Recommendations for Electroencephalography Monitoring in Neurocritical Care Units

Neurocritical Care Committee of the Chinese Society of Neurology (NCC/CSN)

Key words: Electroencephalography; Neurocritical Care; Recommendation

Introduction

Since the 1950s, electroencephalography (EEG) has been used extensively in Neurocritical Care Units (NCUs). At the beginning of this century, China's NCUs underwent rapid development. According to an incomplete statistical report,[1] 76 NCUs had achieved the construction standard in 2010. Therefore, the establishment of EEG monitoring stations and the development of national competency skill standards is imperative. In response to this urgent need, the Neurocritical Care Committee (NCC) of the Chinese Society of Neurology presents this document to set the national criteria to evaluate competencies for performing studies associated with EEG monitoring in NCUs. The NCC organized a writing committee to evaluate the literature and develop an evidence- and expert-based (neurocritical care and neurophysiological experts) consensus for practice recommendations. Literature searches were conducted using the PubMed database (from 1995 to 2013). Studies meeting the criteria established by the writing committee were evaluated. Recommendations were developed based on the literature using grading standards and level-of-evidence confirmation from the 2011 edition of the Oxford-based medicine center.[2] Expert opinions were gathered to improve the recommended level when sufficient data were lacking. The NCC aims to provide help and references for physicians in NCUs, Intensive Care Units (ICUs), and Emergency Medicine Departments.

The application of EEG monitoring in NCUs can be used to detect epileptiform activity, determine the degree of brain injury, guide treatment, and predict prognosis. EEG monitoring has several advantages. EEG has very good time resolution (ms) and relatively good spatial resolution (mm). EEG is capable of real-time dynamic monitoring, and it is easily performed at the bedside. EEG can assist in the identification of epileptic and nonepileptic attacks and differentiate them from nonconvulsive epileptic seizures. EEG can sensitively and rapidly detect early changes in brain function and can facilitate judgments regarding expected improvements or deteriorations prior to the presentation of clinical signs. EEG can be used for early prediction of the prognosis of comatose patients and provide a reliable medical basis for decision making. Finally, EEG can accurately feedback treatment information and guide changes in the treatment plan based on this information.

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Electroencephalography Monitoring Objects

Evidence

Status epilepticus

In 1998, a prospective case series study was conducted in the United States with 164 patients with convulsive status epilepticus (CSE). After antiepileptic therapy, 48% of the patients experienced nonconvulsive seizures (NCS) and 14% of the patients experienced nonconvulsive status epilepticus (NCSE) (Evidence Class IV).[3] An analysis[4] of the data from two randomized controlled trials in China in 2013 revealed positive correlations between interictal epileptiform discharges, periodic epileptic discharges, NCSE patterns, and refractory status epilepticus (RSE) incidence (Evidence

Address for correspondence: Prof. Ying-Ying Su, Department of Neurointensive Care Unit, Xuanwu Hospital, Capital Medical University, Beijing 10053, China
E-Mail: suyingying@xwh.ccmu.edu.cn
Prof. Zhen Hong, Department of Neurology, Huashan Hospital, Fudan University, Shanghai 200040, China
E-Mail: hongzhen@medmail.com.cn

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Class IIa). In 2013, a prospective study of[5] 63 patients with status epilepticus (SE) in the United States demonstrated that interictal epileptiform discharges and the disappearance of EEG reactivity indicated poor prognosis (Evidence Class Ib). In 2013, a prospective study[6] of 104 patients with SE in China demonstrated that the prognosis of patients with interictal epileptiform discharges and periodic epileptic discharges/subtle SE patterns was also poor (Evidence Class Ib).

Severe cerebral infarction

In 2007, a prospective EEG study[7] in Germany of 25 patients with cerebral hemisphere large area cerebral infarction (massive cerebral hemispheric infarction [MCHI]) demonstrated that strong theta and beta activity suggested a good prognosis and general slow background delta activity indicated a poor prognosis (Evidence Class Ib). In 2013, a prospective study[8] in China including 162 cases with MCHI demonstrated that a lack of EEG reaction, regional attenuation without delta mode, burst suppression pattern, alpha/theta coma pattern, and epileptiform discharges (no burst suppression) and an extensive mode of inhibition also indicate poor prognosis (Evidence Class Ib).

Critical subarachnoid hemorrhage

In 2004, a prospective case series study[9] in the United States of 34 cases with subarachnoid hemorrhage (SAH) (Hunt-Hess Grade 4–5) demonstrated that among patients with delayed cerebral ischemia (DCI), 24% had an alpha/delta ratio (alpha energy/delta energy) that was relatively decreased compared to the baseline (as assessed through quantitative EEG monitoring [qEEG]) (Evidence Class IV). In 2011, a Canadian prospective study[10] of 12 SAH cases with high-risk DCI revealed that 66.7% patients demonstrated decreased average alpha wave energy. These patients typically demonstrated changes with milrinone treatment. In 3 cases, EEG detected DCI 24–48 h earlier than the clinical diagnosis (Evidence Class IV). In 2006, a retrospective study[11] in the United States including 116 patients with SAH showed that epileptic discharges and the disappearance of EEG reactivity were prognostic indicators of poor outcomes (Evidence Class IIbb).

Critical traumatic brain injury

In 1995, a prospective study[12] in the United States including 50 patients with traumatic brain injury (TBI) demonstrated that the absence of EEG reactivity indicated poor outcomes (Evidence Class Ib). In 2002, a prospective study[13] in the United States including 89 patients with TBI revealed that alpha variability over 3 days could predict the prognosis of patients (Evidence Class Ib). In 2010, another prospective study[14] from the United States including 105 TBI cases suggested that the application of qEEG frequency band energy analysis showed better predictive sensitivity (92.45%) and specificity (90%) for the assessment of the extent of brain damage in TBI patients compared to computed tomography (Evidence Class Ib).

Cardiopulmonary resuscitation

In 2006, a prospective study[15] of 64 patients who underwent cardiopulmonary resuscitation (CPR) in China showed that a comprehensive inhibition and burst suppression pattern was a predictor of poor prognosis, and the slow wave pattern indicated a good prognosis in patients after CPR (Evidence Class Ib). In 2012, a prospective study[16] of 61 patients who underwent CPR in Switzerland concluded that the absence of EEG reactivity, epileptiform discharges, and intermittent electric silence indicated poor patient prognosis (Evidence Class Ib). In 2013, a study[17] of 190 CPR patients undergoing hypothermia treatment in the United States revealed that intermittent electric silence indicated poor prognosis (Evidence Class Ib). In 2014, a prospective study[18] of 60 CPR patients in China showed that the burst suppression ratio (calculated using qEEG) indicated poor prognosis (Evidence Class Ib).

Brain death

In 1995, the American Standards for BD recommended that electric silence should be recorded for at least 30 min via EEG.[19] In 2013, the Brain Injury Evaluation Quality Control Centre of China recommended the following EEG criteria for BD: EEG voltage of no more than 2 μV, sustained for at least 30 min. These indicators should be used as confirmatory test indicators.[20,21]

Vegetative state

In 2011, a prospective study[22] was conducted with 38 vegetative state (VS) patients in Europe. The approximate entropy of the VS patients was lower than healthy controls, and patients with lower approximate entropy were prone to VS maintenance or death. Patients with higher approximate entropy often partially recovered consciousness (Evidence Class Ib). In 2013, a prospective study[23] including 14 VS patients in Europe showed that patients with decreased network connectivity (using linear EEG analysis) were prone to poor outcomes (Evidence Class Ib).

Currently, there is a lack of published evidence for EEG monitoring in patients with other severe neurological diseases, such as infections of the central nervous system or immune-mediated encephalopathy.

Recommendations

1. EEG recordings are recommended for the diagnosis of NCS or NCSE in CSE patients after drug treatment when they are still in an unexplained coma (Recommendation Level C)
2. EEG monitoring is required for the treatment of SE. EEG monitoring is recommended for the prediction of the recurrence of epilepsy in patients with SE after initial treatment (Recommendation Level C)
3. EEG reactivity, EEG pattern or qEEG analysis is recommended to predict the prognosis of SE, MCHI, TBI, and CPR patients (Recommendation Level A)
4. EEG pattern monitoring is recommended to predict the prognosis of SAH patients (Recommendation Level C). qEEG analysis is recommended to predict preclinical vasospasms or DCI in SAH patients (Recommendation Level C)
5. EEG monitoring is recommended as a confirmatory test

for the diagnosis of BD (Recommendation Level A)
6. qEEG is recommended to predict the prognosis of patients in a VS (Recommendation Level B)
7. Not all patients in NCUs require EEG monitoring. It is reasonable to perform EEG monitoring in the situations described above.

Technical Skills for Electroencephalography Monitoring and Evaluation

Evidence

Electroencephalography monitoring: instruments and equipment

Monitoring can be performed with portable EEG, mobile desktop EEG, and EEG workstations, according to the available models. EEG monitoring can also be subdivided into video EEG monitoring and nonvideo EEG monitoring. Usually, appropriate EEG models with or without video need to be selected based upon the patient's condition. Video EEG is more helpful for the synchronous recording of patients with clinical seizures.[24,25] The use and maintenance of EEG instruments in NCUs requires a dedicated responsible person to ensure appropriate, continuous operation.

The initiation window for Electroencephalography monitoring

Video EEG monitoring should be initiated if ongoing seizures are suspected in patients with SE (Evidence Class IIb).[3,26,27] The recommended time to begin EEG recordings to predict prognosis in comatose patients after brain injury is 1–7 d after the coma onset (Evidence Class Ib).[13,14,16]

The duration of Electroencephalography monitoring

Short time-range EEG monitoring, requiring 0.5–2.0 h, is used mostly to assess the prognosis of comatose patients; continuous EEG monitoring for at least 24–48 h[25] is used mainly for the diagnosis and treatment of patients with SE and NCS. Most of the reviewed research indicates that for brain injury patients and especially patients post-CPR, it is better to perform repeated assessments using short-range EEG monitoring, which could improve the assessment accuracy (Evidence Class Ib).[28-30] In 2013, the duration determination recommended for BD determination using EEG as a confirmatory test in China was at least 30 min.[20,21] In 2004, a large-sample United States retrospective study including 570 patients showed that only 50% of NCS patients were identified during the initial 60 min monitoring time. Therefore, we recommend that the monitoring time should be extended (at least 24–48 h) to better identify NCS (Evidence Class IV).[31]

Electroencephalography monitoring methods

EEG monitoring should utilize independent power, and if necessary, a regulator. Usually, some medical instruments and equipment (such as an infusion pump, vibration sputum elimination apparatus, and anti-bedsore cushion) are suspended to avoid interference on EEG recordings.[25] Most EEG recordings follow the American Clinical Neurophysiology Society International 10–20 System guidelines for head measurements and electrode applications.[26] It is permissible to decrease some electrodes or to change electrode applications due to invasive intracranial pressure monitoring, partial skull defects, or skull drilling drainage. At such times, it is critical to maintain the symmetry of the left and right side electrodes. For the application of long-range EEG monitoring, a 12–24 h suspension is needed after 24–48 h continuous monitoring. Sometimes, it is necessary to clean the skin or change the location of some electrodes to avoid scalp ulcerations or infections. The evaluation of BD requires at least the following 8 recording electrodes: forehead FP1, FP2; central C3, C4; temporal T3, T4; and occipital O1, O2. Inter-electrode impedances should be under 10,000 Ω but over 100 Ω, and electrode impedances should be matched on the whole. The reference electrodes should be at the bilateral earlobes or mastoids. The grounding electrode should be placed at the midpoint of the frontal pole (FPz), and the common reference electrode should be placed at the median central point (Cz). The high-frequency filter should be set between 30 Hz and 75 Hz, the low-frequency filter at 0.5 Hz, and the sensitivity at 2 μV/mm.[20,21] It is necessary to observe EEG reactivity to strong somatosensory, visual, and auditory stimulation in comatose patients. There should be no EEG reactivity in BD patients.

Electroencephalography evaluation and analysis

EEG evaluation analysis can be selected for routine EEG analysis, video EEG analysis, EEG reactivity response (sound, pain and light stimulation) analysis, and qEEG analysis. EEG analysis requires at least two physicians with a history of quality EEG interpretation. Any inconsistent interpretations will need to be resolved through discussion or additional consultation. Interpretation of the results should be timely, including communication with the physician and nurse in charge of the patient and with the patient's family, if necessary.

Electroencephalography monitoring and nursing

Nurses should try to avoid the removal of electrodes during the routine performance of their job duties. If an electrode is removed, it should be placed back as soon as possible. Vigilant monitoring of the vital signs of SE patients and the use of appropriate constraints to prevent tongue bite, body bruising or falling out of bed should be utilized. Patients should be maintained in a target position and sheltered in a private site when performing video monitoring.

Recommendations

1. EEG monitoring instruments and equipment should be chosen for use within NCUs, other departments or other hospitals according to their needs, such as portable EEG, mobile desktop EEG, or EEG workstations (Recommendation Level A). Video EEG monitoring is recommended for patients with SE (Recommendation Level A)
2. Video EEG monitoring should be initiated as soon as possible if ongoing seizures are suspected for patients with SE in the Emergency Department or

NCU (Recommendation Level A). EEG assessment should be performed 3–7 days after coma onset in brain injury patients (Recommendation Level A)

3. Continuous EEG monitoring should be performed in SE patients (Recommendation Level B), RSE patients (A recommendation) and suspicious NCS/NCSE patients (Recommendation Level B). Patients with coma after brain injury should undergo short-term EEG monitoring (Recommendation Level A). The duration of EEG monitoring in SAH patients should be at least 3 – 5 d to facilitate early detection of DCI (Recommendation Level B). The duration of EEG monitoring for BD should be at least 30 min (Recommendation Level A)
4. A pause should be taken for 12–24 h after 24–48 h of continuous EEG monitoring. The electrode placement should be fine-tuned as necessary to avoid scalp ulcerations or infections (Recommendation Level A)
5. A separate power supply should be used. A minimum of 16 scalp electrodes should be placed according to the International 10–20 system (Recommendation Level A)
6. EEG monitoring should be conducted at a warm room temperature in a quiet area. EEG monitoring should be coordinated with the implementation of routine nursing operations (being attentive to the electrode placements during continuous EEG monitoring). Maintaining the target position and protecting the patient's privacy during video EEG monitoringis also important (Recommendation Level A)
7. EEG records should be full and complete, including general information and the impact of drugs on brain electrical activity. EEG monitoring results should be interpreted separately by 2 physicians. An expanded discussion or additional consultation is needed if the opinions are not consistent (Recommendation Level A). The diagnosis of BD using EEG as a confirmatory test requires current relevant qualification certificates (Recommendation Level A).

EEG monitoring also has some limitations. In particular, the results are vulnerable to the effects of anesthetic sedative drugs. Therefore, patients should be monitored both for their clinical manifestations and using other monitoring results, such as evoked potentials, neuroimaging, and biochemical markers.[32]

Along with the rapid development of neural electrophysiological techniques, new EEG monitoring technologies will be more widely applicable in patients in NCUs and EEG interpretation will become much easier. EEG can provide useful information for the diagnosis, treatment and prognostic evaluation of diseases.

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Yan Zhang (Department of Neurointensive Care Unit, Xuanwu Hospital, Capital Medical University), Dong Zhou (Department of Neurology, West China School of Medicine/West China Hospital, Sichuan University), Yi Zhu (Department of Neurology, People's Hospital of Xinjiang Uygur Autonomous Region).

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Conflicts of interest

There are no conflicts of interest.

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