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ARTICLE

Feasibility of predicting improvements in motor function following SCI using the SCAR outcome measure: a retrospective study

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Abstract

Study design A retrospective study.

Objectives To assess improvement in volitional motor function after SCI, using The Spinal Cord Ability Ruler (SCAR) as a metric and investigate participant characteristics and recovery of motor functioning.

Setting A highly-specialized SCI rehabilitation unit (Spinal Cord Injury Centre of Western Denmark, SCIWDK).

Methods Retrospectively, data on all SCI patients admitted to SCIWDK between 1 January 1997 and 1 November 2018 were extracted from a database. The SCAR score (range: 0–100) was calculated by combining items from ISNCSCI and SCIM.

Results Mean (95%CI) improvement in volitional motor function was of 17.2 (CI: 14.5–19.9) equal to an improvement of 43% from baseline after median 155 days in-hospital rehabilitation. Individuals with tetraplegia exerted larger improvement (mean difference of 8.9 (CI: 3.6–14.2) points) as compared to paraplegia. Male gender predicted better improvement ($p < 0.03$), as did no need for mechanical ventilation with a gain of 8.5 (CI: 1.8–15.3) points as compared to those in need.

Conclusions Overall mean improvement of 43% in volitional motor function was found in 84 in-hospitalized patients using SCAR as a metric at a highly-specialized SCI unit. Following factors; level-of-injury, gender, age, need of ventilation support predicted improvement in volitional motor function after a rehabilitation period. Results should be cautiously interpreted as a majority of hospitalized patients did not fulfill criteria for SCAR scoring. Prospectively designed studies with better internal validation and external validations are needed to confirm these findings.

Introduction

Spinal cord injury (SCI) represents a major health concern; the World Health Organization estimates an incidence of 250,000–500,000 per year worldwide [1]. In Denmark an average of 130 new cases of SCI are yearly registered [2]. SCI is a devastating condition, in which loss of motor and sensory function in addition to impairment of bladder and bowel control lead to resulting poor quality of life (QoL) [3–5]. Recovery of motor function is of a high clinical priority and pivotal for accomplishing activities of daily living (ADL) [6]. Additionally, being able to identify predictors for recovery of motor function is crucial in rehabilitation [7]. Despite the conduct of clinical trials with different candidate treatments for SCI, it has been difficult to convincingly demonstrate treatment effects on motor function. Part of the uncertainty of outcome assessment in clinical SCI trial might be overcome by the introduction of the recently introduced "Spinal Cord Ability Ruler" (SCAR) [6], which has been introduced as a valid and reliable linear interval-level outcome measure combining items from the upper limb motor assessments of the International Standards for the Neurological Classification of Spinal Cord Injury (ISNCSCI) and items from the Spinal Cord Independence Measure (SCIM) [6]. SCAR aims to measure the change of volitional performance, and should according to the authors be applied in a majority of SCI persons, regardless of the level or the severity of injury [6]. This produces a unique opportunity to examine existing

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data in a historical cohort and for computing SCAR scores at The Spinal Cord Injury Centre of Western Denmark (SCIWDK).

The primary aim of this retrospective study was to identify and describe the amount of improvement in volitional motor function after a rehabilitation period at a highly-specialized SCI rehabilitation unit using SCAR as a metric in a historic cohort. Furthermore, the aim was to investigate the correlation between core characteristics of SCI persons and the recovery of motor function.

Methods

Study population

SCIWDK accepts referrals of spinal cord injured subjects including both adults and children presenting with a potential for rehabilitation. SCIWDK covers Western Denmark (3.5 million citizen). Prospectively, data from the admitted pediatric and adult SCI population were obtained and collected in a database (Redcap™) in accordance with the national general data protection regulations and were approved by the Data Protection Agency (ref no. 2012–41–0572). From this database, we extracted data on all SCI patients admitted to SCIWDK during 1 January 1997 and 1 November 2018. We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were observed during the course of this research.

Data collection

In accordance with the recommendations from the International Spinal Cord Injury Core Data Set [8], the following variables were extracted for statistical analysis: gender, age, time since injury, trauma etiology, associated injuries, need of mechanical ventilation in addition to the first obtained ISNCSCI-grade and level-of-injury at SCIWDK. Mechanical ventilation was defined as a need for supported ventilation during the stay at SCIWDK. Trauma etiology was dichotomized into traumatic or non-traumatic. Associated injuries were presented as binary variables with a yes or no opportunity. Level-of-injury was dichotomized into tetraplegia (C0-C8) and paraplegia (Th1-S5). Furthermore, all available SCIM-scores and the scores of the upper limb motor assessments of ISNCSCI during in-hospital stay were extracted. In most cases, both a SCIM and ISNCSCI score were available at the time of admission and discharge, making it possible to create an initial and a follow-up SCAR score. In a few cases scores were performed at other occasions than early after admission and close to discharge, and in some cases only one of the two tests were performed upon admission or discharge. Therefore, guidelines were developed to account for an acceptable time span between the performed SCIM score and the ISNCSCI examination in order to combine the two: this is described in detail in the data analysis section.

Main outcome measure

As previously described, SCAR is a one-dimensional linear interval-level outcome measurement for changes in volitional performance. Volitional performance is defined as voluntary task-specific physical actions contributing to independence in ADLs. SCAR is validated for scoring most of the SCI population, regardless of the injury level or the severity of injury. However, central cord lesions (CCS) are less suitable for SCAR measurement [6]. SCAR combines the items from the upper limb motor assessments of C5-C8 of ISNCSCI and the items from SCIM that do not concern respiration, bladder and/or bowel function [6, 9]. The scores from SCIM and ISNCSCI were regrouped into raw SCAR scores (range: 0–57). To determine the overall SCAR score, a formula described by Reed and colleagues was applied to convert the raw SCAR score of either the initial or follow-up SCAR score to a so-called Rash SCAR score (range: 0–100) [6].

Data analysis

Following rules were decided by the research group:

a. If the SCI occurred less than 1 year previous to the obtained SCIM or ISNCSCI score, only 1 month was allowed between the two scores if they were to be grouped to a raw SCAR score.
b. If the injury date was 1 year or above, a maximum of one year between the SCIM and ISNCSCI scores was accepted. This decision was based on previous clinical outcome reports [10] for development of ISNCSCI scores.

Age and time since injury were used as continuous variables when comparing the characteristics of SCI persons with and without a calculated SCAR score. Variables were grouped as recommended by Biering-Sørensen et al. [11]. However, only two individuals aged 0–15 years were identified, and therefore, lumped together with the 16–30 year age-group, as they did not differ in baseline SCAR scores.

Additionally, Biering-Sørensen et al. recommended a grouping of time since injury of <1 year, 1–5 years, 6–10 years, and 5-year increments thereafter [11]. Since only 2 observations were >5 years the variable was divided into either (a) less than, or (b) equal to or more than 1 year.

The computation of SCAR scores was performed with MS Excel 2010™ (Microsoft, California US) and the statistical analysis with STATA/IC 15.0™ (StataCorp, Texas US). If normal distribution was demonstrated, descriptive statistics were presented as means (SD) for continues variables. If QQ-plots and a histogram did not show satisfying normal distribution, variables were presented as median (IQR: 25 to 75% percentiles). Categorical variables were presented as N (%). For comparative statistics, both the initial SCAR and the difference between the initial and the follow-up SCAR score showed normal distribution, and difference was examined using the Student's t-test. Difference between age categories was explored using the Kruskal Wallis. A 5% level of significance was presented for all computations.

Results

A total of 1,714 individuals with SCI were included in the descriptive analysis (Table 1).

A total of 212 individuals obtained at least one SCAR score and 84 individuals obtained two SCAR scores, allowing for calculating an eventual difference in volitional performance. The median time difference between the obtained ISNCSCI and SCIM scores was of 1 day (IQR: 1–7) for the initial SCAR score and 2 (1.0–20) days for the follow-up SCAR score. The median time difference between date of injury and the initial SCAR score was of 34.5 days (11.0–2180.5) and 216 (87.5–2463.0) days for follow-up score. Data were not complete for all variables, hence the total number of included patients, varied upon the variable of interest.

The SCAR population was characterized by a larger proportion of tetraplegia and ISNCSCI D injuries in addition to a shorter time-after-injury. The SCAR group was representative for all in-hospitalized patients at SCIWDK regarding age, gender, trauma etiology, associated injuries and need for ventilation support.

The mean (SD) value of the initial and the follow-up SCAR score are presented in Table 2. After a rehabilitation period of a median of 155.0 (IQR: 108.25–229.0) days, a mean improvement in volitional motor function of 17.2 (95% CI, 14.5–19.9) was found, equivalent to an improvement of 43%.

Individuals with tetraplegia gained more improvement in volitional motor function with a mean increase in SCAR score of 8.9 (95% CI, 3.6–14.2) points as compared to paraplegia (Table 2). Additionally, men obtained a larger improvement of 5.3 (95% CI, 0.5–5.3) as compared to women. The need for mechanical ventilation was also a significant predictor in which individuals with no ventilation assistance need in average gained 8.5 (95% CI, 1.8–15.3) points better SCAR score as compared to those with need of ventilation support. Time since injury, trauma etiology and associated injuries did not significantly predict motor improvements.

Table 1 Characteristics of SCI inpatients with an initial and a follow-up SCAR score as compared to hospitalized SCI patients without SCAR score performed

	SCAR group, *N* (%)	Others, *N* (%)	*P*-value
Level of injury			
Tetraplegia	48 (57.1)	426 (44.8)	
Paraplegia	36 (42.9)	526 (55.3)	0.029[P]
Gender			
Male	59 (70.2%)	1,088 (69.5%)	
Female	25 (29.8)	478 (30.5%)	0.883[P]
Age, Mean (SD)	56.9 (17.5)	57.8 (17,2)	
N	84	1,546	0.637[T]
Time since injury, Years			
Median (25%;75% percentiles)	3.8 (2.8;4,8)	11.9 (7.0;19.3)	
N	53	1,043	< 0.001[W]
Trauma etiology			
Traumatic	35 (52.2)	816 (61.9)	
Non-traumatic	32 (47.8)	502 (38.1)	0.113[P]
Associated injuries			
Yes	33 (52.4)	398 (46.3)	
No	30 (47.6)	461 (53.7)	0.353[P]
Mechanical ventilation			
Yes	17 (21.5)	52 (23.5)	
No	62 (78.5)	169 (76.5)	0.716[P]
ISCNSCI distribution			
ISCNSCI A	15 (17.9)	330 (29.1)	
ISCNSCI B	8 (9.5)	165 (14.6)	
ISCNSCI C	9 (10.7)	135 (11.9)	
ISCNSCI D	52 (61.9)	499 (45.2)	
ISNCSCI E	0 (0.0)	5 (0.4)	0.028[P]

P Pearson Chi^2-test, *T* Student's *t*-test, *W* Wilcoxon rank-sum test

Age influenced improvement in SCAR score as shown in Fig. 1. Increasing age was associated with less expected improvement, and the 46–60 years age group exerted a 12.0 (95% CI, 2.0–22.0) points larger improvement than those of 76 years or above (Kruskal Wallis, $p = 0.019$).

Discussion

SCAR scores were retrospectively obtained after in-hospital rehabilitation in a highly specialized SCI rehabilitation hospital and SCAR measures demonstrated an overall mean improvement of 43% in volitional motor function after a

Table 2 Core characteristics and their influence on improvement in volitional motor performance after a rehabilitation period

	Initial SCAR, Mean (SD)	Follow-up SCAR, Mean (SD)	SCAR diff, Mean (95%CI)	*P*-value
SCAR score ($n = 84$)	39.7 (18.0)	56.9 (20.0)	17.2 (14.5; 19.900)	<0.001[PT]
Level of injury				
Tetraplegia ($n = 44$)	32.4 (19.1)	54.1 (22.2)	21.7 (17.6; 25.7)	
Paraplegia ($n = 36$)	49.7 (9.1)	62.5 (13.4)	12.8 (9.5; 16.0)	0.001[T]
Gender				
Male ($n = 59$)	37.3 (18.9)	56.1 (22.2)	18.8 (15.3; 22.4)	
Female ($n = 25$)	45.3 (14.5)	58.8 (13.5)	13.5 (10.1; 16.9)	0.030[T]
Time since injury				
<1 year ($n = 39$)	36.8 (18.1)	54.9 (20.7)	18.1 (14.0; 22.2)	
≥1 year ($n = 14$)	44.4 (16.3)	55.4 (14.7)	11.0 (5.5; 16.5)	0.063[T]
Trauma etiology				
Traumatic ($n = 38$)	33.7 (18.4)	50.8 (20.4)	17.1 (12.7; 21.5)	
Non-traumatic ($n = 32$)	49.1 (14.4)	63.2 (18.0)	14.1 (10.7; 17.5)	0.274[T]
Associated injuries				
Yes ($n = 33$)	32.1 (15.7)	50.6 (20.7)	18.5 (13.4; 23.6)	
No ($n = 30$)	47.9 (15.4)	62.5 (18.8)	14.6 (9.2; 11.1)	0.203[T]
Mechanical ventilation				
Yes ($n = 17$)	32.0 (19.0)	42.6 (21.5)	10.6 (6.2; 14.9)	
No ($n = 62$)	41.0 (17.4)	60.0 (17.9)	19.1 (15.7; 22.4)	0.014[T]

PT paired Student's *t*-test, *T* Student's *t*-test, *SD* standard deviation, *95% CI* 95% confidence interval

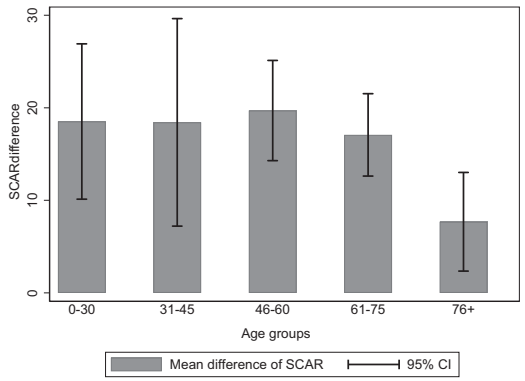

Fig. 1 The mean difference in volitional motor performance by age

median rehabilitation stay of 155.3 (IQR: 102.0–228.3) days at a highly-specialized SCI unit. Applying SCAR scores indicated that level-of-injury, gender, age and the need of mechanical ventilation were predictors of improvement in volitional motor function after a rehabilitation period.

Only few studies have previously investigated gender as a predictor of improvement in motor function. A case series by Sipski et al. found in accordance with this study a gender-related difference in daily life independence in a sample of 14,433 admitted SCI patients. At a given level and degree of neurologic injury, men obtained better function than women at time of discharge from rehabilitation [12]. However, other studies did not report gender difference regarding change in daily life independence [13] and walking function [14].

In a retrospective study Lee et al. found that older persons with traumatic thoracic SCI gained less improvement after 1 year follow-up as compared to younger individuals with SCI [15].

In the present study, patients with non-traumatic and traumatic spinal cord lesions obtained similar degree of improvement of motor function, which is in concordance with previous studies [16–20]. The expert recommendation is to perform the ISNCSCI score at admission for predicting recovery of motor function [21, 22]. This retrospective cohort study did not include the ISNCSCI classification as an explanatory variable, since the ISNCSCI score is part of the overall SCAR score.

In relation to the feasibility of SCAR usage, this new scoring device was found easily applicable to already existing data. In the present study no signs of ceiling effect of the computed SCAR data were detected (Table 2). This indicates that SCAR is useful in an SCI in-hospital setting. However, there have been some challenges in the conversion of the raw SCAR score to the Rasch transformed SCAR value. It is suggested that a future opportunity to ease these challenges could be the development of an online converter app, computing a total SCAR score from ISNCSCI and SCIM inputs.

This study has several limitations due to the nature of data. A small sample size results in some statistical constraints. The prerequisites for using a planned linear regression were not met. The majority of the independent variables did not show satisfying means and variances when they were separately tested against residuals in scatterplots, e.g., large variations were seen regarding time-since-injury. The presented findings are, however, in concordance with the findings from other studies [12, 15–20]. In its design SCAR has some limitations when it comes to central cord syndromes or vertically or more widely distributed lesions of the cord. In this retrospective study one could not clearly identify these subgroups in data. SCAR measures are less precise in these cases. An indicator of this being of less importance in the present study was that variability of SCAR scores in non-traumatic SCI did not differ from SCAR scores obtained from traumatic SCI. Missing values, especially of mechanical ventilation in the non SCAR group in addition to a modest sample size in the SCAR diff group compromise the conclusions from the present study. By the present study design it cannot be certain if the presented population is fully representative of the target population, and the group who did not obtain a SCAR difference score showed different distribution of ISNCSCI, less tetraplegia and longer duration after SCI. However, data on all in-hospital SCI patients were consecutively collected at a highly-specialized rehabilitation unit in Denmark, and the treatment offer is provided to all eligible SCI persons who could possibly benefit from in-hospital rehabilitation at SCIWDK, free of charge and delivered to citizen living in Western Denmark. Further studies are needed in order to confirm the study results.

Conclusion

This retrospective analysis of data from 84 eligible in-hospital SCI persons found an overall mean improvement of 43% in volitional motor function when using SCAR as a metric after a median rehabilitation period of 155 days at a highly-specialized SCI unit. Following factors: level-of-injury, gender, age and the need of mechanical ventilation were important predictors for improvement in volitional motor function after a rehabilitation period. The study was not powered to perform multivariable analysis, making it impossible to estimate the individual effect of included factors' regarding obtained SCAR score difference by predictive models. It is suggested that the present study could serve as a guideline for future sampling processes, stratified randomization in clinical outcome studies in SCI. However, long-term prospective studies with higher internal validation and further external validations studies are needed to confirm the results.

Data archiving

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions ABJ was responsible for conducting literature search, data entry, extracting and analyzing data, interpreting results, creating figures and tables, writing the report. MT was responsible for data entry and provided feedback on the report. SKJ was responsible for data entry and provided feedback on the report. HK contributed to the design of the retrospective study, interpreting results, writing and provided feedback on the report.

Compliance with ethical standards

Statement of ethics We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this study.

Conflict of interest The authors declare that they have no conflict of interest.

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