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Original Article

The importance of polysomnography in the evaluation of prolonged disorders of consciousness: sleep recordings more adequately correlate than stimulus-related evoked potentials with patients' clinical status

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ABSTRACT

Objectives: The aim of our study was to evaluate the importance of sleep recordings and stimulus-related evoked potentials (EPs) in patients with prolonged disorders of consciousness (DOCs) by correlating neurophysiologic variables with clinical evaluation obtained using specific standardized scales.
Methods: There were 27 vegetative state (VS) and 5 minimally conscious state (MCS) patients who were evaluated from a clinical and neurophysiologic perspective. Clinical evaluation included the Coma Recovery Scale-Revised (CRS-R), Disability Rating Scale (DRS), and Glasgow Coma Scale (GCS). Neurophysiologic evaluation included 24-h polysomnography (PSG), somatosensory EPs (SEPs), brainstem auditory EPs (BAEPs), and visual EPs (VEPs).
Results: Patients with preservation of each single sleep element (sleep–wake cycle, sleep spindles, K-complexes, and rapid eye movement [REM] sleep) always showed better clinical scores compared to those who did not have preservation. Statistical significance was only achieved for REM sleep. In 7 patients PSG showed the presence of all considered sleep elements, and they had a CRS-R score of 8.29 ± 1.38. In contrast, 25 patients who lacked one or more of the sleep elements had a CRS-R score of 4.84 ± 1.46 ($P < .05$). Our multivariate analysis clarified that concurrent presence of sleep spindles and REM sleep were associated with a much higher CRS-R score (positive interaction, $P < .0001$). On the other hand, no significant associations were found between EPs and CRS-R scores.
Conclusions: PSG recordings have proved to be a reliable tool in the neurophysiologic assessment of patients with prolonged DOCs, correlating more adequately than EPs with the clinical evaluation and the level of consciousness. The main contribution to higher clinical scores was determined by the concomitant presence of REM sleep and sleep spindles. PSG recordings may be considered inexpensive, non-invasive, and easy-to-perform examinations to provide supplementary information in patients with prolonged DOCs.

1. Introduction

Due to advances in critical care, an increasing number of patients survive from an acute brain injury causing an increased incidence and prevalence of patients with disorders of consciousness (DOCs). Behavioral assessment currently is the main method used to detect signs of awareness in severely brain injured patients recovering from coma [1]. However, disentangling the vegetative state (VS) from the minimally conscious state (MCS) often is difficult when only relying on behavioral observation [2]. Clinical misdiagnosis is partly explained by the inherent difficulties in detecting signs of awareness in patients with fluctuating arousal and possible perceptual, attentional, cognitive, and motor deficits. Previous studies have shown that 37–43% of patients diagnosed with VS demonstrated signs of awareness [3,4].

The most commonly reported error is a false-negative diagnosis of a patient who is actually in MCS being misdiagnosed as VS. The JFK Coma Recovery Scale-Revised (CRS-R) is commonly considered

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the most reliable and validated scale for the standardized evaluation of patients with prolonged DOCs. The CRS-R was developed specifically to differentiate MCS from VS [5,6]. However, evaluating DOCs patients may be extremely challenging, even using standardized scales such as CRS-R. Neuroimaging and neurophysiologic techniques may be helpful to assess residual cerebral functions, which in turn could aid in differentiating between states in which consciousness is impaired [7]. Neurophysiologic assessment represents an option that provides valuable clinical insight while being more accessible than functional imaging modalities [8]. We believe that combining clinical examination with instrumental techniques can be useful to obtain information independent of the patient's ability for overt responses, and thus reduce the rate of misdiagnosis.

The aim of our study was to evaluate the importance of neurophysiologic techniques, in particular sleep recordings, in patients with prolonged DOCs by observing possible correlations between clinical evaluation and neurophysiologic variables.

2. Methods

2.1. Patients

Our study was conducted on 32 patients with severe brain injury whose ages ranged from 26 to 71 years (mean age, 52.94 ± 11.89 years). There were 27 patients who were diagnosed as being in a VS (mean age, 52.56 ± 12.32 years; CRS-R score, 4.89 ± 1.34) and 5 patients were in an MCS (mean age, 55.00 ± 10.12 years; CRS-R score, 9.00 ± 0.71). The diagnoses of VS and MCS were made according to currently accepted diagnostic criteria [9–11]. We recruited patients from different units (e.g., neurology, intensive care, intensive and long-term rehabilitation units) belonging to three different hospitals (''Sacro Cuore-Don Calabria'' Hospital in Negrar, Verona; ''Pineta del Carso'' Hospital in Aurisina, Trieste; and ''Santa Maria della Misericordia'' University Hospital in Udine). All data were collected using the same methods of acquisition and the same portable laptop system. DOCs were caused by traumatic brain injury (10 patients), cardiac or respiratory failure (15 patients), and hemorrhagic stroke (7 patients). The time between DOCs onset and the evaluation ranged between 3 months and 12 years (mean, 3.96 ± 3.37 years).

2.2. Procedure

Patients' inclusion criteria were confirmation of VS or MCS according to currently accepted diagnostic criteria [9–11], age between 18 and 75 years, Glasgow Coma Scale (GCS) score of $\leqslant$10, and Disability Rating Scale (DRS) score between 17 and 29. Clinical evaluation included a full neurologic examination and a clinical assessment with the GCS, the DRS, and the CRS-R. The clinical diagnosis was done by the local specialized personnel who observed and evaluated the patients on a daily basis. The CRS-R and the other clinical scales used for the behavioral assessment were applied right before and at the end of sleep recordings, always by the same investigator (SDB). Evaluations were consistent at different times. Among the clinical scales used we mainly used the CRS-R, as it is the most reliable and validated scale for the evaluation of patients with prolonged DOCs.

Neurophysiologic evaluation included 24-h polysomnography (PSG) and three evoked potentials (EPs), including somatosensory

Table 1
Demographic and clinical data.

Patient	Age (y)	Gender	Years between DOCs onset and registration	Etiology	DOCs level	GCS	DRS	CRS-R	Sleep-wake cycle	K-complexes	Spindles	REM sleep	BAEPs	SEPs	VEPs
1	26	M	6	Traumatic brain injury	VS	8	24	7	P	P	P	P	P	A	A
2	64	M	6	Cardiac failure	VS	6	28	2	P	P	A	P	P	A	P
3	64	M	7	Hemorrhagic stroke	VS	6	26	4	P	P	P	A	A	P	A
4	61	M	12	Traumatic brain injury	VS	6	26	6	P	P	P	P	A	P	P
5	46	M	2	Cardiac failure	VS	7	24	5	P	P	A	A	P	P	NR
6	70	M	1	Cardiac failure	VS	6	26	4	A	A	A	A	NR	NR	NR
7	37	W	3	Traumatic brain injury	VS	6	26	4	P	P	P	A	A	A	NR
8	37	W	1	Cardiac failure	VS	6	26	3	P	P	P	A	P	NR	A
9	41	W	1	Cardiac failure	VS	6	26	3	P	P	P	A	NR	NR	NR
10	55	M	3	Traumatic brain injury	VS	6	25	3	P	P	A	P	P	A	NR
11	61	M	0.3	Hemorrhagic stroke	VS	6	26	5	A	A	A	A	P	P	P
12	58	M	1	Cardiac failure	VS	8	24	6	P	P	P	A	A	P	P
13	50	M	1	Hemorrhagic stroke	VS	8	24	5	P	P	P	A	A	A	P
14	59	M	3	Traumatic brain injury	VS	8	24	5	P	P	P	A	P	P	P
15	71	W	9	Cardiac failure	VS	8	24	5	P	P	P	A	P	P	P
16	33	M	0.25	Hemorrhagic stroke	VS	8	24	6	P	P	P	A	A	P	P
17	52	M	5	Cardiac failure	VS	8	24	6	A	A	A	A	P	A	A
18	52	W	8	Cardiac failure	VS	8	23	7	P	P	A	A	A	A	P
19	51	M	5	Cardiac failure	VS	8	23	5	P	P	A	A	A	P	P
20	53	M	2	Traumatic brain injury	VS	9	22	6	A	A	A	A	A	NR	P
21	71	W	1	Cardiac failure	VS	6	26	4	P	P	P	A	P	P	P
22	65	M	3	Cardiac failure	VS	8	23	3	A	A	A	A	A	A	A
23	50	W	3	Hemorrhagic stroke	VS	6	26	5	P	P	A	A	P	P	P
24	40	M	12	Traumatic brain injury	VS	9	23	7	P	P	P	A	A	P	P
25	65	W	1	Respiratory failure	VS	8	24	5	P	P	P	A	A	P	A
26	50	W	10	Respiratory failure	VS	8	24	5	P	P	P	A	A	P	P
27	37	M	1	Traumatic brain injury	VS	8	24	6	P	P	A	A	P	P	A
28	43	M	6	Cardiac failure	MCS	10	21	8	P	P	P	P	P	P	P
29	46	M	3	Traumatic brain injury	MCS	7	22	9	P	P	P	P	P	A	NR
30	65	M	5	Hemorrhagic stroke	MCS	10	22	9	P	P	P	P	P	P	P
31	57	M	4	Traumatic brain injury	MCS	10	22	9	P	P	P	P	P	P	P
32	64	M	1	Hemorrhagic stroke	MCS	9	23	10	P	P	P	P	P	P	P

Abbreviations: y, years; M, man; W, woman; DOCs, disorders of consciousness; VS, vegetative state; MCS, minimally conscious state; GCS, Glasgow Coma Scale; CRS-R, Coma Recovery Scale-Revised; DRS, Disability Rating Scale; P, present; A, absent; REM, rapid eye movement; BAEP, brainstem auditory evoked potentials; SEP, somatosensory evoked potentials; VEP, visual evoked potentials; NR, not recorded.