Diagnosing Disorders of Consciousness

ARTICLE INFORMATION

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ABSTRACT

The definition of consciousness has long been debated in a scientific and philosophical context due to its ambiguous nature. Recent developments in the concept of consciousness have contributed to a better understanding of associated Disorders of Consciousness (DOC). However, there has not been an equivalent rise in the accuracy of diagnostic measures for DOC. About half of the patients with DOC are incorrectly diagnosed due to significant reliance on subjective and inaccurate behavioural scales. Consequently, the misrepresentation of a patient's present residual consciousness severely affects the treatment and rehabilitation measures that they receive. These inaccurate diagnoses ultimately influence the patient's chance of survival. Thus, it is necessary to critique the current methods of evaluating consciousness. Neurophysiological scales are explored as a possible alternative method of evaluating consciousness, which is characterized by high sensitivity and objectivity. An understanding of the advantages and disadvantages of different consciousness-evaluating techniques can aid in the advocacy of their widespread use for DOC patients.

Keywords: Disorders of consciousness, electroencephalography, event-related potentials

DOC can be categorized into a coma, vegetative state (VS), and minimally conscious state (MCS).[1] Figure 1, adapted from Giacino et al. (2009), illustrates the variations of arousal and awareness in these DOC. Patients suffering from a coma experience complete loss of consciousness and present with their eyes closed and a lack of reactivity/arousal to external stimuli. A patient in a coma is not neurophysiologically aroused, thus, is not aware of the external environment.[1] A coma can be caused by several clinical conditions such as traumatic brain injury, cardiac arrest, stroke, metabolic or infectious diseases, or drugs.[1,2] This state can last anywhere between two weeks to a month, after which the patient may regain consciousness or potentially lapse into VS or MCS.[1,2] Patients in VS appear awake with eyes open but show no response to stimuli (i.e. no awareness).[1] Minimally conscious patients show complete arousal but transient awareness to stimuli, thus displaying inconsistent behavioural response signs.[1,2]

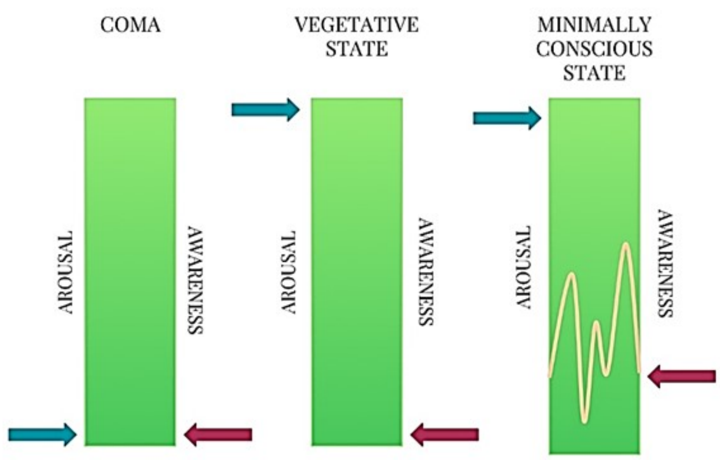

Figure 1. Two dimensions of consciousness: arousal and awareness.[3] For individuals suffering from coma or brain death, both arousal and awareness are absent. In the other two DOC (VS and MCS), arousal is relatively preserved, while awareness is absent in the VS and present in fluctuating quantities in the MCS. This figure was adapted from Giacino et al. (2009).

Limitations of Behavioural Scales

Due to the longstanding ambiguity in the understanding of consciousness and related disorders, DOC have primarily been assessed and diagnosed based on visible behavioural features, described by behavioural scales. These scales are based on subjective interpretations of behavioural signs at particular points in time and are heavily reliant on visible signs to assess the integrity of various sensory and cognitive functions. According to a study by Morlet et al. (2013), 40% of MCS patients were misdiagnosed and incorrectly identified as being in the VS.[4] This paradigm is further complicated in intensive care units, where a patient's critical condition (e.g. intubation, tracheotomy, or immobilization) interferes with the process of identifying behaviours that fit the scope of these scales.[4]

The ideal consciousness measurement scale should provide an accurate analysis of a patient's state since this plays a role in predicting the patient's outcome and the treatment or rehabilitation measures that they receive. Clinical behavioural scales are insufficient to capture the subtle neurophysiological changes in a patient with DOC.[5] For instance, the Glasgow Coma Scale is a behavioural scale that merely assesses visual responses to stimuli, thus, is very limiting during a neurophysiological assessment. Moreover, in patients with DOC, assessment of their consciousness is confounded by the fluctuating states of their awareness and arousal, alongside possible sensorimotor impairment and sedation, all of which affect their responses to the administered stimulus.[3,5] In addition to this, there may be variability in a clinician's diagnosis due to the fluctuating nature of a patient's behavioural responses, if any are observed.[1]

Promising Novel Methods for Assessing Consciousness: Neurophysiological Scales

Neurophysiological scales are comparatively reliable due to their sensitivity for detecting residual consciousness in the form of cortical and brainstem activity without the need to assess visible behavioural responses to stimuli.[6] Electroencephalography (EEG) is highly preferred over other neurophysiological scales due to its feasibility, ease of manipulation, and reliability in measuring minor brain activity.[2] However, standard clinical EEG recordings on their own cannot be relied upon for accurate results due to the low spatial resolution of the brain activity. Thus, the use of EEGs has low diagnostic value.[1,7]

Event-related potentials (ERPs) resolve this limitation by averaging the data from several EEG recordings after stimulus presentation. ERPs can be further divided into two categories: Short Latency ERPs and Cognitive ERPs.[6]

Short-Latency ERPs are elicited between 0-100 ms after stimulus presentation.[1] An example of these ERPs is Brainstem Auditory Evoked Potentials (BAEPs), which are elicited in response to a variety of sound tonalities, pitches, and amplitudes. They are recorded in the first 10-15 ms as the auditory signals travel from the auditory nerve to the inferior colliculus of the brainstem.[1] According to a study by Fischer et al. (2006), BAEPs have been used for over two decades due to their high predictive value for 100% of poor outcomes, i.e. the low probability of awakening from a coma in the absence of this activity.[8, 9] Overall, BAEP activity seems to accurately predict structural damage to the brain and is effective in predicting survival based on the presence of these waveforms.[8, 9]

Another subcategory of ERPs, termed Cognitive or Long Latency ERPs, are elicited in the cortical brain regions after 100 ms of the presentation of a stimulus.[1, 4] One example of a sensitive long latency negative component is Mismatch Negativity (MMN), which is elicited in the primary auditory and prefrontal cortices. MMN is typically evoked 100-250 ms after a sound deviance is produced by a chain of infrequently interrupted repetitive auditory sequences.[7] There has been a significant positive correlation between the display of this component and positive outcomes of consciousness, with 90% of cases waking up from a coma if they displayed MMN.[10] Additionally, another study showed that 12 months after coma onset, MMN activity had a high positive predictive value of a healthy neurological function, measured at 87% accuracy.[6]

Current Limitations and Future Directions

Various studies have demonstrated the enhanced accuracy and sensitivity of neurophysiological scales, compared to the counterpart behavioural scales. As such, standard procedures for the diagnosis of DOC involve the use of both types of scales, behavioural and neurophysiological, to obtain more accurate conclusions.

While the efficacy of neurophysiological scales has been demonstrated through several clinical studies, there are multiple issues to address in order to consider their application for a long-term basis. ERP activity in patients with DOC is known to fluctuate [4] due to the sensitive nature of this scale, and to the variable nature of the residual consciousness observed in these patients. While MMN stands out as one of the most sensitive and reliable ERP components in terms of predicting an accurate functional outcome, more analysis needs to be performed on a long-term basis to prove the efficacy of this scale for widespread clinical application. BAEPs have typically been in use for a longer period of time, mainly to measure the intactness of the hearing pathway in individuals with hearing disabilities. The use of BAEPs to assess the functionality of the auditory pathway prior to EEG/ERP testing is a fairly recent experimental paradigm that has not shown much promise in related research findings. To conclude, extensive research needs to be conducted to assess the reliability of these scales due to their implications on the prognostication and therapy options for the patient, as well as the funding that the patient will receive, which will affect their odds of survival.[3] The grim future of such patients may be partially compensated for by the fast-paced development of research that is dedicated to designing evaluation tests. Additionally, many clinical research institutions around the world are actively exploring the field of cognitive neuroscience, including the Language, Memory and Brain Lab (LMB Lab) under the Centre for Advanced Research in Clinical and Experiential and Applied Linguistics (ARiEAL) at McMaster University.[11] One of LMB Lab's major areas of focus includes research on acquired brain injury and coma.[11] "VoxNeuro" was a program developed by the researchers from this lab in the 1990s that initiated the use of "ERPs in association with computer-adapted neuropsychological tests to assess people with neurologically-based communication problems".[11] This testing method has provided promising results for the assessment of various populations with significant communication impairments, such as those with acquired brain injuries.[11]

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