REVIEW ARTICLE DOI: https://doi.org/10.18502/fem.v6i2.8717

Severity assessment of impairment in spinal cord injury; a systematic review on challenging points about International Standards for Neurological Classification of Spinal Cord Injury

Mahmoud Yousefifard[1], Mostafa Hosseini[2], Alireza Oraii[3], Alexander R. Vaccaro[4], Vafa Rahimi-Movaghar[5,6]*

1. Physiology Research Center, Iran University of Medical Sciences, Tehran, Iran.
2. Department of Epidemiology and Biostatistics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.
3. Department of Medicine, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran.
4. Department of Orthopedics and Neurosurgery, Rothman Institute, Thomas Jefferson University Philadelphia, USA.
5. Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Iran.
6. Brain and Spinal Injuries Research Center (BASIR), Neuroscience Institute, Imam Khomeini Hospital, Tehran University of Medical Sciences, Tehran, Iran.

***Corresponding author:** Vafa Rahimi-Movaghar; **Email:** v_rahimi@sina.tums.ac.ir; v_rahimi@yahoo.com

Published online: 2022-01-01

Abstract: **Objective:** Assessment of spinal cord injuries (SCI) severity is usually done according to the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI). However, a limitation of ISNCSCI has not been thoroughly evaluate; therefore, a systematic review was performed to gather current evidence on the limitations of the ISNCSCI for assessing SCI.

Methods: An extensive literature search was performed using Medline, Embase, Web of Science, Cochrane library, and Scopus for all articles up until the end of 2017 and then was updated to the end of 2020. Data was summarized by two independent reviewers and limitations of the ISNCSCI was further categorized.

Results: Thirty one studies were included in the analysis. The limitations of ISNCSCI were classified into 6 domains: 1) lack of assessment of autonomic nervous system; 2) low value in assessing severity of SCI severity in children; 3) confounding factors which impact outcome are not accounted for by ISNCSCI; 4) lack of an established optimal cut off time point for administering the ISNCSCI; 5) low predictive and diagnostic value for assessing incomplete motor injuries; 6) poor classification and predictive value of the ISNCSCI.

Conclusion: Although the ISNCSCI is a commonly used tool to assess the severity of SCI, there are several limitations.

Keywords: Limitation; Outcome Measures; Spinal Cord Injury; Systematic Review

Cite this article as: Yousefifard, M, Hosseini M, Oraii A, Vaccaro AR, Rahimi-Movaghar V. Severity assessment of impairment in spinal cord injury; a systematic review on challenging points about International Standards for Neurological Classification of Spinal Cord Injury. Front Emerg Med. 2022;6(2):e22.

1. Introduction

Classification of spinal cord injury (SCI) based on injury severity is an important part of the overall evaluation and management. The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) and its component the American Spinal Injury Association (ASIA) Impairment Scale (AIS) are important and commonly used tools in order to assess the severity of SCI (1). Several adaptations have been made to the ISNCSCI and AIS grading system over the last 30 years in order to improve its clinical utility (2). However, it is important for clinicians to be aware of its limitations including its reliability and validity (3). There are two major components to performing the AIS grading system. First, sensory and motor level deficits are identified and second the injury is classified into five groups (grade A-E) based on the completeness of injury. However, the AIS should not be interpreted alone, but has to be interpreted in context of all other classification variables in the ISNCSCI classification system such as the levels, motor and sensory scores, and eventually the zones of partial preservation. The latest reversion of ISNCSCI in 2019 has made two major modifications. However, the 2019 revision has still some limitations (4). Due to the complexity, the injury severity may be incorrectly classified raising questions about the application of the ISNCSCI, its poor sensitivity, validity, and reliability (5-9). The present systematic review summarizes the current evidences on the limitations of the ISNCSCI for assessing SCI.

2. Method

2.1. Search strategy

A systematic review and meta-analysis was performed according previously established guidelines (10). An extensive literature search was performed in Medline and Embase for all articles up until the December 2017 and then was updated to the end of 2020. A specific query was constructed for each database and the specific search strategy for Medline (via PubMed) and Embase are shown in table 1. A manual search was also performed in Google motor search engine, Google Scholar, ProQuest (thesis section) and bibliography of related study and review articles in order to find additional or unpublished studies.

2.2. Selection Criteria

In the present study, cohort and cross-sectional studies that discussed the limitations of the ISNCSCI were included. Both retrospective and prospective studies were assessed. Review articles were excluded.

2.3. Data Gathering

Results of the searches were pooled and duplicated studies were deleted using EndNote (version X8, Thomson Reuters, 2016). The abstract for each study was reviewed as a screening process and then the full text of potentially relevant studies was further assessed by two independent reviewers. In case of conflicting opinions between the two reviewers, a third reviewer attempted to resolve the difference by discussing the findings with the other two reviewers (inter-rate reliability=0.86). All results were recorded in a checklist as designed by the PRISMA guidelines (11). Extracted data included information regarding study setting, patient characteristics (age, sex and sample sizes), ISNCSCI version, assessed outcomes, and main results of the study. Authors were contacted to get access to data of their studies if data could not be extracted.

3. Results

PRISMA flowchart of present study is shown in figure 1. A total of 21341 studies were found in the initial search. After removing duplicates, 14357 studies were screened. The full text of 193 articles were reviewed and 31 studies were included in the analysis (2, 6-9, 12-37).

The limitations of the ISNCSCI were categorized into 6 domains including: 1) lack of autonomic nervous system assessment; 2) low utility in assessing SCI in the pediatric population; 3) confounding factors which impact outcomes are not accounted for by the ISNCSCI; 4) lack of an optimal cut off time point for administer the ISNCSCI; 5) low predictive and diagnostic value for assessing incomplete motor injuries; 6) poor classification and predictive value of the ISNCSCI. All limitations are demonstrated in table 2.

3.1. ISNCSCI does not assess autonomic nervous system injuries

Autonomic nervous system dysfunction is a common problem after SCI leading to dysfunction of the cardiovascular, respiratory, digestive, urinary, thermal regulation and reproductive systems. These injuries can have life-threatening implications (38). The incidence and severity of dysfunction of each these systems are different based on location and severity of the SCI. For example, complete cardiovascular dysfunction can occur in complete spinal cord injuries at the level of T6 while incomplete injuries to T6 (or lower) do not have a significant effect on the cardiovascular system or the sympathetic nervous system (39, 40).

Previnaire and colleagues (24) showed that the autonomic response is absent in paraplegic with an injury at the level of T6 while it is near normal in paraplegic patients at the level of T10; however, the severity of these two injuries are considered to be very similar based on ISNCSCI. Additionally, West and colleagues (30) showed that 9 of 24 (37.5%) with complete motor/sensory injuries had complete autonomic dysfunction, while 7 of 16 (43.8%) patients with an incomplete motor/sensory injury had incomplete autonomic dysfunction. They demonstrated that the ISNCSCI was not able to predict injuries to the autonomic nervous system. Similarly, Previnaire and colleagues (23) showed that 34% of complete AIS A patients have discrepancies between autonomic involvement and neurologic level of injury. In addition, a complete sympathetic injury was seen in patients with AIS B-D. The International Standards to Document Remaining Autonomic Function after Spinal Cord Injury (ISAFSCI) was designed to overcome the limitation of the ISNCSCI in assessing autonomic nervous system injuries (41). Davidson and colleagues (13) showed that the ISAFSCI had moderate to strong interrater reliability for different components. This study suggests that next versions of ISAFSCI should be designed to standardize patient assessment and propose an appropriate educational protocol. Finally, Alexander and colleagues (37) showed simultaneous application of the sacral components of the ISAFSCI and the ISNCSCI may be beneficial to obtain further information on bladder and bowel function.

3.2. ISNCSCI has poor utility in assessing SCI in the pediatric population (ages under 15 years old)

Assessing severity of injuries in children is challenging for physicians in all clinical situations and SCI is no exception. Although SCI are rare under the age of 15 years old, when they do occur the characteristics of SCI are vastly different than the adult population (42).

Overall, assessing SCI in children is challenging due to difficulties following instructions and increased levels of anxiety. The ISNCSCI is the most common tool for assessing the severity of SCI in children just like in adults. However, the value of ISNCSCI in assessing the severity of injury has not

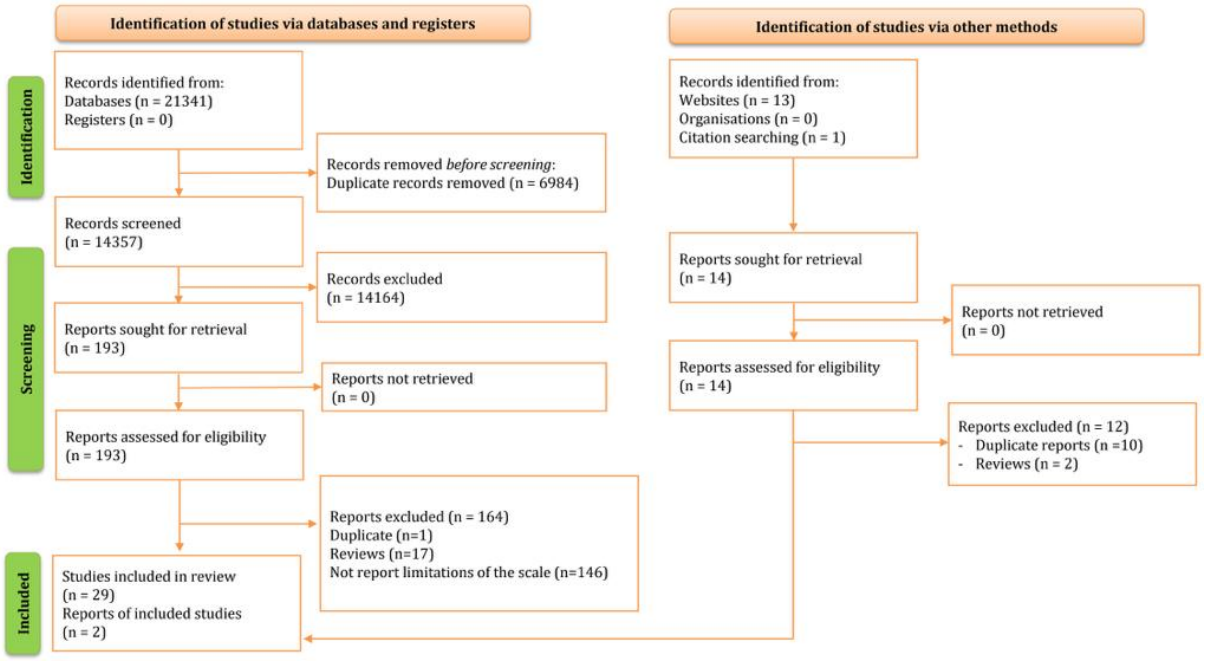

Figure 1 PRISMA flowchart of present study. Other sources include Google motor search engine, Google Scholar, and bibliography of related study and review articles.

been validated. Two studies by Mulcahey and colleagues in 2007 and 2011 showed that ISNCSCI is a poor tool for assessing the severity of SCI in children under 6 years of age. The motor exam of the ISNCSCI had a low accuracy in children between the age of 6 and 15 (7, 8). Similar results were reported by Chafetz and colleagues (33); as the authors assessed 187 children with SCI and showed that the interrater reliability of light touch, pinprick, and total motor scores were low in children under 7 years of age. In addition, Vogel and colleagues showed that anorectal examination is not reliable in children and has a highly variable interrater agreement depending on the age and type of injury (9).

3.3. ISNCSCI does not account for confounding factors which affect outcomes

There are multiple studies indicating that ISNCSCI at the time of injury or admission is a strong predictive factor of outcomes (43-46); however, the severity of injury is not the only factor affecting outcome of SCI. Age, concomitant injuries (like presence of traumatic brain injury), level of injury, chronic infections like pneumonia, etc. are known predictive factors of outcome after SCI (12, 14, 43, 46).

If the physician decides to evaluate the severity of spinal cord injury based on this score, anatomic level of injury is one of the most important factors that yet it is not accounted for AIS evaluation. For example, a patient with a grade A or B SCI in the lower lumbar levels might lead to bladder or intestinal dysfunction, but patients can ultimately walk and have an independent life. However, a patient with a grade C or even D SCI of the upper cervical spine can result in quadriplegia and dependent for many activities of daily living. Coleman and colleagues (12) showed that marked recovery (improvement of at least two grades from AIS at baseline) was more likely to occur in patients with a grade A SCI of the cervical spine (15.2%) than a similar injury of the thoracic spine (7.0%). Marino and colleagues also reported that mean change in upper extremity motor score for patients with a complete SCI in C1 to C3 and C8 to T1 was 2-3 points while these mean change was 9-11 points for other regions (20). Another study showed that conversion of AIS A to AIS C occurred 70.9% in cervical injuries, while it only occurred 1.5-19.5% and 65.2% of the time in thoracic and lumbar injuries, respectively (31). In conclusion, level of injury should be considered as a confounding factor in assessing ISNCSCI.

3.4. The optimal window of time to administer the ISNCSCI is not well defined

The changing ISNCSCI score can occur with or without surgery and they can occur in a short period of time after the initial SCI. One study showed that 22% of patients with grade A AIS convert to grade B AIS or better within a week from admission (8). The potential for such conversions indicates the need to establish an optimal window of time to administer the ISNCSCI.

3.5. Diagnostic value of ISNCSCI is not reliable in incomplete injuries

The recovery rate in complete motor injuries is much lower than incomplete motor injuries. Also, the recovery rate is more predictable in complete motor injuries, while it is more variable in incomplete motor injuries. (6). AIS conversion in patients with incomplete motor injuries might be due to

the "critical zone of conversion" (15). This may be a potential reason for a lower diagnostic value in incomplete injuries compared to patients with complete motor injury. For example, Marino and colleagues (19) showed that ISNCSCI has a good reproducibility in patients with a complete SCI while it is poor in incomplete injuries. Some studies have shown that a motor incomplete injuries according ISNCSCI have a low positive predictive value (39.4% and 61.8%, respectively) and negative predictive value (60.6% and 38.2 %, respectively) for the outcome of walking after one year. (32).

This may be due to a limitation of ISNCSCI in clearly differentiating sensory incomplete and motor complete injuries (AIS B) from sensory-motor incomplete injuries (AIS C). Some studies have even demonstrated that AIS B is incorrectly graded as an AIS C in 29.4% of cases while AIS C is incorrectly categorized as an AIS B in 38.6% of cases (2). This incorrect classification has a significant impact on diagnostic or predictive values of the ISNCSCI classification. In addition, there are other studies indicating that different components of the ISCSCI exam have low predictive values in patients with incomplete injury (22, 26).

3.6. Some studies report a poor classification or poor predictive value for ISNCSCI

There have been multiple studies which have indicated that ISNCSCI has a poor ability to classify some patients. Despite several updates to correct some of the limitations, correctly identifying injuries at C2 to C4 remains a challenge (2). Armstrong et al. showed only 25.5% of ISNCSCI examination is free of error. The authors concluded that there is inherent challenges in ISNCSCI assessment and classification (36). Also, some authors believe that the recent updates have not significantly improved the reliability of classifying all SCI or its ability to prediction outcomes (16). Additionally, in some clinical settings, such as determining the difference between AIS A from AIS B injuries after a gunshot wound may be less clinically meaningful according to certain outcomes such as the incidence and need for pressure ulcer surgeries (21). It seems that, the quality of ISNCSCI documentation is poor regardless of the clinician training grade and injury factors (34). In addition, the utility of AIS grade conversion in predicting one-year outcome is unknown. For example, Van Middendrop and colleagues (28) performed a cohort study with one year follow up of patients and determined that AIS grade conversion has a weak correlation with walking ability at follow-up. Therefore, conversion may not reflect a change in the severity of neurological defects, but rather it may be a consequence of the limitations of the AIS classification system. Spiess and colleagues (27) believe that this might be due to over dependence of AIS grading on sacral region scores. Therefore, a significant AIS conversion might happen in sacral region while motor function or sensory scores of other affected regions remain unchanged. This was also confirmed by Van Middendrop and colleagues (29) which showed that acute anal sensory score does not have a prognostic value for motor function at one-year follow-up. Kirshblum and colleagues (35) believe there is no standard method for evaluation sensory portion of ISNCSCI. They stated previous experiences of patients from ISNCSCI affect the pain perception of the patients.

4. Discussion

Over the last several years there have been multiple improvements to the ISNCSCI. For example, Cohen et al. assessed the1992 version and reported an overall classification performance of 81.7% (47). Schuld and colleagues (48) reported that 91.5% of properly trained individuals correctly classified injuries using the 2003 version, while Chafetz and colleagues reported an overall performance of 89.9% for version of 2006 (49) and Liu et al. reported a performance of 86.5% (50). Schuld et al showed that the overall performance of ISNCSI for versions of 2011 and 2013 were 92.2% and 94.3%, respectively (2). Although the latest reversion of ISNCSCI in 2019 has made two major modifications, including a new taxonomy for non-SCI related conditions and a new definition of the partial preservation zones, it has still some limitations (4). The ISNCSI classification has limitations which have been infrequently reviewed. After conducting a systematic review six major limitations of the ISNCSI classification were identified:

- ISNCSI cannot assess autonomic nervous system injuries
- ISNCSI has a low value in detecting the severity of injuries in children under 15 years old
- ISNCSI only assesses the severity of injury and does not account for other confounding variables that affect outcome
- The optimal window for when the ISNCSI assessment should be performed is not well defined
- The diagnostic value of ISNCSI is less reliable in incomplete injuries
- The ISNCSI poor classification or poor predictive value for ISNCSI

In addition to these limitations, it seems that some items are ignored. One of major limitations of ISNCSI is that all muscles are assessed and scored similarly. This might be misleading because an improvement of one to two grades in important muscle groups can be the difference between walking independently and needing ambulatory assistance, while improvement in thoracic level sensation of one or two grades does not have a similar effect on quality of life. Additionally, disabling sequalae of SCI such as pain, spasticity, or dysesthesia are not accounted for by ISNCSI. ISNCSI only evaluates pinprick and light touch sensation. In other words, a patient would have normal sensation and motor function while having still dealing with serious disabilities such as neuropathic pain. Lack of patient's full cooperation is another limitation of ISNCSI which may be limited by the stress, pain, other injuries, and altered cognition.

American Spinal Injury Association International Standards Committee is working on improving the overall assessment of neurologic injuries through various revisions of the ISNCSCI. However, it seems that these revisions have not signifi-

cantly improved the overall performance of ISNCSI classification (2, 16). In addition, it seems that over valuing sensory and motor function of sacral segments (S4-S5) has led to misclassifying some injuries (2, 27, 29).

The optimal window of time to assess the severity of SCI using the ISNCSI is unknown. Some authors believe that an assessment performed immediately upon arrival is most important. However, it should must be noted that others factors such as patient's stress, anxiety, and pain in the first few hours of an injury, the need for ventilation, intoxication, the use of analgesia, and other injuries will alter the accuracy of any assessment in an acute setting. For example, Burns and colleagues reported that presence of at least one of the previously mentioned factors leads to conversion of almost 13% of motor complete patients to motor incomplete over a year later while an absence of these factors lead to no conversion (51). Some have suggested that the best cut off time point to assess ISNCSI grade is 72 hours after injury (52, 53) while others suggest one month after the initial injury (54, 55). Although the accuracy of ISNCSI at 72 hours or one month after an injury may improve, the appropriate management of patients with SCI depends on an immediate assessment of an injury realistically, it cannot be withheld for 72 hours.

Some studies have shown that predictive value of ISNCSI or its value in classifying the severity of injury is poor (2, 16, 19, 22, 26-30, 32). In contrast, there are multiple studies indicating that ISNCSI has a reasonable value in assessing patients with SCI. For example, a systematic review reported that ISNCSI is appropriate tool to assess adults with SCI; however, the same authors mentioned that more studies are needed to evaluate the psychometric characteristics of this tool (3). The overall performance of the ISNCSI is highly variable. The cause of such variability is unknown, but it can be attributed to difference among certain patient populations, mechanism of injury, and the level of training of the individual assessing the injury.

Inability of the ISNCSI classification to assess the severity of autonomic nervous system injury has led to an emergence of ISAFSCI (37, 41). However, data regarding the validity and reliability of this tool is lacking. Few studies have shown a moderate to strong interrater reliability for different components of this tool (13). Therefore, future studies should attempt to assess the value of ISAFSCI in detecting autonomic nervous system injuries on a larger scale.

5. Conclusion

The ISNCSI grading scale is widely used for assessing SCI severity and is a part of the initial and long term evaluation and management of SCI; however, physicians and researchers must be aware of its limitations. In the present study, a systematic review was performed to identify the major limitations of the ISNCSI are reported. Future studies should evaluate the value of other tools such as the ISAFSCI exam, especially in detecting autonomic nervous system injuries and injury severity in the pediatric population. Also, a comprehensive list of factors that may affect outcome after a SCI should be developed for physicians to consider during their initial assessment.

6. Declarations

6.1. Acknowledgment

None.

6.2. Authors' contribution

VR, MH and MY contributed for designing the study, developing the protocol of review and conducting the search strategy. MY and AO were responsible for reviewing and data extraction of the eligible studies. VR, MH and ARV contributed in interpreting the results and creating 'Characteristics of included studies' table. MY and AO wrote the first draft and other authors critically revised the manuscript.

6.3. Conflict of interest

The authors have declared no conflicts of interest.

6.4. Funding

This research was supported by a Tehran University of Medical Sciences and Health Services grant and Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences grant (grant number: 94-02-38-29150).

References

1. Kirshblum SC, Waring W, Biering-Sorensen F, Burns SP, Johansen M, Schmidt-Read M, et al. Reference for the 2011 revision of the international standards for neurological classification of spinal cord injury. J Spinal Cord Med. 2011;34(6):547-54.
2. Schuld C, Franz S, Bruggemann K, Heutehaus L, Weidner N, Kirshblum SC, et al. International standards for neurological classification of spinal cord injury: impact of the revised worksheet (revision 02/13) on classification performance. J Spinal Cord Med. 2016;39(5):504-12.
3. Furlan JC, Noonan V, Singh A, Fehlings MG. Assessment of impairment in patients with acute traumatic spinal cord injury: a systematic review of the literature. J Neurotrauma. 2011;28(8):1445-77.
4. ASIA and ISCoS International Standards Committee. The 2019 revision of the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)—What's new? Spinal Cord. 2019;57(10):815-7.
5. Hayes KC, Wolfe DL, Hsieh JT, Potter PJ, Krassioukov A, Durham CE. Clinical and electrophysiologic correlates of quantitative sensory testing in patients with incomplete spinal cord injury. Arch Phys Med Rehabil. 2002;83(11):1612-9.
6. Fawcett JW, Curt A, Steeves JD, Coleman WP, Tuszynski MH, Lammertse D, et al. Guidelines for the conduct of clinical trials for spinal cord injury as developed by the

ICCP panel: spontaneous recovery after spinal cord injury and statistical power needed for therapeutic clinical trials. Spinal Cord. 2007;45(3):190-205.
7. Mulcahey MJ, Gaughan J, Betz RR, Johansen KJ. The International Standards for Neurological Classification of Spinal Cord Injury: reliability of data when applied to children and youths. Spinal Cord. 2007;45(6):452-9.
8. Mulcahey MJ, Gaughan JP, Chafetz RS, Vogel LC, Samdani AF, Betz RR. Interrater reliability of the international standards for neurological classification of spinal cord injury in youths with chronic spinal cord injury. Arch Phys Med Rehabil. 2011;92(8):1264-9.
9. Vogel L, Samdani A, Chafetz R, Gaughan J, Betz R, Mulcahey MJ. Intra-rater agreement of the anorectal exam and classification of injury severity in children with spinal cord injury. Spinal Cord. 2009;47(9):687-91.
10. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology. JAMA. 2000;283(15):2008-12.
11. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med. 2009;151(4):264-9.
12. Coleman WP, Geisler FH. Injury severity as primary predictor of outcome in acute spinal cord injury: retrospective results from a large multicenter clinical trial. Spine J. 2004;4(4):373-8.
13. Davidson RA, Carlson M, Fallah N, Noonan VK, Elliott SL, Joseph J, et al. Inter-Rater Reliability of the International Standards to Document Remaining Autonomic Function after Spinal Cord Injury. J Neurotrauma. 2017;34(3):552-8.
14. Failli V, Kopp MA, Gericke C, Martus P, Klingbeil S, Brommer B, et al. Functional neurological recovery after spinal cord injury is impaired in patients with infections. Brain. 2012;135(Pt 11):3238-50.
15. Gundogdu I, Akyuz M, Ozturk EA, Cakci FA. Can spinal cord injury patients show a worsening in ASIA impairment scale classification despite actually having neurological improvement? The limitation of ASIA Impairment Scale Classification. Spinal Cord. 2014;52(9):667-70.
16. Kirshblum SC, Memmo P, Kim N, Campagnolo D, Millis S. Comparison of the revised 2000 American Spinal Injury Association classification standards with the 1996 guidelines. Am J Phys Med Rehabil. 2002;81(7):502-5.
17. Marino RJ, Rider-Foster D, Maissel G, Ditunno JF. Superiority of motes level over single neurological level in categorizing tetraplegia. Paraplegia. 1995;33(9):510-3.
18. Marino RJ, Graves DE. Metric properties of the ASIA motor score: subscales improve correlation with functional activities. Arch Phys Med Rehabil. 2004;85(11):1804-10.
19. Marino RJ, Jones L, Kirshblum S, Tal J, Dasgupta A. Reliability and repeatability of the motor and sensory examination of the international standards for neurological classification of spinal cord injury. J Spinal Cord Med. 2008;31(2):166-70.
20. Marino RJ, Burns S, Graves DE, Leiby BE, Kirshblum S, Lammertse DP. Upper- and lower-extremity motor recovery after traumatic cervical spinal cord injury: an update from the national spinal cord injury database. Arch Phys Med Rehabil. 2011;92(3):369-75.
21. McCoy E, Eftekhary N, Nwosu K, Fukunaga D, Liu C, Rolfe K. American Spinal Injury Association A (sensory and motor complete) is not different from American Spinal Injury Association B (sensory incomplete, motor complete) in gunshot-related spinal cord injury. Spine J. 2017;17(12):1846-9.
22. Menaker J, Kufera JA, Glaser J, Stein DM, Scalea TM. Admission ASIA motor score predicting the need for tracheostomy after cervical spinal cord injury. J Trauma Acute Care Surg. 2013;75(4):629-34.
23. Previnaire JG, Soler JM, El Masri W, Denys P. Assessment of the sympathetic level of lesion in patients with spinal cord injury. Spinal Cord. 2009;47(2):122-7.
24. Previnaire JG, Mathias CJ, El Masri W, Soler JM, Leclercq V, Denys P. The isolated sympathetic spinal cord: Cardiovascular and sudomotor assessment in spinal cord injury patients: A literature survey. Ann Phys Rehabil Med. 2010;53(8):520-32.
25. Schuld C, Franz S, van Hedel HJ, Moosburger J, Maier D, Abel R, et al. International standards for neurological classification of spinal cord injury: classification skills of clinicians versus computational algorithms. Spinal Cord. 2015;53(4):324-31.
26. Shin JC, Yoo JH, Jung TH, Goo HR. Comparison of lower extremity motor score parameters for patients with motor incomplete spinal cord injury using gait parameters. Spinal Cord. 2011;49(4):529-33.
27. Spiess MR, Muller RM, Rupp R, Schuld C, van Hedel HJ. Conversion in ASIA impairment scale during the first year after traumatic spinal cord injury. J Neurotrauma. 2009;26(11):2027-36.
28. van Middendorp JJ, Hosman AJ, Pouw MH, Van de Meent H. ASIA impairment scale conversion in traumatic SCI: is it related with the ability to walk? A descriptive comparison with functional ambulation outcome measures in 273 patients. Spinal Cord. 2009;47(7):555-60.
29. van Middendorp JJ, Hosman AJ, Pouw MH, Van de Meent H. Is determination between complete and incomplete traumatic spinal cord injury clinically relevant? Validation of the ASIA sacral sparing criteria in a prospective cohort of 432 patients. Spinal Cord. 2009;47(11):809-16.
30. West CR, Wong SC, Krassioukov AV. Autonomic cardiovascular control in Paralympic athletes with spinal cord injury. Med Sci Sports Exerc. 2014;46(1):60-8.
31. Zariffa J, Curt A, Steeves JD. Functional motor preservation below the level of injury in subjects with American Spinal Injury Association Impairment Scale grade A spinal cord injuries. Arch Phys Med Rehabil. 2012;93(5):905-7.

32. van Middendorp JJ, Hosman AJ, Donders AR, Pouw MH, Ditunno JF, Jr., Curt A, et al. A clinical prediction rule for ambulation outcomes after traumatic spinal cord injury: a longitudinal cohort study. Lancet (London, England). 2011;377(9770):1004-10.
33. Chafetz RS, Gaughan JP, Vogel LC, Betz R, Mulcahey MJ. The international standards for neurological classification of spinal cord injury: intra-rater agreement of total motor and sensory scores in the pediatric population. J Spin Cord Med. 2009;32(2):157-61.
34. Osunronbi T, Sharma H. International Standards for Neurological Classification of Spinal Cord Injury: factors influencing the frequency, completion and accuracy of documentation of neurology for patients with traumatic spinal cord injuries. Eur J Orthop Surg Traumatol. 2019;29(8):1639-48.
35. Kirshblum S, Didesch M, Botticello A, Kong B, Androwis D. Patient preferences for order of the sensory portion of the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) examination. J Spinal Cord Med. 2019;42(6):719-24.
36. Armstrong AJ, Clark JM, Ho DT, Payne CJ, Nolan S, Goodes LM, et al. Achieving assessor accuracy on the International Standards for Neurological Classification of Spinal Cord Injury. Spinal Cord. 2017;55(11):994-1001.
37. Alexander M, Carr C, Alexander J, Chen Y, McLain A. Assessing the ability of the Sacral Autonomic Standards to document bladder and bowel function based upon the Asia Impairment Scale. Spinal Cord Ser Cases. 2019;5(1):85.
38. Hou S, Rabchevsky AG. Autonomic consequences of spinal cord injury. Compr Physiol. 2014;4(4):1419-53.
39. Hou S, Lu P, Blesch A. Characterization of supraspinal vasomotor pathways and autonomic dysreflexia after spinal cord injury in F344 rats. Auton Neurosci. 2013;176(1-2):54-63.
40. Krassioukov A. Which pathways must be spared in the injured human spinal cord to retain cardiovascular control? Prog Brain Res. 2006;152:39-47.
41. Alexander MS, Biering-Sorensen F, Bodner D, Brackett NL, Cardenas D, Charlifue S, et al. International standards to document remaining autonomic function after spinal cord injury. Spinal Cord. 2009;47(1):36-43.
42. Parent S, Mac-Thiong J-M, Roy-Beaudry M, Sosa JF, Labelle H. Spinal Cord Injury in the Pediatric Population: A Systematic Review of the Literature. J Neurotrauma. 2011;28(8):1515-24.
43. Scivoletto G, Di Donna V. Prediction of walking recovery after spinal cord injury. Brain Res Bull. 2009;78(1):43-51.
44. Kaminski L, Cordemans V, Cernat E, M'Bra KI, Mac-Thiong JM. Functional Outcome Prediction after Traumatic Spinal Cord Injury Based on Acute Clinical Factors. J Neurotrauma. 2017;34(12):2027-33.
45. Childs BR, Moore TA, Como JJ, Vallier HA. American Spinal Injury Association Impairment Scale Predicts the Need for Tracheostomy After Cervical Spinal Cord Injury. Spine. 2015;40(18):1407-13.
46. Wilson JR, Grossman RG, Frankowski RF, Kiss A, Davis AM, Kulkarni AV, et al. A Clinical Prediction Model for Long-Term Functional Outcome after Traumatic Spinal Cord Injury Based on Acute Clinical and Imaging Factors. J Neurotrauma. 2012;29(13):2263-71.
47. Maynard Jr FM, Bracken MB, Creasey G, Ditunno Jr JF, Donovan WH, Ducker TB, et al. International standards for neurological and functional classification of spinal cord injury. Spinal Cord. 1997;35(5):266.
48. Schuld C, Wiese J, Franz S, Putz C, Stierle I, Smoor I, et al. Effect of formal training in scaling, scoring and classification of the International Standards for Neurological Classification of Spinal Cord Injury. Spinal Cord. 2013;51(4):282-8.
49. Chafetz RS, Vogel LC, Betz RR, Gaughan JP, Mulcahey MJ. International standards for neurological classification of spinal cord injury: training effect on accurate classification. J Spinal Cord Med. 2008;31(5):538-42.
50. Liu N, Zhou MW, Krassioukov AV, Biering-Sorensen F. Training effectiveness when teaching the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) to medical students. Spinal Cord. 2013;51(10):768-71.
51. Burns AS, Lee BS, Ditunno JF, Jr., Tessler A. Patient selection for clinical trials: the reliability of the early spinal cord injury examination. J Neurotrauma. 2003;20(5):477-82.
52. Maynard FM, Reynolds GG, Fountain S, Wilmot C, Hamilton R. Neurological prognosis after traumatic quadriplegia: three-year experience of California Regional Spinal Cord Injury Care System. J Neurosurg. 1979;50(5):611-6.
53. Ditunno JF, Cohen ME, Hauck WW, Jackson AB, Sipski ML. Recovery of upper-extremity strength in complete and incomplete tetraplegia: a multicenter study. Arch Phys Med Rehabil. 2000;81(4):389-93.
54. Waters RL, Adkins RH, Yakura JS, Sie I. Motor and sensory recovery following complete tetraplegia. Arch Phys Med Rehabil. 1993;74(3):242-7.
55. Waters RL, Adkins RH, Yakura JS, Sie I. Motor and sensory recovery following incomplete paraplegia. Arch Phys Med Rehabil. 1994;75(1):67-72.

Table 1 The query used for searching Medline and Embase databases

Database	Query
Medline	(International Standards for Neurological Classification of Spinal Cord Injury[tiab] OR American Spinal Injury Association Impairment Scale[tiab] OR American Spinal Injury Association[tiab] OR ASIA[tiab] OR AIS[tiab] OR Outcome masseurs[tiab] OR Psychometric properties [tiab] OR Metric properties[tiab] OR Measurement properties[tiab] OR Psychometric[tiab] OR Characteristics[tiab] OR Reliability[tiab] OR Interobserver reliability[tiab] OR Interrater reliability[tiab] OR Rater reliability[tiab] OR Inter-rater reliability[tiab] OR Test-retest reliability[tiab] OR Validity[tiab] OR Validation[tiab] OR Internal consistency[tiab] OR Stability [tiab] OR Agreement[tiab] OR Responsiveness[tiab] OR Reproducibility[tiab] OR Interpretability [tiab] OR Capability[tiab] OR Capabilities[tiab] OR Repeatability[tiab]) AND (((((((("spinal"[All Fields] AND "cord"[All Fields]))) AND (((Contusion) OR injury) OR trauma OR Transection))) OR "Spinal Cord Injuries"[Mesh])))))
Embase	1- 'spinal cord injury'/exp OR 'spinal cord injury':ab,ti OR 'spinal cord contusion':ab,ti OR 'spinal cord hemisection':ab,ti OR 'spinal cord transection':ab,ti OR 'cervical spine injury':ab,ti OR 'spinal compression':ab,ti OR 'spinal cord trauma':ab,ti OR 'trauma, spinal cord':ab,ti OR 'injured spinal cord':ab,ti OR 'spinal cord injured':ab,ti OR 'spinal cord injuries':ab,ti OR 'nerve transection':ab,ti 2- 'international standards for neurological classification of spinal cord injury'/exp OR 'american spinal injury association impairment scale'/exp OR 'american spinal injury association':ab,ti OR 'asia':ab,ti OR 'ais':ab,ti OR 'american spinal injury association grade':ab,ti OR 'american spinal injury association motor score':ab,ti OR 'american spinal injury association score':ab,ti OR 'asia impairment scale':ab,ti OR 'asia motor score':ab,ti OR 'asia score':ab,ti OR 'outcome masseurs':ab,ti OR 'psychometric properties':ab,ti OR 'metric properties':ab,ti OR 'measurement properties':ab,ti OR 'psychometric':ab,ti OR 'characteristics':ab,ti OR 'reliability':ab,ti OR 'interobserver reliability':ab,ti OR 'interrater reliability':ab,ti OR 'rater reliability':ab,ti OR 'inter-rater reliability':ab,ti OR 'test-retest reliability':ab,ti OR 'validity':ab,ti OR 'validation':ab,ti OR 'internal consistency':ab,ti OR 'stability':ab,ti OR 'agreement':ab,ti OR 'responsiveness':ab,ti OR 'reproducibility':ab,ti OR 'interpretability':ab,ti OR 'capability':ab,ti OR 'capabilities':ab,ti OR 'repeatability':ab,ti 3- #1 AND #2

Table 2 Characteristics of included studies

Study; Year	Type of study	Sample size	Age	Male	Amount of training	Version of IS-NCSCI	Outcome	Results
Autonomic system evaluation								
Alexander; 2019 (37)	Retrospective	72	35±13.0	41	NR	2000	bladder and bowel function	Simultaneous application of the sacral components of the ISAFSCI and the ISNCSCI may be beneficial to obtain further information on bladder and bowel function.
Davidson; 2017 (13)	Cross-sectional	48	45+12	41	NR	NA	Interrater agreement	ISAFSCI have moderate and up to strong interrater reliability in different components.
Previnaire; 2010 (24)	Retrospective	NA	NA	NA	NA	NA	Sympathetic response	Autonomic response of T6 paraplegia patients are absence but in T10 paraplegia is near normal
Previnaire; 2009 (23)	Cross-sectional	81	38.2 (10.7)	71	NR	NR	Sympathetic response	There was a strong correlation between motor complete injuries and complete sympathetic lesions, while an incomplete motor or sensory lesion was often associated with a complete sympathetic injury.
West; 2014 (30)	Cross-sectional	52	34.8 + 72	52	20 year experience	2011	Cardiovascular response	Neurological level and sympathetic skin responses score should be combined to provide the optimal evaluation of cardiovascular abnormality.
Accuracy of AIS in children								
Mulcahey; 2007 (7)	Cross-sectional	74	0.7 to 21	NR	two formal workshops	2000	Interrater agreement	The utility of ISCSCI may have poor in children under 4 years. Although reliability of the motor and sensory exams are excellent, wide confidence interval suggest low precision of the motor and sensory exams test in children.
Mulcahey; 2011 (8)	Cross-sectional	236	0.2 to 21	109	Formal training	2000	Interrater agreement	The value of ISNCSCI in determining of severity of impairment is poor for children younger than 6 years.
Chafetz 2009 (33)	Cross-sectional	187	4 to 21	110	Formal training	2002	Interrater agreement	Interrater agreement on repeated pinprick, light touch, and total motor scores were poor in children younger than 6 years. The poor low limit of confidence interval values for above-mentioned tests indicating poor precision of ISNCSCI.
Vogel; 2012 (9)	Cross-sectional	180	6 to 21	103	1 year experience	2000	Interrater agreement	Anorectal examination in children had poor to moderate-high value. The findings do not fully support the use of anorectal examination in children.
Optimum evaluation timing is not clear								
Marino; 2011 (20)	Cross-sectional	1436	41 +17	1151	NA	1996	One week outcome	The authors found that 22% of patients with AIS grade A converted to AIS grade B or higher by rehabilitation discharge over first week after injury.
Confounding effects								
Coleman; 2004 (12)	Retrospective	760	NR	NR	NR	1992	One year outcome	In the assessment of SCI severity the injury region/severity variable keeps the strong prognostic value of using both region and severity
Failli; 2012 (14)	Cohort	1436	28 (21 to 40)	1163	NR	NR	One year outcome	AIS conversion in pneumonia or wound infection group is lesser than the control patients.

Table 2 Characteristics of included studies

Study; Year	Type of study	Sample size	Age	Male	Amount of training	Version of IS-NCSCI	Outcome	Results
Zariffa; 2012 (31)	Retrospective	2557	NR	-	NR	NR	One year outcome	One year follow up of lumbar SCI depicted 16.3% of AIS A assessments were found to meet the AIS D motor score criteria. In addition, the overall frequency of AIS A changes to AIS C was 34.3%.
Incomplete injuries								
Fawcett; 2006 (6)	Cross-sectional	NR	NR	NR	NR	NR	One year outcome	Recovery in incomplete SCI patients is more considerable and highly inconstant
Gundalou; 2014 (15)	Cross-sectional	NA	NA	NA	NA	2011	AIS conversion	All AIS conversions in motor incomplete might be in the 'critical zone of conversion' as they resulted from changes in a single motor or sensory level, and may reflect a problem concerning the ASIA definition rather than a true neurological recovery or deterioration.
Marino; 2008 (19)	Cross-sectional	16	18 to 65	10	NR	2002	Reliability and repeatability	Repeatability values of AIS are good for complete injuries but poor for incomplete injuries.
Menaker ; 2013 (22)	Retrospective	128	41 + 26	106	NR	NR	Need to for tracheostomy	Lower admission ASIA motor score and "complete" cSCI are significantly associated with the need for tracheostomy. When looking only at patients with an "incomplete" cSCI, those with an admission ASIA score of less than 10 should have an early tracheostomy
Schuld; 2015 (25)	Retrospective	185	NR	NR	Formal training	NR	Agreement	AIS B was most often misinterpreted as AIS C and vice versa (AIS B as C: 29.4% and AIS C as B: 38.6%)
Shin; 2011 (26)	Cohort	43	15 to 60	20	NR	NR	patients outcome	For the tetraplegic group, both ASIA motor score and LEMS do not provide adequate evidence for motor recovery of the incomplete SCI patients.
van Middendorp; 2011 (32)	Retrospective	1671	18 to 92	673	1 year of experience	2002	Positive and Negative predictive value	Positive and Negative predictive value of being classified as ASIA B (PPV= 39.4; NPV= 60.6) or C (PPV= 61.8; NPV= 38.2) on ambulation at one year are weak
Poor classification and prediction								
Armstrong; 2017 (36)	Retrospective	91	184	NR	2-hours seminar	2015	Correct classification	Only 25.5% of ISNCSCI examination had no error. There is inherent challenges in ISNCSCI assessment and classification.
Schuld; 2016 (2)	Cohort	125	NR	NR	5 session formal training	2013	Correct classification	Even with proven advantages of the 2013 revision of ASIA score, the correct assessment of motor levels in the segments C2–C4 remains challenging.
Kirshblum; 2002 (16)	Retrospective	94	NA	87	NA	2000	One year outcome	The 2000 revisions of AIS do not offer a significant difference in classification of severity of injury

Table 2 Characteristics of included studies

Study; Year	Type of study	Sample size	Age	Male	Amount of training	Version of ISNCSCI	Outcome	Results
Kirshblum; 2019 (35)	Cross-sectional	91	>18	74	Well trained clinicians	2015	Sensory perception of patients	There is no standard method for evaluation sensory portion of ISNCSCI. In addition, previous experiences patients from ISNCSCI affect the pain perception of the patients.
Marino; 1995 (17)	Cross-sectional	50	16 to 67	47	NA	1992	One year outcome	The ASIA motor level and the UEMS better reveal the severity of SCI and disability after motor complete injury than neurological level
Marino; 2004 (18)	Cross-sectional	4338	33 (22 to 46	3443	NA	NR	Patient status in discharge	Use of UEMS and LEMS for assessment of SCI severity should improve ability of AIS in prediction of functional outcome of patients.
McCoy; 2017 (21)	Retrospective	487	10 to 62	463	NA	NR	Occurrence of pressure ulcers or and pressure ulcer surgeries	AIS A and B distinctions are not meaningful at spinal cord levels in the cervicothoracic spine due to gunshot.
Osunronbi and Sharma; 2019 (34)	Retrospective	50	20 to 93	35	Several years of experience	2006 and 2015	Accuracy of patient documentation	Completion rate of ISNCSCI: 39% Accuracy rates of the ISNCSCI: 78.1%. The quality of ISNCSCI documentation is poor regardless of the clinician training grade and injury factors.
Spiess; 2009 (27)	Retrospective	284	NR	NR	2-day trainings	NR	One year outcome	The authors concluded that there is an over dependence of AIS on sacral region scores. They stated that a significant AIS conversion might happen in sacral region while motor function or sensory score of other affected regions remains unchanged. Therefore, conversion in AIS score might not reveal a change in severity of neurological deficit, but rather be an artefact of the assessment itself.
van Middendorp; 2009 (28)	Cohort	273	15 to 92	210	NR	2000	One year outcome	The AIS conversion is poorly predicted the ability to walk in SCI patients.
van Middendorp; 2009 (29)	Cohort	432	15 to 92	341	NR	2000	One year outcome	The overall frequency of one year AIS A conversion to AIS C was 34.3%. For C4-8 injuries, the proportion was 70.9%, for T2-5 it was 1.5%, for the T6-9 it was 4.7%, for T10-12 it was 19.5%, and for L1-5 it was 65.2%.

AIS: American Spinal Injury Association (ASIA) Impairment Scale
cSCI: Cervical spinal cord injury
ISNCSCI: International Standards for Neurological Classification of Spinal Cord Injury
ISAFSCI: International Standards to Document Remaining Autonomic Function after Spinal Cord Injury
LEMS: Lower extremity motor score
UEMS: Upper extremity motor score