antihypertensive drugs and their impact on AD are anticipated for future research.

Flexible cystoscopy is widely accepted as an effective alternative to rigid endoscopy in minimizing occurrence of AD. Rivas et al.[66] proposed that reduced caliber of the flexible cystoscope would markedly decrease the incidence and severity of AD during examination when compared with the use of rigid endoscope. Cystoscopy, transurethral litholapaxy and ESWL were considered as surgical procedures; however, the majority of studies related to these procedures focused on the effectiveness of anesthesia on AD or the consequence of not using anesthesia. Common types of anesthesia used for individuals with SCI include local, subarachnoid, epidural

and general anesthesia. Topical anesthesia, such as lidocaine 2% gel, was suggested for routine use during cystoscopy to decrease the afferent impulse, thereby preventing the triggering of an AD response.[66] However, other studies have shown that SCI patients undergoing surgical procedures under local anesthesia can still develop AD. Yoo et al.[67] presented a case involving a tetraplegic male who suffered from left basal ganglia and thalamic hemorrhage associated with AD during surgery for a pressure sore while under local anesthesia. Cosman et al. found that topical lidocaine was ineffective in limiting or preventing AD during anorectal procedures,[68] whereas lidocaine anal block was effective.[69] The mechanism of subarachnoid block or epidural meperidine in preventing AD is explained by its ability to block the nociceptive reflexes from the urinary bladder below the level of the neurological lesion.[48,49] Alderson et al.[29] reported halothane anesthesia as useful in controlling hypertension from AD during transurethral surgery. Yoo et al.[52,53] discovered that sevoflurane was effective in blocking AD during transurethral litholapaxy and that remifentanil could decrease sevoflurane requirements to block AD in high complete SCI patients. Chen et al.[57] concluded that anesthesia, monitoring and sedation with treatment of hypertensive episodes as both adequate and safe before ESWL. It has been suggested that 'either sufficient general anesthesia or an adequate level of regional anesthesia' can diminish the deleterious hemodynamic changes of AD, if occurring during ESWL.[31]

Other iatrogenic urological triggers of AD are mostly related to bladder distension where catheterization is the leading choice for management.[59,60] If, however, AD is not managed after catheterization, antihypertensive drugs should be considered.[60]

CONCLUSION

Among the LUT triggers evoking episodes of AD, iatrogenic factors are common and include urodynamic investigations and cystometry, cystoscopy and transurethral litholapaxy, ESWL and other procedures that may lead to distension of the bladder. AD was more prevalent in cervical SCI than in thoracic SCI, but the relationship between completeness and AD remain controversial. Therefore, future studies should report AD incidence in relation to autonomic completeness of injury. In addition, although preoperative measures (that is, anesthesia) are recommended in some studies, the effectiveness and choice of anesthesia still requires further investigation. Most importantly, BP monitoring should always be performed to detect AD development during iatrogenic procedures in individuals with SCI. It is suggested that changes in the urodynamic parameters and AD following SCI could be determined through urodynamic follow-up.[70] Upon detection of AD, appropriate management should follow according to the guidelines and protocols recommended in the Consortium for Spinal Cord Medicine guideline.[71]

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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