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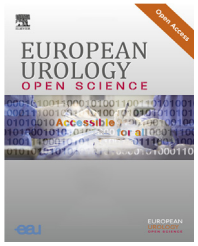

Neuro-urology

Urological Management at Discharge from Acute Spinal Cord Injury Rehabilitation: A Descriptive Analysis from a Population-based Prospective Cohort

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Abstract

Background: There is limited epidemiological evidence describing contemporary neuro-urological management of persons with acute spinal cord injury (SCI).
Objective: To describe neurogenic lower urinary tract dysfunction (NLUTD) management at discharge from SCI rehabilitation.
Design, setting, and participants: The population-based Swiss Spinal Cord Injury (SwiSCI) cohort study prospectively collected data from 602 adults undergoing specialized postacute SCI rehabilitation from 2013 to 2020. The management strategy was based on the European Association of Urology (EAU) Guidelines on Neuro-Urology.
Outcome measurements and statistical analysis: Data were collected at discharge using the International SCI Lower Urinary Tract Function Basic Data Set. Multivariable logistic regression adjusting for demographics, SCI characteristics, and center, with inverse probability weighting accounting for sampling bias, was used to produce prevalence estimates and identify predictors of lower urinary tract symptoms (LUTS) and NLUTD management outcomes.
Results and limitations: At discharge (median time after SCI: 5.0 mo [Q1-Q3: 3.0–7.2]), the prevalence of LUTS or managed NLUTD was 82% (95% confidence interval [CI]: 79–85%). SCI completeness was the main predictor of LUTS and managed NLUTD. The risk of urinary incontinence was elevated in females (odds ratio 1.98 [95% CI: 1.18–3.32]) and with complete lesions (odds ratio 4.71 [95% CI: 2.52–8.81]). Voiding dysfunction was most commonly managed with intermittent catheterization (prevalence 39% [95% CI: 35–42%]), followed by indwelling catheterization (prevalence 22% [95% CI: 18–25%]). The prevalence of

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antimuscarinic or mirabegron use was 29% (95% CI: 26–33%). Urodynamic and renal function data were not collected.

Conclusions: Our population-based description of urological management in Swiss SCI centers utilizing the EAU Guidelines on Neuro-Urology may be used as a reference for evaluation in other settings. Data further indicate a need for sex-specific neuro-urological management research.

Patient summary: At discharge from spinal cord injury (SCI) rehabilitation, a majority of patients have lower urinary tract problems, especially those with complete SCI. Women have a higher risk of urinary incontinence.

1. Introduction

Management of neurogenic lower urinary tract (LUT) dysfunction (NLUTD) after spinal cord injury (SCI) is a patient [1] and clinical priority, because NLUTD can negatively impact quality of life and may lead to severe secondary complications [2]. Contemporary guidelines for the management of NLUTD aim at providing standardized best urological care to patients with acute SCI. However, the characteristics of persons with acute SCI have changed considerably within the past decades. Today, acute SCI patients tend to be older, and nontraumatic SCI (NTSCI) is more frequent, often presenting with significant comorbidities [3]. As these factors can influence individualized patient care, a population-based evaluation of bladder management is thereby warranted so as to provide a foundation for comparative effectiveness evaluations [4,5]. The existing epidemiological database for such evaluation is limited, mainly consisting of smaller cohorts with unclear sampling frames of limited generalizability [6]. A comparison study of three major neuro-urology guidelines, including those of the European Association of Urology (EAU) [7], concluded that points of divergence often reflected differing expert opinion where the evidence base is weak [8].

The EAU Guidelines on Neuro-Urology prioritize protecting the upper urinary tract and recovering LUT function, thereby optimizing quality of life [7]. In the 1st year after SCI, the management approach is usually conservative, as both LUT and overall function have not stabilized [9–11]. Antimuscarinics are the first-line treatment for storage dysfunction [12], while intermittent self-catheterization is preferred for managing voiding dysfunction [13,14]. Discharge from SCI inpatient rehabilitation is an important milestone that generally occurs within the 1st year after injury, reflecting the outcomes of rehabilitation and setting the stage for the transition to the community setting [15]. The objective of this study is to provide a comprehensive description of NLUTD management at discharge from postacute specialized SCI rehabilitation using data from a national, population-based cohort. The specific aims include the following: (1) to estimate the prevalence and identify predictors of lower urinary tract symptoms (LUTS) and managed NLUTD, (2) to describe bladder emptying method according to SCI characteristics, (3) to describe medication and incontinence collection device use according to bladder emptying method, and (4) to describe neuro-urological management in traumatic and NTSCI. We anticipated that the majority of the population would have LUTS or managed NLUTD, with SCI level and completeness as key contributing factors.

2. Patients and methods

2.1. Study design and patient population

The Swiss Spinal Cord Injury (SwiSCI) Inception Cohort is a population-based, multicenter, prospective longitudinal study, which has been reported elsewhere in detail [16]. In brief, Swiss residents (age ≥16 yr), with an acute traumatic SCI (TSCI) or NTSCI undergoing rehabilitation in one of the four specialized SCI centers in Switzerland are included. Patients with a new SCI in the context of palliative care, SCI from a congenital condition, and neurodegenerative disorders are excluded. This study uses data collected 4 wk (timeframe: 16–40 d) after SCI and from 15 to 0 d before discharge, from patients admitted and discharged between May 2013 and June 2020. During this study period, 90% of the eligible population agreed to the use of clinical routine data (source data set), 48% of the eligible population consented to SwiSCI-specific assessments (study data set [SDS]), while 10% did not agree to any data collection. Patients who died in the rehabilitation facility or shortly after being discharged to a hospital or nursing home (total n = 11), or had no lesion level or lesion completeness information (n = 6), were dropped from this analysis. All responsible ethics committees approved this study (ethics committee numbers: LU 12090, EKBB 100/13, CCVEM 032/13, KEK Zürich 2013-0249, and EKNZ PB_2016-00183).

2.2. Neuro-urological management

All participating rehabilitation centers used a patient-tailored management approach based on the most recent version of the EAU Guidelines on Neuro-Urology (latest summary publication [7]).

2.3. Study measures

2.3.1. Lower urinary tract function

For SDS participants, a healthcare professional, usually a trained nurse on the patient ward, collected data on LUT function at discharge from primary rehabilitation using the expert-generated International Spinal Cord Society International Spinal Cord Injury Lower Urinary Tract Function Basic Data Set (ISCoS LUT data set) [17]. Medications for bladder overactivity (ie, the antimuscarinics oxybutynin, tolterodine, solifenacin, trospium chloride, darifenacin, fesoterodine, as well as mirabegron) and bladder outlet obstruction problems (alfuzosin, silodosin, tamsulosin, and terazosin) were extracted from pharmacy lists. Symptomatic or

managed storage dysfunction was defined as follows: presence of urinary frequency (average eight or more episodes of bladder emptying per 24 h in the past week) [7] or incontinence (any incontinence in the last 4 wk), use of bladder medication or intradetrusor onabotulinumtoxinA injections, or collection appliances for urinary incontinence. Symptomatic or managed voiding dysfunction was defined as any bladder emptying method that was not spontaneous voiding (reflex triggering, bladder expression, transurethral/suprapubic indwelling catheter, or intermittent catheterization), slow or strained spontaneous voiding, sphincterotomy/urethral stent, or use of bladder outlet obstruction medication. LUTS or managed NLUTD was defined as the presence of any symptomatic or managed storage and/or voiding dysfunction.

2.3.2. *Routine clinical data, neurological assessment, and functional independence*

Routine data extracted from the clinical records included demographics (age and sex), rehabilitation characteristics (center, dates of admission, and discharge), comorbidities (collected in text format; Supplementary material), SCI etiology (TSCI or NTSCI), and date of SCI diagnosis. The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) assessment was used to evaluate neurological condition (lesion level, American Spinal Injury Association Impairment Scale [AIS] grade) [18,19]. Functional independence was assessed with the Spinal Cord Independence Measure (SCIM) III [20].

2.4. *Statistical analyses*

Descriptive statistics were displayed according to the ISCoS recommendations [21]. Nonparametric testing (Kruskal-Wallis) was employed for univariable analyses, with chi-square or Fisher's exact testing for categorical variables. Proportions are reported with binomial exact confidence intervals (CIs).

Inverse probability weighting (IPW) was used to account for sampling bias in the SDS due to informed study refusal, using data from the study population to facilitate inference on the source population (Supplementary material). Multivariable logistic regression with inverse probability weights produced marginal prevalence estimates and predictions for LUTS, symptomatic or managed storage dysfunction, voiding dysfunction, lack of bladder sensation, and the various management approaches at the time of discharge. All regression models were adjusted for categorized age, sex, SCI etiology, center, AIS grade, and lesion level at discharge. Regression models were used to derive marginal estimates for selected predictor variables, that is, the estimated average outcome adjusted for the remaining predictor variables. Marginal predictions were derived separately for TSCI and NTSCI. Interactions and outliers were investigated. Missing SCI characteristic data were handled using a last observation carried forward approach in unadjusted presentations of NLUTD management, presuming relative stability after the acute period [22]. For incontinence, the unweighted model is the primary model because it contains fewer assumptions (IPW model in Supplementary Table 6). Statistical analyses were performed with Stata version 16.0 (StataCorp, College Station, TX, USA).

3. Results

During the study period, 602 patients (59% TSCI) were included in the SDS. The TSCI population was younger, comprised a larger portion of males, and had a smaller portion of persons with AIS D or E grade lesions than the NTSCI population (Table 1). A multivariable analysis indicated some sampling bias in the SDS toward younger age, earlier admission to rehabilitation, and across centers (Supplementary material). Discharge occurred a median of 5.0 (Q1-Q3: 3.0–7.2) mo (152 [Q1-Q3: 90–219 d]) after SCI, and LUT function was assessed a median of 143 (Q1-Q3: 84–212) d after SCI. Urological surgeries during the rehabilitation period were uncommon (missing data: n = 51, 8%) and included intradetrusor onabotulinumtoxinA injections (n = 20, 3%), sphincterotomy/urethral stent placement (n = 3), circumcision (n = 3), and urethral sling insertion (n = 1).

The marginal estimated prevalence of LUTS or managed NLUTD in the source population was 82% (95% CI: 79–85%). All marginal prevalence estimates are displayed in Table 2, alongside unadjusted prevalence figures for the SDS. In an alternative scenario, assuming that missing data regarding LUTS reflected a lack of symptoms in persons who exclusively used spontaneous voiding as their bladder emptying method (spontaneous voiders with missing data for storage symptoms [22%] were assigned to the "no symptoms or management" group), the marginal prevalence estimated in the source population was 75% (95% CI: 72–79%). Symptomatic or managed storage dysfunction had a marginal prevalence of 58% (95% CI: 53–62%), while 68% (95% CI: 65–72%) had symptomatic or managed voiding dysfunction. Less than half of the population (41%, 95% CI: 38–45%) had no bladder sensation. The predominant predictor of LUTS or managed NLUTD was AIS grade, and all persons with an AIS grade A had managed voiding dysfunction (see Fig. 1 for adjusted prevalence estimates stratified on AIS grade and lesion level, Supplementary Table 4 for unadjusted proportions).

Incontinence was the most commonly reported storage symptom; in the month before discharge, the marginal prevalence (unweighted) was 24% (95% CI: 20–27%). Only a small percentage of the population (n = 23, 5%, 95% CI: 3–8%, unweighted) had frequency symptoms. In the SDS, females (adjusted odds ratio [aOR]: 1.98 [95% CI: 1.18–3.32]) and persons with more complete lesions (aOR AIS A: 4.71 [95% CI: 2.52–8.81]) referenced to AIS D/E were more likely to have incontinence (Fig. 2, and Supplementary Fig. 2 & Tables 5,6).

Voiding dysfunction was most commonly managed using catheters; 60% (95% CI: 56–63%) of the population used a catheter to empty the bladder at least some of the time. Indwelling catheterization was used by 22% (95% CI: 18–25%), intermittent catheterization was used by 39% (95% CI: 35–42%), and 38% (95% CI: 34–41%) could void spontaneously. The remaining patients (n = 11, 2%, unweighted) used only reflex triggering and/or bladder expression. A small portion of the population used multiple bladder emptying methods (n = 26, 4%, unweighted). The bladder emptying method is displayed, stratified according to SCI characteristics, in Figure 3 (Supplementary Table 7). Bladder outlet obstruction medications were used by a minority of the population (11%, 95% CI: 8–14%).

Antimuscarinics and mirabegron were used by 29% (95% CI: 26–33%) of the population. Of these 166 patients, 34 (20%) used mirabegron. Finally, 14% (95% CI: 11–17%) used collection appliances for urinary incontinence at discharge. The use of medications and urinary incontinence collection devices is displayed, stratified according to bladder emptying method, in Figure 4 (Supplementary Table 8).

The population with NTSCI tentatively had a lower prevalence of LUTS or managed NLUTD than the population

Table 1 – Characteristics of the study population at discharge from SCI rehabilitation, stratified on SCI etiology (TSCI/NTSCI)

Characteristic [% missing]	Overall	TSCI	NTSCI	*p* value
Study population	*N* = 602	*N* = 354	*N* = 248	
Continuous variables	*Median (Q1-Q3)*	*Median (Q1-Q3)*	*Median (Q1-Q3)*	
Age at SCI [0]	55 (41–66)	51 (34–62)	60 (50–70)	<0.0001
SCIM III score [2]	76 (58–91)	73 (57–91)	80 (62–92)	0.035
Length of stay (d) [0]	130 (70–191)	161 (91–211)	96 (52–154)	<0.0001
Time to rehab admission (d) [0]	14 (9–24)	13 (8–22)	14 (9–26)	0.010
Categorical variables	*n* (%)	*n* (%)	*n* (%)	
Age at SCI [0]				<0.0001
16–30	81 (13)	70 (20)	11 (4)	
31–45	112 (19)	78 (22)	34 (14)	
46–60	194 (32)	110 (31)	84 (34)	
61–75	170 (28)	79 (22)	91 (37)	
76+	45 (7)	17 (5)	28 (11)	
Sex [0]				0.0006
Female	191 (32)	93 (26)	98 (40)	
Male	411 (68)	261 (74)	150 (60)	
Neurological category [7][a]				<0.0001
C1-C4 AIS A (*n* = 13), B (*n* = 4), C (*n* = 8)	25 (4)	23 (6)	2 (1)	
C5-C8 AIS A (*n* = 13), B (*n* = 6), C (*n* = 10)	29 (5)	25 (7)	4 (2)	
T1-T12 AIS A (*n* = 61), B (*n* = 20), C (*n* = 21)	102 (17)	76 (21)	26 (10)	
L1-S5 AIS A (*n* = 14), B (*n* = 14), C (*n* = 13)	41 (7)	27 (8)	14 (6)	
All AIS D	390 (65)	195 (55)	195 (79)	
All AIS E	15 (2)	8 (2)	7 (3)	
SCIM III score [2]				0.006
0–24	38 (6)	30 (9)	8 (3)	
25–49	70 (12)	40 (12)	30 (12)	
50–74	171 (29)	111 (32)	60 (25)	
75–100	310 (53)	166 (48)	144 (60)	
Comorbidities [NA][b]				0.009
Neurological	117 (19)	63 (18)	54 (22)	
Genitourinary	77 (13)	32 (9)	45 (18)	
Renal	26 (4)	12 (3)	14 (6)	
Psychological	97 (16)	56 (16)	41 (17)	
Metabolic	60 (10)	23 (6)	37 (15)	
Multiple relevant comorbidities	76 (13)	33 (9)	43 (17)	
Admission after day 40 [0]				0.29
No	541 (90)	322 (91)	219 (88)	
Yes	61 (10)	32 (9)	29 (12)	
Length of stay (d) [0]				<0.0001
1–60	122 (20)	50 (14)	72 (29)	
61–120	150 (25)	68 (19)	82 (33)	
121–180	154 (26)	101 (29)	53 (21)	
181+	176 (29)	135 (38)	41 (17)	
Center [0]				<0.0001
Center 1	161 (27)	78 (22)	83 (33)	
Center 2	95 (16)	45 (13)	50 (20)	
Center 3	100 (17)	59 (17)	41 (17)	
Center 4	246 (41)	172 (49)	74 (30)	

AIS = American Spinal Injury Association Impairment Scale; ISNCSCI = International Standards for Neurological Classification of Spinal Cord Injury; NA = not available; NTSCI = nontraumatic SCI; SCI = spinal cord injury; SCIM = Spinal Cord Independence Measure; TSCI = traumatic SCI.

[a] ISNCSCI information was missing at discharge in 7% of observations; these cases are categorized according to their most recent ISNCSCI assessment.

[b] Due to data format (free text), missing data cannot be definitively identified in the comorbidity variables.

with TSCI (see the Supplementary material for additional stratified results). Differences in many outcomes were explained by sociodemographic and SCI characteristics (Table 2). Patients with NTSCI were less likely to have LUTS or managed storage symptoms (aOR 0.53 [95% CI: 0.32–0.88]) or to use bladder medication at discharge (aOR 0.41 [95% CI: 0.25–0.67]).

4. Discussion

This population-based study presents a comprehensive description of NLUTD and its management at discharge from SCI rehabilitation. LUTS or managed NLUTD was predominantly determined by AIS grade and was present in the majority of the population. Female sex and lesion completeness were predictors of incontinence. Intermittent, followed by indwelling, catheterization was the most common management approach for voiding dysfunction, while antimuscarinics and mirabegron were used most frequently to manage storage dysfunction. The NTSCI population showed a lower prevalence of LUTS or managed NLUTD, and persons with NTSCI were less likely to use antimuscarinics and mirabegron than those with TSCI.

Neuro-urological management was not strongly affected by etiology, with the exception of medication use. This is in line with guidance that bladder management should be aligned to the neuro-urological symptoms and dysfunction rather than the underlying condition. The more complex comorbidity profile in persons with NTSCI may lead to

Table 2 – Overall proportions (unadjusted and unweighted) and marginal (adjusted and weighted) prevalence estimates of lower urinary tract symptoms (LUTS), managed neurogenic lower urinary tract dysfunction (NLUTD), and the use of various management strategies

Outcome [% missing]	Overall proportion (95% CI)	Overall marginal prevalence (95% CI)	Adjusted odds ratio NTSCI (vs TSCI; 95% CI), *p* value	TSCI proportion (95% CI)	TSCI marginal prevalence (95% CI)	NTSCI proportion (95% CI)	NTSCI marginal prevalence (95% CI)
Symptoms and/or dysfunction							
LUTS and/or managed NLUTD [12]	0.79 (0.75–0.82)	0.82 (0.79–0.85)	0.74 (0.41–1.33), $p = 0.31$	0.83 (0.79–0.87)	0.86 (0.82–0.89)	0.73 (0.67–0.79)	0.77 (0.71–0.82)
LUTS and/or managed NLUTD sensitivity [3] [a]	0.72 (0.68–0.76)	0.75 (0.72–0.79)	0.91 (0.55–1.52), $p = 0.73$	0.75 (0.71–0.80)	0.79 (0.75–0.83)	0.68 (0.61–0.74)	0.71 (0.65–0.77)
Symptomatic and/or managed storage dysfunction [25]	0.54 (0.49–0.59)	0.58 (0.53–0.62)	0.53 (0.32–0.88), $p = 0.014$	0.62 (0.56–0.68)	0.65 (0.60–0.71)	0.42 (0.35–0.49)	0.46 (0.39–0.53)
Symptomatic and/or managed voiding dysfunction [4]	0.66 (0.62–0.69)	0.68 (0.65–0.72)	1.00 (0.61–1.64), $p = 0.99$	0.70 (0.64–0.74)	0.73 (0.69–0.77)	0.60 (0.53–0.66)	0.62 (0.56–0.68)
Lack of bladder sensation [11]	0.38 (0.34–0.42)	0.41 (0.38–0.45)	1.01 (0.56–1.80), $p = 1.00$	0.43 (0.38–0.49)	0.48 (0.43–0.52)	0.30 (0.24–0.37)	0.32 (0.26–0.38)
Incontinence [20]	0.22 (0.19–0.26)	0.24 (0.20–0.27)	0.92 (0.53–1.59), $p = 0.77$	0.25 (0.20–0.31)	0.26 (0.21–0.31)	0.18 (0.13–0.69)	0.20 (0.15–0.25)
Management strategies							
Any catheter use [4]	0.57 (0.53–0.61)	0.60 (0.56–0.63)	0.74 (0.46–1.21), $p = 0.23$	0.63 (0.58–0.68)	0.66 (0.62–0.71)	0.47 (0.41–0.54)	0.45 (0.38–0.52)
Indwelling catheter [4]	0.19 (0.16–0.22)	0.22 (0.18–0.25)	1.21 (0.65–2.23), $p = 0.55$	0.19 (0.15–0.23)	0.21 (0.17–0.24)	0.19 (0.14–0.24)	0.24 (0.18–0.29)
Intermittent catheter [4]	0.38 (0.34–0.42)	0.39 (0.35–0.42)	0.74 (0.45–1.19), $p = 0.21$	0.44 (0.39–0.50)	0.46 (0.41–0.50)	0.30 (0.24–0.36)	0.29 (0.23–0.34)
Spontaneous voiding [4]	0.41 (0.37–0.45)	0.38 (0.34–0.41)	1.39 (0.84–2.28), $p = 0.20$	0.34 (0.29–0.39)	0.30 (0.26–0.34)	0.50 (0.43–0.57)	0.48 (0.42–0.54)
Bladder medication [2]	0.28 (0.24–0.32)	0.29 (0.26–0.33)	0.41 (0.25–0.67), $p = 0.0004$	0.35 (0.30–0.40)	0.38 (0.33–0.43)	0.18 (0.13–0.23)	0.17 (0.12–0.23)
Bladder outlet obstruction medication [2]	0.11 (0.08–0.13)	0.11 (0.08–0.14)	2.15 (1.13–4.09), $p = 0.020$	0.08 (0.05–0.11)	0.11 (0.07–0.14)	0.15 (0.11–0.20)	0.18 (0.12–0.23)
Incontinence collection appliances [20]	0.13 (0.10–0.17)	0.14 (0.11–0.17)	0.79 (0.38–1.63), $p = 0.52$	0.14 (0.10–0.18)	0.14 (0.10–0.19)	0.13 (0.09–0.18)	0.14 (0.10–0.19)

CI = confidence interval; LUTS = lower urinary tract symptoms; NLUTD = neurogenic lower urinary tract dysfunction; NTSCI = nontraumatic SCI; SCI = spinal cord injury; TSCI = traumatic SCI.
The weighted prevalence estimates are based on marginal predictions from logistic regression analyses adjusting for age, sex, SCI completeness, SCI level, and study center in addition to SCI etiology. Adjusted odds ratios for etiology are derived from the same regression analyses.

[a] LUTS or managed NLUTD—sensitivity is an alternative scenario for handling missing data where the 22% of spontaneous voiders with missing data for storage symptoms were assigned to the "no symptoms or management" group.

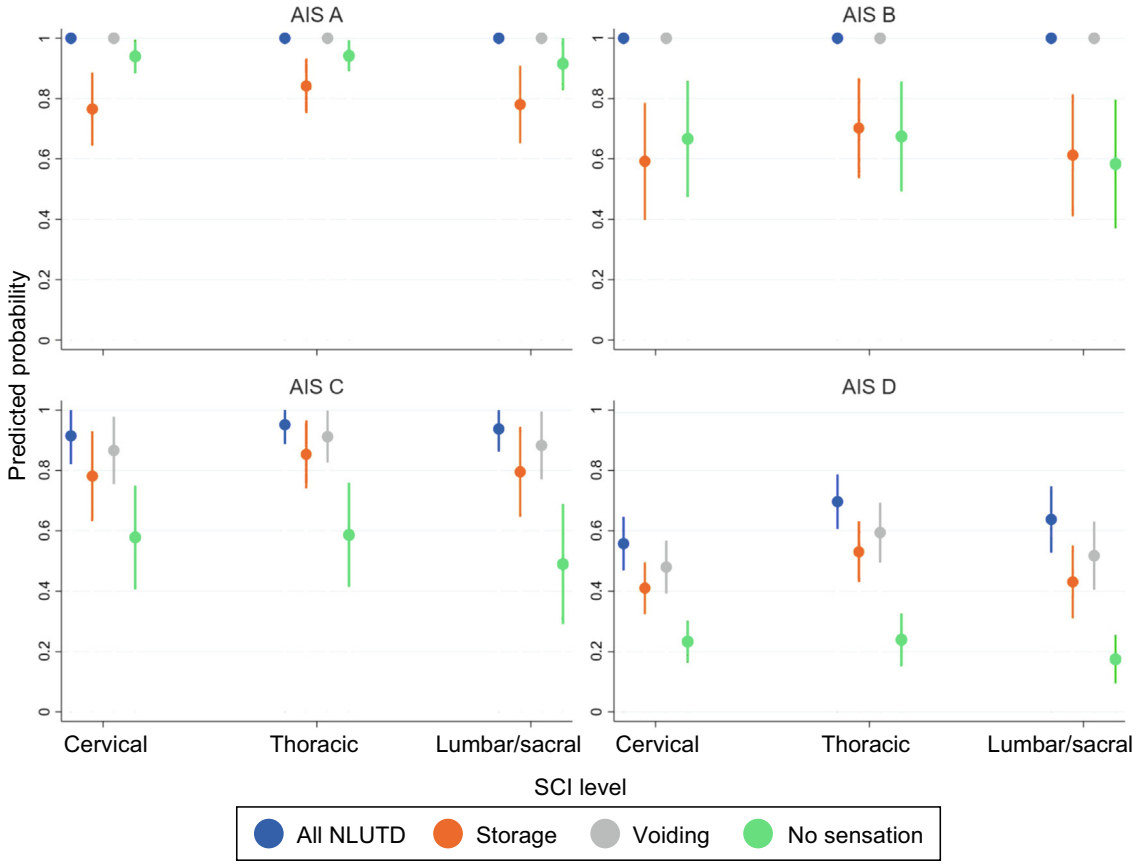

Fig. 1 – Marginal prevalence estimates and 95% CIs of symptomatic or managed neurogenic lower urinary tract dysfunction (NLUTD) in the population with spinal cord injury (SCI), including a lack of awareness of the need to empty the bladder (no sensation). These estimates are based on marginal predications from logistic regression analyses, adjusting for age, sex, SCI etiology (traumatic or nontraumatic), AIS grade, SCI level, and center, with inverse probability weighting to account for sampling bias. AIS = American Spinal Injury Association Impairment Scale.

decreased antimuscarinic tolerability and safety [12], which could explain the reduced prescription of antimuscarinics among persons with NTSCI.

This study supports the use of lesion completeness information, especially AIS grade, for population-level comparisons of NLUTD requiring treatment in SCI. However, it is indisputable that AIS grade cannot replace urodynamics as an individual-level diagnostic tool [7,23], as the ISNCSCI assessment does not evaluate autonomic nervous system function and thereby misses an important component of LUT function [24]. Indeed, a study that included urodynamics found that, as opposed to bladder emptying method, 1 yr after SCI detrusor overactivity and low compliance bladder were not associated with lesion completeness [25]. A further factor that might contribute to the ambiguity in the literature regarding the relevance of lesion completeness is the varying definitions utilized across studies. In agreement with guidance from SCI rehabilitation field [21], the results reported here indicate that for outcomes such as the bladder emptying method, persons with AIS B and C grade lesions are similar to those with AIS A lesions and should be grouped accordingly. Furthermore, reporting of AIS grade should be routine, as it is a useful supplement to urodynamic information, facilitating comparative analyses and meta-analyses of studies utilizing differing urodynamic techniques or where urodynamic data are simply not available.

The finding that females with SCI might have a higher risk of urinary incontinence than males has preliminary support in the community setting [26,27]. A possible explanation for the discrepancy between sexes is that at least some of the incontinence in females may be linked to stress urinary incontinence rather than being of neurogenic origin [26,28]. As urinary incontinence is associated with decreased quality of life [29], further research to identify the source of the difference between sexes should be prioritized, including urodynamic studies, in order to provide a foundation for sex-specific recommendations for incontinence treatment.

To the best of our knowledge, no prior studies have presented an overview of both catheterization and medication use at the time of discharge from SCI rehabilitation. A study from a North American cohort reported higher levels of catheter use—with only 19% of the population voiding spontaneously at discharge, but lesion completeness was not reported [15]. A European cohort found that about one-third of the population had urinary continence and complete emptying 1 yr after SCI, based on information from the SCIM III [10]. Our estimate that 15–28% of the patients do not have recorded LUTS or managed NLUTD is slightly lower, but the measure used in the current study was more comprehensive, so likely more sensitive. A further study from North America reported that 20% of persons with SCI had incontinence at discharge from inpatient rehabilitation,

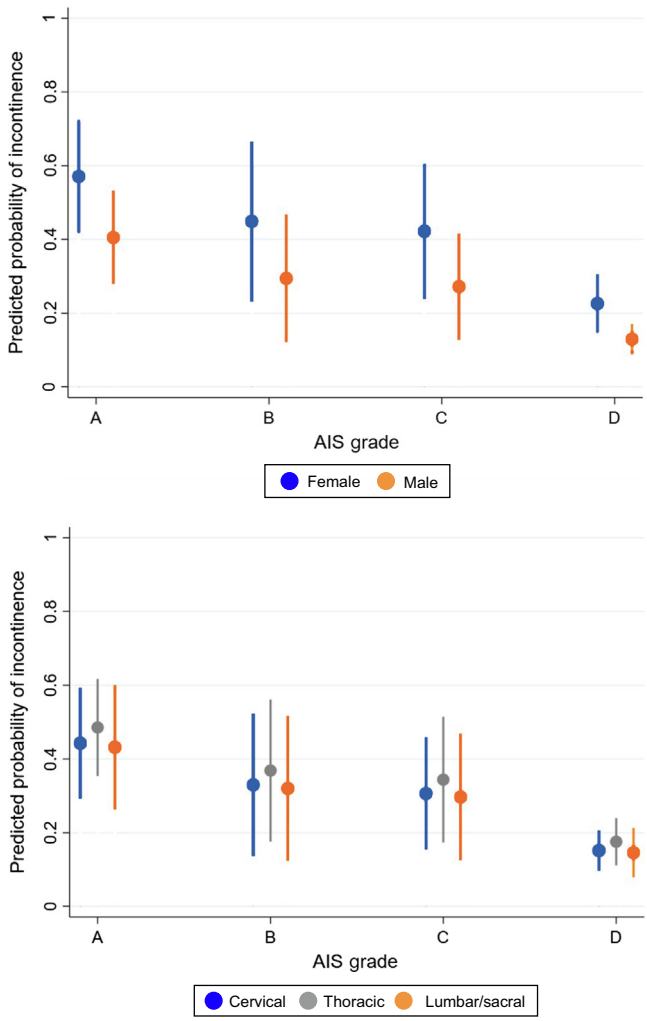

Fig. 2 – Predicted probabilities of incontinence at discharge from rehabilitation. Marginal adjusted predictions based on a multivariable logistic regression model (1 = any incontinence within the last 4 wk before discharge). AIS = American Spinal Injury Association Impairment Scale.

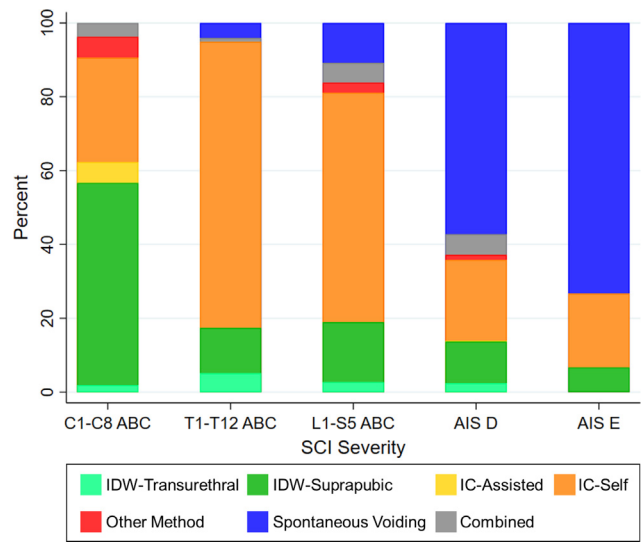

Fig. 3 – Bladder emptying method at discharge according to SCI characteristics. Percentage of the population using each bladder emptying method at discharge stratified on SCI characteristics (C1-C8 AIS A, B, C: *n* = 54; T1-T12 AIS A, B, C: *n* = 102; L1-S5 AIS A, B, C: *n* = 41; AIS D: *n* = 390; AIS E [intact]: *n* = 15). When SCI characteristics were not available at discharge they were taken from the closest time point. Other bladder emptying method refers to reflex triggering and/or bladder expression. AIS = American Spinal Injury Association Impairment Scale; C = cervical; IC = intermittent catheter; IDW = indwelling catheter; L = lumbar; S = sacral; SCI = spinal cord injury; T = thoracic.

but here also lesion completeness was not reported, hindering a systematic comparative analysis [30]. Consistent reporting of lesion completeness would facilitate the comparison and effectiveness evaluations of "whole patient" urological outcomes across different settings that are needed to inform and improve guideline recommendations.

A notable strength of this study is the population-based sampling frame, including at least some routine data from 90% of patients admitted for specialized postacute SCI rehabilitation on a national level, allowing us to utilize inverse probability weights to correct for sampling bias and make inferences on the source population. However, we cannot make reliable inferences about the 10% of the population that refused any data collection. A further strength of this study is that the LUT function data were collected by healthcare professionals, based on the expert-generated ISCoS data set, supporting comparability with other studies. Yet, one item—presence of urological impairment unrelated to SCI—was not collected, meaning that we cannot be certain that all LUTS and treatments here directly reflect the SCI and not another underlying condition. While data on comorbidity, associated injury, and secondary health conditions are collected, these consist of lists of diagnoses, without structured information about disease severity, limiting the usefulness for inference.

As a further limitation, urodynamic and renal function data were not collected and could not be considered in our analyses. Indications for treatment or management were also not recorded by the cohort study, which might lead to an underestimation of the prevalence of symptomatic or managed storage dysfunction because catheter use was grouped with voiding dysfunction. Moreover, our study was not powered to conclusively evaluate differences in management related to specific NTSCI etiologies. A final limitation is that the differing time windows for incontinence (past month) and bladder emptying method (discharge) did not allow us to meaningfully combine these outcomes in a cross-sectional analysis.

5. Conclusions

Our study provides a population-based description of LUTS and NLUTD management at discharge from specialized SCI rehabilitation. Further research is needed to identify the source of potential discrepancy between sexes in terms of incontinence. Etiological differences in medication use is a further potentially relevant topic. This description of neuro-urological management, overall and by patient characteristics, can serve as a reference for the evaluation and improvement of guidelines for the individualized clinical management of NLUTD in SCI.

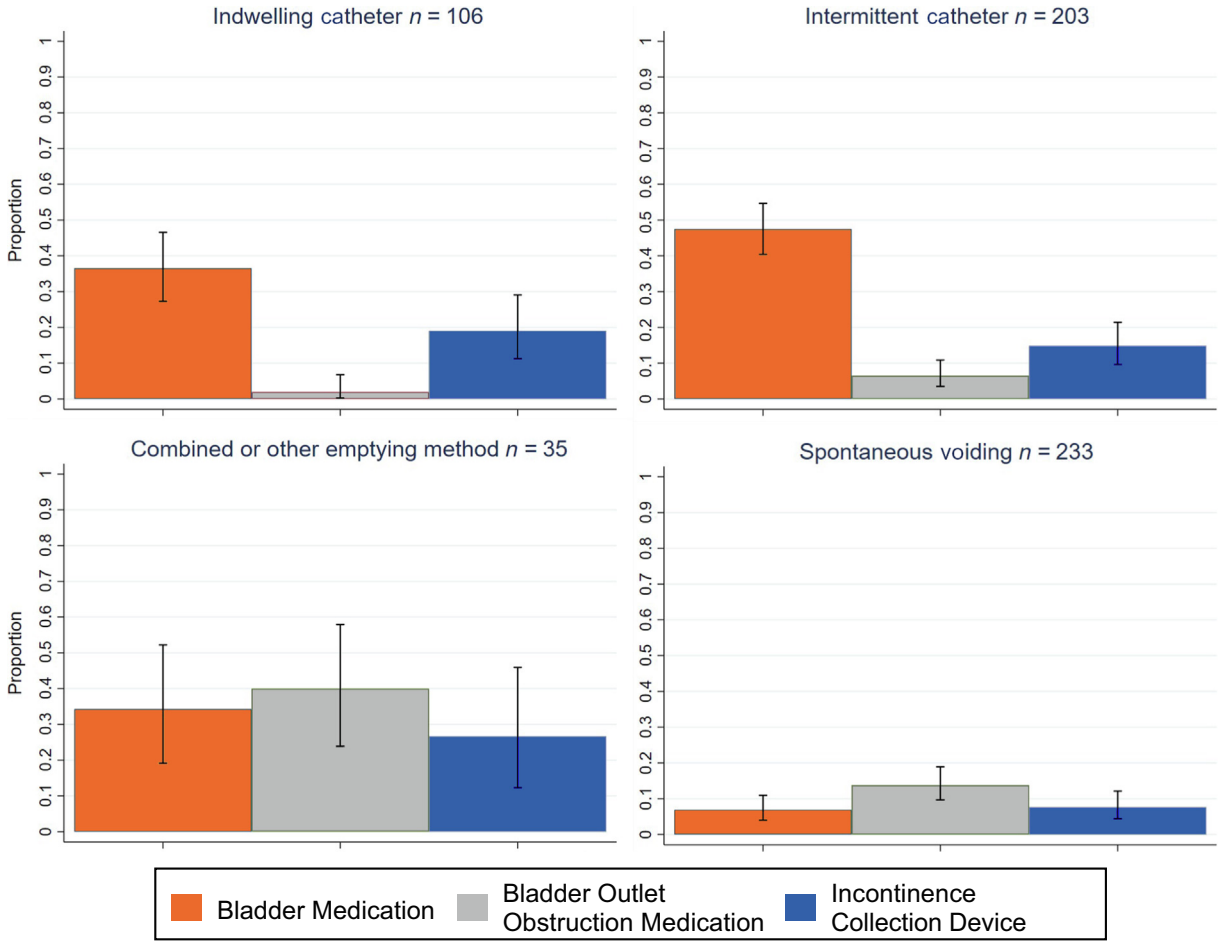

Fig. 4 – Medications and urinary incontinence collection devices according to bladder emptying method. Bladder (antimuscarinics or b3-adrenergic agonists) and bladder outlet obstruction (alpha-blockers) medication and urinary incontinence collection devices: proportion of the population (95% CI) using the respective bladder management method, stratified on bladder emptying method. Other bladder emptying method = reflex triggering and/or bladder expression. Differences were statistically significant across bladder emptying methods ($p < 0.003$, all). CI = confidence interval.

***Author contributions*:** Martin W.G. Brinkhof had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Anderson, Birkhäuser, Kessler, Brinkhof.
Acquisition of data: Anderson and Brinkhof acquired data from the Swiss Spinal Cord Injury (SwiSCI) cohort study.
Analysis and interpretation of data: Anderson, Birkhäuser, Jordan, Liechti, Luca, Möhr, Pannek, Kessler, Brinkhof.
Drafting of the manuscript: Anderson, Birkhäuser, Kessler, Brinkhof.
Critical revision of the manuscript for important intellectual content: Anderson, Birkhäuser, Jordan, Liechti, Luca, Möhr, Pannek, Kessler, Brinkhof.
Statistical analysis: Anderson, Brinkhof.
Obtaining funding: Pannek, Kessler, Brinkhof.
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Other: None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.euros.2022.01.005.

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