Research Progress of EEG Combined with Brainstem Auditory Evoked Potential in Prognosis Assessment of Patients with Consciousness Disturbance

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Abstract: Disorders of consciousness (DOC) Serious brain injury with long treatment and recovery cycles. Today, with the dedicated research of clinicians and the rapid development of neuroimaging, we have made remarkable achievements in identifying patients' residual consciousness, explaining the biological mechanisms of consciousness recovery, and reconstructing damaged neural pathways with precision therapy techniques. Accurate assessment of brain function of patients with consciousness disorders should be continuously improved, so as to provide clinical guarantee for the diagnosis and treatment of patients with consciousness disorders. Electroencephalogram (EEG) can reflect cerebral cortex function; while brainstem auditory evoked potential (BAEP) can reflect brainstem function. Both of them are widely used to assess the prognosis of consciousness disorders due to their simple operation. It has been found that using EEG or BAEP alone to predict the prognosis of DOC patients has certain limitations. Therefore this article reviews the progress of EEG combined with brainstem auditory evoked potentials in the prognosis assessment of patients with consciousness disorder, in order to provide reference for relevant professionals.

1. Introduction

The incidence of craniocerebral injury is not only rising, but also the scope of its impact is becoming more and more extensive. Craniocerebral injury can not only lead to death, but also cause serious disability, which has become one of the major diseases threatening human life safety in today's society. In recent years, with the progress of emergency medicine, many lives of patients with severe craniocerebral injury have been saved, and the resulting disability rate has also increased, most of which will evolve into disorders of consciousness (DOC). There are an estimated 300,000 adults and 120,000 children with DOC in the United States (see Figure 1). It is conservatively estimated that the annual increase of 70,000-150,000 patients in China will require at least 30-50 billion yuan/year in treatment costs, which will bring huge economic burden and mental

pressure to society and families [1]. With the progress of medical industry, people's understanding of the pathogenesis, prognosis assessment and treatment of DOC patients has been continuously improved, and reasonable prognosis assessment will speed up the recovery process of patients. Therefore, how to use the existing technology to accurately judge the prognosis is still a very challenging work.
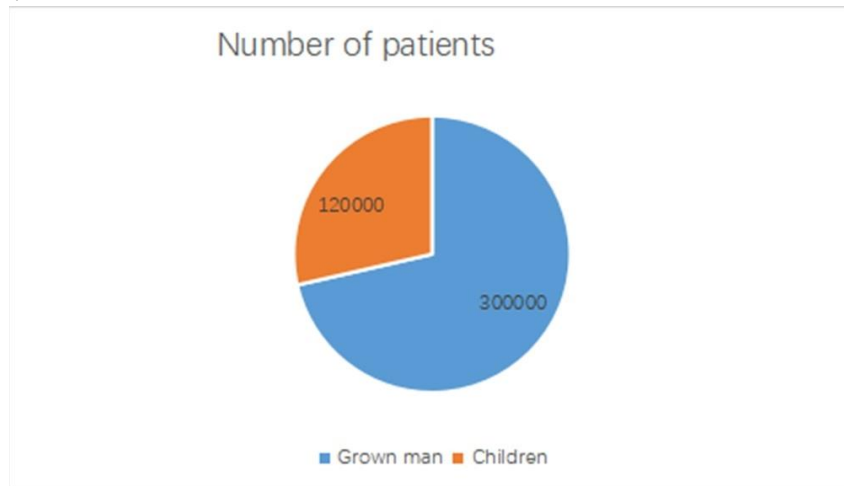

Figure 1: Prevalence in the United States

2. DOC Overview

2.1. Definitions

DOC refers to a state of loss of consciousness caused by severe brain damage, including coma, vegetative state (VS) and minimal consciousness state (MCS). Although the duration and recovery time of patients vary, the level of consciousness can gradually reach a state of wakefulness through exit from microconscious states (eMCS) [2].

2.2. Pathogenesis of DOC

Western medicine believes that human consciousness is the result of the cooperation between the ascending reticular activation system of the brainstem and the cerebral cortex, which defines the cognitive ability of people to the outside world and their own environment. Currently, it is clinically believed that the cerebral cortex is related to the content of consciousness, and the ascending reticular activation system of the brain stem is related to excitability. When both structures and functions are damaged at the same time, patients will become conscious disorders [3].

3. Prognosis Assessment of DOC

According to literature [4], the current clinical evaluation methods for DoC patients are clinical observation and behavioral evaluation. The Glasgow coma scale (GCS) [5], the full outline of unresponsiveness (FOUR) [6], and the modified coma recovery Scale (coma recovery) scale-reviseds cale, CRS-R) [7] etc. are common scales for behavioral assessment. In addition, neuroelectrophysiology, imaging, brain-computer interface, blood markers, electroencephalogram, brainstem auditory evoked potential and other auxiliary tests were evaluated. Because the behavioral assessment scale is subject to subjective influence, the misdiagnosis rate is 37%-43% [8], so a more accurate assessment is particularly important.

3.1. Electroencephalogram

Electroencephalography (EEG) technology provides an objective basis for the prognosis assessment of patients with DOC [9], and the brain function is usually evaluated by analyzing the frequency, amplitude and waveform of brain waves [10]. EEG is simple and safe to operate, especially in patients with traumatic brain injury (TBI) who are in coma [11]. Although the mechanism of TBI injury is heterogeneous, the dynamic characteristics of EEG are consistent throughout the process from coma to recovery -- EEG activity is concentrated below 1 Hz after the most severe injury. During the lowest state of consciousness during wakefulness, there is a peak of activity in the 3-7 Hz range, which is usually coherent throughout the brain, and there is also usually activity in the belta (15-30 Hz) range [12]. Delta or theta waves, known as slow wave frequencies, are produced by neurons in the thalamus and layers II-VI of the cerebral cortex. The alpha wave frequency is derived from the cells of layers IV and V of the cerebral cortex, which are regulated by the reticular activation system of the brain [13, 14]. Some researchers have found that spectral power, coherence and entropy are commonly used to distinguish the level of consciousness, predict the outcome of the response, or measure the cortical response of patients to brain intervention. The permutation entropy at θ frequency has a high accuracy in distinguishing MCS from VS, and θ and alpha bands are also a key frequency band for evaluating cortical relationships of brain intervention [15]. The frontal lobe band power of patients with DOC is significantly different, which has been shown to distinguish patients with DoC and can be distinguished into patients with MCS and VS/ unresponsive wakefulness syndrome (UWS) [16]. Patients with DOC showed a lower frontal delta source pattern [17]. Frontal lobe regions in VS/UWS patients showed higher delta power, but lower θ, alpha, and beta power than in MCS patients [18]. Liu Y [19] et al. recorded the resting EEG of 25 patients with DOC, measured the Lempel-Ziv complexity (LZC) and the displacement Lempel-Ziv complexity (PLZC) on the EEG, and found that PLZC was more sensitive than LZC in the classification of consciousness level by analyzing the relationship between them. PLZC was globally correlated with consciousness in DOC patients and performed better than LZC in capturing neural differences between VS/UWS and MCS at the population level, and the sample should be expanded in the future to test this conclusion based on the limitations of sample size.

3.2. Brainstem Auditory Evoked Potential

Brainstem Auditory evoked potential (BAEP) is a diagnostic technique for collecting information about the brain stem of the central nervous system [20] through short sound stimulation. It changes significantly in response to minor damage to the brain stem and is mainly used to assess the function of the brain stem [21]. BAEP classification criteria [22]: Level 1 is called normal wave; Grade 2 is called mild abnormality (i-V wave differentiation is clear, but there is prolonged latency or decreased amplitude); Grade 3 is called moderate abnormality (only I wave latency and amplitude are normal, and the other wave shapes are poorly differentiated or absent); Grade 4 is called severe abnormality (all waves are absent or only wave I). Through reading the literature, it was found that different professionals had different views on the prognosis of BAEP for patients with consciousness disorders. It has been documented [23] that BAEP grading has little or no correlation with prognostic assessment. However, Xu Leyi [24] and Li Wenjuan [25] et al. found in the diagnosis and prognosis assessment of craniocerebral injury that the smaller the degree of BAEP abnormality in patients with craniocerebral injury, the better the prognosis. If the grading improved, the good prognosis rate increased. Li Baisheng et al. [26] evaluated the treatment effect and heard that BAEP test showed that 55 cases were good and 57 cases were actually improved, with a prediction accuracy of 96.49%. 31 cases were predicted to be bad, 29 cases were actually bad, and

the prediction accuracy was 93.55%. Ren Erpeng et al. [27] used GCS score and BAEP to predict 51 patients respectively and found that the prediction accuracy of GCS score was 78% and that of BAEP 96%. Through a series of verification, it is not difficult to find that brainstem auditory evoked potentials can more accurately reflect the brain stem function of patients with brain injury, which is worthy of clinical promotion.

3.3. EEG Combined with Brainstem Auditory Evoked Potential

After reading a lot of literature, it is found that EEG combined with BAEP is better than single factor prediction in the prognosis of patients with consciousness disturbance. Example: Weng Qizhen et al. [28] performed EEG and BAEP detection on 71 patients with consciousness disorder, and compared pure EEG and EEG combined with BAEP detection, found: The accuracy and sensitivity of EEG combined with BAEP were 98.59% and 100.00%, respectively, higher than 80.28% and 83.05% of EEG. Zhu Zhenxin et al. [29] also evaluated 114 coma patients and found that the accuracy and sensitivity of EEG combined with BAEP for prognosis assessment were 91.23% and 95.56%, respectively. Qin Nan et al. [30] analyzed 50 coma patients in ICU by GCS score, EEG, BAEP and EEG combined with BAEP, and concluded: The sensitivity, specificity, accuracy and misdiagnosis rate of EEG combined with BAEP were significantly better than those of GCS score assessment in patients with consciousness disorders (84.38% vs 60.00%, 88.89% vs 70.00%, 86.00% vs 60.00%, 11.11% vs 30.00%) see Figure 2. Liu Xijin et al. [31] studied 100 patients with severe cranial injury and found that the accuracy of EEG detection alone was 76.4%, which was close to the value reported in China. When combined with BAEP, the accuracy was as high as 91.0%, which may be due to the fact that EEG can only record electrical activities located in the cortex. Electrical activity deep in the brain is usually not recorded. It can be concluded that EEG combined with BAEP will effectively improve the accuracy, sensitivity and reduce the misdiagnosis rate of patients with consciousness disorders, and it is a reliable prediction method.
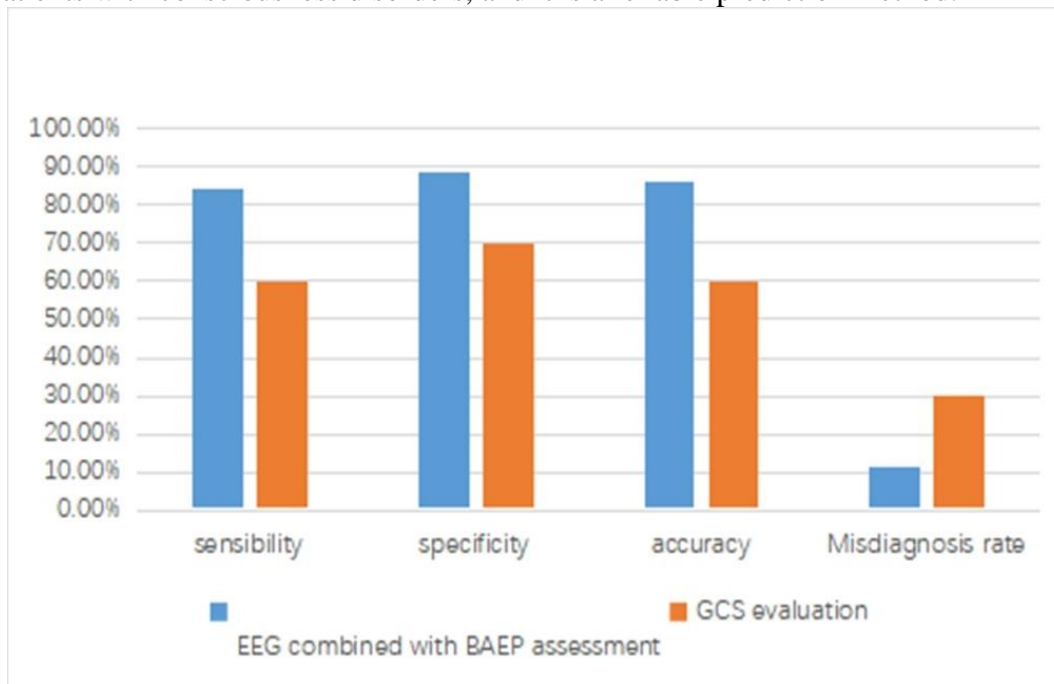

Figure 2: Score comparison chart

4. Conclusions

The electroencephalogram (EEG) is a graph of the extremely fine bioelectricity recorded by the brain itself, which is an auxiliary means of examination - modern diagnosis of disease, and it can reflect the function of the cerebral cortex. However, brainstem auditory evoked potential is the electrical activity generated by nerve impulse induced by acoustic stimulation in the auditory transmission pathway of the brainstem, which can objectively and sensitively reflect the function of the central nervous system. BAEP records the nerve potential activity in the auditory conduction pathway, reflecting the functional status of related structures from the cochlea to the brainstem. Any lesion or injury involving the auditory pathway will affect BAEP, and BAEP is usually altered when the brain stem is slightly impaired and the patient is clinically asymptomatic and pathological. It was found that the accuracy and sensitivity of EEG combined with brainstem evoked potential in prognosis assessment were higher than that of single assessment. Due to the rapid progression of the disease, the fatality rate and disability rate of the patients with consciousness disorders are higher than other diseases, which bring a huge economic burden to the society and a huge mental pressure to the family. Therefore, accurate prognosis assessment can effectively solve this problem and benefit the country, society and family. Nowadays, with the increasing development of medicine, the evaluation methods include GCS score, FOUR score, CRS-R score, neuroelectrophysiology, imaging, brain-computer interface, blood markers, electroencephalogram, brainstem auditory evoked potential and other auxiliary tests. Although there are a lot of studies at home and abroad, most of them are single factor. In recent years, although there are multimodal detection, due to the difficulty of practice and clinical limitations, there are few studies on correlation than single factor. It is hoped that in the future, more clinicians will consider the combination of multi-factor prognosis assessment to build a more accurate prediction model, so that it can more effectively predict and evaluate DOC patients more accurately, timely adjust more accurate treatment plans, and reduce the disability rate.

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