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ORIGINAL RESEARCH

Validation of Upper Extremity Motor Function as a Key Predictor of Bladder Management After Spinal Cord Injury

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Abstract

Objective: To validate if better upper extremity (UE) motor function predicts clean intermittent catheterization (CIC) adoption and adherence after spinal cord injury (SCI) using a validated instrument (as opposed to prior research using scales based on expert opinion).

Design: We examined data from the Neurogenic Bladder Research Group SCI registry, a multicenter, prospective, observational study assessing persons with neurogenic bladder following SCI. All participants who were unable to volitionally void and were >1 year post injury were included. Participants were dichotomized into those performing CIC vs those using other bladder management methods. In addition to demographic and clinical characteristics, UE motor function was examined using the SCI-Fine Motor Function Index using validated categorization levels: (1) no activities requiring hand function, (2) some activities involving gross hand movement, (3) some activities requiring dexterity or coordinated UE movement, or (4) most activities requiring dexterity and coordinated UE movement. Associations were examined using logistic regression.

Setting: Multicenter study.

Participants: Registry participants unable to volitionally void after SCI (N = 1236).

Intervention: Not applicable.

Main Outcome Measure: Upper extremity motor function association with CIC.

Results: A total of 1326 individuals met inclusion criteria (66% performing CIC, 60% male, and 82% white). On multivariate analysis, better UE motor function was associated with a statistically increased odds of performing CIC (odds ratio, 3.10 [Level 3] and odds ratio, 8.12 [Level 4] vs Levels 1 and 2 [P<.001]).

Conclusion: In persons with SCI who are unable to volitionally void, UE motor function is highly associated with CIC. These results validate prior findings and continue to suggest that following SCI, the degree of preserved UE motor function is associated with CIC more than any other factor.

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Bladder dysfunction following spinal cord injury (SCI) is a common problem that can greatly affect an individual's quality of life.[1-7] In the 70% of persons who are unable to volitionally void after SCI, clean intermittent catheterization (CIC) is considered the criterion standard in bladder management because it is typically associated with fewer long-term complications.[8,9] However, as most experts in SCI care have found a "CIC for all" approach is not realistic and in certain instances only leads to patient frustration and dissatisfaction. This disconnect is evidenced by the significant proportion of persons with SCI who on extended follow-up choose other bladder management methods, such as

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condom catheter drainage and indwelling catheters.[10] The reasons for not adopting and adhering to CIC can vary but include age, sex, individual preference, and mental or physical limitations.[5,10-12]

Of the factors affecting bladder management after SCI, our prior research has indicated that restrictions in upper extremity (UE) motor function is by far the best predictor for a lack of CIC implementation.[13,14] These findings have been limited, however, by the fact that validated instruments to assess UE motor function in the SCI population have not commonly been included in prospective studies. As a result, our evaluation of UE motor function in a large national cohort of SCI patients using the Model Systems Spinal Cord Injury Dataset required us to generate an algorithm of UE motor function scores based on an expert opinion and not a validated instrument.[13,14]

Recently, a validated questionnaire-based measure of UE motor function (the SCI-Fine Motor Function Index)[15] was developed for use in the SCI population. Our aim was to determine if using this UE function instrument, validated for the SCI population, would confirm our prior findings that UE function predicts the use of CIC for bladder management after SCI.

Methods

With institutional review board approval, we assessed the Neurogenic Bladder Research Group SCI Registry, a national quality of life study of individuals with SCI. Between January 1, 2016, and June 30, 2017, we enrolled adults older than 18 years with a history of SCI. Consenting participants engaging in web-based questionnaires were included. The trial protocol details and methods have been previously published[16] (NCT0261608, www.clinicaltrials.gov, and HSRP20153564, US National Library of Medicine, wwwcf.nlm.nih.gov). All data are patient reported.

We included participants who reported that they were unable to volitionally void and were >1 year after their SCI. The participants were then dichotomized by bladder management method, which consisted of those performing CIC vs those using other bladder management methods (ie, indwelling catheters, condom catheters, ileal conduit, or leaking into diapers). Upper extremity motor function was examined using the SCI-Fine Motor Function Index from enrollment into the registry. The SCI-Fine Motor Function Index is an itemized response, theory-calibrated item bank, consisting of 35 items that is administered as a computer adaptive test.[15] Individual results were classified using a validated categorization scheme based on what participants were predicted to be able to perform: Level 1, no activities requiring hand function (score≤32); Level 2, some activities involving gross hand movement (score 33-43); Level 3, some activities requiring dexterity or coordinated upper extremity movement (score 44-51); or Level 4, most activities requiring dexterity and coordinated upper extremity movement (score ≥52). Subjects were further characterized by demographic data from the registry, including body mass index (BMI, calculated as weight in kilograms divided by height in meters squared), race and/or ethnicity, education level, household income, Charlson comorbidity score (0, 1, ≥2), marital status, chronic pain status, history of autonomic dysreflexia, 12-Item Short Form Health Survey (SF-12) physical and mental scores, and Neurogenic Bowel Dysfunction Score, all of which were included to control for their potential confounding effects on bladder management. The SF-12 physical and mental scores are validated shortened forms of the 36-Item Short Form Health Survey quality of life surveys.[17] The forms measure physical and mental well-being with scores ranging from 0-100 (where 0 indicates the lowest level of health and 100 indicates the highest level of health). The Neurogenic Bowel Dysfunction score is a validated 10-question survey that is scored on a scale from 0-47 with the severity of bowel dysfunction worsening with increasing score.[18] Because sex and BMI have been previously shown to potentially affect CIC adoption and adherence (specifically with obese women having decreased rates of CIC use), an interaction term was specified a priori to investigate potential associations.[13,14]

All data analysis and statistics were performed using Stata version 12.1.[a] Cross-sectional comparisons among demographic characteristics, quality-of-life instruments, and UE fine motor scores between those performing CIC vs other bladder management strategies were performed. Univariate and multivariate associations with bladder management were performed using logistic regression. Because very few participants were classified as being able to do "no activities requiring hand function" (Level 1), we combined these individuals with persons classified as able to do "some activities requiring gross hand movement" (Level 2) for the purposes of a regression analysis reference group.

List of abbreviations:

BMI	**body mass index**
CIC	**clean intermittent catheterization**
OR	**odds ratio**
SCI	**spinal cord injury**
SF-12	**12-Item Short Form Health Survey**
UE	**upper extremity**

Results

We identified 1425 individuals in the Neurogenic Bladder Research Group SCI Registry who were >1 year out from SCI. After excluding 99 persons who reported volitional voiding, the final study cohort consisted of 1326 individuals. The cohort was 60% male, with an average time of 15.4 years since their SCI and with an average age of 44.6 years. Roughly two-thirds of the study group performed CIC (n=879), with the other third (n=447) reporting that their bladder management method consisted of an indwelling catheter (20.1%), leaking into diaper (6.6%), condom catheter (4.5%), or an ileal conduit (2.6%). Approximately 13% (n=111) of individuals performing CIC did so with the aid of an assistant. Most individuals scored high on the SCI-Fine Motor Index and were classified as either Level 4 (57.1%) or Level 3 (29%). The rest of the cohort had more limited UE motor function and were classified as Level 2 (11.7%) or Level 1 (2.2%).

When comparing persons performing CIC with those using other bladder management methods, significant differences were seen. Specifically, persons performing CIC were less likely to be obese (BMI≥30) or have autonomic dysreflexia and were more likely to be younger, closer to the time of their SCI, of white race and/or ethnicity, have higher SF-12 physical scores, and have better UE motor function. When examining UE motor function in persons performing CIC, the vast majority (67.7%) were classified as Level 4 with another 25% classified as Level 3. Very few persons performing CIC (7.9%) were classified as having significant UE limitations (Level 1 or 2) (table 1).

Table 1 Cohort characteristics

Characteristics	CIC (n=879)	Indwelling Catheter/ Conduit/Condom Cath/ Diapers (n=447)
Age (y), median (IQR)	42.7 (32.9-52.8)	48.5 (37.9-55.6)
Time since injury (y), median (IQR)	11 (5.7-21.5)	14.6 (6.1-26.2)
Sex, n (%)		
Male	527 (60.0)	270 (60.4)
Female	352 (40.0)	177 (39.6)
BMI, n (%)		
Normal/underweight	433 (49.3)	209 (46.8)
Overweight	249 (28.3)	112 (25.1)
Obese	197 (22.4)	126 (28.2)
Race/ethnicity, n (%)		
White	736 (83.7)	349 (78.1)
Other	143 (16.3)	
Education, n (%)		
College degree or more	364 (41.5)	98 (21.9)
Less than college degree	514 (58.5)	175 (39.2)
Household income, no (%)		
<$20,000	156 (17.8)	108 (24.2)
$20,000-$39,999	151 (17.2)	83 (18.6)
$40,000-$74,999	163 (18.5)	81 (18.1)
$75,000-$99,999	82 (9.3)	27 (6.0)
≥$100,000	104 (11.8)	41 (9.2)
Unknown	223 (25.4)	107 (23.9)
Fine motor coordination of upper extremity, n (%)		
No activities requiring upper extremity movement (Level 1)	11 (1.3)	18 (4.0)
Some activities requiring gross hand movement (Level 2)	53 (6.0)	102 (22.8)
Some activities requiring dexterity and coordination of upper extremity movement (Level 3)	220 (25.0)	165 (36.9)
Most activities requiring dexterity and coordination of upper extremity movement (Level 4)	595 (67.7)	162 (36.2)
Charlson comorbidity, n (%)		
0	791 (88.2)	375 (83.9)
1	60 (6.8)	46 (10.3)
≥2	28 (3.2)	26 (5.8)
Married, n (%)	600 (68.3)	318 (71.1)
Chronic pain, n (%)	600 (68.3)	318 (71.1)
Autonomic dysreflexia, n (%)	305 (34.7)	221 (49.4)
SF-12 physical, median (IQR)	41.8 (33.4-51.7)	36.3 (29.2-48.0)
SF-12 mental, median (IQR)	52.2 (40.5-57.7)	50.1 (39.1-56.8)
Bowel QOL, median (IQR)	55.3 (50.8-58.1)	55.6 (50.9-58.7)

Abbreviations: IQR, interquartile range; QOL, quality of life.

On multivariate modeling these trends continued to be significant with better UE motor function being strongly associated with performing CIC compared with other bladder management methods (odds ratio [OR], 3.10 for Level 3 and OR, 8.22 for Level 4 compared with Levels 1 and 2 ($P<.001$ for both) (table 2). Factors that were associated with a decreased odds of performing CIC were older age (OR, 0.98; $P<.001$), increasing time since injury (OR, 0.98; $P<.001$), female obesity (OR, 0.43; $P=.006$), nonwhite race and/or ethnicity (OR, 0.56; $P=.001$), decreasing SF-12 physical scores (OR, 0.98; $P=.002$), and Charlson comorbidity scores≥2 (OR, 0.51; $P=.03$).

When the group performing CIC was further stratified by their ability to perform CIC independently or with the aid of a caregiver, the results for UE motor function became more pronounced. Specifically, of those performing CIC independently, no individual was classified as Level 1 and <1% were classified as Level 2. Rather, the majority (~75%) were classified in the highest category of UE motor function (Level 4) with the other quarter in Level 3 (table 3). When modeled, this almost perfect dichotomy lead to UE motor score ORs that were exceedingly high but did not affect other model variables (OR, 26.1 for Level 3 and OR, 91.6 for Level 4 [$P<.001$ for both]) (data not shown).

Discussion

Similar to our prior research observations, we find that individuals with SCI who have higher levels of preserved UE motor function

Table 2 Univariate and multivariate model findings predicting the odds of performing CIC rather than other forms of bladder management (indwelling catheter/conduit/condom cath/diapers)

Characteristics	Univariate	*P* Value	Multivariate	*P* Value
Age (y)	0.97 (0.96-0.98)	<.001	0.98 (0.97-0.99)	<.001
Time since injury (y)	0.97 (0.96-0.99)	<.001	0.98 (0.97-0.99)	.002
Sex				
Male	Ref	-	Ref	-
Female	1.01 (0.81-1.29)	.875	1.13 (0.78-1.55)	.448
BMI				
Normal/underweight	Ref	-	Ref	-
Overweight	1.07 (0.81-1.41)	.618	1.02 (0.75-1.41)	.879
Obese	0.75 (0.57-0.99)	.047	1.05 (0.68-1.61)	.839
Sex × obesity				
Nonfemale/Nonobese	-	-	Ref	-
Female-obese	-	-	0.43 (0.24-0.79)	.006
Race/ethnicity				
White	Ref	-	Ref	-
Other	0.69 (0.51-0.92)	.012	0.56 (0.40-0.78)	.001
Education				
College degree or more	Ref	-	Ref	-
Less than college degree	0.91 (0.72-1.15)	.42	0.95 (0.69-1.33)	.784
Household income				
>$20,000	Ref	-	Ref	-
$20,000-$39,999	1.26 (0.88-1.81)	.213	1.04 (0.69-1.60)	.823
$40,000-$74,999	1.39 (0.97-2.00)	.73	1.21 (0.76-1.92)	.425
$75,000-$99,999	2.10 (1.27-3.46)	.004	1.65 (0.89-3.06)	.111
≥$100,000	1.75 (1.13-2.72)	.012	1.39 (0.78-2.47)	.260
Fine motor coordination of upper extremity				
No activities requiring upper extremity movement OR Some activities requiring gross hand movement (Level 1 and 2)	Ref	-	Ref	-
Some activities requiring dexterity and coordination of upper extremity movement (Level 3)	2.50 (1.74-3.60)	<.001	3.10 (2.08-4.61)	<.001
Most activities requiring dexterity and coordination of upper extremity movement (Level 4)	6.89 (4.85-9.77)	<.001	8.22 (5.46-12.37)	<.001
Charlson comorbidity				
0	Ref	-	Ref	-
1	1.27 (0.12-13.6)	0.84	0.79 (0.50-1.26)	.328
≥2	0.84 (.07-10.3)	0.89	0.51 (0.27-0.94)	.030
Married	1.10 (0.87-1.39)	.406	0.98 (0.74-1.29)	.899
Chronic pain	0.88 (0.68-1.12)	.309	1.00 (0.74-1.37)	.978
Autonomic dysreflexia	0.54 (0.43-0.69)	<.001	0.82 (0.61-1.10)	.189
SF-12 physical	1.03 (1.02-1.04)	<.001	1.02 (1.01-1.03)	.002
SF-12 mental	1.00 (0.99-1.02)	.175	1.00 (0.99-1.02)	.191
Bowel QOL	0.98 (0.97-1.01)	.059	1.01 (0.99-1.02)	.112

Abbreviation: QOL, quality of life.

exhibit a significantly increased odds of performing CIC compared with other bladder management strategies.[14] That we come to similar conclusions in the current investigation with a different study population, with a different instrument of UE motor function, and with even longer follow-up (mean, 15 years out from SCI) further solidifies that UE motor function likely matters most in terms of long-term bladder management choice. Our comparable outcomes, albeit with a different UE motor function instrument, also appears to validate the prior algorithm we have used in other studies, which was based on expert opinion. Most striking is that when the cohort performing CIC is segregated into those performing CIC with and without assistance, those that are independently performing CIC are found to almost exclusively have significant if not complete UE motor function (Level 3 or 4) that leads to exceedingly high ORs ranging from 26-91.

While it may seem intuitive that significant UE motor function must be present for an individual to independently perform CIC, there is evidence to suggest that in many cases CIC is prescribed after SCI no matter the circumstances. Specifically, we have previously noted that ~1 in 5 individuals discharged from SCI rehabilitation with CIC as their method of bladder management lack the UE motor function to independently self-catheterize.[13] In these individuals, an increased burden of care is placed on their caregivers and the resultant patient-specific quality of life is likely negatively affected

Table 3 SCI fine motor classification by bladder management method and further stratified by CIC with assistance vs independent CIC

Fine Motor Coordination of Upper Extremity, n (%)	Independent CIC (n=768)	CIC With Assistance (n=111)	Indwelling Catheter/ Conduit/Condom Cath/ Diapers (n=447)
No activities requiring upper extremity movement (Level 1)	0	11 (9.9)	18 (4.0)
Some activities requiring gross hand movement (Level 2)	7 (0.9)	46 (41.4)	102 (22.8)
Some activities requiring dexterity and coordination of upper extremity movement (Level 3)	183 (23.8)	37 (33.3)	165 (36.9)
Most activities requiring dexterity and coordination of upper extremity movement (Level 4)	578 (75.3)	17 (15.3)	162 (36.2)

secondary to a complete reliance on others. The overwhelming associations between UE motor function and choice of long-term bladder management strategy observed in this study hopefully serve to further highlight the importance of proper patient counseling and realistic expectations (ie, while CIC is considered the criterion standard by multiple practice guidelines, it is not a practical bladder management option for every individual with SCI, and randomized trials have not shown CIC to be superior to other bladder management forms).[19]

In the study cohort not performing CIC, almost a third have UE motor function in the upper quartile (able to do most activities requiring dexterity and coordination of UE movement), and another third are categorized as able to do some activities requiring dexterity and coordination of UE movement (Levels 4 and 3, respectively). It is in this group where a lack of CIC adoption and/or adherence is at least partially explained by other model factors such as age, time since injury, other underlying comorbidities, and overall health, factors which have also been noted to be related in other studies.[5,10-12] We also find that obese women and persons of nonwhite race or ethnicity have higher associated odds of performing a bladder management method other than CIC, something that to our knowledge has not been previously noted. Previously, we had documented a trend suggesting women with increasing BMI were less likely to perform CIC; however, that study was limited by sample size because the Model Systems SCI dataset did not record height and weight until 2006.[13] The reason that BMI is more likely to affect a woman than a man in terms of CIC (as shown by a sizable effect modification) likely relates to increasing difficulties with anatomic accessibility of the urethra accented by using a wheelchair. Given a >2-fold decrease in the odds of CIC use in obese women, BMI should likely be considered when discussing bladder management choices. Why racial or ethnic differences might affect a bladder management decision is unclear and may suggest variations in access to care, insurance status, cultural influence, or medical biases that our analysis (which is limited in its ability to identify socioeconomic barriers) is unable to detect.

Study limitations

An individual's particular reasons for performing a bladder management method other than CIC, especially in those with adequate UE motor function, were not included in this analysis. To this end, the Neurogenic Bladder Research Group has recently shown in a separate study that urinary tract infection, urinary incontinence, and inconvenience were the 3 most common reasons for CIC discontinuation.[20] These reasons appear to highlight a failure of specialized urologic care to improve bladder storage (via medication, onabotulinum toxin, or bladder augmentation) or to make self-catheterization simpler (via occupational therapy evaluation, tenodesis aids, or catheterizable stoma creation) and suggest areas to improve SCI bladder-related care. In addition to the current study being unable to fully capture all the possible explanations that an individual might consider in choosing a particular bladder management strategy, several other limitations exist. Among these are the facts that fewer than expected participants had limited hand function, and the study cohort, likely by nature of its online questionnaire format, is skewed away from persons with limited computer access, both of which might limit study generalizability. However, the current analysis is strengthened via its use of a valid UE motor function questionnaire and allows us to examine factors affecting bladder management in a manner never before investigated. In addition, the long-term follow-up from the time of SCI (mean, 15 years) permits an analysis of long-term bladder management choice rather than the short-term choices noted in most studies.

Ultimately, we envision that during an individual's rehabilitation after SCI, an instrument of UE motor function (whether the SCI Fine Motor Function Index, the Capabilities of UE Questionnaire [CUE-Q],[21] the Graded and Redefined Assessment of Strength, Sensibility, and Prehension [GRASSP] test,[22] or other instrument) be used to confirm the rehabilitation teams' bladder management recommendations. The SCI Fine Motor Function Index may be an ideal measure because it is easily administered and could be followed longitudinally in the first year after SCI (when UE function as it pertains to self-catheterization may change significantly).[23] Using such a strategy would help to ensure realistic bladder management expectations for individuals with SCI and their caregivers and would ensure that CIC is reconsidered in instances where UE motor function improves with time.

Conclusions

In persons with neurogenic bladder after SCI, UE motor function is highly associated with long-term CIC adoption and adherence. These results validate prior study findings and continue to suggest that when considering long term bladder management recommendations, practitioners consider UE motor function as much or more than any other individual factor.

Supplier

a. Stata, version 12.1; StataCorp.

Keywords

Intermittent urethral catheterization; Rehabilitation; Spinal cord injuries; Urinary bladder, neurogenic

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