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REVIEW

Diagnostic criteria of traumatic central cord syndrome. Part 1: A systematic review of clinical descriptors and scores

MH Pouw[1], JJ van Middendorp[1], A van Kampen[1], S Hirschfeld[2], RPH Veth[1], EM-SCI study group, A Curt[3], AJF Hosman[1] and H van de Meent[4]

[1]Department of Orthopedic Surgery, Spine Unit, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands; [2]Spinal Cord Injury Center, BG Trauma Hospital Hamburg, Hamburg, Germany; [3]Spinal Cord Injury Center, University of Zürich, University Hospital Balgrist, Zürich, Switzerland and [4]Department of Rehabilitation Medicine, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands

Study design: Systematic review.
Background: The applied definition of traumatic central cord syndrome (TCCS) lacks specific quantified diagnostic criteria.
Objective: To review currently applied TCCS diagnostic criteria and quantitative data regarding the 'disproportionate weakness' between the upper and lower extremities described in original studies reporting on TCCS subjects.
Methods: A MEDLINE (1966 to 2008) literature search was conducted. The descriptors applied to define TCCS were extracted from all included articles. We included original studies that reported on the differences in motor score (based on the Medical Research Council scale) between the total upper extremity motor score (UEMS) and the total lower extremity motor score (LEMS), in a minimum of five TCCS patients at the time of hospital admission. The mean difference between the total UEMS and the total LEMS of the patients included in each study was calculated. Case reports were excluded.
Results: None of the identified studies on TCCS patients reported inclusion and/or exclusion criteria using a quantified difference between the UEMS and LEMS. Out of 30 retrieved studies, we identified seven different clinical descriptors that have been applied as TCCS diagnostic criteria. Nine studies reporting on a total of 312 TCCS patients were eligible for analysis. The mean total UEMS was 10.5 motor points lower than the mean total LEMS.
Conclusions: There is no consensus on the diagnostic criteria for TCCS. Nevertheless, this review revealed an average of 10 motor points between the UEMS and LEMS as a possible TCCS diagnostic criterion. However, further discussion by an expert panel will be required to establish definitive diagnostic criteria.
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Keywords: spinal cord injury; central cord syndrome; cruciate paralysis; diagnostic criteria; upper extremity motor score; lower extremity motor score

Introduction

Traumatic central cord syndrome (TCCS) is a clinical diagnosis that was first described by Schneider *et al*. in 1954.[1] TCCS is characterized by (1) a disproportionate impairment (weakness and reduced function) of the upper limbs as compared with the lower limbs, (2) neurogenic bladder dysfunction, and (3) varying degrees of sensory loss at and below the level of the lesion.[1] A TCCS is considered the most prevalent incomplete spinal cord injury (SCI) syndrome, accounting for ~9% of all traumatic SCI's.[2,3] In TCCS patients, recovery of a certain degree of ambulation, participation in daily life activities, bowel and bladder function has been reported to be favorable in several studies.[2–10]

TCCS also occurs frequently in elderly subjects due to rather minor spine trauma (hyperextension injury) based on underlying cervical spondylosis. The pathophysiological mechanisms inducing the TCCS are probably multimodal. One hypothesis is that a spinal cord compression occurs between bony spurs anteriorly and buckling of the ligamentum flavum posteriorly.[1,11] This cord compression may cause

Correspondence: Dr MH Pouw, Department of Orthopedic Surgery, Radboud University Nijmegen Medical Centre, Postbox 9101, Nijmegen 6500 HB, The Netherlands.
E-mail: Martinpouw@yahoo.com
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direct damage of neural structures located in the central gray matter and/or attenuation of the segmental blood supply. These mechanisms affect the cervical enlargement at the levels of the alpha motor neurons supplying predominantly hand muscles and to a lesser extent fibers of the corticospinal tracts (CSTs). Such a pattern of injury that spares the descending CSTs but damages the alpha motor neurons is assumed to result in a syndrome of disproportionate arm and leg weakness.[12] An alternative hypothesis is that the TCCS results from an injury to the CSTs. The CST tends to produce relatively greater dysfunction in the hand and arms than in the legs, as the main function of the CST is to support fine motor movements in the distal musculature, especially of the upper limbs.[13,14]

Since the introduction of the TCCS diagnostic criteria more than five decades ago, it has been one of the most frequently cited definitions of an incomplete SCI syndrome.[3] However, the TCCS lacks uniform and broadly accepted diagnostic criteria. In other words, the diagnosis of TCCS is based on non-specific criteria and interpretation of physical examination. Therefore, the utility of currently applied TCCS diagnostic criteria can be considered as limited.

The primary objective of this review was to investigate the current literature on applied TCCS diagnostic criteria. The secondary objective was to analyze the quantitative differences between the total upper extremity motor score (UEMS) and the total lower extremity motor score (LEMS) described in these original studies.

Methods

Retrieval of publications

All clinical studies reporting on TCCS were eligible for this review. Case reports were excluded in this review. A MEDLINE (PubMed interface) search was performed to compile a reference list of articles published between 1966 and November 2008 identified by the following keywords: SCI, central cord syndrome, cruciate paralysis, incomplete SCI, spinal cord syndromes, ASIA motor score, LEMS, UEMS, and cervical spondylosis. Furthermore, the retrieved list of references was manually checked for additional studies potentially meeting the inclusion criteria.

Analysis of applied TCCS diagnostic criteria

All retrieved original studies reporting on TCCS patients, irrespective of whether the total UEMS and LEMS were reported, were analyzed with regard to the TCCS diagnostic criteria applied. All descriptors used to define the TCCS were extracted from the included articles.

Analysis of scores

To calculate the mean difference between the total UEMS and total LEMS, we included only original studies that reported on the total UEMS and total LEMS (based on the Medical Research Council scale), for a minimum of five TCCS patients, on their admission to the hospital. Each study's reported difference between the total UEMS and LEMS in TCCS patients was recorded to identify which difference in motor loss the authors regarded as a 'disproportionate impairment of the upper limbs as compared with the lower limbs.' To calculate these 'disproportionate' differences, the mean differences between the total UEMS and LEMS were multiplied by the number of patients reported in each study. These numbers were added and divided by the total number of pooled patients.

Results

Out of 177 articles from MEDLINE identified by the predefined keywords, only 30 studies could be accepted after accounting for the inclusion/exclusion criteria. In these 30 articles, seven different clinical descriptors were provided that have been applied as criteria to diagnose TCCS (Table 1).

As the UEMS and LEMS were not reported in TCCS patients, 21 studies,[1-4,7-9,14,18-20,22–24,27–33] were excluded in the analysis of the scores. Out of the 30 retrieved studies, nine studies[5,6,10,15–17,21,25,26] that reported the UEMS and LEMS at admission were included in our analysis. In two articles,[6,21] a scatter diagram[6] and a bar graph[21] were used to determine the UEMS and LEMS. An overview of the studies included for analysis is shown in Table 2. Furthermore, no

Table 1 Details of the TCCS diagnostic criteria applied in of 30 retrieved articles

Diagnostic criteria	*Number of articles included for analysis*	*Number of articles excluded from analysis*
Disproportionate weakness of the UE compared with the LE, variable sensory loss, and bladder dysfunction	3[15–17]	5[1,7,18–20]
Disproportionate weakness of the UE compared with the LE, variable sensory loss, bladder dysfunction and associated with sacral sparing	1[21]	0
Disproportionate weakness of the UE compared with the LE and associated with sacral sparing	1[5]	1[22]
Greater weakness of the UE than the LE and associated with sacral sparing	0	2[3,23]
Greater weakness of the UE than the LE	1[10]	3[9,14,24]
Symmetric motor impairment of the UE without motor weakness in the LE and associated with sacral sparing	1[6]	0
Symmetric incomplete tetraplegia	0	1[8]
None given	2[25,26]	9[2,4,27–33]
Total	9	21

Abbreviations: TCCS, traumatic central cord syndrome; UE, upper extremities; LE, lower extremities.

Table 2 Studies included for analysis

Author	*Details of study (sub) groups*	*Design*	*Average ASIA motor score at admission*	*Difference between LEMS and UEMS*
Tow *et al.*[10]	73 Patients	Retrospective study	UEMS 22.8 LEMS 31.8	9 Motor points
Newey *et al.*[21]	32 Patients	Retrospective study	UEMS 18 LEMS 33.9	15.9 Motor points
Collignon *et al.*[15]	18 Patients	Retrospective study	UEMS 32 LEMS 42.3	10.3 Motor points
Guest *et al.*[16]	50 Patients	Retrospective study	UEMS 24.8 LEMS 34.9	10.1 Motor points
Ishida *et al.*[6]	22 Patients	Prospective study	UEMS 32.2 LEMS 50	17.8 Motor points
Dvorak *et al.*[5]	70 Patients	Retrospective review with cross-sectional outcome analysis	UEMS 25.9 LEMS 32.7	6.8 Motor points
Song *et al.*[25]	23 Patients	Retrospective study	UEMS 29.3 LEMS 42.7	13.4 Motor points
Miranda *et al.*[17]	15 Patients	Retrospective study	UEMS 32.6 LEMS 41.2	8.6 Motor points
Waters *et al.*[26]	9 Patients	Retrospective study	UEMS 7.3 LEMS 18.4	11.1 Motor points

Abbreviations: UEMS, upper extremity motor score; LEMS, lower extremity motor score.

study on TCCS patients was identified that reported inclusion and/or exclusion criteria using a quantified difference between the UEMS and LEMS.

Differences in motor scores between the upper and lower extremities

Guest *et al.*[16] investigated the neurological outcome in 50 patients who underwent early ($\leqslant$24 h after injury) or late ($>$24 h after injury) surgery. The preoperative mean difference between the UEMS and LEMS of these 50 patients was 10.1 motor points. Another retrospective study[21] reported on the long-term outcome in 32 conservatively treated patients with symptoms consistent with the TCCS. Patients were divided by age into three groups. In this study, the mean difference between the UEMS and LEMS of these three groups was 15.9 motor points.[21] Tow and Kong[10] reported the UEMS and LEMS at admission in patients who were identified to have greater weakness of the upper than the lower extremities. In 73 TCCS patients, a mean difference of nine motor points was identified. Another retrospective study[5] assessed the improvement in ASIA motor score in 70 TCCS patients. This study[5] identified a mean difference between the UEMS and LEMS of 6.8 motor points. Waters *et al.*[26] identified a mean difference between the UEMS and LEMS of 11.1 motor points in a prospective study reporting on nine patients with TCCS. The study by Ishida and Tominaga[6] examined neurological recovery in 22 TCCS patients. Only patients with an LEMS of 50 were included. The mean difference between the UEMS and LEMS in this study was 17.8 motor points.

Three studies[15,17,25] evaluated the radiological findings in TCCS patients. In 15 patients, Miranda *et al.*[17] identified a mean difference between the UEMS and LEMS of 8.6 motor points. Collignon *et al.*[15] performed a retrospective study of 18 TCCS patients to assess the presence of intramedullary blood in the spinal cord. The mean difference identified between the UEMS and LEMS was 10.3 motor points. Another study[25] evaluated the value of radiological findings in 23 TCCS patients. We identified a mean difference between the UEMS and LEMS of 13.4 motor points.

Analysis

We calculated the mean difference between the total UEMS and total LEMS for the nine studies[5,6,10,15–17,21,25,26] depicted in Table 2. This analysis showed that in 312 TCCS patients, the mean total UEMS was 10.5 (range, 6.8–17.8) motor points lower than the mean total LEMS.

Discussion

In this review, seven different descriptors to define the TCCS were identified among 30 retrieved articles. Furthermore, no study on TCCS patients reported inclusion and/or exclusion criteria regarding a quantified difference between the UEMS and LEMS. Our analysis showed that out of the 312 pooled subjects with TCCS, the mean total UEMS was $\sim$10 motor points lower than the mean total LEMS.

The currently applied TCCS diagnostic criteria can be interpreted broadly, so that patients with incomplete tetraplegia are diagnosed with TCCS and vice versa. As quantified, diagnostic criteria for TCCS are lacking, and the incidence of TCCS can be expected to increase in SCI patients older than 60 years.[34] Thus, it is necessary to define not only univocal TCCS diagnostic criteria, but also a quantified difference between the UEMS and LEMS.

Quantifying the term 'disproportionate' to a specific minimum of motor points could lead to a more adequate

and reliable TCCS diagnosis. In addition, TCCS diagnostic criteria would also be valuable for research purposes. If quantified TCCS diagnostic criteria are applied, investigators would be able to stratify and constrain the heterogeneity of SCI patient samples. This is important, as TCCS patients probably have a favorable recovery pattern compared with incomplete tetraplegia.[2–10] In future SCI trials, analyzing outcome data for TCCS patients as a separate group could be important for a more sensitive detection of treatment effects.

Although Schneider *et al*.[1] reported bladder dysfunction to be a characteristic of TCCS, the International Standards for Neurological and Functional Classification of Spinal Cord Injury Patients[35] did not include the presence of bladder dysfunction as a diagnostic criterion for TCCS. Therefore, the analysis of the scores in our review has been focused on the difference between the total UEMS and the total LEMS.

As a 'disproportionate' weakness of the arms with better (or normal) strength in the legs can occur in both TCCS and cruciate paralysis,[36,37] we also searched for articles in which patients with cruciate paralysis were described. Cruciate paralysis is characterized by an isolated injury to the cervicomedullary junction that results in paralysis of the arms with minimal or absent lower extremity involvement.[37,38] The pathophysiology is based on neuroanatomy: the motor tract of the upper extremities crosses rostrally in the cervicomedullary junction, whereas that of the lower extremities crosses caudally in the superior cervical spinal cord.[37,39,40] Despite the fact that TCCS and cruciate paralysis have been reported separately in the literature, it is suggested that both syndromes are expressions of the same mechanism rather than two separate entities based on damage to the pyramidal crossing arm fibers.[40] As the clinical presentations of TCCS and cruciate paralysis are comparable, and we were only interested in the quantitative details of the difference between the upper and lower extremity motor scores, TCCS and cruciate paralysis were grouped in our analysis.[36]

In one of our earlier studies,[41] we decided to define TCCS as a total LEMS of 10 or more points higher than the total UEMS. Although no study was identified that reported inclusion and/or exclusion criteria using a quantified difference between the UEMS and LEMS, Hayes *et al*.[23] described an approach to classify patients with incomplete SCI according to SCI syndromes. In this study,[23] the choice was made to diagnose TCCS based on a total LEMS of five or more points higher than the total UEMS. However, both proposals were arbitrary and had not been validated earlier.[23,41]

Conclusion

To our knowledge, no study on TCCS patients reported inclusion and/or exclusion criteria using a quantified difference between the UEMS and LEMS. In addition, seven different clinical descriptors were identified that have been applied as criteria to diagnose TCCS. This study is a first attempt to provide a quantified approach to determine whether an incomplete SCI can be labeled as TCCS. Our analysis showed that out of the 312 pooled subjects with TCCS, the mean total UEMS was ~10 motor points lower than the mean total LEMS.

Further discussion by an expert panel will be required to establish definitive diagnostic criteria for TCCS.

Conflict of interest

The authors declare no conflict of interest.

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