HHS Public Access

Author manuscript

Semin Neurol. Author manuscript; available in PMC 2024 November 01.

Published in final edited form as:

Semin Neurol. 2022 June ; 42(3): 249–258. doi:10.1055/s-0042-1756298.

Behavioral Assessment of Patients with Disorders of Consciousness

Yelena G. Bodien, PhD[1,2], **Douglas I. Katz, MD**[3,4], **Nicholas D. Schiff, MD**[5,6], **Joseph T. Giacino, PhD**[2]

[1]Center for Neurotechnology and Neurorecovery, Department of Neurology, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts

[2]Department of Physical Medicine and Rehabilitation, Spaulding Rehabilitation Hospital, Harvard Medical School, Charlestown, Massachusetts

[3]Department of Neurology, Boston University School of Medicine, Boston, Massachusetts

[4]Brain Injury Program, Encompass Health Braintree Rehabilitation Hospital, Braintree, Massachusetts

[5]Feil Family Brain and Mind Institute, Weill Cornell Medicine, New York, New York

[6]Department of Neurology, Weill Cornell Brain and Spine Institute, Weill Cornell Medicine, New York, NY, United States

Abstract

Severe brain injury is associated with a period of impaired level of consciousness that can last from days to months and results in chronic impairment. Systematic assessment of level of function in patients with disorders of consciousness (DoC) is critical for diagnosis, prognostication, and evaluation of treatment efficacy. Approximately 40% of patients who are thought to be unconscious based on clinical bedside behavioral assessment demonstrate some signs of consciousness on standardized behavioral assessment. This finding, in addition to a growing body of literature demonstrating the advantages of standardized behavioral assessment of DoC, has led multiple professional societies and clinical guidelines to recommend standardized assessment over routine clinical evaluation of consciousness. Nevertheless, even standardized assessment is susceptible to biases and misdiagnosis, and examiners should consider factors, such as fluctuating arousal and aphasia, that may confound evaluation. We review approaches to behavioral assessment of consciousness, recent clinical guideline recommendations for use of specific measures to evaluate patients with DoC, and strategies for mitigating common biases that may confound the examination.

Keywords

brain injury; coma; consciousness; assessment

Address for correspondence Yelena G. Bodien, PhD, Center for Neurotechnology and Neurorecovery, Massachusetts General Hospital, 101 Merrimac Street – Suite 310, Boston, MA 02114 (ybodien@mgh.harvard.edu).

Behavioral Assessment of Consciousness

Recovery from severe brain injury often follows a trajectory[1] that includes: (1) emergence from coma into a vegetative state (VS;[2] also known as unresponsive wakefulness syndrome [UWS][3]), followed by (2) a minimally conscious state *minus* (MCS −), (3) MCS *plus* (MCS +), and finally, (4) emergence from MCS (eMCS). VS/UWS is characterized by spontaneous eye-opening and no signs of conscious awareness. Patients in MCS demonstrate inconsistent but convincing evidence of purposeful behaviors, either without (MCS −) or with (MCS +)[4,5] some preservation of language function. Finally, eMCS, which is generally consistent with an acute confusional state,[6] and has been termed post-traumatic confusional state (PTCS)[7] in patients with traumatic brain injury (TBI), is marked by functional use of common objects or reliable, basic yes/no communication.[4] The behaviors distinguishing VS/UWS from MCS and MCS from eMCS were established in 2002,[4] although revisions to the criteria for eMCS have been recently proposed.[8–10,90]

Historically, assessment of consciousness, and thus the diagnostic characterization of disorders of consciousness (DoC), has relied almost exclusively on bedside neurological examinations. However, due to biases introduced by examiner error (e.g., failing to assess a broad range of behaviors, over-/under-interpretation of observations) and patient-related factors (e.g., fluctuating arousal, motor deficits, language deficits, pain, sensory impairments, sedating medications), the bedside clinical examination can be an unreliable marker of level of consciousness. Indeed, the approximate rate of misdiagnosing a patient with at least minimal consciousness (MCS) as unconscious (VS/UWS) on routine clinical examination is 40%.[11–15] This alarming rate of misdiagnosis may affect critical clinical decisions, lead to premature withdrawal of life-sustaining treatment, and restrict access to rehabilitation services.

In the past 3 years, clinical guidelines published in the United States,[16] Europe,[17] and United Kingdom[18] have all strongly recommended the use of specialized, standardized measures for assessment of DoC. Developed through a collaboration of the American Academy of Neurology (AAN), the American Congress of Rehabilitation Medicine (ACRM), and the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR), the 2018 practice guideline recommendations for DoC state that clinicians should use serial, standardized neurobehavioral assessment measures that have been shown to be valid and reliable that, to improve diagnostic accuracy, clinicians should use serial, standerdized.[16] The European Academy of Neurology (EAN) guidelines published in 2020 alsosupport useofa standardized behavioral assessment of DoC,[17] as do the 2020 Royal College of Physicians guidelines.[18] An ACRM and NIDILRR position statement on the minimum competency recommendations for rehabilitation programs that provide services for individuals diagnosed with DoC includes repeated diagnostic assessment with a standardized and validated tool.[19] However, even standardized behavioral evaluation is susceptible to biases and confounders that may affect diagnostic assessment, and examiners should ensure that testing conditions are optimized to promote maximal responsiveness. Table 1 lists strategies that can increase the reliability and validity of clinical examinations of persons with DoC and improve the accuracy of diagnosis.

Standardized Scales for Assessment of DoC

Use of a standardized assessment of DoC may reduce diagnostic error, improve the accuracy of prognostication, and enable monitoring of recovery and response to interventions. Systematic and standardized evaluation of level of consciousness ensures consistency within and across examiners in how subtle behaviors are assessed and documented. When compared with qualitative bedside examination, the increased reliability associated with the use of standardized tools adds confidence that behavioral observations represent the patient's true level of function rather than artifacts caused by variations in clinical examination techniques. Standardized assessment also facilitates clear communication across clinical teams and with caregivers. Although multiple tools for assessing DoC are available, not all have equally robust psychometric properties. Among 13 behavioral scales reviewed by ACRM in 2010, 7 were recommended, with some variation in level of confidence, for patients with DoC. However, only the Coma Recovery Scale-Revised (CRS-R)[20] was recommended with minor reservations for both clinical and research applications (Table 2).[21] The National Institutes of Neurological Disorders and Stroke (NINDS) includes the CRS-R as a Common Data Element (CDE), strongly encouraging its use in studies enrolling persons with DoC.[22] Importantly, the CRS-R was the "reference-standard" behavioral assessment tool that revealed evidence of consciousness (i.e., MCS) in the approximately 40% of patients who were misdiagnosed as VS/UWS in the aforementioned study.[11] All three recently published clinical guidelines recommend the CRS-R above or in addition to other behavioral assessments.[16–18]

The CRS-R (Table 3) is a 23-item rating scale composed of six subscales that assess behaviors mediated by language, visuoperceptual, and motor networks.[6] The items are hierarchically arranged reflecting brainstem, subcortical, and cortically mediated functions.[23,24] Importantly, the diagnostic criteria for VS/UWS, MCS − , MCS + , and eMCS are embedded into the CRS-R profile, enabling differentiation of these states. The CRS-R total score ranges from 0 to 23 and, although scores of 10 or greater indicate MCS or eMCS, individual subscale scores provide a more precise diagnostic classification.[25] Serial CRS-R assessment has high sensitivity for detecting signs of consciousness,[26] and the CRS-R diagnosis, total score, and rate of change may assist with prediction of subsequent functional outcome.[27–29] The CRS-R meets minimum standards for measurement and evaluation tools as well as criteria as an interval scale, which allows for both intra-individual and between-patient comparisons.[23]

The CRS-R assessment manual, recommended training, and ancillary materials were updated in 2020 and are available online at: https://www.sralab.org/rehabilitation-measures/coma-recovery-scale-revised.

Extensions and adaptations of the CRS-R have expanded its use globally and to special populations and clinical questions. The CRS-R has been translated and validated in Spanish,[30] Italian,[31–33] French,[34] Portuguese,[35] Norwegian,[36] Russian,[37] German,[38] Polish,[39] Korean,[40] and Chinese[41,42] with validated versions forthcoming in Japanese, Hebrew and Brazilian Portuguese. The CRS-R is also available in Dutch, Swedish, Danish, and Greek, but has not been validated in these languages.[43] A pediatric version, the

Coma Recovery Scale for Pediatrics, was validated in healthy subjects to determine which behaviors should be assessed in children with DoC who are at different developmental milestones.[44] The Motor Behavior Tool, which was developed to complement the CRS-R, identifies subtle motor behaviors that may identify residual cognition,[45] signaling the potential for recovery in persons with DoC. The Nociception Coma Scale and its revised version were specifically developed to assess pain perception in patients with VS/UWS and MCS.[46] Additional scales that complement the CRS-R but focus specifically on language assessment[47] and swallowing[48] have also been recently developed. Alternate CRS-R scoring criteria have been proposed to improve the utility of the total score for differentiating VS/UWS from MCS,[49,50] and a new measure, the Brain Injury Functional Outcome Measure,[51] which expands the floor and ceiling of the Functional Independence Measure instrument (FIM),[52] incorporates multiple CRS-R subscales.

Individuals who transition to eMCS typically demonstrate clinical features consistent with a confusional state or PTCS, including disorientation, impairment in attention and memory, behavioral dysregulation, disturbance in sleep–wake cycles, and fluctuation in the severity of these symptoms.[6,7] Although no currently available behavioral scales assess all symptoms of the confusional state, the Confusion Assessment Protocol (CAP), a composite measure of cognitive assessments and clinical signs, captures most aspects of the recently published PTCS case definition.[53] The CAP may therefore be used to fill the assessment gap for patients who are able to respond to basic yes/no questions, indicating eMCS, but are still in a confusional state and unable to participate in a full neuropsychological assessment.

The use of standardized scales for assessment of patients with DoC is most common in the rehabilitation setting and in clinical trials. In the intensive care unit (ICU), the preferred approach to assessment is the Glasgow Coma Scale (GCS)[54] which, developed in the 1970s, was the first attempt to measure "depth of coma" and track recovery. The GCS is simple to administer, takes only a few minutes, and has been adopted internationally for both diagnostic and prognostic[55] applications in prehospital, emergency department, and ICU settings. The GCS is a core TBI CDE[22,56] and is used in clinical trials both as a criterion for subject inclusion and as an approach for subject stratification.[57] Despite its widespread use, the psychometric strength of the GCS is moderate,[58,59] which may be attributed to the lack of standardized procedures for administration and scoring (though new online materials provide some additional guidance; https://www.glasgowcomascale.org). The GCS was also not designed to provide a DoC diagnosis and therefore multiple behaviors that differentiate between MCS and VS/UWS are not assessed (e.g., visual pursuit, which, along with localization of noxious stimulation, is an early indicator of emerging consciousness[60]). Furthermore, most GCS total scores represent a wide range of potential DoC diagnoses, suggesting that the total score is not an adequate proxy for level of consciosuess.[61]

The Full Outline of UnResponsiveness (FOUR) score was developed to address some of the limitations inherent to the GCS and replaces the GCS verbal subscale, which is often untestable due to intubation, with an assessment of respiratory patterns and brainstem reflexes.[62,63] A systematic review published in 2019 found that both the GCS and FOUR score predicted in-hospital mortality and 3-month outcome with similar accuracy, but that the brainstem and respiratory subscales of the FOUR had lower accuracy as compared with the visual and motor subscales.[64] Like the GCS, the FOUR score does not assess all behaviors that differentiate between MCS and VS/UWS and is not rigorously standardized.[21,65] A comparison between the CRS-R, GCS, and FOUR score is provided in Table 4.

In contrast to the GCS, the CRS-R is standardized, has strong psychometric properties, and differentiates between DoC diagnoses, but the duration of the assessment, approximately 25 to 45 minutes, may be too lengthy for some patients in the ICU setting who can only tolerate a few minutes of sedation-free behavioral assessment. Accurate assessment of level of consciousness is arguably most critical in the ICU because the behavioral exam serves as the primary proxy for brain function and recovery potential, and is therefore a driving factor in decisions around continuing or withdrawing life-sustaining therapies.[66,67] Moreover, access to rehabilitation services hinges on the ability to participate in therapy and on the trajectory of improvement, both derived from the behavioral exam. Abbreviated, standardized, and validated assessments of consciousness that account for common acute care confounding factors are needed to improve early diagnostic and prognostic precision. The SECONDs score was developed as an abbreviated standardized assessment of consciousness[68] and a rapid version of the CRS-R (CRS-R for Accelerated Standardized Assessment [CRSR-FAST], clinicaltrails.gov NCT03549572) is being developed specifically for use in the ICU.

Individualized Quantitative Behavioral Assessment

When questions arise regarding individual behaviors−for example, the volitional nature of low-frequency, simple movements−even standardized measures that rigorously prescribe all aspects of an assessment, including approach to eliciting responses, number of trials, inter-trial interval, and other parameters, may not be sufficient to distinguish purposeful from random, spontaneous behaviors. Individualized Quantitative Behavioral Assessments (IQBAs) are customized protocols based on principles of single-subject research design that assess the cognitive and behavioral capacities of individuals with marked limitations in responsiveness.[69,70] In this technique, focused clinical questions are probed using a personalized behavioral protocol that operationally defines stimuli and response criteria, and statistically analyzes response frequency to determine whether a behavior of interest occurs more often than chance or more often under specific conditions compared with others. For example, if the CRS-R cannot differentiate between random movement and purposeful low-frequency movement to command, an IQBA can be designed to quantify whether the movement is more likely to occur to a command rather than spontaneously. A finger movement observed on two of four trials immediately after the command to “move your fingers” raises the possibility of verbal comprehension. However, if finger movement fails to occur during the next 20 trials administered, the probability that the two initial responses represented evidence of verbal comprehension is diminished. Conversely, a patient may move his or her fingers following command on 10 consecutive trials, but if the same finger movement also precedes the command or persists well after the last command is administered, it is less likely that this response is an indication of verbal comprehension. IQBA addresses these problems by creating a standardized protocol to assess finger movement with different commands presented in random order (e.g., “give me a thumbs up,” “move your toe,” “hold still”), during multiple sessions on different days over time, to establish a statistical likelihood that the movement is under volitional control. This approach has been successfully applied to command-following, visual attention to stimuli of varying salience (e.g., a photograph vs. a white card), accuracy of yes/no responses, and other behaviors.[69,70]

Standardized and individualized procedures are complementary as they serve different purposes. Standardized methods provide a broad overview of the integrity of sensory, motor, and cognitive processes. These findings can help establish diagnosis, prognosis and lesion locus, and may inform the optimal approach to treatment. Moreover, standardized measures are necessary for clinical trials that rely on a systematic and harmonized approach to assessment of all participants. Conversely, the flexibility offered by IQBA provides an opportunity to assess case-specific influences on behavior which may contribute to diagnostic inaccuracy and erroneous judgments concerning consciousness. IQBA may also supplement standardized scales in providing additional quantitative evidence of change, such as number of correct behavioral responses over serial sessions.

Test Completion Codes

As outlined in Table 1, standardized assessment of patients with DoC may be influenced by a variety of factors that affect the accuracy of an evaluation. In addition to these factors, there may be overt threats to assessment validity that result in failure to complete a measure or a completed, but invalid measure. For example, if cortical blindness is suspected, an examiner may choose not to administer portions of a measure that require intact basic visual function due to the high likelihood of an inaccurate result. Alternatively, if sedation is being weaned to support a behavioral assessment, it may become apparent that items administered at the beginning of the assessment were confounded by residual effects of the sedation (e.g., if there is gradual increasing responsiveness throughout an assessment independent of exam procedures aimed at increasing arousal). Given the heavy reliance of most behavioral assessments on language function, aphasia would also compromise assessment of consciousness.[71,72] Under these circumstances, it is important to consider using a tool designed for assessing patients with suspected aphasia,[47] avoid scoring items that may be confounded by language impairment, and to record, in a systematic way, reasons an assessment could not be completed. One approach to documenting test interference is to apply a Test Completion Code (TCC) each time an assessment is planned, to indicate that the test was completed and valid, attempted but not completed, or completed but not valid. TCCs may provide additional information about a patient's level of function and assure that missing test scores are not interpreted inaccurately as scores at the floor of the assessment. A list of suggested TCCs for the CRS-R is provided in Table 5.

Discussion

In the absence of a ground-truth index of consciousness, behavioral evaluation remains the recommended approach for establishing level of consciousness after severe brain injury. However, routine clinical testing aimed at detecting preserved or recovered brain function is mired by methodological limitations. When the process for eliciting behaviors and interpreting responses varies among examiners, it is not possible to disambiguate change in level of function from inconsistencies in assessment methodology. Furthermore, there are differences in how observers of the same behaviors interpret and document responses. Standardizing assessment of level of consciousness reduces the variability of the evaluation procedure and the ambiguity in the interpretation and documentation of behavioral responses. When conducted systematically and serially,[26] standardized assessments minimize examiner biases and maximize the opportunity for detecting a patient's highest level of function.

However, even measures such as the CRS-R, which provides precise instructions for item administration and scoring, are susceptible to biases and may miss or misattribute subtle signs of awareness. IQBA is a complementary approach to diagnostic assessment that provides additional insight into the volitional nature of subtle or infrequent behaviors. Studies conducted over the past 15 years have shown that task-based functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) detect covert command-following in some patients who are unable to follow commands at the bedside.[15,73–76] Termed covert consciousness or cognitive-motor dissociation,[77] the presence of this phenomenon may be a prognostic marker of further recovery.[73] Although not reflective of diagnosis, fMRI and EEG responses to passive stimuli (i.e., covert cortical processing)[75,78,79] or the presence of intact resting-state networks[80,81] may also suggest the potential for recovery of consciousness. The AAN-ACRM-NIDILRR guidelines recommend supplementing the behavioral examination with multimodal assessment when the behavioral examination remains ambiguous or when confounding factors may interfere with the ability to follow commands behaviorally.[16] The EAN guidelines recommend task-based, stimulus-based, and resting-state multimodal assessment for all patients with DoC.[18] It is important to note, however, that many patients diagnosed with MCS on standardized assessment do not show evidence of command-following on fMRI[28,74,76] or EEG,[15,74] and thus these approaches are complimentary and not intended to be used in isolation. Efforts to expand implementation of these techniques outside of major academic centers and establish reimbursement procedures to integrate advanced fMRI and EEG into clinical practice are ongoing.[82]

In summary, repeated, standardized behavioral assessment is the most reliable and valid approach to evaluating patients with DoC. However, examiners should be cognizant of the limitations inherent in behavioral assessment and should consider strategies to mitigate biases and confounders. Developing brief standardized assessment measures to detect conscious awareness in the ICU setting is an active area of research and is needed to improve diagnostic and prognostic precision, as well as to establish a common language among clinicians, with families, and across care settings.

Acknowledgments

Y. G. Bodien reports funding from: NIH National Institute of Neurological Disorders and Stroke (U01 NS1365885, U01-NS086090), National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR), Administration for Community Living (90DPCP0008–01–00, 90DP0039), James S. McDonnell Foundation, and Tiny Blue Dot Foundation; N. D. Schiff reports funding from: NIH National Institute of Neurological Disorders and Stroke and the James S. McDonnell Foundation; J. T. Giacino reports funding from: NIH National Institute of Neurological Disorders and Stroke (U01-NS086090, UH3NS095554), U.S. Department of Defense (W81XWH-14–2-0176), NIDILRR, Administration for Community Living (90DPCP0008–01–00, 90DP0039), and the Epstein

Foundation; D. I. Katz receives royalties from a text on Brain Injury (Demos Medical/Springer) and reports funding from NINDS (1U01NS093334–01 and U54NS115266).

Funding

Epstein Foundation, James S. McDonnell Foundation, U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Neurological Disorders and Stroke, U01 NS1365885, National Institute of Neurological Disorders and Stroke, U01-NS086090, National Institute of Neurological Disorders and Stroke, 1U01NS093334-01, National Institute of Neurological Disorders and Stroke, U54N, National Institute on Disability, Independent Living, and Rehabilitation Research, 90DPCP0008-01-00, National Institute on Disability, Independent Living, and Rehabilitation Research, 90DP0039, Tiny Blue Dot Foundation, U.S. Department of Defense, W81XWH-14-2-0176.

References

1. Katz DI, Polyak M, Coughlan D, Nichols M, Roche A. Natural history of recovery from brain injury after prolonged disorders of consciousness: outcome of patients admitted to inpatient rehabilitation with 1–4 year follow-up. Prog Brain Res 2009;177:73–88 [PubMed: 19818896]
2. Giacino JT. Disorders of consciousness: differential diagnosis and neuropathologic features. Semin Neurol 1997;17(02):105–111 [PubMed: 9195652]
3. Laureys S, Celesia GG, Cohadon F, et al. l; European Task Force on Disorders of Consciousness. Unresponsive wakefulness syndrome: a new name for the vegetative state or apallic syndrome. BMC Med 2010;8:68 [PubMed: 21040571]
4. Giacino JT, Ashwal S, Childs N, et al. The minimally conscious state: definition and diagnostic criteria. Neurology 2002;58(03): 349–353 [PubMed: 11839831]
5. Thibaut A, Bodien YG, Laureys S, Giacino JT. Minimally conscious state “plus”: diagnostic criteria and relation to functional recovery. J Neurol 2020;267(05):1245–1254 [PubMed: 31773246]
6. Bodien YG, Martens G, Ostrow J, Sheau K, Giacino JT. Cognitive impairment, clinical symptoms and functional disability in patients emerging from the minimally conscious state. NeuroRehabilitation 2020;46(01):65–74 [PubMed: 32039868]
7. Sherer M, Katz DI, Bodien YG, et al. Post-traumatic confusional state: a case definition and diagnostic criteria. Arch Phys Med Rehabil 2020;101(11):2041–2050 [PubMed: 32738198]
8. Nakase-Richardson R, Yablon SA, Sherer M, Evans CC, Nick TG. Serial yes/no reliability after traumatic brain injury: implications regarding the operational criteria for emergence from the minimally conscious state. J Neurol Neurosurg Psychiatry 2008;79 (02):216–218 [PubMed: 18202213]
9. Nakase-Richardson R, Yablon SA, Sherer M, Nick TG, Evans CC. Emergence from minimally conscious state: insights from evaluation of posttraumatic confusion. Neurology 2009;73(14): 1120–1126 [PubMed: 19805728]
10. Golden K, Erler KS, Wong J, Giacino JT, Bodien YG. Should consistent command-following be added to the criteria for emergence from the minimally conscious state? Arch Phys Med Rehabil 2022 Apr 6:S0003–9993(22)00294–5. Doi: 10.1016/j.apmr.2022.03.010
11. Schnakers C, Vanhaudenhuyse A, Giacino J, et al. Diagnostic accuracy of the vegetative and minimally conscious state: clinical consensus versus standardized neurobehavioral assessment. BMC Neurol 2009;9:35 [PubMed: 19622138]
12. Andrews K, Murphy L, Munday R, Littlewood C. Misdiagnosis of the vegetative state: retrospective study in a rehabilitation unit. BMJ 1996;313(7048):13–16 [PubMed: 8664760]
13. Childs NL, Mercer WN, Childs HW. Accuracy of diagnosis of persistent vegetative state. Neurology 1993;43(08):1465–1467 [PubMed: 8350997]
14. Wang J, Hu X, Hu Z, Sun Z, Laureys S, Di H. The misdiagnosis of prolonged disorders of consciousness by a clinical consensus compared with repeated coma-recovery scale-revised assessment. BMC Neurol 2020;20(01):343 [PubMed: 32919461]
15. Stender J, Gosseries O, Bruno M-A, et al. Diagnostic precision of PET imaging and functional MRI in disorders of consciousness: a clinical validation study. Lancet 2014;384(9942):514–522 [PubMed: 24746174]

16. Giacino JT, Katz DI, Schiff ND, et al. Practice guideline update recommendations summary: disorders of consciousness: report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology; the American Congress of Rehabilitation Medicine; and the National Institute on Disability, Independent Living, and Rehabilitation Research. Neurology 2018;91(10):450–460 [PubMed: 30089618]
17. Kondziella D, Bender A, Diserens K, et al. ; EAN Panel on Coma, Disorders of Consciousness. European Academy of Neurology guideline on the diagnosis of coma and other disorders of consciousness. Eur J Neurol 2020;27(05):741–756 [PubMed: 32090418]
18. Royal College of Physicians. Prolonged disorders of consciousness following sudden onset brain injury: national clinical guidelines. 2020 London: RCP Accessed July 19, 2022 at:https://www.rcplondon.ac.uk/guidelines-policy/prolonged-disorders-consciousness-following-sudden-onset-brain-injury-national-clinical-guidelines
19. Giacino JT, Whyte J, Nakase-Richardson R, et al. Minimum competency recommendations for programs that provide rehabilitation services for persons with disorders of consciousness: a position statement of the American Congress of Rehabilitation Medicine and the National Institute on Disability, Independent Living and Rehabilitation Research Traumatic Brain Injury Model Systems. Arch Phys Med Rehabil 2020;101(06):1072–1089 [PubMed: 32087109]
20. Giacino JT, Kalmar K, Whyte J. The JFK Coma Recovery Scale-Revised: measurement characteristics and diagnostic utility. Arch Phys Med Rehabil 2004;85(12):2020–2029 [PubMed: 15605342]
21. Seel RT, Sherer M, Whyte J, et al. ; American Congress of Rehabilitation Medicine, Brain Injury-Interdisciplinary Special Interest Group, Disorders of Consciousness Task Force. Assessment scales for disorders of consciousness: evidence-based recommendations for clinical practice and research. Arch Phys Med Rehabil 2010;91(12):1795–1813 [PubMed: 21112421]
22. Hicks R, Giacino J, Harrison-Felix C, Manley G, Valadka A, Wilde EA. Progress in developing common data elements for traumatic brain injury research: version two–the end of the beginning. J Neurotrauma 2013;30(22):1852–1861 [PubMed: 23725058]
23. La Porta F, Caselli S, Ianes AB, et al. Can we scientifically and reliably measure the level of consciousness in vegetative and minimally conscious States? Rasch analysis of the coma recovery scale-revised. Arch Phys Med Rehabil 2013;94(03):527–535.e1
24. Gerrard P, Zafonte R, Giacino JT. Coma Recovery Scale-Revised: evidentiary support for hierarchical grading of level of consciousness. Arch Phys Med Rehabil 2014;95(12): 2335–2341 [PubMed: 25010536]
25. Bodien YG, Carlowicz CA, Chatelle C, Giacino JT. Sensitivity and specificity of the Coma Recovery Scale–Revised total score in detection of conscious awareness. Arch Phys Med Rehabil 2016; 97(03):490–492.e1
26. Wannez S, Heine L, Thonnard M, Gosseries O, Laureys SComa Science Group collaborators. The repetition of behavioral assessments in diagnosis of disorders of consciousness. Ann Neurol 2017;81(06):883–889 [PubMed: 28543735]
27. Lucca LF, Lofaro D, Pignolo L, et al. Outcome prediction in disorders of consciousness: the role of coma recovery scale revised. BMC Neurol 2019;19(01):68–68 [PubMed: 30999877]
28. Portaccio E, Morrocchesi A, Romoli AM, et al. Score on Coma Recovery Scale-Revised at admission predicts outcome at discharge in intensive rehabilitation after severe brain injury. Brain Inj 2018;32(06):730–734 [PubMed: 29482376]
29. Portaccio E, Morrocchesi A, Romoli AM, et al. ; Intensive Rehabilitation Unit Study Group of the IRCCS Don Gnocchi Foundation, Italy. Improvement on the Coma Recovery Scale-Revised during the first four weeks of hospital stay predicts outcome at discharge in intensive rehabilitation after severe brain injury. Arch Phys Med Rehabil 2018;99(05):914–919 [PubMed: 29428346]
30. Tamashiro M, Rivas ME, Ron M, Salierno F, Dalera M, Olmos L. A Spanish validation of the Coma Recovery Scale-Revised (CRS-R). Brain Inj 2014;28(13–14):1744–1747 [PubMed: 25264811]
31. Estraneo A, Moretta P, De Tanti A, Gatta G, Giacino JT, Trojano LItalian Crs-R Multicentre Validation Group. An Italian multicentre validation study of the coma recovery scale-revised. Eur J Phys Rehabil Med 2015;51(05):627–634 [PubMed: 24603937]

32. Lombardi F, Gatta G, Sacco S, Muratori A, Carolei A. The Italian version of the Coma Recovery Scale-Revised (CRS-R). Funct Neurol 2007;22(01):47–61 [PubMed: 17509244]
33. Sacco S, Altobelli E, Pistarini C, Cerone D, Cazzulani B, Carolei A. Validation of the Italian version of the Coma Recovery Scale-Revised (CRS-R). Brain Inj 2011;25(05):488–495 [PubMed: 21401371]
34. Schnakers C, Majerus S, Giacino J, et al. A French validation study of the Coma Recovery Scale-Revised (CRS-R). Brain Inj 2008;22 (10):786–792 [PubMed: 18787989]
35. Simões JF, Jesus LM, Voegeli D, Sá-Couto P, Fernandes J, Morgado M. Assessment of comatose patients: a Portuguese instrument based on the Coma Recovery Scale - revised and using nursing standard terminology. J Adv Nurs 2011;67(05):1129–1141 [PubMed: 21231953]
36. Løvstad M, Frøslie KF, Giacino JT, Skandsen T, Anke A, Schanke AK. Reliability and diagnostic characteristics of the JFK coma recovery scale-revised: exploring the influence of rater's level of experience. J Head Trauma Rehabil 2010;25(05):349–356 [PubMed: 20142758]
37. Iazeva EG, Legostaeva LA, Zimin AA, et al. . A Russian validation study of the Coma Recovery Scale-Revised (CRS-R). Brain Inj 2018 (e-pub ahead of print). Doi: 10.1080/02699052.2018.1539248
38. Maurer-Karattup P, Giacino J, Luther M, Eifert B. Diagnosis of disorders of consciousness with the German version of Coma Recovery Scale-Revised (CRS-R). Neurol Rehabil 2010; 16:232–246
39. Binder M, Górska U, Wójcik-Krzemień A, Gociewicz K. A validation of the Polish version of the Coma Recovery Scale-Revised (CRSR). Brain Inj 2018;32(02):242–246 [PubMed: 29182381]
40. Han HJ, Kim EJ, Lee HJ, Pyun SB, Joa KL, Jung HY. Validation of Korean Version of Coma Recovery Scale-Revised (K-CRSR). Ann Rehabil Med 2018;42(04):536–541 [PubMed: 30180522]
41. Di H, He M, Zhang Y, et al. Chinese translation of the Coma Recovery Scale-Revised. Brain Inj 2017;31(03):363–365 [PubMed: 28125307]
42. Zhang Y, Wang J, Schnakers C, et al. Validation of the Chinese version of the Coma Recovery Scale-Revised (CRS-R). Brain Inj 2019;33(04):529–533 [PubMed: 30663434]
43. Bodien YG, Chatelle C, Taubert A, Uchani S, Giacino JT, Ehrlich-Jones L. Updated measurement characteristics and clinical utility of the Coma Recovery Scale-Revised among individuals with acquired brain injury. Arch Phys Med Rehabil 2021;102(01): 169–171
44. Slomine BSSS Suskauer SJ, Nicholson R Giacino JT. Preliminary validation of the coma recovery scale for pediatrics in typically developing young children. Brain Inj 2019;33(13–14):1640–1645 [PubMed: 31462082]
45. Pincherle A, Jöhr J, Chatelle C, et al. Motor behavior unmasks residual cognition in disorders of consciousness. Ann Neurol 2019;85(03):443–447 [PubMed: 30661258]
46. Schnakers C, Chatelle C, Vanhaudenhuyse A, et al. The Nociception Coma Scale: a new tool to assess nociception in disorders of consciousness. Pain 2010;148(02):215–219 [PubMed: 19854576]
47. Aubinet C, Chatelle C, Gillet S, et al. The brief evaluation of receptive aphasia test for the detection of language impairment in patients with severe brain injury. Brain Inj 2021;35(06): 705–717 [PubMed: 33678094]
48. Mélotte E, Belorgeot M, Herr R, et al. The development and validation of the SWADOC: a study protocol for a multicenter prospective cohort study. Front Neurol 2021;12:662634
49. Annen J, Filippini MM, Bonin E, et al. Diagnostic accuracy of the CRS-R index in patients with disorders of consciousness. Brain Inj 2019;33(11):1409–1412 [PubMed: 31319707]
50. Sattin D, Minati L, Rossi D, et al. The Coma Recovery Scale Modified Score: a new scoring system for the Coma Recovery Scale-revised for assessment of patients with disorders of consciousness. Int J Rehabil Res 2015;38(04):350–356 [PubMed: 26465775]
51. Whyte J, Giacino JT, Heinemann AW, et al. Brain Injury Functional Outcome Measure (BI-FOM): a single instrument capturing the range of recovery in moderate-severe traumatic brain injury. Arch Phys Med Rehabil 2021;102(01):87–96 [PubMed: 33022273]
52. Ottenbacher KJ, Hsu Y, Granger CV, Fiedler RC. The reliability of the Functional Independence Measure: a quantitative review. Arch Phys Med Rehabil 1996;77(12):1226–1232 [PubMed: 8976303]

53. Sherer M, Nakase-Thompson R, Yablon SA, Gontkovsky ST. Multi-dimensional assessment of acute confusion after traumatic brain injury. Arch Phys Med Rehabil 2005;86(05):896–904 [PubMed: 15895334]

54. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet 1974;2(7872):81–84 [PubMed: 4136544]

55. Marmarou A, Lu J, Butcher I, et al. Prognostic value of the Glasgow Coma Scale and pupil reactivity in traumatic brain injury assessed pre-hospital and on enrollment: an IMPACT analysis. J Neurotrauma 2007;24(02):270–280 [PubMed: 17375991]

56. Wilde EA, Whiteneck GG, Bogner J, et al. Recommendations for the use of common outcome measures in traumatic brain injury research. Arch Phys Med Rehabil 2010;91(11):1650–1660.e17

57. Maas AI, Roozenbeek B, Manley GT. Clinical trials in traumatic brain injury: past experience and current developments. Neurotherapeutics 2010;7(01):115–126 [PubMed: 20129503]

58. Reith FC, Brennan PM, Maas AI, Teasdale GM. Lack of standardization in the use of the Glasgow Coma Scale: results of international surveys. J Neurotrauma 2016;33(01):89–94 [PubMed: 25951090]

59. Fischer M, Rüegg S, Czaplinski A, et al. Inter-rater reliability of the Full Outline of UnResponsiveness score and the Glasgow Coma Scale in critically ill patients: a prospective observational study. Crit Care 2010;14(02):R64 [PubMed: 20398274]

60. Martens G, Bodien Y, Sheau K, Christoforou A, Giacino JT. Which behaviours are first to emerge during recovery of consciousness after severe brain injury? Ann Phys Rehabil Med 2020;63(04): 263–269 [PubMed: 31783144]

61. Bodien YG, Barra A, Temkin NR, et al. ; TRACK-TBI Investigators. Diagnosing Level of Consciousness: the limits of the Glasgow Coma Scale total score. J Neurotrauma 2021;38(23):3295–3305 [PubMed: 34605668]

62. Wijdicks EF, Bamlet WR, Maramattom BV, Manno EM, McClelland RL. Validation of a new coma scale: the FOUR score. Ann Neurol 2005;58(04):585–593 [PubMed: 16178024]

63. Iyer VN, Mandrekar JN, Danielson RD, Zubkov AY, Elmer JL, Wijdicks EF. Validity of the FOUR score coma scale in the medical intensive care unit. Mayo Clin Proc 2009;84(08):694–701 [PubMed: 19648386]

64. Foo CC, Loan JJM, Brennan PM. The relationship of the FOUR score to patient outcome: a systematic review. J Neurotrauma 2019;36 (17):2469–2483 [PubMed: 31044668]

65. Schnakers C, Giacino J, Kalmar K, et al. Does the FOUR score correctly diagnose the vegetative and minimally conscious states? Ann Neurol 2006;60(06):744–745, author reply 745 [PubMed: 16847951]

66. Turgeon AF, Lauzier F, Simard JF, et al. ; Canadian Critical Care Trials Group. Mortality associated with withdrawal of life-sustaining therapy for patients with severe traumatic brain injury: a Canadian multicentre cohort study. CMAJ 2011;183(14): 1581–1588 [PubMed: 21876014]

67. Fins JJ. Rights Come to Mind: Brain Injury, Ethics, and the Struggle for Consciousness. New York, NY: Cambridge University Press; 2015

68. Aubinet C, Cassol H, Bodart O, et al. Simplified evaluation of CONsciousness disorders (SECONDs) in individuals with severe brain injury: a validation study. Ann Phys Rehabil Med 2021;64 (05):101432

69. Whyte J, DiPasquale MC, Vaccaro M. Assessment of commandfollowing in minimally conscious brain injured patients. Arch Phys Med Rehabil 1999;80(06):653–660 [PubMed: 10378491]

70. DiPasquale MC, Whyte J. The use of quantitative data in treatment planning for minimally conscious patients. J Head Trauma Rehabil 1996;11(06):9–17

71. Schnakers C, Bessou H, Rubi-Fessen I, et al. Impact of aphasia on consciousness assessment: a cross-sectional study. Neurorehabil Neural Repair 2015;29(01):41–47 [PubMed: 24743226]

72. Aubinet C, Chatelle C, Gosseries O, Carrière M, Laureys S, Majerus S. Residual implicit and explicit language abilities in patients with disorders of consciousness: a systematic review. Neurosci Biobehav Rev 2022;132:391–409 [PubMed: 34864003]

73. Claassen J, Doyle K, Matory A, et al. Detection of brain activation in unresponsive patients with acute brain injury. N Engl J Med 2019; 380(26):2497–2505 [PubMed: 31242361]

74. Edlow BL, Chatelle C, Spencer CA, et al. Early detection of consciousness in patients with acute severe traumatic brain injury. Brain 2017;140(09):2399–2414 [PubMed: 29050383]
75. Edlow BL, Claassen J, Schiff ND, Greer DM. Recovery from disorders of consciousness: mechanisms, prognosis and emerging therapies. Nat Rev Neurol 2021;17(03):135–156 [PubMed: 33318675]
76. Monti MM, Vanhaudenhuyse A, Coleman MR, et al. Willful modulation of brain activity in disorders of consciousness. N Engl J Med 2010;362(07):579–589 [PubMed: 20130250]
77. Schiff ND. Cognitive motor dissociation following severe brain injuries. JAMA Neurol 2015;72(12):1413–1415 [PubMed: 26502348]
78. Wang F, Di H, Hu X, et al. Cerebral response to subject's own name showed high prognostic value in traumatic vegetative state. BMC Med 2015;13:83 [PubMed: 25880206]
79. Sokoliuk R, Degano G, Banellis L, et al. . Covert speech comprehension predicts recovery from acute unresponsive states. Ann Neurol 2021;89(04):646–656 [PubMed: 33368496]
80. Threlkeld ZD, Bodien YG, Rosenthal ES, et al. Functional networks reemerge during recovery of consciousness after acute severe traumatic brain injury. Cortex 2018;106:299–308 [PubMed: 29871771]
81. Bodien YG, Chatelle C, Edlow BL. Functional networks in disorders of consciousness. Semin Neurol 2017;37(05):485–502 [PubMed: 29207410]
82. Monti MM, Schnakers C. Flowchart for implementing advanced imaging and electrophysiology in patients with disorders of consciousness: to fMRI or not to fMRI? Neurology 2022;98(11): 452–459 [PubMed: 35058337]
83. Curley WH, Bodien YG, Zhou DW, et al. Electrophysiological correlates of thalamocortical function in acute severe traumatic brain injury. Cortex 2022;152:136–152 [PubMed: 35569326]
84. Gill-Thwaites H, Munday R. The Sensory Modality Assessment and Rehabilitation Technique (SMART): a valid and reliable assessment for vegetative state and minimally conscious state patients. Brain Inj 2004;18(12):1255–1269 [PubMed: 15666569]
85. Shiel A, Horn SA, Wilson BA, Watson MJ, Campbell MJ, McLellan DL. The Wessex Head Injury Matrix (WHIM) main scale: a preliminary report on a scale to assess and monitor patient recovery after severe head injury. Clin Rehabil 2000;14(04): 408–416 [PubMed: 10945425]
86. Rader MA, Ellis DW. The Sensory Stimulation Assessment Measure (SSAM): a tool for early evaluation of severely brain-injured patients. Brain Inj 1994;8(04):309–321 [PubMed: 8081346]
87. Ansell BJ, Keenan JE. The Western Neuro Sensory Stimulation Profile: a tool for assessing slow-to-recover head-injured patients. Arch Phys Med Rehabil 1989;70(02):104–108 [PubMed: 2916926]
88. Pape TL, Mallinson T, Guernon A. Psychometric properties of the disorders of consciousness scale. Arch Phys Med Rehabil 2014;95 (09):1672–1684 [PubMed: 24814459]
89. Rappaport M, Dougherty AM, Kelting DL. Evaluation of coma and vegetative states. Arch Phys Med Rehabil 1992;73(07):628–634 [PubMed: 1622317]
90. Weaver JA, Cogan AM, O'Brien KA, Hansen P, Giacino JT, Whyte J, Bender Pape T, van der Wees P, Mallinson T. Determining the Hierarchy of Coma Recovery Scale-Revised Rating Scale Categories and Alignment with Aspen Consensus Criteria for Patients with Brain Injury: A Rasch Analysis. J Neurotrauma. 2022 Jun 16. Doi: 10.1089/neu.2022.0095. Epub ahead of print.

Table 1

Strategies for optimizing the behavioral assessment of patients with disorders of consciousness

Factors contributing to inaccurate behavioral diagnosis of level of consciousness	Mitigating actions that maximize the chance of detecting signs of consciousness
Failure to ensure adequate arousal prior to beginning assessment	• Increase arousal before performing evaluations (e.g., with the CRS-R Arousal Facilitation Protocol[83]). • Optimize positioning to promote arousal (e.g., wakefulness may improve when sitting up vs. laying down). • Consider the time of day and fatigue from activities preceding the behavioral examination. • Avoid sedating medications, or if unavoidable and provided continuously in an infusion, wean for a sufficient amount of time to promote maximal responsiveness.
Failure to identify medical contributors to low responsiveness	• Identify and treat conditions that may mask evidence of conscious awareness (e.g., infections, metabolic disturbances, seizures, hydrocephalus, chronic subdural hemorrhage, adverse medication effects). • Consider neuromuscular status in choosing commands. Use commands that incorporate motor responses that appear to be within the patient's capabilities, such as those that occur spontaneously, but not repeatedly. • Provide timely medical evaluation in situations of decline or plateau in clinical status.
Lack of consideration of the impact of environmental factors	• Systematically evaluate environmental factors that may influence arousal and cognitive performance and avoid distractions (e.g., turn off music, request that others in the room minimize noise). • Provide adequate lighting. • Remove physical restrictions to movement (e.g., restraints). • Position stimuli to the patient's best advantage (e.g., vertical vs. horizontal placement depending on gaze deviation). • Ensure visual and hearing aids are available if used premorbidly. • Request an interpreter if language barrier is suspected.
Attributing purposeful intent to responses that are reflexive or generalized	• Avoid commands that are difficult to distinguish from reflexive or random behavior (e.g., handsqueeze and eyelid closure commands are difficult to differentiate from grasp reflex and blinking, respectively). • Attribute purposeful behaviors only to accurate and clearly discernible responses. • Do not confound assessment of command following by cuing with gestures or tactile stimulation. • Failure to respond to a command designed to elicit no behavior (e.g., do not kick your leg) should not be mistaken as command-following given the inability to disambiguate a correct response from no response in this situation. • Use a fixed response window to standardize the allowable period for a response within and across assessments.
Inadequate evaluation of conscious behaviors	• Assess behaviors multiple times to determine consistency and reproducibility of responses. • Use a long enough presentation time and inter-stimulus interval to allow time for the patient to respond but recognize that as the interval between stimulus and response increases, the chance that a spurious response is mistakenly attributed to a stimulus also increases. • Assess behaviors across different domains (e.g., motor, language, visual). • Attempt to elicit responses to commands that recruit different motor pathways−e.g., limb movement (i.e., corticospinal tract) versus head movement (corticobulbar tract). • Avoid unnecessary complexity in command-following trials. Use simple declarative language, one request at a time. • Watch for signs of response fatigue (e.g., responses to the first two, but not the last two of multiple commands). • Consider whether responses may be due to perseveration. • If aphasia is suspected, conduct further language evaluation. • Use test completion codes to document assessment validity.
Over- or under-consideration of family or other's observations of purposeful behavior	• Incorporate the observations of families, nurses, and therapists, who are more familiar or spend more time with the patient, but not base diagnosis solely on the report of other clinicians or family. • Encourage family to video record observed behaviors that may be undetected on formal assessment.
Establishing a diagnosis after a single assessment	• Inconsistency and fluctuations in levels of responsiveness are expected in patients with DoC. • Quick bedside evaluations, such as typical morning rounds, are often not adequate in detecting responses in patients with DoC. • Conduct repeated assessments to establish response consistency, validity of examination findings, and accuracy of the diagnosis.

Abbreviations: CRS-R, Coma Recovery Scale-Revised; DoC, disorders of consciousness.

Table 2

DoC rating scales with standardized assessment and scoring protocols

Rating scale	Public domain	Time to administer	ACRM level of recommendation	Guidelines with recommendation	Online resources
CRS-R[20]	Y	25 min	Minor reservation	• AAN/ACRM/NIDILRR • EAN • RCP	www.sralab.org/rehabilitation-measures/coma-recovery-scale-revised
SMART[84]	N	5–6 h	Moderate reservation	RCP	www.rhn.org.uk/what-makes-us-special/services/smart/
WHIM[85]	N	20 min	Moderate reservation	RCP	https://www.pearsonclinical.ca/store/caassessments/en/Store/Professional-Assessments/Cognition-%26-Neuro/Wessex-Head-lnjury-Matrix/p/Pl 00008239.html
SSAM[86]	Y	30 min	Moderate reservation	None	https://www.sralab.org/rehabilitation-measures/sensory-stimulation-assessment-measure
WNSSP[87]	Y	45 min	Moderate reservation	None	https://www.sralab.org/rehabilitation-measures/western-neuro-sensory-stimulation-profile
DOCS[88]	Y	40 min	Moderate reservation	None	https://www.sralab.org/rehabilitation-measures/disorders-consciousness-scale
CNC[89]	Y	10 min	Major reservation	None	https://www.tbims.org/combi/cnc/

Abbreviations: AAN/ACRM/NIDILRR, American Academy of Neurology/American Congress of Rehabilitation Medicine/National Institute on Disability Independent Living and Rehabilitation Research; CNC, Coma/Near-Coma Scale; DOCS, Disorders of Consciousness Scale; EAN, European Academy of Neurology; N, no; RCP, Royal College of Physicians; SMART, Sensory Modality Assessment and Rehabilitation Technique; SSAM, Sensory Stimulation Assessment Measure; WHIM, Wessex Head Injury Matrix, WNSSP, Western Neuro Sensory Stimulation Profile; Y yes.

Table 3

Coma Recovery Scale - Revised subscales and items

Auditory function scale
4—Consistent movement to command[a]
3—Reproducible movement to command[a]
2—Localization to sound
1—Auditory startle
0—None
Visual function scale
5—Object recognition[a]
4—Object localization: reaching[b]
3—Visual pursuit[b]
2—Fixation[b]
1—Visual startle
0—None
Motor function scale
6—Functional object use[c]
5—Automatic motor response[b]
4—Object manipulation[b]
3—Localization to noxious stimulation[b]
2—Flexion withdrawal
1—Abnormal posturing
0—None
Oromotor/verbal function scale
3—Intelligible verbalization[a]
2—Vocalization/oral movement
1—Oral reflexive movement
0—None
Communication scale
2—Functional: accurate[c]
1—Non-functional: intentional[a]
0—None
Arousal scale
3—Attention
2—Eye opening without stimulation
1—Eye Opening with stimulation
0—Unarousable

[a]Denotes minimally conscious state plus (MCS+).

[b]Denotes minimally conscious state minus (MCS−).

[c] Denotes emergence from MCS (eMCS).

Table 4

A comparison of behavioral scales that may be used to assess acute disorders of consciousness

Scale	Total score range	Domains (score range)	Criteria for MCS *minus* diagnosis	Criteria for MCS *plus* diagnosis	Criteria for eMCS diagnosis
GCS	3–15	• Eye-opening (1–4) • Verbal (1–5) • Motor (1 –6)	MCS *minus*[a] Localization to noxious stimulation (motor = 5)	MCS *plus*[a] Intelligible words (verbal = 3) Following Commands (motor = 6)	eMCS[a] Confused (verbal = 4)
FOUR	0–16	• Eye response (0–4) • Motor response (0–4) • Brainstem reflexes (0–4) • Respiration pattern (0–4)	MCS *minus* or MCS *plus*[a,b] Eyelids open or opened, tracking (MCS *minus*), or blinking to command (MCS *plus*) (eye response = 4) MCS *minus*[a] Localizing pain (motor = 3)	MCS *plus*[a] Thumbs up, fist or peace sign (motor = 4)	NA
CRS-R	0–23	• Auditory (0–4) • Visual (0–5) • Motor (0–6) • Oromotor/verbal (0–3) • Communication (0–2) • Arousal (0–3)	MCS *minus* Visual fixation or pursuit, object localization ($2 \leq$ visual ≥ 4) Localization to noxious stimulation, object manipulation, automatic motor response ($3 \leq$ motor ≤ 5)	MCS *plus* Reproducible or consistent command-following (auditory ≥ 3) Object recognition (visual = 5) Intelligible speech (verbal/oromotor = 3) Non-intentional communication (communication = 1)	eMCS Functional object use (motor = 6) Functional communication (communication = 2)

Abbreviations: CRS-R, Coma Recovery Scale-Revised; eMCS, emerged from minimally conscious state; FOUR, Full Outline of UnResponsiveness Score; GCS, Glasgow Coma Scale; MCS, minimally conscious state.

[a] Criteria for MCS and eMCS are not explicitly stated, but some behaviors map onto diagnostic criteria for MCS and eMCS.

[b] The FOUR Motor score of 4 could indicate MCS plus or MCS minus depending on whether the observed behavior is blinking to command or tracking, respectively.

Table 5

Coma Recovery Scale-Revised test completion codes

1.0	Test completed in full, results valid		
Test attempted, not completed due to:		*Test not attempted* due to:	
2.1	Impaired sensory function (cortical or peripheral)	3.1	Impaired sensory function (cortical or peripheral)
2.2	Aphasia	3.2	Aphasia
2.3	Physical limitation restricting movement (e.g., fracture, brachial plexus, hemiparesis)	3.3	Physical limitation restricting movement (e.g., fracture, brachial plexus, hemiparesis)
2.4	Primary language barrier	3.4	Primary language barrier
2.5	Illness/medical instability	3.5	Illness/medical instability
2.6	Examiner error	3.6	Examiner error
2.7	Logistical reasons	3.7	Logistical reasons
2.8	Other (specify):	3.8	Other (specify):