Clinical notes

Motor levels in high cervical spinal cord injuries: Implications for the International Standards for Neurological Classification of Spinal Cord Injury

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Context/Objective: To verify the hypothesis that motor levels (ML) inferred from sensory levels in the upper cervical segments C2–C4 according to the current version of the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) are counterintuitive in cases where the most rostral myotomes C5 and C6 are graded as intact.

Design: Prospective cohort study of ISNCSCI instructional course participants completing a post-test after the workshop to determine the MLs in two variants of a complete, high cervical spinal cord injury (SCI) case scenario. Both variants were based on the same ISNCSCI sensory and MLs of C2. In the first variant myotomes C5 and C6 were bilaterally graded as intact, while in variant 2 only active movements against gravity were possible (grade 3).

Setting: Eight ISNCSCI instructional courses conducted during the study period from November 2012 until March 2015 in the framework of the European Multicenter Study on Human Spinal Cord Injury (EMSCI—http//emsci.org).

Participants: Ninety-two clinicians from twenty-two SCI centers. Most of the attendees were physicians (58.7%) or physical therapists (33.7%) and had less than one year (44.6%) experience in SCI medicine.

Interventions: Not applicable.

Outcome Measure: The classification performance described as percentage of correctly determined MLs by the clinicians.

Results: Variant 2 (89.13%) was significantly ($P < 0.0001$) better classified than variant 1 (65.76%). In variant 1 with intact myotomes at C5 and C6, C6 was incorrectly classified as the ML by the clinicians in 33.15% of all cases, whereas in variant 2 with non-intact C5 / C6 myotomes, C6 was rarely chosen (2.17%).

Conclusions: Sensory level deferred MLs in the high cervical region of C2–C4 are counterintuitive whenever the most rostral cervical myotomes are intact. An adjustment of the ML definition in ISNCSCI may be needed.

Keywords: Spinal cord injuries, Outcomes research, Rehabilitation, Recovery of function

Introduction

The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)[1] is the most frequently used clinical neurological assessment to determine the location and severity of a spinal cord injury (SCI). Although originally developed for clinical purposes,[2] ISNCSCI is nowadays widely adopted in research. The ISNCSCI tool serves as a basis for inclusion and exclusion criteria, for stratification and subgrouping, and also as primary[3] and secondary outcome measures.[4] Consequently, ISNCSCI plays a crucial role in the study design of future interventional studies including stem cell-based clinical trials.[5] In preparation of those trials, work on

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ISNCSCI quality improvements is part of the ongoing quality management system (ISO 9001:2008) initiative of the European Multicenter Study on Human Spinal Cord Injury (EMSCI—http://emsci.org) since 2010.

Comprehensive training is required[6–8] for the correct application of ISNCSCI. This includes the clinical examination, motor and sensory scoring, and the classification aspects.[9] The latter requires elaborate skills to ensure the correct determination of the severity (ASIA Impairment Scale [AIS]) and location (neurological level of injury [NLI], derived from the sensory [SL] and motor levels [ML] for each body side) of a SCI. The determination rules of these variables are based on a standardized clinical examination, more precisely on the motor and sensory function scored bilaterally in 10 "key" upper (C5–T1) and lower extremity (L2–S1) myotomes and 28 dermatomes. The AIS and the ML are the most error-prone variables with an error rate of approximately 20% in difficult cases.[6,8] In the latest update of the ISNCSCI the ML is defined by: "The ML is defined by the lowest key muscle function that has a grade of at least 3, providing the key muscle functions represented by segments above that level are judged to be intact. This may be different for the right and left side of the body. […] For those myotomes that are not clinically testable by a manual muscle exam, i.e. C1 to C4, T2 to L1, and S2 to S5, the motor level is presumed to be the same as the sensory level if testable motor function above (rostral to) that level is normal as well."[10] While this rule of motor level deferring to sensory level is widely known to be applied for thoracic lesions (T2–L1), it is less known for high cervical lesions (i.e. C2–4 segments). Not surprisingly, misclassification rates regarding this "motor follows sensory" rule are almost exclusively located (98.5%) in high cervical lesions.[8]

The aim of this work was to conduct a detailed ML error analysis in two slightly varying ISNCSCI cases of a high cervical SCI, where the rule of "the motor level defers to the sensory level" is employed. The hypothesis was that the ML determined from the sensory level is counterintuitive in cases where the most rostral testable key muscles of C5/C6 are graded as intact. The results may support the International Standards Committee of the American Spinal Injury Association (ASIA), custodian of ISNCSCI, to plan and conduct the next revision, because changes to ISNCSCI should be underlined by scientific support.[9]

Materials and methods

Two ISNCSCI cases of the ongoing ISNCSCI instructional courses within the EMSCI network were analyzed in this study for the specific purpose of quality control measure. The EMSCI study is approved (S-188/2003) by the ethics commission of the medical faculty of the Heidelberg University. The pre- and post-tests setup is part of the quality management system of the EMSCI ISO-certification framework. In the 1.5-day course, experienced ISNCSCI trainers teach up to 12 attendees in the clinical examination (~9 hours) and classification (~4 hours). For quality control, attendees are asked to classify several ISNCSCI cases before (pre-course) and after (post-course) training. Details on the EMSCI ISNCSCI instructional courses are published elsewhere.[8] For this work, the classification results of two post-course test cases are analyzed in detail. These cases represent variations of the same lesion type (Fig. 1) sharing the same sensory level (SL) (bilaterally C2), ML (bilaterally C2), as well as the ASIA Impairment Scale (A). In variant 1, both myotomes C5 and C6 are bilaterally graded as intact (bold scores in Fig. 1). In contrast, in variant 2 these myotomes are both graded as 3 (active movement against gravity, full range of motion; italic scores in Fig. 1). The primary outcome measure was the classification performance described as percentage of correctly determined MLs by the clinicians in the post-course test.

Results

Ninety-two clinicians from 22 SCI centers attended 8 workshops (6 German / 2 English) during the study period (November 2012 until March 2015). Detailed group characteristics are listed in Table 1. Most of the attendees were physicians (58.7%) or physical therapists (33.7%) and had less than one year (44.6%) experience in SCI medicine. A previous study[8] revealed that neither occupation, teaching language nor ISNCSCI experience is correlated with post-course test classification performance, although ISNCSCI experience is positively correlated with pre-course test performance. Accordingly, no detailed correlation analysis was undertaken.

Although the correct MLs of both variants are bilaterally C2 according to the current ISNCSCI revision, the percentages of correctly determined MLs significantly differed between the two variants of ISNCSCI cases (variant 1: 65.76%; variant 2: 89.13%; two-sided Fisher's exact test: $P < 0.0001$). The motor level distribution for both groups is shown in Figure 2 revealing that the typical error pattern for misclassifying C6 as the ML (33.15%) in variant 1 is not present in variant 2 (2.17%).

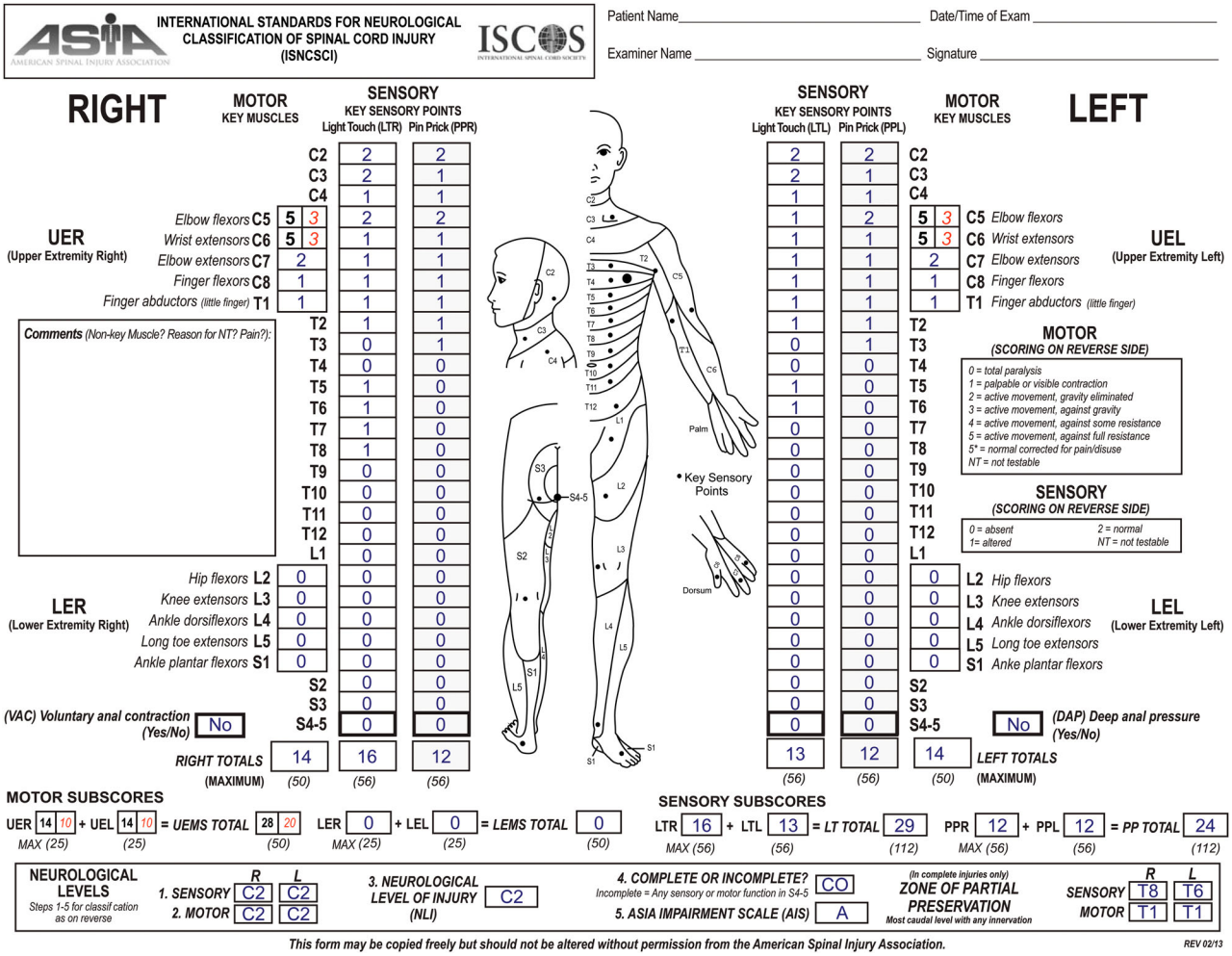

Figure 1 Two variants of a high cervical lesion.
Variants only differ in motor scores of myotomes C5 and C6 for both body sides. In variant 1 bold (black) scores for both myotomes are graded as 5 (intact), in variant 2 italic (red) scores of both myotomes are graded as 3 (active movement against gravity, full range of motion). Both variants lead to the same neurological levels and ASIA Impairment Scale grade.

Table 1 Characteristics of the attendees of the ISNCSCI workshops

Characteristics	
Participants	92
Workshops	8
SCI units	22
Language	23.91% English 76.09% German
Profession	58.70% physician 33.70% physical therapist 03.26% other 04.35% occupational therapist
Experience in SCI medicine	44.57% <1 year 27.17% 1-5 years 10.87% 6-10 years 14.13% >10 years
ISNCSCI worksheet revision	39.13% revision 2011 60.87% revision 2013

Post-test motor level determination results		
	Variant 1	Variant 2
Motor levels	65.76%	89.13%

Discussion

The present study evaluates the determination of MLs according to ISNCSCI for the most rostral cervical segments of the spinal cord, where no key muscle functions are assessable by manual muscle testing. According to the current International Standards, a high cervical sensory level above C5 (most rostral assessable key muscle function) also determines the motor level ("motor follows sensory" rule). Thus, the NLI and the MLs are C2 determined by the SLs of C2 in both investigated variants, regardless of the examined cervical motor scores. However, we found a significantly better ML classification performance (89.13%) in variant 2, having myotomes C5 and C6 graded as 3, as compared to variant 1, in which myotomes C5 and C6 are graded as 5 (65.76%). The more frequent misclassification of MLs in variant 1 strongly supports the hypothesis that the "motor follows sensory" rule is counterintuitive, if

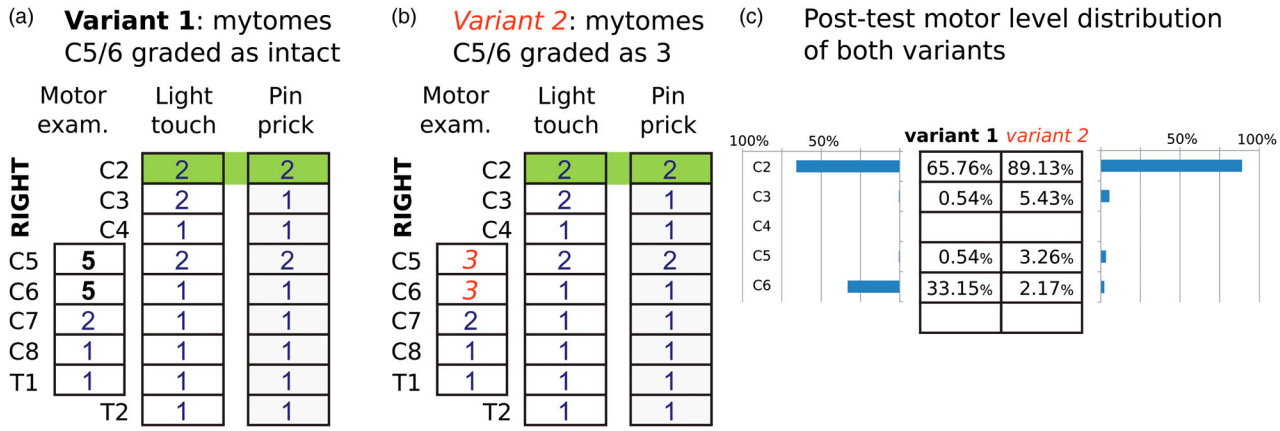

Figure 2 Motor level distributions of both variants
Motor level distributions (C) of both variants (A, B). The correct motor level is C2 for both body sides. Attendees most often (33.15%) misclassified the motor level as C6 in variant 1.

the most rostral tested key muscle functions C5 and C6 are graded as intact.

The classification performance of variant 2 (~90%) is in line[8] with or even better[6] than previously reported results. This stands in contrast to the poor performance in variant 1 (~66%), which is far below the reported performances. Based on this difference in ML determination performance, the reason for the error is not due to the misunderstanding of the "motor follows sensory" rule, since the performance in ML determination in variant 2 (~90%) is comparable to other ISNCSCI variables like SLs (~97%)[8] or the completeness of a lesion (96%).[8] We therefore feel that it is generally not intuitive to infer the ML from the sensory levels C2–C4 in cases, where C5 and C6 key muscle functions are graded as intact indicating substantial functional capabilities of the individual with tetraplegia.

The poor intuitiveness in variant 1 might be explained by the fact that clinically experienced professionals do not commonly expect unimpaired motor function of biceps (C5) and wrist extensor muscles (C6) in patients with a motor level of C2, as determined by intact sensory function at C2, but not at C3. In such high level lesion types one would rather expect relevant respiratory deficits, accompanied by at least a certain degree of limited elbow flexion and/or wrist extension strength and function. Reporting such a motor level of C2 would also not allow for easy communication between clinicians of what a patient could perform functionally.

From a clinical point of view, the issues in variant 1 may also be explained by variations in the assessment of the C3/C4 sensory function rather than by motor level designation issues. Either the examiners or the patients are maybe too stringent in the interpretation of the criteria that the sensation in the dermatome of interest is identical to the face. In persons with high cervical injuries, there are limited options for spots to serve as the normal reference. It may better to use a less sensitive area such as the forehead or scalp as the reference for normal sensation instead of the cheek. Future studies are needed to investigate these validity issues in the sensory and motor level designation.

Nevertheless, in terms of intuitiveness and clinical impression, consideration for a change in ISNCSCI's ML definition seems advisable. A potential consideration for change in definition would be the omission of the "motor follows sensory" rule if the cut-off myotome C5 is graded as intact, as this option is the most conservative approach and reflects the more intuitive clinical approach as revealed by this work. Another option could the definition of be a grade of 3/5 as a threshold value, since 3/5 is considered as intact according to the ISNCSCI guidelines: "if a muscle function has at least a grade of 3, it is considered to have intact innervation by the more rostral of the innervating segments."[10] A possible argument against using a score of 3 is that in determining the ML, the next rostral key muscle function must test as 5, and this cannot be determined in case of sensory levels above C4. In addition, this single myotome approach would not prevent possible ML fluctuations, e.g. from C5 to C2 based on the loss of only one motor point in C5 (from 5/5 to 4/5). A combination of myotomes C5 and C6 as omission condition (e.g. C5 + C6 > 8/10) could reduce such fluctuations over the course of rehabilitation. Therefore, our next step will be the evaluation of the proposed change options to ISNCSCI by simulating the effects in a large SCI cohort like from the EMSCI or other similar databases. For this purpose, computer algorithms[11] for

automated reclassification of ISNCSCI datasets are important to investigate the effects of a modified ML determination rule on the distribution and conversion rates of MLs. Preliminary analysis from all initial (<30 days after injury) ISNCSCI datasets (1,290 subjects) of the EMSCI database reveals that 46% (cervical: 11%, thoracic: 34%, sacral: 1%) of all motor levels are determined by sensory levels using the current ISNCSCI ML definition. Overall 93 MLs (55 in the cervical segments) and 4 AIS grades changed after reclassification using the first of our proposed definitions.[12] The 93 changed MLs are equivalent to 7.9% of all sensory determined MLs and 3.6% of all MLs.

A change in the definition of the ML can even affect the AIS classification, because in some cases the discrimination between AIS B and AIS C or D is based on the motor level. More precisely, an individual with sensory incomplete SCI is classified as motor incomplete (AIS C or D), if either voluntary anal contraction is present or if motor function more than three levels below the ipsilateral ML is spared. Therefore, the effect of the modified ML determination rule on the AIS distribution also needs to be evaluated.

Study limitations

A limitation of this study is that the order of case variants in the pre-course and post-course tests was not randomized. Variant 1 was presented first in the post-course test while variant 2 was the 7th ISNCSCI case. This might have introduced a bias in the results to some extent. Between case 1 and case 7 the attendees had to classify 5 ISNCSCI cases. Thus, they could familiarize themselves with the motor level determination process, which may contribute to the higher percentage of correct ML classification of variant 2. However, none of these intermediate cases had its NLI in the high cervical segments.

Conclusion

The determination of MLs in the high cervical region of C2–C4 is counterintuitive when the most rostral myotomes C5/C6 are graded as intact. An adjustment of the ML definition in ISNCSCI should be considered to address this issue. A possible proposal would be to (1) solely apply the "motor follows sensory" rule, if the cut-off myotome C5 is impaired and (2) determine the ML only on the basis of the actually examined myotomes without any consideration of sensory scores, if the cut-off myotome C5 is graded as intact. The same consideration should be taken into account for the cut-off segment L2.

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