ORIGINAL ARTICLE

Factors associated with ultrasound diagnosed neurogenic bladder complications following spinal cord injury

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ABSTRACT

Introduction: Neurogenic bladder (NB) is a recognized secondary medical impairment following spinal cord injury (SCI). Ultrasound (US) of the kidneys, ureters and bladder (KUB) has been recommended as a useful, non-invasive surveillance method with good diagnostic sensitivity. This study aims to understand US diagnosed NB complications and identify its associated factors.

Methods: We enrolled all patients referred for SCI rehabilitation from 2012 to 2015 that fulfilled our study criteria. Data that were retrospectively reviewed included demographic and clinical characteristic data; and US KUB surveillance studies.

Results: Out of 136 electronic medical records reviewed, 110 fulfilled the study criteria. The prevalence of NB in our study population was 80.9%. We found 22(20%) of the patients showed evidence of US diagnosed NB complications with the mean detection of 9.61±7.91 months following initial SCI. The reported NB complications were specific morphological changes in the bladder wall 8(36.4%); followed by unilateral/bilateral hydronephrosis 7(31.8%); bladder and/or renal calculi 5(22.7%); and mixed complication 2(9.1%) respectively. Half of the patients with NB complications had urodynamic diagnosis of neurogenic detrusor overactivity with/without evidence of detrusor sphincter dyssynergia. We found co-existing neurogenic bowel, presence of spasticity and mode of bladder management were significantly associated factors with US diagnosed NB complications ($p<0.05$), while spasticity was its predictor with adjusted Odds Ratio value of 3.93 (1.14, 13.56).

Conclusion: NB is a common secondary medical impairment in our SCI population. A proportion of them had US diagnosed NB complications. Co-existing neurogenic bowel, presence of spasticity and mode of bladder management were its associated factors; while spasticity was its predictor.

KEYWORDS:
Neurogenic bladder, spinal cord injury, ultrasound KUB, urodynamic, intermittent catheterization

INTRODUCTION

Spinal cord injury (SCI) can occur secondary to spinal column fracture following a traumatic event or as a consequence of disease. It may significantly impair every major organ systems and one of the most commonly recognised secondary medical impairments following SCI is neurogenic bladder (NB). The severity of NB following SCI principally depends on the neurological level as well as severity of the injury.[1,2] The primary goals of NB management are to prevent the upper and lower urinary tract complications such as urinary tract infection, hydronephrosis, renal calculi, bladder calculi, and vesicoureteral reflux. Improperly managed NB dysfunction may result in upper and lower tract deterioration and in the extreme cases renal failure with potential for significant morbidity and eventually fatal outcome.[3,4]

Cameron et al. in their systematic review reported that there is sufficient knowledge and scientific evidence to recommend ultrasound (US) of the kidneys and urinary tract as a useful, non invasive and cost effective method for routine long-term follow-up to detect upper urinary tract problems in individuals with SCI. Compared to intravenous pyelogram (IVP) or renal scan, US has good sensitivity for diagnosing upper tract abnormalities and it does not expose patients to radiation. It was also suggested that computed tomography (CT) Urography to follow if ultrasound findings are positive.[5]

Available publications regarding NB complications following SCI mainly described generalized complications including genital infections, urinary tract infections, calculi, urethral damage, fistula formation, urethral strictures, renal dysfunction, and bladder cancer.[6,7] To the best of our knowledge, there is lack of scientific evidence that specifically described US diagnosed NB complications following SCI. These include morphological and structural changes of the bladder wall such as thickening, trabeculation, sacculation or diverticulation; calculi formation such as bladder and/or renal calculi; and upper tract dilatation such as unilateral or bilateral hydronephrosis. Therefore, the objective of this study was to understand US diagnosed NB complications and identify its associated factors.

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MATERIALS AND METHODS

This study was conducted at Rehabilitation Medicine Department of Hospital Sungai Buloh. Medical Research & Ethics Committee (MREC), Ministry of Health Malaysia approval was obtained with reference 5/KKM/NIH/SEC/P17-398.

We enrolled all patients referred for the SCI rehabilitation from 2012 to 2015 who fulfilled our study criteria. Their electronic medical records were retrospectively reviewed; relevant demographic and clinical data were retrieved. Inclusion criteria were confirmed diagnosis of SCI (both of traumatic and non-traumatic aetiology); presence of neurological deficits; persistent evidence of NB; available follow up data for at least 2 years; and availability of radiological report of US kidneys, ureters and bladder (KUB) surveillance studies. Those with known pre-existing genito-urinary dysfunction and/or complication were excluded. The data retrieved included demographic background; etiology of SCI; neurological level and severity of SCI; ambulation status (only functional ambulation with/without assistive device were considered as able to ambulate); mode of NB management; and other SCI secondary medical impairment including spasticity, neurogenic bowel and sexual dysfunction.

Diagnosis confirmation of SCI were made by clinical and neuroimaging studies by the primary team. Definitive acute SCI management were completed prior to referral for the SCI Rehabilitation program. The International Standards for Neurological Classification of Spinal Cord Injury findings was retrieved to classify traumatic SCI;[8] while neurological assessment findings were used to classify those with non-traumatic SCI. The neurological categorised of SCI were based on American Spinal Injury Association (ASIA) Impairment Scale abbreviated as AIS. The definition used were AIS A (complete): No motor or sensory function is preserved in the sacral segments S4-S5; AIS B (sensory incomplete): Sensory function preserved but no motor function is preserved below the neurological level and includes the sacral segments S4-S5; AIS C (motor incomplete): Motor function is preserved below the neurological level and more than half of key muscles below the neurological level have a muscle grade less than 3; D (motor incomplete): Motor function is preserved below the neurological level and more than half of key muscles below the neurological level have a muscle grade of 3 or more; E (Normal): Motor and sensory function are normal.[8] Based on the AIS assessment of the study subjects, we combined the neurological category group based on measure of completeness of SCI into motor complete (AIS A and AIS B) and motor incomplete (AIS C and AIS D).

In this study, we defined NB as dysfunction of the lower urinary tract specifically in consequence to SCI. Clinical diagnosis of NB was made based on persistence of voiding dysfunction symptoms as per bladder diary documentation and assessment of post voiding residual (PVR) volume whenever applicable. Symptoms such as impaired or absent bladder sensation, urge or stress incontinence, frequency, high post voiding residual (PVR) volume or urinary retention were identified in the presence of persistent neurological deficits due to SCI. Urinary tract infection whenever diagnosed, were treated prior to further management of voiding dysfunction.

The mode of bladder management considered in this study was the main mode of bladder management practiced throughout most clinical documentation. Patients who had partial NB recovery, i.e., regained some voluntary voiding ability but requires occasional assistive method of any types to empty the bladder were grouped under regained some voluntary voiding. US KUB surveillance reports were analyzed for all patients within 6 months (first baseline evaluation) and then the annual surveillance studies.

The end-point of review was documented evidence of US diagnosed NB complications including calculi formation (bladder and/or renal); upper tract dilatation (unilateral or bilateral hydronephrosis of any grade of severity); and morphological/ structural changes of the bladder wall (thickening, trabeculation, sacculation and/or diverticulation). Presence of bladder sediments was not considered as US diagnosed NB complication in this study. Urodynamic report whenever available was also retrieved for all patients with US diagnosed NB complications.

Statistical Analyses

The data were analysed using Statistical Package for Social Sciences (SPSS) 20.0 for windows. Frequencies and percentages were used to describe categorical data, while means and standard deviation were calculated for all continuous variables. To test the association between the US diagnoses of NB complication and the socio-demographic and clinical variables, Independent t-test, Mann-Whitney U test, Chi-Square test and Fisher's Exact test were used where applicable. For all tests, the p values of <0.05 was deemed statistically significant. Logistic regression analyses were performed for specific variables if it fulfilled the assumptions and statistical criteria for it to be carried out.

RESULTS

Out of 136 electronic medical records reviewed, 110 (80.9%) fulfilled the study criteria. The prevalence of NB was 80.9%. Demographic characteristics of the study subjects were shown in Table I. The mean age was 39.6±16.95 years (range 14-71 years).

Clinical characteristic of patients is shown in Table II. The reported US diagnosed NB complications were specific morphological changes in the bladder wall (thickening, trabeculation, sacculation and/or diverticulation) in 8(36.4%), followed by upper tract dilatation (unilateral or bilateral hydronephrosis of any grade of severity) in 7(31.8%), calculi formation (bladder and/or renal) in 5(22.7%) and mixed complication in 2(9.1%) respectively.

As illustrated by the Kaplan–Meier curve in Figure 1, the median time since SCI diagnosis to the first detection of US diagnosed NB complication was 330 days (95% Confidence Interval : 55.3, 604.7). All patients with US diagnoses of calculi formation (bladder and/or renal) had surgical intervention performed by the Urologist.

Table I: Demographic characteristics and its association with ultrasound diagnosed neurogenic bladder complications. (n=110)

Variable	Ultrasound diagnosed NB complication					p-value
	Total	Yes		No		
	n (%)	n	%	n	%	
Age, mean (SD)	39.6 (16.95)	38.6	17.95	40.6	15.95	0.609[c]
Gender						0.501[a]
Male	84 (76.4)	18	21.4	66	78.6	
Female	26 (23.6)	4	15.4	22	84.6	
Race*						0.633[b]
Malay	65 (59.0)	12	18.5	53	81.5	
Chinese	22 (20.0)	6	27.3	16	72.7	
Indian	18 (16.4)	4	22.2	14	77.8	
Others	5 (4.6)	0	0	5	100	
Marital Status*						0.811[b]
Married	68 (61.8)	13	19.1	55	80.9	
Single	39 (35.5)	9	23.1	30	76.9	
Divorced	3 (2.7)	0	0	3	100	
Family Support*						0.341[b]
Yes	103 (93.6)	22	21.4	81	78.6	
No	7 (6.4)	0	0	7	100	
Education						0.840[b]
Primary / Secondary	69 (62.7)	15	21.7	54	78.3	
Tertiary	21 (19.1)	3	14.3	18	85.7	
No formal education	20 (18.2)	4	20	16	80	

Note: *The assumptions of Logistics Regression were not met, there must be at least two cases for each category of the dependent
n = Frequency; % = Percentage; SD = Standard Deviation; IQR = Interquartile Range;
[a]Chi-square test; [b]Fisher's exact test, [c]Independent t-test

Table II: Clinical characteristics and its association with ultrasound diagnosed neurogenic bladder complications. (n=110)

Variables	Ultrasound diagnosed neurogenic bladder complication					p-value
	Total	Yes		No		
	n (%)	n	%	n	%	
Aetiology of spinal cord injury						0.542[a]
Non-Traumatic	36 (32.7)	6	16.7	30	83.3	
Traumatic	74 (67.3)	16	21.6	58	78.4	
Neurological level of injury						0.497[a]
Cervical	43 (39.0)	11	26.5	32	74.4	
Thoracic	35 (31.8)	6	17.1	29	82.9	
Lumbar	32 (29.2)	5	15.6	27	84.4	
Severity of injury						0.516[a]
Motor complete	29 (26.4)	7	24.1	22	75.9	
Motor incomplete	81 (73.6)	15	18.5	66	81.5	
Neurogenic bowel dysfunction*						<0.001[a]
Yes	84 (76.4)	22	26.5	62	73.5	
No	26 (23.6)	0	0	26	100	
Spasticity						0.008[a]
Yes	57 (51.8)	17	29.8	40	70.2	
No	53 (48.2)	5	9.4	48	90.6	
Ambulation status						0.151[a]
Yes	60 (54.5)	9	15	51	85	
No	50 (45.5)	13	26	37	74	
Sexual impairment						0.291[a]
Yes	49 (44.5)	12	24.5	37	75.5	
No	61 (55.5)	10	16.4	51	83.6	
Mode of bladder management						<0.001[b]
Continuous bladder drainage	6 (8.6)	2	33.3	4	66.7	
Suprapubic catheterization	9 (13.0)	3	33.3	6	66.7	
Intermittent self-catheterization	47 (68.1)	11	23.4	36	76.6	
Reflex voiding/Valsalva	7 (10.3)	6	85.7	1	14.3	
Regained some voluntary voiding	41 (37.2)	0	0	41	100	

Note: *The assumptions of Logistics Regression were not met, there must be at least two cases for each category of the dependent
n = Frequency; % = Percentage; SD = Standard Deviation; IQR = Interquartile Range; [a]Chi-square test; [b]Fisher's exact test

Table III: Predictive factors associated with ultrasound diagnosed neurogenic bladder complications

	Crude OR	95% CI	p-value	Adj. OR	95% CI	p-value
Gender			0.503			0.609
Male	1.50	(0.46, 4.91)		1.42	(0.37, 5.53)	
Female	1.00					
Age	0.99	(0.96, 1.02)	0.610	0.99	(0.96, 1.03)	0.536
Education			0.759			0.612
Primary / Secondary	1.11	(0.32, 3.82)		1.66	(0.33, 8.28)	
Tertiary	0.67	(0.13, 3.4)		0.85	(0.11, 6.48)	
No formal Education	1.00			1.00		
Aetiology			0.543			0.600
Non-Traumatic	1.00			1.00		
Traumatic	1.38	(0.49, 3.89)		1.41	(0.39, 5.12)	
Severity			0.517			0.810
Motor complete	1.40	(0.51, 3.88)		0.86	(0.26, 2.88)	
Motor incomplete	1.00			1.00		
Spasticity			0.011			0.030
Yes	4.08	(1.38, 12.04)		3.93	(1.14, 13.56)	
No	1.00			1.00		
Ambulation status			0.155			0.168
Yes	0.50	(0.19, 1.30)		0.44	(0.14, 1.42)	
No	1.00			1.00		
Sexual impairment			0.294			0.880
Yes	1.65	(0.65, 4.23)		1.10	(0.34, 3.59)	
No	1.00			1.00		

Note: Some variable not in this model because the variable not met the assumptions of Logistics Regression, there must be at least two cases for each category of the dependent.
CI = Confidence Interval; OR = Odds Ratio
Adj OR = Adjusted Odds Ratio

Of patients with US diagnosed NB complications (N=22), the mean duration for its first detection was 9.5±7.87 months (range 6-32 months) following initial neurological insult. Half of the patients, 12 (54.4%), had urodynamic diagnosis of neurogenic detrusor overactivity with/without evidence of detrusor sphincter dyssynergia (DSD); 7 patients (31.8%) had neurogenic detrusor acontractility whereas urodynamic report was unavailable for 3(13.8%) cases. Within the patients with urodynamic diagnosis of neurogenic detrusor overactivity with/without evidence of DSD, the mean maximum recorded detrusor pressure (P_{detmax}) was 62.6 ± 17.84 cmH_2O (range 40–80 cmH_2O). The mean serum Creatinine level taken after the detection of US diagnosed NBD complications was 76.8±22.3 (range 45.4–122.7 µmol/L). Patients with urodynamic diagnosis of neurogenic detrusor overactivity were conservatively treated with anti-cholinergic medications.

As shown in Table II, 41(37.2%) of our patients had partial NB recovery in which voluntary voiding has been regained. However, they still required occasional need of assistive methods to empty their bladder.

Referring to the statistical analyses in Table II; we found factors such as co-existing neurogenic bowel, presence of spasticity and mode of bladder management were significantly associated with US diagnosed NB complications ($p<0.05$). Multiple logistic regression analyses were performed and as shown in Table III, we found spasticity as a significant predictor of US diagnosed NB complications with adjusted Odds Ratio value of 3.93 (Confidence interval 1.14, 13.56). For both analyses the p-value was <0.05.

DISCUSSION

In this study, we evaluated patients with NB specifically in consequence to SCI. Though the actual prevalence of NB in population of patients with SCI is not known, an approximate figure of 81% of patients with SCI were estimated to report some degree of impaired bladder function within one year of injury.[4] Other reports documented an estimated prevalence rate of NB following SCI of between 70-84%.[1,9,10] We found that the prevalence of NB in our study population was 80.9%, which was comparable to the previous studies.

A proportion (20%) of our patients had evidence of US diagnosed NB complications with a mean duration of detection at 9.61 months post SCI. The commonest US diagnosed NB complications found in our study were morphological changes of the bladder wall (36.4%, N=22) which included thickening, trabeculation, sacculation and/or diverticulation. Hoffberg and Cardenas in their study suggested that bladder trabeculation may occur as an early manifestation of neurogenic bladder following SCI. In his retrospective review of 90 SCI individuals' chart, bladder trabeculation rate of 57% overall and in 31% of patients within 12 months of injury were reported.[11]

We found unilateral/bilateral hydronephrosis detection in 31.8% of those with US diagnosed NB complications. Vesicoureteral reflux which may potentially results in hydronephrosis were reported to occur in more than 20% of patients with neurogenic bladder, especially common when the lesion is suprasacral.[12] Edokpolo and Foster in their retrospective review of 40 records of SCI patients reported pelvicaliectasis occurrence rate of 8% while mild to moderate hydronephrosis occurrence rate was 6%.[13] Ogawa in a study involving 231 patients with NB evaluated for bladder

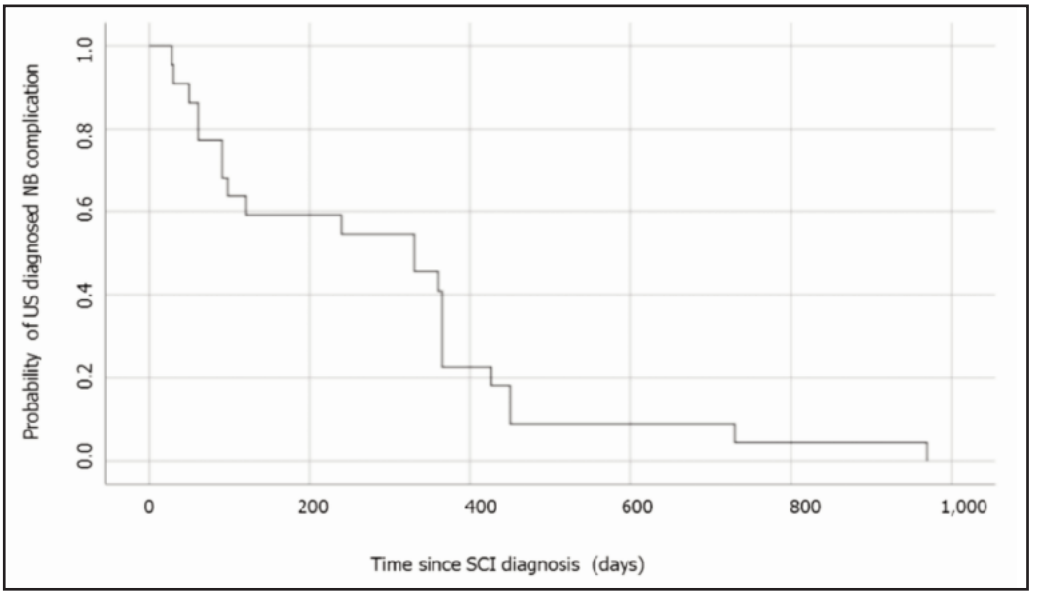

Fig. 1: Kaplan–Meier curve of time since diagnosis of spinal cord injury until the first detection of ultrasound diagnosed neurogenic bladder complications.

deformities including bladder trabeculation and abnormal bladder shape such as pine tree shape, found that the severity and extent of the deformities were associated with higher risk of upper urinary tract deterioration (hydronephrosis and/or reflux).[14]

Bladder and/or renal calculi were found in 22.7% of those with US diagnosed NB complications in our study. This finding was comparatively higher compared to an earlier report by Chen et al. whom in their study reported an overall incidence of renal stones of 3.5% in patients with neurogenic bladder, the most common being struvite stones.[15] Conversely, Edokpolo and Foster in their study reported a higher occurrence rate of renal/ureteral calculi of 13% in their studied population.[13] Meanwhile, Ost and Lee in their study reported that recurrent urinary tract infections, indwelling catheters, vesicoureteral reflux, and immobilization hypercalcuria were identified as few of the major risk factors for the development of urolithiasis among SCI patients.[16]

In this study, none of the demographic variables were found to be statistically associated with US diagnosed NB complications. For clinical characteristics however, among all variables analysed in our study; co-existing neurogenic bowel, presence of spasticity and mode of bladder management were found to be significantly associated with US diagnosed NB complication. Further analyses found spasticity as its predictor.

Principally, the bladder and bowel including sexual function primarily shares the lumbosacral innervation of the spinal cord.[17-19] Thus, rarely NB affected SCI individuals in isolation. Co-existing neurogenic bowel dysfunction denotes more severe extent of the neurological impairment, thus poses a higher risk of NB complications. Cameron et al. in their study involving 175 patients with 60.6% traumatic SCI found a significant correlation between the bladder symptom scores on Michigan Incontinence Symptom Index (M-ISI) (p=0.05) and American Urological Association symptom index (AUA-SI) (p=0.03) with the severity of neurogenic bowel symptoms score based on the Faecal Incontinence Severity Index (FISI).[20]

In this study, spasticity was significantly associated with US diagnosed NB complications. Additionally, we found that spasticity was its significant predictor. Spasticity has been regarded as a feature of an upper motor neuron syndrome.[21-23] Our study involved a majority of SCI individuals (70.8%) with cervical and thoracic injury, thus a predominant upper motor neuron NB correlated with spasticity was expected. In principle, injury proximal to the sacral spinal cord should lead to an upper motor neuron bladder manifested by detrusor overactivity while injuries that involve the sacral spinal cord or cauda equina should result in a lower motor neuron NB manifested by detrusor areflexia.[1,10] Both of these classifications assume the presence of a complete neurological lesion; however, the presentation of an incomplete lesion may be variable. In addition to detrusor overactivity, upper motor neuron bladder is often associated with detrusor sphincter dyssynergia whereby simultaneous detrusor and urinary sphincter contractions produce high pressures in the bladder leading to complications such as bladder trabeculation, vesicoureteral reflux and hydronephrosis, which may eventually result in renal damage.[1,2,4,10,24] In our study, 54.5% of those with US diagnosed NB complications (N=22) had urodynamic evidence of upper motor neuron bladder type i.e. neurogenic detrusor overactivity with/without evidence of DSD with a mean maximum recorded detrusor pressure of 62.6cmH_2O. These could possibly be the likely reasons leading to the detected complications. Meanwhile, it has been reported that the presence of NB complications (bladder calculi) had drastically influenced the extent and severity of spasticity of an individual with SCI.[25]

Our study findings showed the mode of bladder management to be significantly associated with US diagnosed NB complications ($p<0.05$) with the highest rate in SCI individuals practicing reflex voiding / Valsalva maneuver to empty their bladder (85.7%). Wyndaele et al., suggested that reflex voiding and Valsalva maneuver may be a potentially dangerous method of bladder management as it may lead to further deterioration of bladder function, hydronephrosis and eventually lead to renal impairment. Its indication shall be guided based on video-urodynamics to ensure safe detrusor pressure during the episodes of triggered detrusor contraction or Valsalva maneuver.[24]

We also found similar occurrence rate of US diagnosed NB complications in SCI individuals managing their bladder with continuous indwelling urethral and suprapubic bladder drainage (33.3%) in both groups. Our study findings were consistent to the study by Linsenmeyer and Linsenmeyer.[27] In their study involving 49 individuals with both indwelling urethral and suprapubic catheters, an overall 17/49 (35%) bladder stones complication was reported. Encrustation of a catheter was found to be highly predictive of the presence of bladder stones. Thus, they recommended cystoscopy evaluation should catheter encrustation was noted during catheter change of individuals with indwelling catheterization.[27] Igawa et al., in their review reported a high incidence (46–53%) of bladder stones in patients managed with long-term indwelling urethral catheter.[6] Ku et al., in their study found renal stone to be significantly more common in patients with indwelling urethral catheterisation than for those voiding spontaneously. They suggested suprapubic cystostomy as the preferred bladder management option than indwelling urethral catheterisation to avoid renal stone formation in patients with inability to void spontaneously or practice intermittent catheterization.[26]

Of those dependent fully on assistive method to empty their bladder, intermittent catheterisation was found to be the mode of bladder management with the least reported US diagnosed NB complications (23.4%). Our findings were consistent with previously reported studies which concluded that the incidence of both urinary tract dilatation and vesicoureteral reflux was significantly lower in the intermittent catheterisation group compared to those practising abdominal straining, Crede manoeuvre, tapping and indwelling catheterisation for their bladder management.[28,29] Intermittent catheterisation or intermittent self-catheterisation is regarded as the preferred and safer choice of bladder management in applicable patients with NB dysfunction.[1,3,4,12,24] Anti-cholinergic medications may also be an adjunctive treatment to intermittent catheterization to ensure safe bladder pressure and compliance even in the long term.[12,24] Complications including hydronephrosis, vesico-ureteral reflux and bladder cancer are believed to relate rather to infection, bladder trabeculation, detrusor pressure or neuropathy than to intermittent catheterization itself.[24,30] However, other unexpected complications including urethral trauma, bleeding, strictures, false passage has been associated with intermittent catheterisation use, thus patient and caregiver education on compliance and proper catheterisation techniques are of utmost important.[30]

Although this study has reasonably good sample size, it is limited by the retrospective study nature whereby the findings were dependent on the accuracy of documentation in the electronic records of the patients. For future study, we suggest a multicentered and follow up study to overcome these limitations.

CONCLUSION

NB is a common secondary medical impairment in our local SCI population with a proportion of patients had US diagnosed NB complications. Co-existing neurogenic bowel, presence of spasticity and mode of bladder management were its associated factor; whereby spasticity was its predictor. These findings may potentially contribute to better understanding among the clinicians and health care providers involved in SCI care, thus facilitate their management decision.

CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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Not applicable

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