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Early Rapid Neurological Assessment for Acute Spinal Cord Injury Trials

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Abstract

Clinical trials evaluating early therapies after spinal cord injury (SCI) are challenging because of the absence of a rapid assessment. The aim of this study was to determine whether the severity and level of SCI could be established from a brief neurological assessment capable of being used in an emergency setting. A brief assessment called the SPinal Emergency Evaluation of Deficits (SPEED) was developed and retrospectively evaluated in a cohort of 118 patients with SCI. Foot motor and sensory function was used to indicate injury severity. C3 dermatome sensation, handgrip strength and location of spinal pain were used to indicate the level of injury. With regard to injury severity, a high proportion of patients (94%) with no foot movement at the time of injury were initially diagnosed as motor complete (American Spinal Injury Association Impairment Scale [AIS] grade A–B), whereas all patients with foot movement were identified as motor incomplete (AIS grade C–D). This was reflected by a good correlation ($r_s = 0.79$) and agreement ($\kappa = 0.85$) between the SPEED motor score and the acute hospital assessment. With respect to injury level, the majority of cases with cervical SCI (92%) had no or weak handgrip at the time of paramedic assessment, whereas all cases with thoracolumbar SCI had a strong handgrip. The location of spinal pain was also in accordance with the level of spinal injury. The SPEED assessment appears capable of accurately determining the severity and level of cervical SCI in the first hours post-injury. A neurological assessment that can be performed rapidly after injury is important for clinical trials of early therapy and to identify patients most likely to benefit from intervention.

Key words: injury severity; level of injury; rapid neurological assessment; SCI

Introduction

Although treatments for spinal cord injury (SCI) remain limited, the recognition that the spinal cord is subject to differing forms of secondary injury has led to the development of a number of therapeutic approaches, including early decompression and hypothermia. Pre-clinical and clinical evidence suggest that these therapies should optimally be initiated within a few hours following injury.[1–3]

A requirement for a clinical trial evaluating early treatment is a pre-therapy assessment capable of determining the severity and neurological level of injury. Because these two factors principally determine outcome, it is essential that they are determined before initiating therapy.[4,5] The existing International Standardisation of Neurological Classification of Spinal Cord Injury (ISNCSCI) assessment, even to establish the grade of injury, can be time consuming and requires considerable experience, and it relies heavily on accurate evaluation of anal sphincter motor and sensory function.[6] These factors render this assessment impractical in the pre-hospital and emergency setting, where trial enrolment may occur and early therapy may be initiated. An abbreviated examination, involving assessment of L3 and S1 motor and sensory function has been shown to accurately predict walking function after SCI.[7] However, as noted by van Middendorp and colleagues, the person performing this examination needs to be experienced for it to be reliable. Paramedics or other emergency personnel may only see a case of traumatic SCI every few years; therefore, the accuracy of an examination requiring substantial training may not be sustained.

Based on the study of van Middendorp and colleagues,[7] and other studies of brief assessment for patients with SCI, we developed a simple neurological examination called SPinal Emergency Evaluation of Deficits (SPEED) to rapidly determine both the severity and level of SCI.[8–10] The aim of this retrospective study was to determine whether the SPEED assessment in the first hours post-injury predicts the severity and level of cervical SCI acutely and 6 months post-injury.

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Methods

Study design

A retrospective data analysis of patients with isolated SCI between 2010 and 2014 was conducted. A list of all SCI admissions over this period was obtained from the Austin Hospital (Melbourne, VIC, Australia). Approval was obtained from the Austin Health Human Research Ethics Committee (No. H2012/04869).

Inclusion and exclusion criteria

Patients between 15 and 70 years of age presenting with a vertebral column injury and a C3–C8 (cervical) neurological level of injury were included, provided that there was a documented neurological examination recorded in ambulance patient care records (PCRs) together with an ISNCSCI assessment (or detailed neurological assessment) within 24 h of injury. These patients, as well as patients who met these inclusion criteria and had a neurological level of injury above C3 (high cervical) or between T1 and L5 (thoracolumbar), were also included in the analysis of the level of injury component of SPEED.

Patients with penetrating SCIs were excluded, as were patients with multiple traumatic injuries (defined as trauma to at least one other major organ, significant abdominal bleeding or retroperitoneal hemorrhage likely to require intervention, pelvic fracture likely to require intervention, or more than two long bone fractures requiring operative fixation), or with a Glasgow Coma Scale (GCS) score <13 at the scene. Patients with pre-existing major neurological deficits or disease (e.g., stroke, Parkinson's disease) were also excluded.

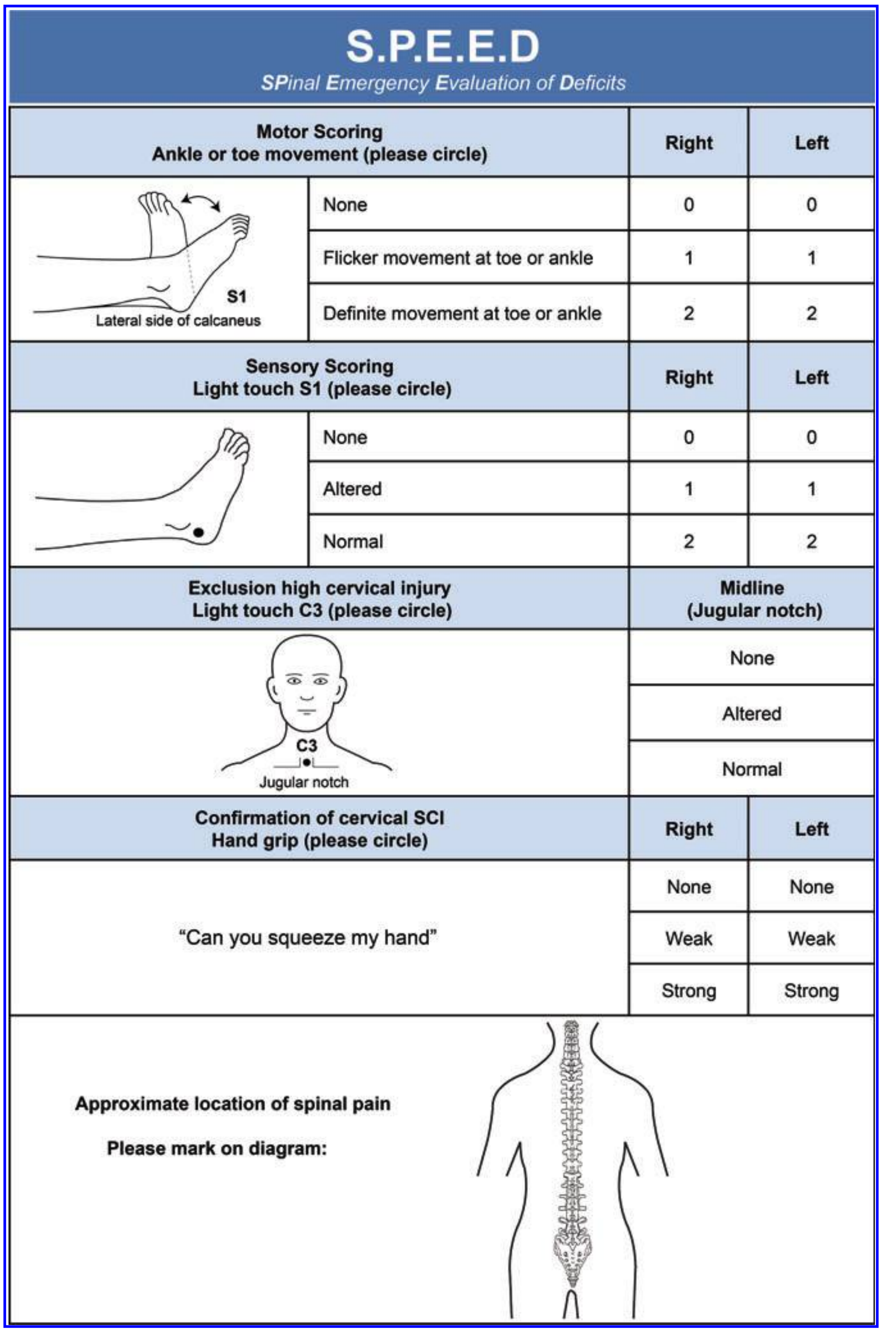

FIG. 1. SPinal Emergency Evaluation of Deficits (SPEED) assessment. Color image is available online at www.liebertpub.com/neu

After screening, the PCRs for patients meeting inclusion criteria were retrieved. Two independent assessors (C.R.B. and P.E.B.) used the PCR neurological examination data to derive the SPEED scores. The neurological paramedic examination normally consisted of a brief upper limb (e.g., handgrip or arm/hand movement) and lower limb (e.g., ankle/toe or foot movement) motor assessment. Sensation was also assessed in both extremities, and was often reported as ''no sensation,'' ''numbness,'' or ''tingling.'' The SPEED motor and sensory components were obtained from both left and right sides where available. If the neurological assessment was not specified to a specific side (left or right), the same score was given for both sides.

The independent assessors were blinded to the patient's injury severity (American Spinal Injury Association Impairment Scale [AIS] grade) and level. The initial AIS grade (< 24 h post-injury), follow-up AIS grade (24–72 h post-injury), and the final AIS grade (rehabilitation discharge) were obtained from hospital medical records.

Data extraction and management

The following data fields were collected: demographic data (date of birth and gender), injury details (date and time of injury, cause of accident), time of paramedic arrival, paramedic neurological examination, spinal pain, and date and time of the initial (< 24 h post-injury), follow-up (24–72 h post-injury), and final (rehabilitation discharge) ISNCSCI assessments. ISNCSCI assessments and grades were obtained from medical records where available. If ISNCSCI assessments were not performed within these time periods, the details of the neurological examination (motor, sensory, and anal function) performed by medical staff were collected and the AIS grade was derived using the ISNCSCI computational algorithm.[11]

Data were entered into REDCap, a secure (username and password protected) web-based database.[12]

SPEED

On the basis of previous studies,[7–10] we developed the SPEED assessment. This assessment evaluates foot motor and sensory function to indicate the severity of injury, and C3 sensation, handgrip strength, and the level of spinal pain to indicate whether injury is in the high cervical, low and mid cervical, or thoracolumbar regions.

The SPEED assessment of *injury severity* was composed of two components with a maximum score of 8 (Fig. 1). The SPEED motor (ankle or toe movement) score was determined from a three point scale ranging from 0 (no movement) to 2 (definite movement at toe or ankle). The SPEED sensory (light touch at S1 dermatome) score was determined from a three point scale ranging from 0 (none) to 2 (normal). The SPEED assessment of the *level of injury* was composed of three components: light touch at C3 (none, altered, or

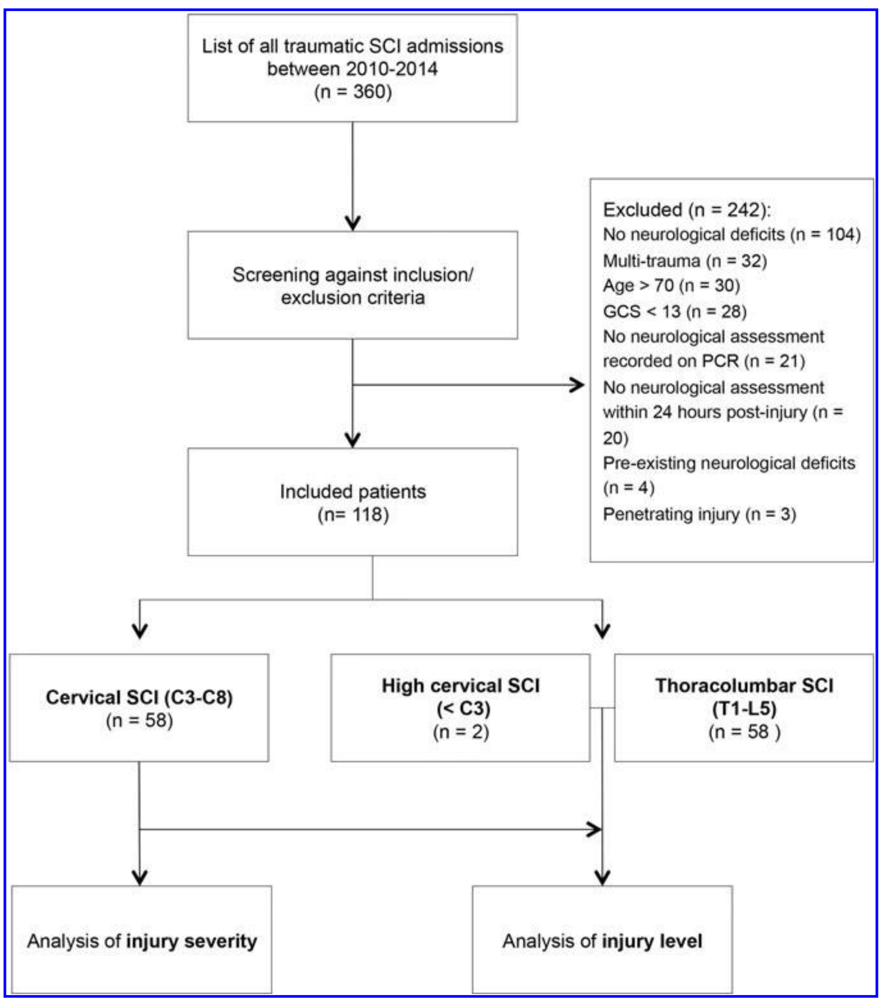

FIG. 2. Flow chart of patients included in the analysis of severity and level of spinal cord injury (SCI). PCR, ambulance patient care record.

normal), handgrip strength (none, weak, or strong), and location of spinal pain.

Data and statistical analysis

The time of SPEED assessment was defined as the period between time of injury and time of paramedic arrival. The time of each ISNCSCI assessment was calculated as the duration between time of injury and the each time of assessment. As clinical trials may randomize patients according to whether they are motor complete or motor incomplete,[13] analysis was also performed with patients graded AIS A and B combined (motor complete) and AIS C and D combined (motor incomplete).

Cohen's κ was used to measure the degree of agreement between the AIS grade at the time of each time point and the SPEED assessment (total score and motor and sensory scores). Cohen's κ represents the level of agreement corrected for chance where 1 is perfect agreement and 0 is that expected by chance.[14] Descriptors for the strength of agreement for the κ coefficient are: ≤0 = poor, 0.01–0.20 = slight, 0.21–0.40 = fair, 0.41–0.60 = moderate, 0.61–0.80 = substantial, and 0.81–0.99 = almost perfect. The sensitivity, specificity, and positive and negative predictive values as well as 95% confidence intervals (CI) were calculated to assess the ability of the SPEED motor score to accurately identify AIS A–B versus AIS C–D patients. Correlation between nonparametric variables was performed using Spearman's ρ correlation coefficient (r_s). Data are presented as median and interquartile range (IQR), unless otherwise stated. Statistical analyses were performed using Prism software (version 6, GraphPad, CA).

Results

A total of 360 patients were screened during the study period (Fig. 2). Fifty-eight cases of cervical (C3–C8) SCI met the inclusion criteria and were analyzed for severity of injury. This cohort was also included in the analysis of the level of injury as well as two patients with high cervical (< C3) SCI and 58 cases with thoracolumbar SCI (T1–L5).

Demographics

The mean age (± SD) of included patients was 38 (± 17) years and the majority (83%) were male (Table 1). The median time between injury and paramedic neurological assessment (SPEED) was 0.6 h (IQR: 0.3–1.4). The median time between injury and the initial ISNCSCI assessment was 8 h (IQR: 3–11), whereas the median time for the follow-up ISNCSCI assessment was 48 h (IQR: 24–72). Assessment on discharge from rehabilitation was undertaken at a median time of 6 months post-injury (IQR: 4–9).

AIS grade conversions

The AIS grade conversions between initial and follow-up, initial and final, and follow-up and final assessments are shown in Figure 3. The majority of patients remained neurologically unchanged between the initial and follow-up assessments (Fig. 3A). Rates of AIS grade conversion between the follow-up and final assessments were similar to those between the initial and final assessments (Fig. 3B and C). The AIS conversions when AIS grades A and B were combined and when AIS grades C and D were combined are shown in Figure 4.

The κ agreement between AIS grades at the initial and follow-up assessments was 0.68 (Fig. 3A). The κ agreement between AIS grades at the initial and final assessment was 0.37 (fair agreement) and this was similar to the agreement between AIS grades at the follow-up and final assessments (0.39, Fig. 3B and C).

Table 1. Demographics and Timing of Assessments

Patient and assessment characteristics	*n* (%)
Age (mean ± SD)	38 ± 17
Male	48 (83)
Accident category	
Water related	11 (19)
High fall (≥1 m)	9 (16)
Struck by or collision with person or object	9 (16)
Unprotected road user	8 (14)
Motor vehicle occupants (speed ≥60 km/h)	7 (12)
Motor vehicle occupants (speed unknown)	4 (7)
Low fall (same level or height <1 m)	4 (7)
Others	4 (7)
Motor vehicle occupants (speed <60 km/h)	2 (3)
Initial AIS grade	
AIS A	39 (67)
AIS B	5 (9)
AIS C	7 (12)
AIS D	7 (12)
Follow-up AIS grade	
AIS A	37 (64)
AIS B	8 (14)
AIS C	5 (9)
AIS D	8 (14)
Final AIS grade*	
AIS A	20 (36)
AIS B	12 (22)
AIS C	7 (13)
AIS D	16 (29)
Median between injury and assessment (IQR)	
SPEED (h)	0.6 (0.3–1.4)
Initial AIS (h)	8 (3–11)
Follow-up AIS (h)	48 (24–72)
Final AIS (months)	6 (4–9)

*Data based on 55 cases. Data are *n* (%) unless otherwise stated.
AIS, American Spinal Injury Association Impairment Scale; SPEED, Spinal Emergency Evaluation of Deficits.

When AIS grades A and B were combined and AIS grades C and D were combined, the κ agreement between the initial and follow-up assessments was 0.86 (Fig. 4A). Grouping the AIS grades this way resulted in a κ agreement of 0.67 between the initial and final assessments.

SPEED scores

The κ agreement between the two assessors of the paramedic neurological examination data was 0.89. The majority of patients (72%) had a total SPEED score of 0, with the remaining patients scoring 2 (9%), 4 (7%), 6 (7%), and 8 (5%), respectively. There was also a good correlation between the SPEED motor score and initial AIS grade ($r_s = 0.79$, $p < 0.0001$) and between the SPEED motor score and follow-up AIS grade ($r_s = 0.75$, $p < 0.0001$). There was a lower correlation between the final AIS grade and the SPEED motor score ($r_s = 0.57$, $p < 0.0001$). Correlations between the total SPEED score and AIS grades were similar to the correlations between the SPEED motor score and initial AIS grades (Table 2).

A high proportion (94%) of patients with a SPEED motor score equal to 0 were graded AIS A–B at the initial assessment, whereas all patients with a SPEED motor score of >0 were graded AIS C–D

A

Initial AIS grade (8 hours) \ Follow-up AIS grade (48 hours)				
%	A	B	C	D
A	87	10	3	-
B	40	60	-	-
C	14	14	57	14
D	-	-	-	100
				Kappa = 0.68

B

Initial AIS grade (8 hours) \ Final AIS grade (6 months)				
%	A	B	C	D
A	56	28	8	8
B	-	40	40	20
C	-	-	29	71
D	-	-	-	100
				Kappa = 0.37

C

Follow-up AIS grade (48 hours) \ Final AIS grade (6 months)				
%	A	B	C	D
A	56	24	12	9
B	13	50	25	13
C	-	-	20	80
D	-	-	-	100
				Kappa = 0.39

FIG. 3. AIS grade conversion between **(A)** initial and follow-up assessments, **(B)** follow-up and final assessments, and **(C)** initial and final assessments. AIS, American Spinal Injury Association Impairment Scale.

on the initial assessment (Fig. 5A). At final assessment, the majority of patients (73%) with a SPEED motor score equal to 0 were graded AIS A–B (Fig. 2B), and all patients with a SPEED motor score >0 were graded AIS C–D. Results for the total SPEED score were similar (Fig. 2C and D).

These results suggest that a SPEED score (total and motor) of 0 might be particularly important in differentiating motor complete patients (AIS grade A–B) from motor incomplete patients (AIS grade C–D). To analyze this further, the κ agreement between SPEED scores of 0 or >0 and AIS grades of A and B combined (A–B) or C and D combined (C–D) were determined for the initial, follow-up, and final AIS assessments.

There was almost perfect agreement between the absence or presence of motor function on the SPEED (i.e., SPEED motor of 0 vs. >0) and the initial AIS grades A–B versus C–D ($\kappa = 0.85$). The sensitivity of the SPEED motor score (proportion of patients with a SPEED motor score of 0 correctly identified as having AIS A–B SCI) was 100% (CI = 92–100). The specificity of the SPEED motor score (proportion of patients with a SPEED motor score >0 correctly identified as having AIS C–D SCI) was 79% (CI = 49–95). The positive predictive value (PPV) of the SPEED motor score (probability that a patient with a SPEED motor score of 0 actually will be AIS A–B) was 94% (CI = 82–99), whereas the negative predictive value (NPV) of the SPEED motor score (probability that a patient with a SPEED motor score >0 actually will be AIS C–D) was 100% (CI = 72–100).

There was also substantial agreement between an AIS grade of A–B and C–D on the follow-up assessment and the SPEED motor score ($\kappa = 0.78$). There was moderate agreement between the absence or presence of motor function on the SPEED motor and a final AIS grade of A–B and C–D ($\kappa = 0.55$). κ agreements for the total SPEED score were generally inferior to the SPEED motor score agreements (Table 3).

Sensory function was examined to determine if AIS grade A injuries could be distinguished from higher AIS grades. There was substantial agreement between the absence or presence of sensation on the SPEED and AIS grade A or B–D at initial and follow-up assessment ($\kappa = 0.64$ and 0.65, respectively) and fair agreement at final assessment ($\kappa = 0.33$).

SPEED and level of injury

The ability of SPEED to identify high cervical injuries (< C3) via impaired C3 light touch sensation was unable to be determined because of the absence of a paramedic neurological assessment in the two patients with these injuries. Both patients were intubated within 2 h of injury because of poor respiratory effort.

Of the 58 patients with a C3–C8 neurological level of injury, 46 had handgrip recorded by paramedics. The majority of these cases (92%) had no or weak handgrip strength at the time of assessment. The remaining cases (8%) had strong handgrip. Interestingly, all cases with strong handgrip had a total SPEED score of ≥4 and were classified as AIS grade D at all time points of assessment. Of the 58 cases identified with thoracolumbar (T1–L5) injuries, only 15 had handgrip assessed by paramedics. All of these cases had a strong handgrip at the time of accident.

Spinal pain was assessed and reported by paramedics in 45 of the 58 patients with cervical SCI. A high proportion (78%) of these patients had pain in the cervical/neck region. The remaining cases reported no pain (7%), or pain in the cervical and thoracic region (9%), cervical and lumbar region (4%), or lumbar region only (2%). Of the 58 cases with thoracolumbar SCI, 43 had spinal pain assessed by paramedics. The majority reported pain either in the thoracic (49%) or lumbar region (40%). Pain was reported in the thoracic and lumbar regions by 7%, in the cervical region by 2%, and in all spine regions by 2% of patients.

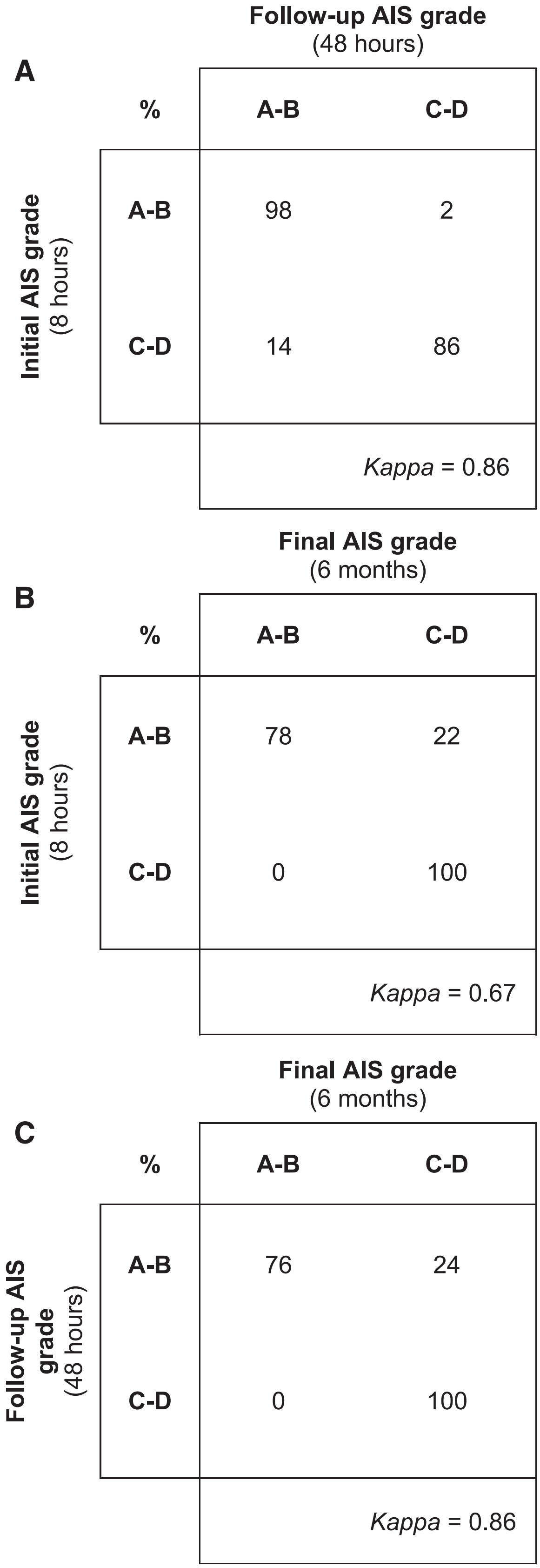

FIG. 4. AIS grade conversion between **(A)** initial and follow-up assessments, **(B)** follow-up and final assessments, and **(C)** initial and final assessments. AIS, American Spinal Injury Association Impairment Scale.

TABLE 2. CORRELATION BETWEEN AIS GRADE (A, B, C, D) AT EACH ASSESSMENT AND SPEED

Assessment	*Total SPEED score*	*SPEED motor score*
Initial	0.75	0.79
Follow-up	0.78	0.75
Final	0.60	0.57

AIS, American Spinal Injury Association Impairment Scale; SPEED, SPinal Emergency Evaluation of Deficits.

Discussion

The main finding of this study is that the severity and level of cervical SCI can be determined by a simple neurological assessment performed in the first hours after injury. Foot motor function appears to be useful and accurate in determining the severity of injury, whereas impaired handgrip strength, together with the location of spinal pain, are sufficient to establish the presence of cervical cord injury. To our knowledge, no previous study has examined neurological function very early after injury and whether or not this has prognostic significance. This information is critical for clinical trials of early therapy in the field of SCI.

Early neurological assessment to determine injury severity

A number of potential therapies for SCI, such as early decompression and hypothermia, are time critical and should ideally be delivered as soon as possible following injury.[15,16] This creates the need for an accurate examination that can be rapidly performed early after injury by non-spinal specialists such as paramedics and emergency staff. The level and severity of injury are the major factors determining prognosis following SCI[17,18] and are essential to establish prior to initiation of therapy so that treatment is applied to patients likely to benefit, and sample size is minimized.[5,19] Although the ISNCSCI classification is commonly used to determine the level and grade of SCI, this assessment can be time consuming, and accurately determining limb and anal motor and sensory function requires considerable experience.[19] Moreover, paramedics do not assess anal function and are unwilling to conduct complicated assessments that would prolong time at the accident scene. In the acute setting, where time is paramount and assessors generally do not have extensive neurological training, the ISNCSCI classification system is impractical.

Recovery following SCI is favored by the presence of even a small amount of neurological function in the lumbar and sacral regions (e.g., motor function of quadriceps and gastrocnemius/soleus muscles) in the first weeks after injury.[7–10,20] These studies suggest that a simple lower limb examination early after injury might usefully indicate prognosis. The SPEED assessment was developed on the basis of these studies, with the key requirement of simplicity, so as to enable examination to be rapidly performed with little or no training by paramedics and emergency personnel. Our data demonstrate that this brief assessment of lower limb motor function is sufficient to accurately establish the severity of injury in the field. We found that absence of motor movement in the foot (SPEED motor score of 0) shortly after injury (0.6 h) accurately distinguished AIS grade A–B injuries from AIS grade C–D injuries. The majority of patients without foot motor movement were classified as AIS grade A or B on the initial (8 h) and follow-up (48 h) assessments (PPV = 94%), whereas all patients with motor

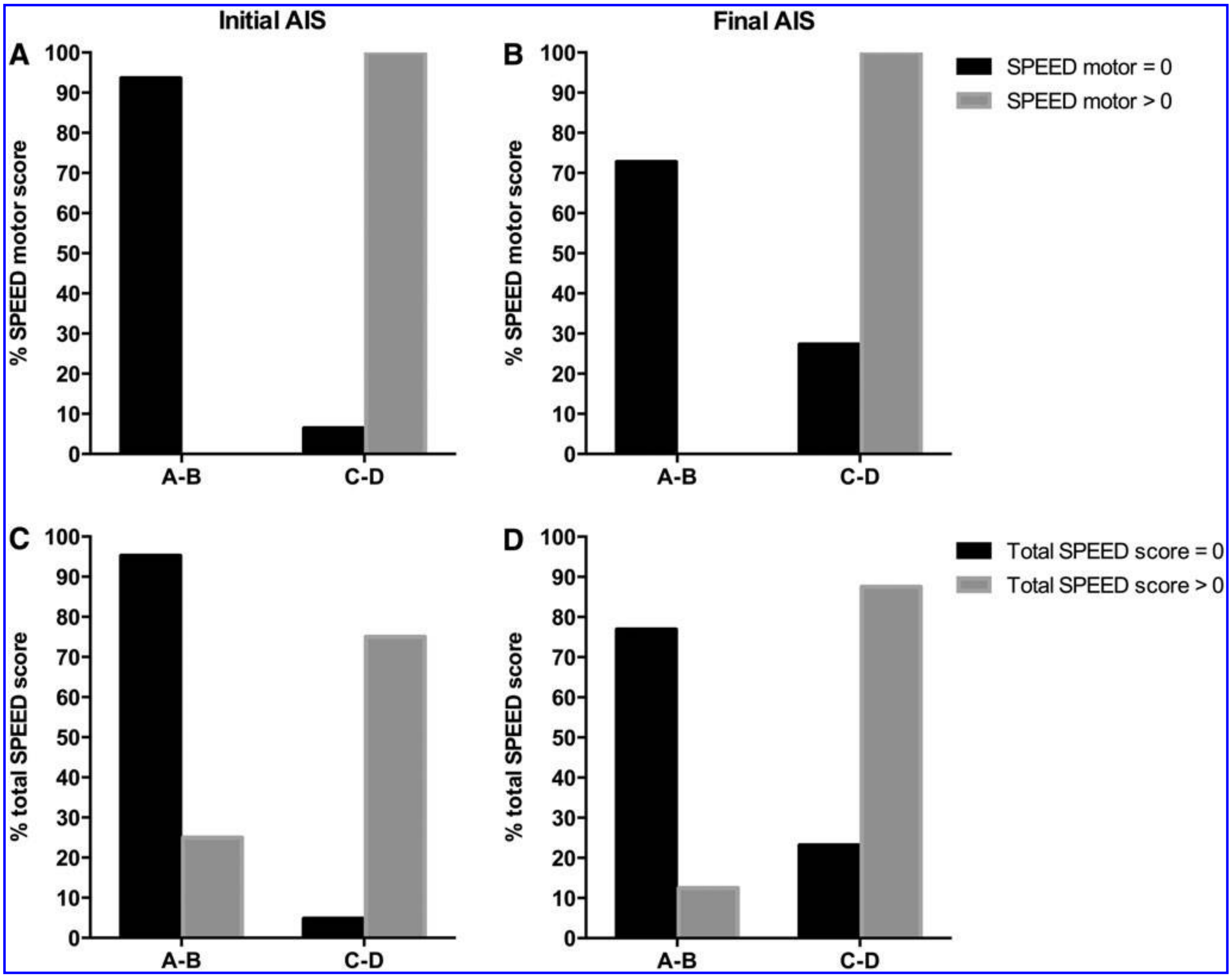

FIG. 5. Proportion of patients with SPinal Emergency Evaluation of Deficits (SPEED) score of 0 or >0 and American Spinal Injury Association Impairment Scale (AIS) grades. **(A)** The majority of patients with a SPEED motor score of 0 were initially graded AIS A–B, and all patients with a SPEED motor score of >0 were graded AIS C–D. **(B)** By the time of final assessment, some patients who were initially A–B had converted to C–D. However, most patients with total SPEED motor score of 0 or >0 remained AIS A–B or AIS C–D, respectively. **(C)** Similarly, the majority of patients with a total SPEED score of 0 were initially graded AIS A–B and **(D)** remained AIS A–B at the final assessment.

movement were found to be AIS grade C–D (NPV = 100%). This clear differentiation was reflected in an almost perfect κ agreement (0.85).[14] Absence of foot sensation was also able to reasonably differentiate acute AIS grade A injuries from higher grade injuries. However, the addition of sensation did not improve the overall ability of the SPEED assessment to determine injury severity 6 months following injury.

Table 3. Agreement (κ) between AIS Grade (A–B, C–D) at Each Assessment and SPEED

Assessment	*Total SPEED score*	*SPEED motor score*
Initial	0.70	0.75
Follow-up	0.78	0.80
Final	0.60	0.55

AIS, American Spinal Injury Association Impairment Scale; SPEED, SPinal Emergency Evaluation of Deficits.

The ability to rapidly differentiate motor complete from motor incomplete injuries by emergency personnel without spinal expertise may be clinically useful in a number of ways. First, it may allow appropriate patients for specific therapies to be identified and directed to specialist medical care. For example, in New Zealand, a recent policy mandates that patients with SCI and lower extremity paralysis be directly transported to a surgical center for immediate decompression. Rapid neurological assessment in the field may also allow patients suitable for clinical trials to be rapidly identified and directed to trial centers. Ultimately, once prospectively validated, the SPEED assessment might be used as an entry criterion for clinical trials commenced in the emergency setting, with further more extensive assessment conducted once patients reach specialist spinal centers. Hypothermia is an example of a neuroprotective therapy that has been initiated by paramedics in the field in clinical conditions such as cardiac arrest and brain injury.[21–23] There is preclinical evidence that cooling early after SCI may be of value in extending the time window for decompressive surgery,[24,25] and there is clinical evidence that cooling following cervical SCI is safe.[1,13] However, conducting a clinical trial commencing hypothermia in the field is difficult without a simple pre-therapy assessment, such as SPEED, to select a uniform cohort of patients.

Early assessment to determine the level of injury

Our results also suggest that it is possible to rapidly determine whether injury is in the cervical or thoracolumbar cord using a combination of handgrip strength and location of spinal pain. We could not establish whether impaired C3 sensation might indicate a high cervical injury, because a paramedic neurological examination was not documented for the two patients with these injuries. However, both patients were intubated within 2 h of injury, and the need for early intubation could be a useful indicator of high cervical injury. The identification of high-level SCIs early after injury is important as management differs, the rate of respiratory complications is higher, and altered motor recovery in upper limbs may cause trial imbalance.[18] Handgrip strength and location of spinal pain are already routinely determined by paramedics in the field, and appear to simply and accurately distinguish cervical from thoracolumbar injuries.

Early assessment and long-term prognosis

The two major factors determining long-term prognosis following SCI are the level and severity of injury.[17–19,26] Acute AIS grade is the standard method of determining long-term prognosis, and anal function forms a critical part of this assessment.[6] However, it is possible to determine prognosis by evaluating function in non-anal dermatomes and myotomes in the distal spinal cord. The presence of S4 and S5 sensation appears to better predict eventual recovery than anal sensation alone.[20] Most patients with just a flicker of movement in the lower limbs early after injury regain useful motor function, with the majority regaining the ability to walk again.[9] Similarly, the acute presence of quadriceps or hip flexor function favors the return of good motor strength and function.[8,10] In a large and well-conducted study, van Middendorp and coworkers[7] found that a combination of acute L3 and S1 sensory and motor scores better predicted eventual return to walking than AIS grade.

These studies demonstrate that outcome following SCI can be determined from neurological examinations other than the ISNCSCI assessment. The current study also suggests that even a simple assessment of caudal function early after injury provides accurate long-term prognostic information. In common with other non-ISNCSCI methods of assessment, SPEED determines long tract integrity through examination of sacral and distal lumbar motor and sensory function. We found that the presence or absence of motor movement in the foot was able to prognosticate AIS A–B or C–D grade injury at 6 months moderately well (κ 0.55). The agreement between the initial or follow-up AIS grade and the final AIS grade was only slightly better (Fig. 3) than the agreement between SPEED and the final AIS grade.

Influence of timing on the prognostic accuracy of assessment

Early assessment to determine the severity and prognosis of SCI is generally believed to be most useful if performed ≥72 h post-injury, with examination before 24 h considered unreliable.[5] The data on which this belief rests are not vast. Data on the recovery of upper limb muscles within the zone of partial preservation are conflicting, with one study showing the superiority of 72 h over 24 h assessment, and another showing equivalence.[27,28] Early ISNCSCI assessment appears reliable if confounding factors such as intubation, sedation, and brain injury are not present.[29] van Middendorp and coworkers[7] found that a combination of acute L3 and S1 sensory and motor scores was prognostically accurate and not affected by the timing (<24 h, <72 h or <15 days post-injury) of assessment.

The data from the current study accord with findings from previous studies.[20,27,28] We found that ISNCSCI assessment performed with a median time of 8 h or 48 h post-injury predicted the AIS grade on rehabilitation discharge (6 months) equally well, with the majority of patients remaining neurologically unchanged. A minority (20%) of patients' injury grades did change between the two early assessments, and for half of these patients the injury grade improved, whereas for the other half the injury grade deteriorated. These data accord with previous studies examining early neurological change in the zone of partial preservation, which demonstrate that, whereas some patients deteriorate over the first few days post-injury, others improve.[27,28] It is unclear whether these changes are real and whether they reflect the influence of secondary injury processes such as compression, edema, and hemorrhage, or result from factors such as sedation, drugs, pain, fever, and other injuries.[29] To our knowledge, no previous studies have examined change in AIS grade very early after injury. It can be argued that the presence of spinal shock may be a barrier to early assessment of SCI. However, our data indicate that it is possible to assess neurological function and to determine the severity of injury in the first hours after injury, and spinal shock mainly seems to be of relevance to the initial depression and subsequent gradual return of spinal reflexes. This result may not be especially remarkable; in a sense, all early neurological assessments are undertaken in the period of spinal shock in which the spinal reflexes progressively return over weeks to months.[30]

Limitations

In this study, analysis was retrospective and limited to patients with isolated cervical SCI. Patients with multi-trauma were excluded as were patients >70 years of age, because of the higher mortality rate and possibly differing prognosis in elderly patients.[31,32] Patients were also excluded if an adequate paramedic or initial AIS neurological examination was not performed. The exclusion of patients for these reasons may have unwittingly introduced study bias. In addition, paramedics were conducting and recording examinations routinely and may have missed subtle motor movement or sensation. When uncertain, examiners may tend to overestimate injury severity.[29] As the SPEED scores were retrospectively derived from the ambulance and hospital PCRs, the interpretation of the paramedic neurological assessment and scoring of SPEED by the blinded assessors is a further potential source of error. A prospective study is needed to overcome these limitations and validate the ability of SPEED to prognosticate outcome acutely and 6 months post-injury.

Another limitation of SPEED is that it focuses mainly on lower limb recovery. Recovery of upper limb function is highly important to patients with cervical SCI, predicts functional recovery and independence, and is mainly dependent on the motor level of injury.[33] The motor level of injury has been proposed as an alternative outcome measure in clinical trials in cervical SCI.[33] The motor level of injury is not captured in the SPEED assessment, and determining this reliably by testing individual muscles in the emergency setting would be difficult for medical personnel without spinal expertise.

Conclusion

The SPEED assessment appears capable of rapidly determining both the severity and level of isolated cervical SCI. It is simple and quick to perform, without the need for removal of large amounts of clothing or positioning of the limbs. The assessment can be conducted soon after injury and may be useful to identify patients who might benefit from acute interventions such as decompressive surgery, and to select patients for clinical trials evaluating the efficacy of early therapy.

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Author Disclosure Statement

No competing financial interests exist.

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