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ORIGINAL RESEARCH

Detection and Interpretation of Impossible and Improbable Coma Recovery Scale-Revised Scores

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Abstract

Objective: To determine the frequency with which specific Coma Recovery Scale-Revised (CRS-R) subscale scores co-occur as a means of providing clinicians and researchers with an empirical method of assessing CRS-R data quality.

Design: We retrospectively analyzed CRS-R subscale scores in hospital inpatients diagnosed with disorders of consciousness (DOCs) to identify impossible and improbable subscore combinations as a means of detecting inaccurate and unusual scores. Impossible subscore combinations were based on violations of CRS-R scoring guidelines. To determine improbable subscore combinations, we relied on the Mahalanobis distance, which detects outliers within a distribution of scores. Subscore pairs that were not observed at all in the database (ie, frequency of occurrence = 0%) were also considered improbable.

Setting: Specialized DOC program and university hospital.

Participants: Patients diagnosed with DOCs (N = 1190; coma: n = 76, vegetative state: n = 464, minimally conscious state: n = 586, emerged from minimally conscious state: n = 64; 794 men; mean age, 43±20y; traumatic etiology: n = 747; time postinjury, 162±568d).

Interventions: Not applicable.

Main Outcome Measure: Impossible and improbable CRS-R subscore combinations.

Results: Of the 1190 CRS-R profiles analyzed, 4.7% were excluded because they met scoring criteria for impossible co-occurrence. Among the 1137 remaining profiles, 12.2% (41/336) of possible subscore combinations were classified as improbable.

Conclusions: Clinicians and researchers should take steps to ensure the accuracy of CRS-R scores. To minimize the risk of diagnostic error and erroneous research findings, we have identified 9 impossible and 36 improbable CRS-R subscore combinations. The presence of any one of these subscore combinations should trigger additional data quality review.

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Patients surviving severe injury to the brain may remain in a coma for up to several weeks before transitioning into either a vegetative state (VS) (also coined unresponsive wakefulness syndrome[1]) or a minimally conscious state (MCS). Individuals in a VS show periods of wakefulness of varying duration but do not demonstrate any behavioral signs of consciousness.[2] An MCS is a severely altered state of consciousness in which the person demonstrates minimal but definite behavioral evidence of comprehension of simple commands, intelligible verbalizations, gestural or verbal yes-no

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responses, object manipulation, or nonreflexive behaviors that occur in contingent relation to specific environmental stimuli (eg, visual pursuit).[3] Emerged from minimally conscious state (EMCS) is marked by the reemergence of a reliable yes-no communication system and/or functional object use.[3] Detecting behavioral signs of awareness and differentiating between these disorders of consciousness (DOCs) can be challenging and has led to the development of standardized approaches to diagnostic assessment.[4,5] The Coma Recovery Scale-Revised (CRS-R)[6] has strong evidence of reliability and validity for assessment of patients with DOCs, based on a recent systematic review completed by the American Congress of Rehabilitation Medicine.[7]

The CRS-R consists of 23 hierarchically organized items parcellated into 6 subscales designed to interrogate functional brain networks responsible for mediating auditory, visual, motor, language, and arousal functions. Weighted scores are assigned to reflect the presence or absence of specific behaviors, ranging from brain stem reflexes to those that are cognitively mediated (table 1). All assessment procedures and scoring criteria are operationally defined, and the diagnostic criteria for coma, VS, MCS, and EMCS are embedded within the scale. The total score can be used to gauge the general trajectory of recovery over time because higher scores reflect progressively increasing levels of neurobehavioral function.[8]

The hierarchical framework of the items included in the CRS-R is supported by psychometric studies demonstrating the properties of unidimensionality (ie, all items on the scale are related to a single underlying construct), monotonicity (ie, as the total score increases, the score on any single item increases or remains stable), mutual independence (ie, the only source of correlation between $\geq$2 subscales is the underlying construct measured by the scale as a whole), and invariant item ordering (ie, for any given ability level, the order of difficulty of items remains the same).[9,10]

In view of the broad use of the CRS-R in research and clinical practice, we were interested in developing an empirical approach to data quality analysis. More specifically, our objective was to develop a methodology that could be used to alert the examiner to erroneous or unusual scores. Based on the previously described psychometric characteristics of the CRS-R, the probability of receiving a specific score on a given subscale should be largely related to the scores received on the other subscales. Therefore, establishing the incidence of specific subscale score combinations may serve to identify rare subscore combinations that could indicate an invalid assessment because of use of improper administration or scoring procedures. Alternatively, improbable subscore combinations may signal the presence of an underlying functional impairment, which may have diagnostic relevance. For example, a very low score on the auditory subscale coupled with a high score on the motor subscale raises the possibility of an underlying aphasia or impairment in auditory processing. Detection of highly improbable subscore combinations can serve as a red flag, triggering the need for further investigation.

The primary aim of this retrospective study was to determine the probability with which specific CRS-R subscale score combinations occur as a means to establish an empirical method of data quality analysis. We hypothesized that subscore combinations that fail to respect the hierarchical structure of the scale (eg, scores that concurrently fall at the floor and ceiling of 2 different subscales) will have a low probability of occurrence. We also identified a list of impossible subscore combinations (ie, scores that in combination violate the standardized scoring procedures of the CRS-R). For example, object recognition on the visual subscale cannot co-occur with auditory localization on the auditory subscale. The presence of object recognition requires command following; however, scoring auditory localization as the best response on the auditory subscale implies the absence of command following.

Table 1 Coma Recovery Scale-Revised

Score	Test
Auditory function scale	
4	Consistent movement to command*
3	Reproducible movement to command*
2	Localization to sound
1	Auditory startle
0	None
Visual function scale	
5	Object recognition*
4	Object localization: reaching*
3	Visual pursuit*
2	Fixation*
1	Visual startle
0	None
Motor function scale	
6	Functional object use†
5	Automatic motor response*
4	Object manipulation*
3	Localization to noxious stimulation*
2	Flexion withdrawal
1	Abnormal posturing
0	None/flaccid
Oromotor/verbal function scale	
3	Intelligible verbalization*
2	Vocalization/oral movement
1	Oral reflexive movement
0	None
Communication scale	
2	Functional: accurate†
1	Nonfunctional: intentional*
0	None
Arousal scale	
3	Attention
2	Eye opening without stimulation
1	Eye opening with stimulation
0	Unarousable

* Indicates a minimally conscious state.
† Indicates emergence from the minimally conscious state.

List of abbreviations:

CRS-R **Coma Recovery Scale-Revised**
DOC **disorder of consciousness**
EMCS **emerged from minimally conscious state**
MCS **minimally conscious state**
VS **vegetative state**

Methods

Demographic data and CRS-R scores were retrospectively obtained from the databases of 2 specialized inpatient rehabilitation