汇编：脑电长程监测在神经科临床的应用

北京太阳电子科技有限公司

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目　录

1 国内外文献汇编

1.1 Continuous EEG Monitoring in the Intensive Care Unit

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Summary: Continuous EEG (CEEG) monitoring allows uninterrupted assessment of cerebral cortical activity with good spatial resolution and excellent temporal resolution. Thus, this procedure provides a means of constantly assessing brain function in critically ill obtunded and comatose patients. Recent advances in digital EEG acquisition, storage, quantitative analysis, and transmission have made CEEG monitoring in the intensive care unit (ICU) technically feasible and useful. This article summarizes the indications and methodology of CEEG monitoring in the ICU, and discusses the role of some quantitative EEG analysis techniques in near real-time remote observation of CEEG recordings. Clinical examples of CEEG use, including monitoring of status epilepticus, assessment of ongoing therapy for treatment of seizures in critically ill pateints, and monitoring for cerebral ischemia, are presented. Areas requiring further development of CEEG monitoring techniques and indications are discussed. Key Words: EEG—Continuous—Seizure—ICU—Head injury.

In patients with severe cerebral dysfunction, substantial alterations in brain function or structure must occur before significant changes become evident in an already abnormal neurologic examination. Because of this, our ability to assess for clinically significant neurologic deterioration (or improvement) in critically ill patients has been limited. Deterioration may become evident only at the time of irreversible catastrophe. These difficulties have prompted the development of new clinical assessment tools. Recent clinical experience and an expanding body of literature suggest that the use of continuous EEG (CEEG) monitoring techniques can greatly enhance the neurologic assessment and care of critically ill patients.

BRAIN MONITORING: ADVANTAGES OF CONTINUOUS EEG (CEEG) MONITORING

Of available techniques for brain monitoring (Table 1), EEG presents several advantages. The EEG provides reasonable spatial resolution (i.e., activity in different brain regions can be assessed simultaneously) and excellent temporal resolution (to 2–4 ms in conventional digital EEG machines). It can be applied in either structural disorders (such as potentially expanding mass lesions) or metabolic/physiological disorders (seizures, metabolic encephalopathies, postanoxic injury). Previous difficulties associated with bedside use of the EEG, such as excessive paper use, mechanical malfunctions, and problems in providing real-time review, have been largely eliminated with the advent of computerized digital recording techniques and data transmission via computer networks. The major remaining problem concerns the availability of expertise for continuous real-time or near real-time interpretation of EEG patterns. Some persons with relatively little training in EEG can be trained to recognize some patterns correctly (1). However, definitive interpretation of changing patterns and distinction of cerebral activity from artifact remain the realm of the experienced electroencephalographer. Current approaches to decreasing the complexity in EEG analysis and expanding the availability of interpretive expertise are discussed.

Indications

Continuous EEG monitoring in the intensive care unit (ICU) can now provide timely and therapeutically important data regarding cerebral function. These data are most often used in decision making regarding antiepileptic drug (AED) manipulations, the need for immediate neuroimaging studies, and alterations in therapy to assure adequate cerebral perfusion. Additional areas of potential use include management of metabolic coma and decision making regarding prognosis for cerebral recovery after severe brain injury.

Monitoring of nonconvulsive seizure activity

Accumulating evidence indicates that nonconvulsive seizures probably occur in a substantial fraction of obtunded or unresponsive patients in ICU settings. Although large patient populations have not been studied.

	Bedside use	Spatial resolution	Temporal resolution	Scope of use	Ease of interpretation
CEEG	excellent	good	excellent	excellent	poor
Evoked potentials	god	fair	fair	fair	poor
Transcranial Doppler	good	fair	fair	fair	poor
MRI	poor	excellent	poor	good	fair
Functional MRI	poor	excellent	good	poor	poor
CT	poor	excellent	poor	good	fair
Xenon CT	poor	good	poor	fair	poor
ICP monitoring	excellent	poor	good	fair	good

CEEG, continuous EEG; MRI, magnetic resonance imaging; CT, computed tomography;

ICP, intracranial pressure.

prospectively, retrospective analyses suggest that 11– 55% of patients in neurologic ICUs may be experiencing nonconvulsive seizures. Such seizures may prolong the need for intensive care and may worsen the degree of brain injury associated with a prior insult such as severe head trauma. Jordan (2), with continuous EEG techniques in a neurologic ICU, documented seizures in 35% of 124 patients. Nonconvulsive seizure activity or non-convulsive status epilepticus occurred in about three fourths of this group, and these patients had no significant clinical signs indicative of possible nonconvulsive seizures. Loewenstein and Aminoff (3) reported that 70% of comatose patients with nonconvulsive seizures had only subtle motor movements, and 10% had no clinical signs. Thus, accumulating evidence suggests that we are currently unaware of the presence of nonconvulsive seizure activity in many obtunded or comatose critically ill patients. A diagnosis of intermittent or ongoing subclinical seizure activity usually results in introduction or intensification of AED therapy. However, because the occurrence of such seizures is often recognized only late in the course of an illness, the clinical impact of treatment may be suboptimal. Litt et al. (4) noted no improvement in outcome in critically ill elderly patients in nonconvulsive status epilepticus treated with higher doses or a greater number of AEDs. They also noted an increased risk of mortality in elderly patients who had received benzodiazepines (BZDs)as part of their therapy. Current data suggest that duration of status epilepticus before treatment correlates with the likelihood of treatment failure (5), but we do not know whether earlier identification and treatment of nonconvulsive status epilepticus in the critically ill would improve outcome.

Data from the recent Veterans Administration cooperative trial concerning treatment of status epilepticus (6,7) and from the Richmond, Virginia, area prospective study of status epilepticus (8) also indicate a role for continuous EEG monitoring in patients with cessation of generalized convulsive seizure activity after treatment. In the Veterans Administration trial, 20%, and in the Richmond study, 14% of patients with cessation of clinical generalized convulsive seizure activity proved to have ongoing nonconvulsive status epilepticus documented on

EEG. An additional 34% of patients in the Richmond study had persistent intermittent electrographic seizures. These findings suggest that continuous EEG monitoring should be performed after resolution of convulsive status epilepticus, especially when rapid cognitive recovery is not evident. Because rapid cognitive recovery is usually not present immediately after resolution of convulsive status (6), a strong argument can be made for evaluating the majority of patients in status epilepticus with extended EEG monitoring. When nonconvulsive status epilepticus is diagnosed, only CEEG monitoring can provide sufficient information to guide ongoing AED therapy. Claassen et al. (9), using CEEG monitoring, recently assessed the effect of intravenous midazolam (MDL) on the course of refractory nonconvulsive status epilepticus. They found that seizures that recurred during MDL therapy were almost always either clinically subtle or purely electrographic, and required EEG monitoring for their detection.

Cerebral ischemia

The EEG becomes substantially abnormal (suppressed) when cerebral blood flow declines to 20–30 ml/100 g/min (10–12). More subtle abnormalities accompany lesser degrees of hypoperfusion, including initial loss of beta activity, slowing to the theta range, and then to the delta range (13,14). Irreversible injury to brain tissue occurs at cerebral flows of 10–12 ml/100 g/min. Thus, the EEG sensitivity to ischemia allows its use in situations where cerebral perfusion is at risk. Vespa et al. (13) and Labar et al. (15) demonstrated the utility of CEEG and quantitative EEG analysis in recognizing vasospasm after subarachnoid hemorrhage. Vespa et al. found that a reduction in variability of the theta– alpha content (ratio of power in the 6-to 14-Hz band relative to total power in the 1-to 20-Hz band) in the EEG preceded clinical onset of vasospasm by a mean of

2.9 days in 10 of 19 patients with postsubarachnoid hemorrhage vasospasm.

Observations from the use of CEEG monitoring in patients with subarachnoid hemorrhage suggest that this technique also may be useful in patients with cerebral ischemia from vascular diseases of other causes. For in-

FIG. 1. EEG demonstrating occipital driving in response to 12-Hz photic stimulation. The driving response ends at the comment “photic off.” Ten seconds of EEG displayed using a common average reference.

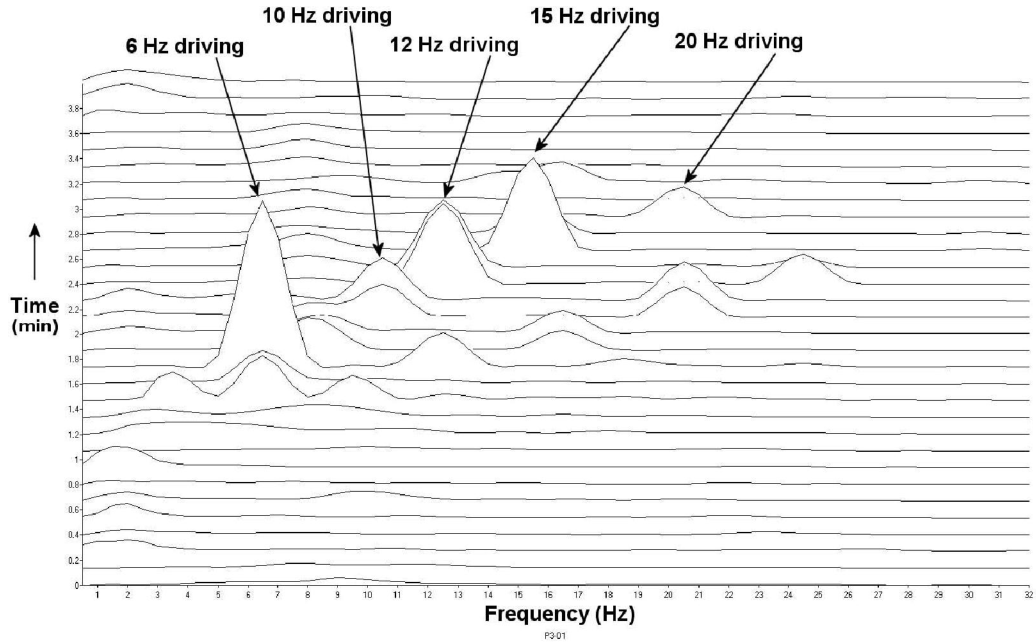

FIG. 2. Hidden-line compressed spectral array from P3-O1 bipolar linkage demonstrating responses to intermittent photic stimulation. The traces represent power spectra from consecutive 8-s EEG epochs. See text for additional explanation.

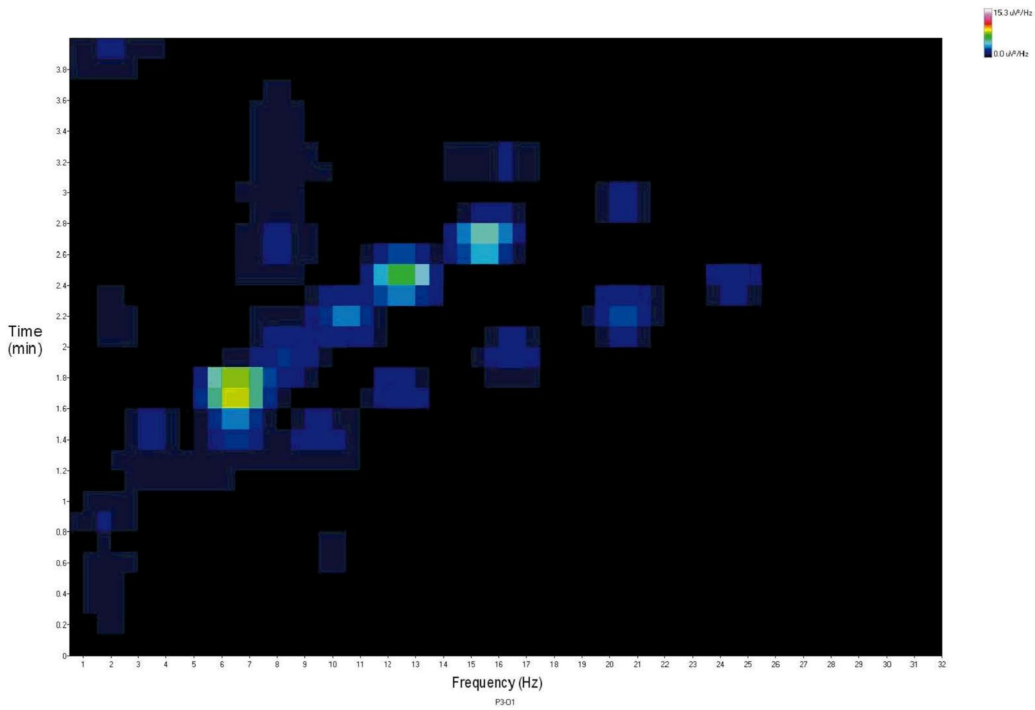

FIG. 3. Color spectrogram (color contour compressed spectral array) from P3-O1 bipolar linkage demonstrating responses to intermittent photic stimulation. Compare with Fig. 2, which is derived from the same source EEG data. All EEG data originally obtained using

Bio-logic Systems Ceegraph digital EEG recording devices; all quantitative EEG analyses and displays performed using Persyst Development Corporation MagicMarker and Prism programs. See text for additional explanation.

stance, it might be used in patients with transient ischemic attacks under observation for stroke evolution. In such cases, especially when the patient is sleeping and cannot report new symptoms, the finding of significant EEG changes might prompt earlier clinical reassessment and so foster better outcomes with thrombolytic or neuroprotective therapies.

Acute severe head injury assessment

Convulsive and nonconvulsive seizures commonly occur soon after severe head injury. Because severely injured patients are frequently sedated and chemically paralyzed, assessment of brain function becomes very difficult. Using CEEG monitoring, Vespa et al. (16) prospectively studied and identified nonconvulsive seizures or nonconvulsive status epilepticus in 11 of 92 patients after acute moderate-to-severe head injury. Seizures occurred despite prophylactic phenytoin (PHT) administration resulting in adequate serum PHT concentrations. Because the excessive metabolic demands of ictal activity may further compromise at-risk brain tissue after severe head injury, the early recognition and prompt treatment of nonconvulsive seizures and nonconvulsive

status epilepticus should, in principle, improve outcome. However, no prospective or comparative studies have addressed this question.

When induction of pentobarbital (PTB) coma is necessary for management of elevated intracranial pressure, CEEG monitoring is the test of choice for assessing brain activity and efficacy of therapy. Using continuous EEG, the PTB dosage is adjusted to produce a suppression– burst pattern. Further loss of EEG activity does not generally lessen intracranial pressure and is associated with an increased risk of systemic hypotension and cerebral hypoperfusion (17,18).

Finally, CEEG monitoring can potentially be used to assess for focal changes suggestive of new or worsening focal mass effects in patients with severe head injury. Such changes could prompt imaging evaluations and therapeutic interventions before irreversible injuries occur.

Coma diagnosis and prognosis

Routine EEG, depicting only a brief sample of brain activity, can yield incomplete or misleading data concerning cerebral function in comatose patients. Prolonged EEGs allow better assessment of variability in

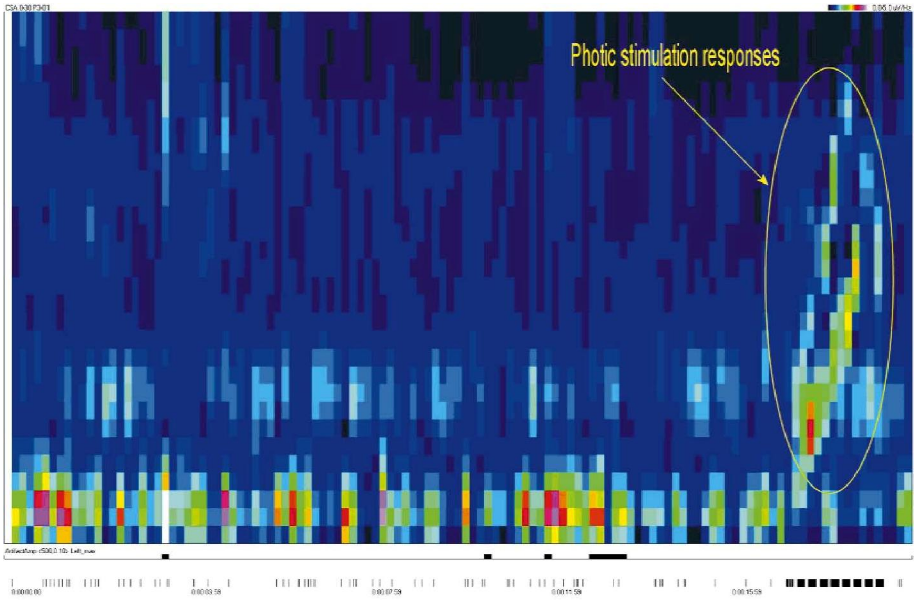

FIG. 4. Color spectrogram depicting 20 min of quantitatively transformed EEG data. Photic stimulation responses are evident on the right side of the graph. These responses correspond to those seen in Figs. 1–3. The y-axis depicts 0–30 Hz; time is displayed on the x-axis. See text for additional explanation.

EEG function, dependency of abnormalities on state, and the presence of intermittent nonconvulsive seizure activity. Detection of seizure activity is of obvious value, but recognition of other EEG findings in comatose patients is of yet unproven merit. Systems for grading EEG findings in the setting of coma have been proposed (19,20) but have not yet been applied to data from prolonged or CEEG studies. Pressler et al. (21) recently found that serial neonatal EEGs provided useful prognostic data concerning neurologic outcome in the setting of neonatal hypoxic–ischemic encephalopathy. It seems likely that assessment of variability in EEG pattern—over hours as opposed to minutes—will increase the value of EEG data in establishing prognosis in comatose patients. Whether CEEG recording will provide independently useful and clinically compelling prognostic data in obtunded or comatose patients remains unanswered.

In a subset of patients with severe motor abnormalities resulting from brainstem injury (i.e., locked-in syndrome), severe polyradiculopathies (e.g., Guillian-Barré syndrome), or chemical paralysis (neuromuscular blocking agents; botulism), CEEG monitoring provides a means of assessing cerebral function, state, and response to sedation. It also allows assessment of cerebral function

for the appearance of secondary insults such as excessive medication effects or metabolic encephalopathies.

TECHNICAL METHODS

The use and widespread applicability of CEEG monitoring has been made possible by rapid progress in computer and computer network technologies.

CEEG is recorded digitally to storage media with standard or small-footprint EEG recording devices. For most ICU applications, recording rates of 128–256 samples/s/channel provide adequate resolution for reliable interpretation. At a sampling rate of 256 samples/s/channel, collecting a 32-channel EEG (more than is needed for most indications) will require 1.5 GB (750 MB compressed) of storage capacity per day per patient. Additional files concerning quantitative EEG analyses and various display formats may add another 500 megabytes/ day/patient. Thus, 2 GB of available storage per patient per day suffices for detailed EEG studies. With an 80-GB hard drive now costing <$300, the previously daunting issue of affordable data-storage capacity for continuous EEG monitoring has vanished.

The connection to the recording device to the patient

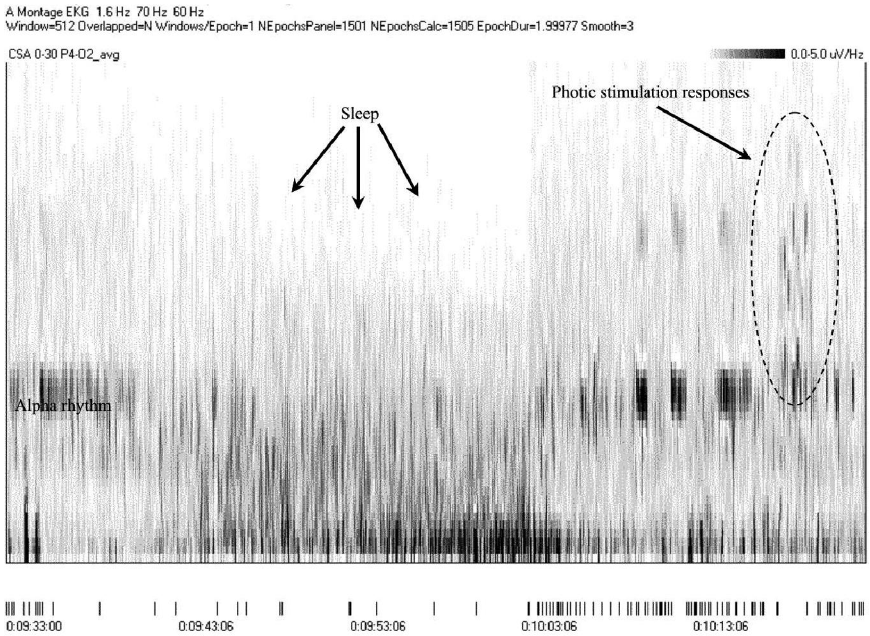

FIG. 5. Gray scale spectrogram depicting 50 min of quantitatively transformed EEG data from a P4 O2 electrode linkage. Photic stimulation, sleep responses, and waking alpha rhythm are evident, as marked by arrows and text. Consecutive 2-s EEG epochs used for analysis. See text for additional explanation.

remains one of the greatest challenges to adequate CEEG recording. This problem is magnified by the prolonged nature of the recordings and a frequent need to perform neuroimaging studies [computed tomography (CT) and magnetic resonance imaging (MRI) scans] on patients with structural abnormalities of the brain and brainstem. Centers performing CEEG have used several approaches to maintain the patient-to-EEG interface in obtunded or comatose patients. These include subdermal needle electrodes glued to the scalp with collodion, subdermal needles stapled to the scalp with surgical staples, and standard disk electrodes glued to the scalp with collodion. Young et al. (22) recently reviewed some of the problems inherent in CEEG monitoring in the ICU.

In general, given the high level of 60-Hz background activity in the ICU and the likelihood of electrode impedance mismatches during prolonged recording, it is advisable to record or at least display EEG with a 60-Hz notch filter in place.

After acquisition of EEG, the data must be made available for review by staff in the ICU and by the observing

and interpretative team of EEG technologists and electroencephalographers. Until recently, this step of the process had severely limited the practical utility of CEEG monitoring in the ICU. Because reliable interpretation of significant EEG changes must be available shortly after such changes occur, both raw and quantitatively displayed EEG data must be available for remote near real-time review by personnel proficient in EEG interpretation. Although there has been some success in training ICU nursing staff to recognize certain significant EEG patterns (1), definitive interpretation of the often technically complicated CEEG recordings ultimately falls to the electroencephalographer. The need for intermittent review and interpretation continues day and night, making both in-hospital and outside-the-hospital review capabilities a necessity. To accomplish this, secure data access must be available from remote locations. This can be accomplished through Web-based access to the EEG (using virtual private networks and a secure password-protected Web server providing images of EEG and quantitative analy-

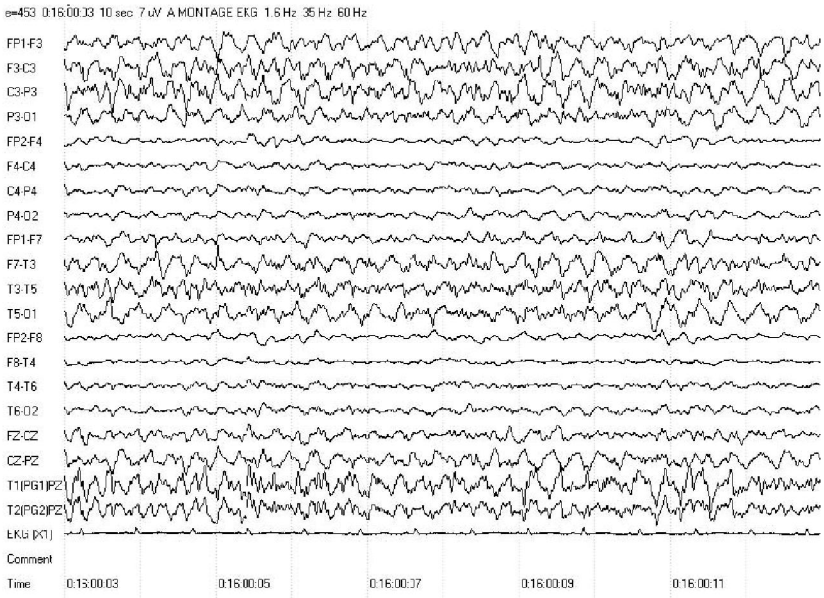

FIG. 6. Left hemispheric electrographic seizure without associated clinical changes. Baseline (interictal) EEG demonstrated moderate diffuse suppression and sporadic multifocal sharp waves. Please see text for additional information.

sis data) or via dedicated connections to a hospital-based EEG server. In general, Internet-based solutions are most robust, as the electroencephalographer must have access to the EEG for review at any time and from any place. The rapidly developing availability of wireless access to the Internet has made on-the-go CEEG data review possible. Within a few years, there will likely be no barrier to reviewing CEEG data from a countryside park almost as easily as from the patient’s bedside or the primary EEG laboratory.

Review of each minute of CEEG data is generally neither practical nor necessary. To aid in data reduction without loss of sensitivity to significant changes, a variety of quantitative EEG analysis and display techniques have been harnessed for use in CEEG monitoring. For the most part, these involve fast Fourier transforms of EEG data performed in near real-time and subsequently displayed in a variety of ways. Common display techniques include color spectrograms, hidden line compressed spectral arrays, displays of total power in certain EEG frequency bands (e.g., 6–14 Hz), ratios of power in certain bands to a broader spectrum of EEG power (e.g.,
ratio of power in 6-to 14-Hz band vs. 1-to 20-Hz band), and spectral edge displays. Such displays can be generated for individual channels or a combination of channels to provide overviews of right and left hemispheric activities.

Review of quantitative displays usually quickly reveals significant EEG changes such as seizures, worsening of focal slowing, generalized suppression, loss of faster frequencies, or increasing or decreasing EEG variability. To assess the significance of the change seen on a quantitative EEG display graph, it is critical that the associated raw EEG be immediately available for review and comparison. This allows ready distinction of a significant change in cerebral activity from artifact-related changes, and for specific interpretation of the nature and significance of such changes. Such findings can then be conveyed immediately to the ICU staff for appropriate integration into the patient’s care. In the past, an inability to access immediately the raw EEG data used to generate quantitative displays severely limited the applicability of quantitative techniques to continuous EEG monitoring in the ICU.

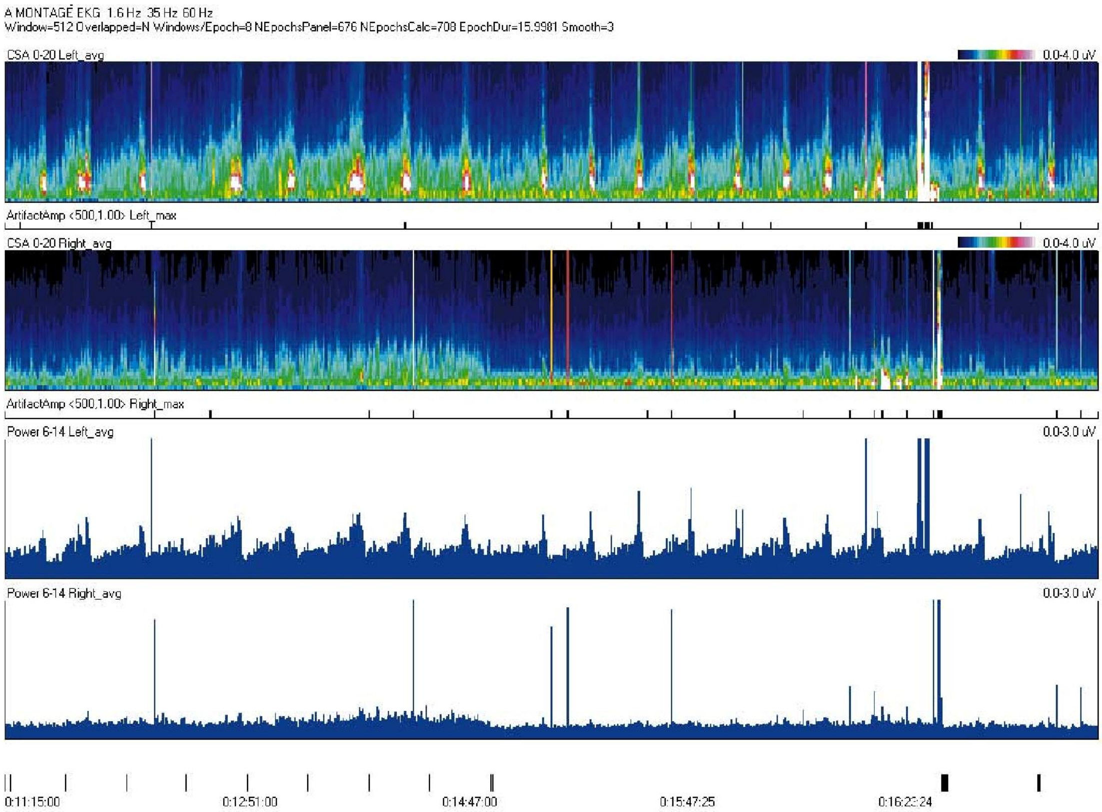

FIG. 7. Color spectrogram depicting 5 h of quantitatively transformed EEG data. The label CSA 0-20 Left_avg indicates a compressed spectral array obtained from left-sided electrodes, with 0–20 Hertz represented on the y-axis and time on the x-axis. Power 6–14 Left_avg indicates a graph of summated power in the 6-to 14-Hz band from a set of left-sided electrodes. Right-sided data are also depicted. Consecutive 16-s epochs of EEG data were used for these analyses. See text for additional explanation.

The ongoing review of EEG can involve several layers of observation. These include personnel at the bedside, who may be observing both the EEG in real time and the quantitative display graphs, a remotely located technologist with a much higher level of interpretative skills, and the attending electroencephalographer. Skilled EEG technologists can monitor multiple patients simultaneously, thus greatly increasing cost efficiency. The skilled technologist can act as a first-level filter, alerting the electroencephalographer when a potentially significant EEG change occurs so that rapid definitive review and interpretation can occur. In addition, or sometimes alternatively, alarms can be programmed to activate automatically and alert ICU personnel and the electroencephalographer if certain conditions are evident in the ongoing quantitative EEG data or processed EEG. For example, many seizures are associated with a sudden substantial increase in the mid-theta plus alpha power of the EEG. A computerized observation paradigm can be programmed to generate alerts for such a condition, and to exclude events likely to be of artifactual origin. Seizure-detection programs also can be used independently or in concert with other types of quantitative analyses. Despite such techniques, however, our current computer-assisted observation techniques are still too insensitive and nonspecific to replace a skilled human observer effectively.

CLINICAL EXAMPLES Quantitative transformations of the EEG

The following examples illustrate some techniques used to depict the EEG as simplified graphical data. In the first example, a segment of EEG containing photic driving responses (Fig. 1) is converted to a hidden-line compressed spectral array (Fig. 2), and then to a spectrogram using similar graphing axes (Fig. 3).

The 12-Hz driving response evident in Fig. 1 and additional driving responses at 6, 10, 12, 15, and 20 Hz are evident in the hidden line compressed spectral array

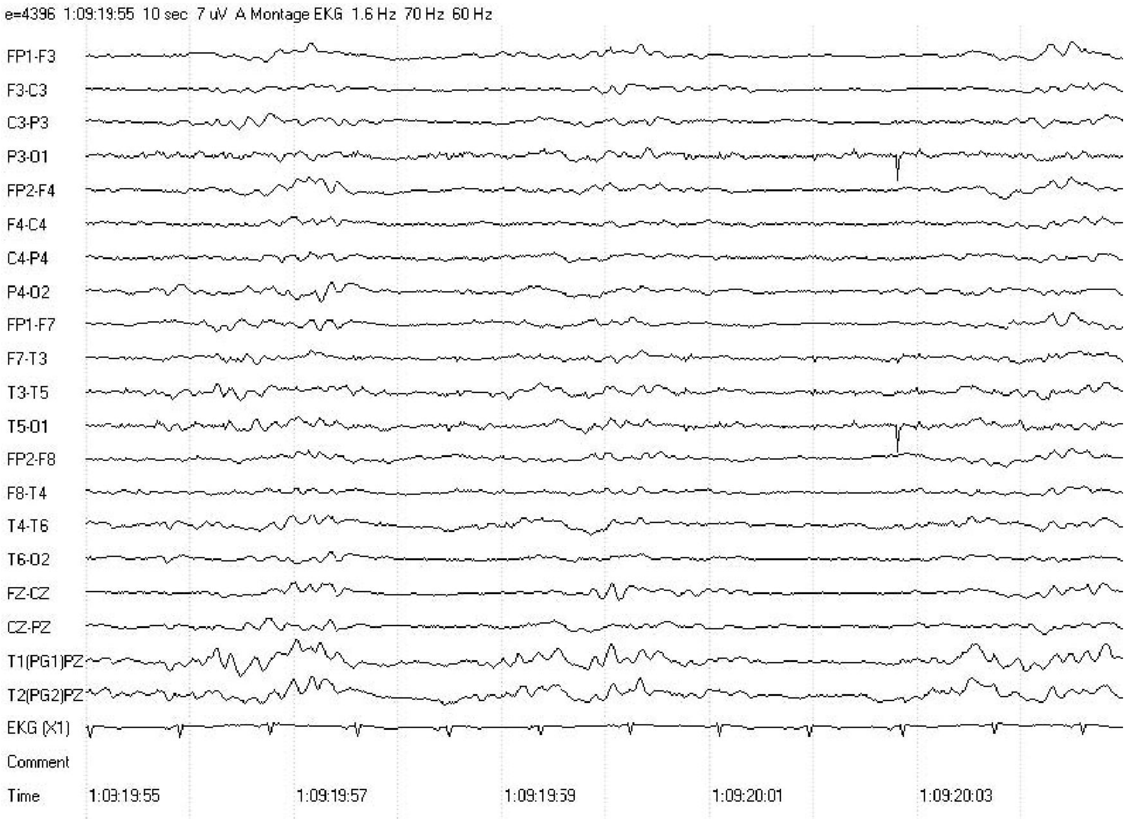

FIG. 8. Ten-second EEG segment demonstrating diffuse slowing and intermittent diffuse suppression. See text for additional explanation.

(CSA; Fig. 2) depicting 240 s of EEG obtained from a P3-O1 derivation. Each line in the CSA represents the frequency-specific power from 0 to 30 Hz contained in the EEG during consecutive 8-s epochs (P3-O1 derivation). The spectrogram (color contour compressed spectral array; Fig. 3) depicts the same data in yet another manner, expressing the power present at a particular frequency as graded color map rather than the height of a line. In this example, black represents low power in the EEG at a particular frequency, whereas blue, green, and yellow indicate progressively greater amounts of EEG power. This simplified display continues to depict the same data as the hidden-line CSA. As shown in these figures, the driving responses remain clearly evident despite progressive visual simplification of the quantitative EEG representation.

Now consider Fig. 4, which depicts the entire EEG as a color spectrogram. To conform to common convention, time is now expressed on the x-axis, and frequency on the y-axis (i.e., this graph is rotated compared with the prior graphs, with time now represented as would be present on an EEG, flowing from left to right). The circled responses to photic stimulation clearly stand out from the remainder of the 20-min waking EEG.

Figure 5 depicts a quantitative color spectrogram display of wake and sleep EEG from a different patient. Transient photic driving responses can be easily distinguished from epochs of resting wakefulness and sleep during a 50-min recording. These graphs illustrate the information-rich nature of the quantitative spectrogram when applied to long EEG segments and displayed in an efficient fashion.

Monitoring of status epilepticus

The EEG segment shown in Fig. 6 documents a non-convulsive seizure discovered during an EEG performed to evaluate a 52-year-old man with hepatic failure and prolonged obtundation of uncertain origin. Clinical seizure activity was not evident despite the repetitive occurrence of electrographic seizures arising from the left hemisphere. Continuous EEG monitoring was initiated to evaluate the effects of therapy.

The results of 5 h of EEG monitoring are depicted in a series of graphs in Fig. 7. These graphs display color-

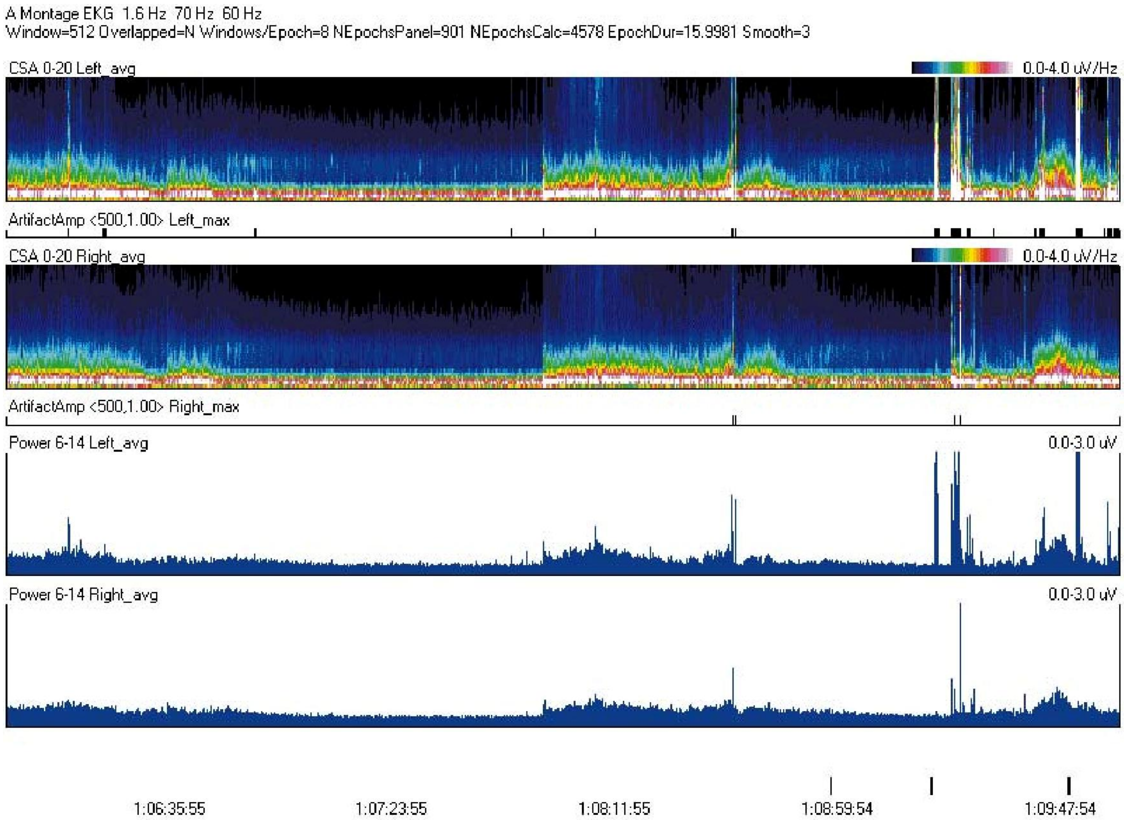

FIG. 9. Color spectrogram depicting 4 h of quantitatively transformed EEG data. See Fig. 7 legend for explanation of graph labels. Consecutive 16-s epochs of EEG data were used for these analyses. See text for additional explanation.

compressed spectral arrays created by analyzing consecutive 16-s epochs of averaged power from a combination of four bipolar linkages in the left and right hemispheres, respectively. Artifact channels are used to detect EEG epochs containing very high amplitude transients of probable artifactual origin, and line graphs depict total power in the 6-to 14-Hz band from the right and left hemispheres.

Both the spectrogram and 6-to 14-Hz power graph depicting left hemispheric activity show clear sudden peaks of activity that correspond to seizures evident on the raw EEG tracings (as shown in Fig. 6). Despite treatment with BZDs, PHT, and phenobarbital (PB), refractory nonconvulsive seizure activity persisted. Propofol anesthesia finally controlled the patient’s refractory electrographic seizure activity.

Use of continuous EEG monitoring to assess ongoing therapy

Figures 8 and 9 depict ongoing EEG findings in a 72-year-old woman under treatment with PHT, valproate

(VPA), topiramate (TPM), and propofol for therapy of refractory nonconvulsive status epilepticus. Before intensification of standard AED therapy, she had been having intermittent clinical seizures, but later only electrographic seizures were evident (rhythmically repetitive high-amplitude generalized sharp-wave complexes, frequently left hemisphere maximal, recurring at 1.5–2 Hz). The EEG in Fig. 8 depicts the patterns evident during an ongoing propofol infusion.

When the propofol infusion was interrupted at about (1:) 09:47:54 because of a technical malfunction, a rapid change was evident on the quantitative EEG spectrogram display (see Fig. 9). This consisted of a fairly sudden increase in EEG power in the theta and alpha bands in both hemispheres. No clinical changes were evident. Recognition of this change prompted immediate analysis of the accompanying raw EEG data (see Fig. 10), which showed recurrence of repetitive high-amplitude generalized sharp-wave complexes, suggestive of recrudescence of nonconvulsive status epilepticus. These findings led to the discovery of an intravenous malfunction that had interrupted the ongoing propofol infusion. Reinitiation of

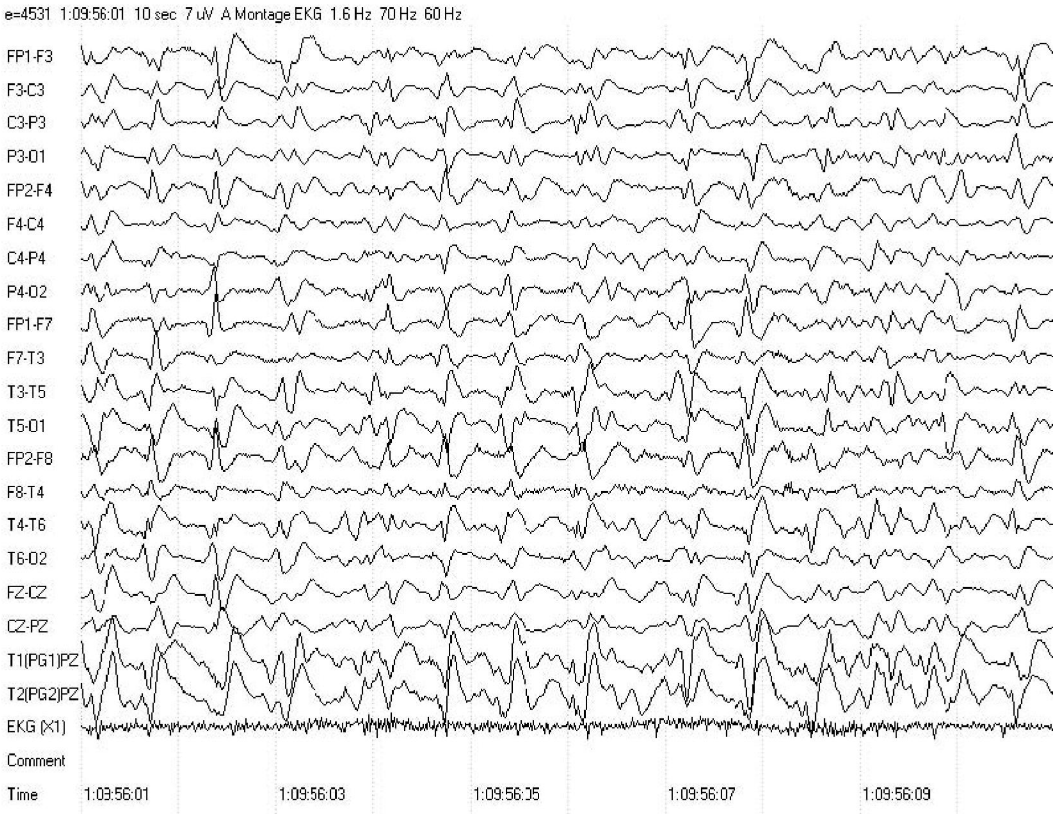

FIG. 10. Ten-second EEG segment demonstrating repetitive high-amplitude generalized sharp-wave complexes. See text for additional explanation.

the infusion led to rapid abatement of the repetitive sharp-wave complexes.

Continuous EEG monitoring for cerebral ischemia

The EEG segment depicted in Fig. 11, recorded during a left carotid endarterectomy, shows a 40-s epoch (20 s above and 20 s below) during which the patient's left carotid artery was initially clamped. Loss of power in the beta and alpha bands on the left developed rapidly after clamping of the carotid. This change prompted release of the carotid clamp, after which EEG patterns rapidly returned to baseline.

The observation of this change was followed by placement of a vascular shunt to maintain left hemispheric perfusion. Carotid clamping again led to changes similar to those seen in Fig. 11, but these changes resolved when the vascular shunt was opened. Quantitative EEG panels (Fig. 12, depicting 150 min of quantitative intraoperative EEG) allowed ready identification of the loss of EEG power associated with carotid clamping and subsequent left hemispheric ischemia (see arrow at A). Baseline activity returned with opening of a synthetic vascular shunt. Note that left hemispheric ischemia developed again (see arrow at B, Fig. 12) when the shunt was removed in preparation for opening the repaired carotid artery. After opening of the carotid, baseline activity rapidly returned, indicating reestablishment of adequate blood flow and cerebral recovery. The patient awoke from the operation without neurologic changes.

COST-EFFECTIVENESS

Little information is available regarding the cost-effectiveness of CEEG monitoring. In part, this is due to the early stage of development of this technique. This also is related to rapid changes in the technology used to perform CEEG monitoring. Each year provides new capabilities, often at decreased overall cost, making timely assessment of cost-effectiveness difficult.

Vespa et al. (23) assessed available data from their monitoring experience at UCLA, and concluded that CEEG accounted for only 1% of hospital costs and, during its use, significantly affected critical decision making in >90% of 300 patients who underwent monitoring. They concluded, "CEEG is cost-effective and appears to offer additional quality to intensive care." Claassen et al. (24), evaluating their experience in 15 patients undergo-

ing CEEG for evaluation of status epilepticus or nonconvulsive seizures associated with altered consciousness, determined that CEEG monitoring influenced clinical management—usually decisively—in 50 of 109 monitoring days. Assessing the cost-effectiveness of CEEG will, however, remain a difficult task (1). This is because the technology and capabilities continue to evolve rapidly, and because, given the clear diagnostic and therapy-guiding benefits evident to many patients undergoing monitoring, randomization of comatose and obtunded patients to receive or forego such monitoring may not be ethical.

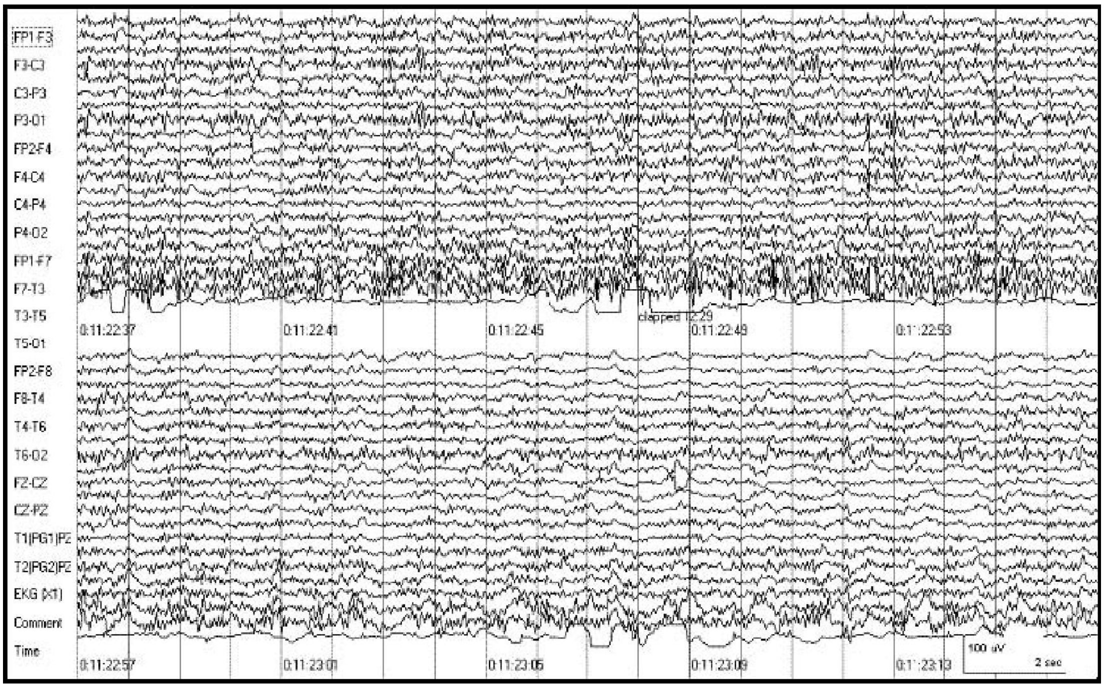

FIG. 11. EEG segment, 40 s; longitudinal bipolar montage (channel order as labeled on left). EEG (20 s) is shown in the top set of traces, with the next 20 s below. Carotid clamping occurred at time marked by comment “clapped” [sic]. See text for additional explanation.

AREAS REQUIRING ADDITIONAL DEVELOPMENT AND DEFINITION

Many aspects of the application and interpretation of CEEG monitoring remain poorly defined. Some of these areas of uncertainty were recently reviewed by Vespa et al. (23). Outstanding questions include

What EEG patterns should prompt aggressive treatment (e.g., what patterns constitute nonconvulsive status epilepticus)?

What duration of monitoring is appropriate in any particular patient? Does a point of minimal clinical return occur in some patients?

What relative importance should CEEG findings play in clinical decision making?

Should CEEG be performed in all obtunded or comatose patients?

In general, what role should quantitative versus raw EEG interpretation play in CEEG monitoring?

What are the best quantitative screening techniques?

How should available spike and seizure–detection programs be integrated into CEEG monitoring?

What is the role of computerized tools to assess state and determine whether particular states of interest appear or reappear during recording?

How can a functional electrode interface be best maintained during long-term ICU recordings?

CONCLUSION

CEEG monitoring can now be used as a powerful adjunctive tool in the evaluation and treatment of obtunded and comatose patients. Technologic advances have minimized the previously problematic areas of data storage and near real-time availability of EEG data for rapid analysis and interpretation. Although many areas of potential use require additional study, indications such as observation for nonconvulsive seizure activity merit immediate widespread use of this tool. CEEG monitoring provides a much-needed means for the assessment of brain function in critically ill patients. It is likely that ongoing refinements in this technique will enhance its utility and lead to extensive application of CEEG monitoring in ICU settings over the next decade.

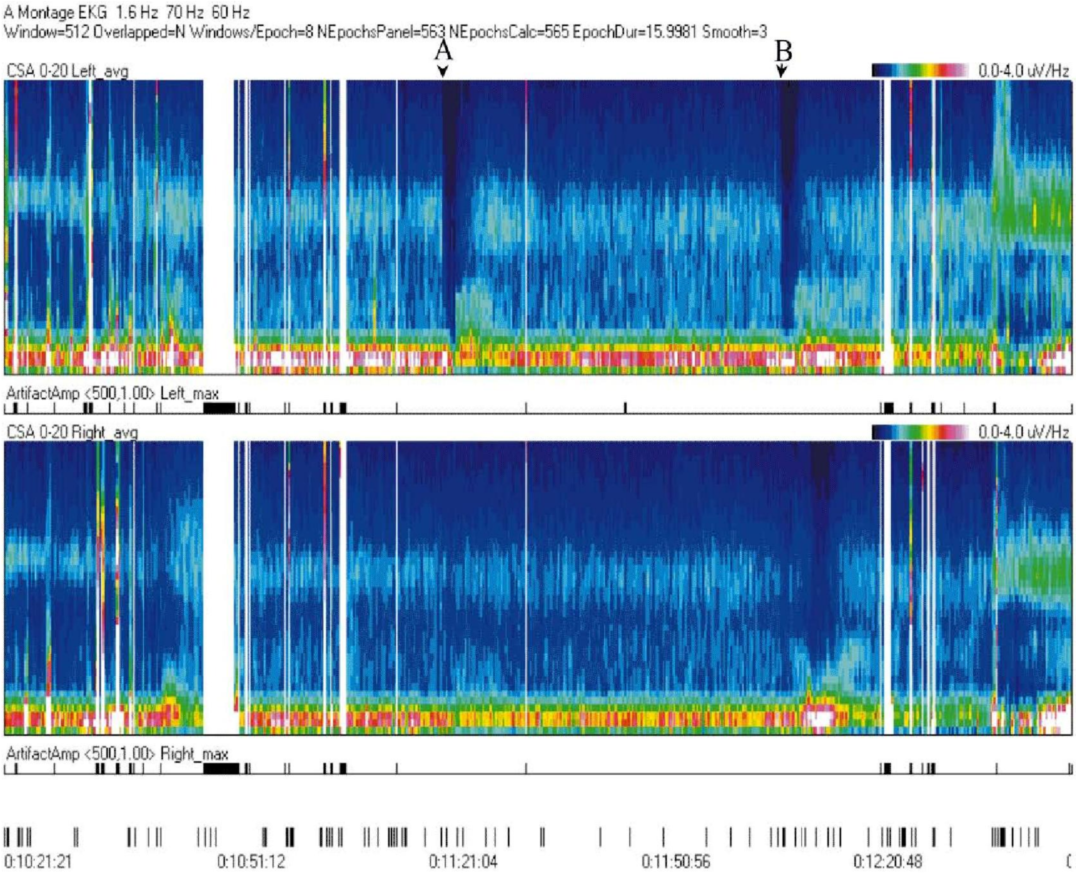

FIG. 12. Color spectrogram depicting 2.5 h of quantitatively transformed EEG data

obtained during a left carotid endarterectomy. The label CSA 0-20 Left_avg indicates a compressed spectral array obtained from left-sided electrodes, with 0–20 Hertz represented on the y-axis and time on the x-axis. Right-sided data are also depicted. Consecutive 16-s epochs of EEG data were used for these analyses. See text for additional explanation.

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[译文摘要]

连续 EEG（CEEG）监测可以不间断地评价大脑皮层的活动，同时具有较好的空间分辨率和极好的时间分辨率。这样，这一措施提供了一个在疾病急症期和对昏迷病人的持续性评价脑功能的方法。最近在数字 EEG 采集，储存，定量分析和传输方面的进展使得 ICU 中 CEEG 监测在技术上可行，有用。本文总结 ICU 中 CEEG 监测的适应症和方法学，并讨论一些定量 EEG 分析技术在对 CEEG 监测实施接近

实时远程观察的作用，同时提供了 CEEG 应用的临床案例，包括 SE 监测，对重症患者出现发作时治疗效果的评价，以及脑缺血的监测。并讨论了 CEEG 监测技术和应用领域进一步开拓所要面临的问题。

・脑功能检测：CEEG 监测的优势

在目前可以采用的脑检测技术中（表 1），EEG 具有几个优势：EEG 提供了可信的空间分辨率和极好的时间分辨率，不但可以用于器质性疾病，还可用于代谢性，生理性疾病的监测。先前涉及到常规 EEG 用于床旁监测的种种困难，特别是涉及实时分析，现已被数字定量分析技术的进步所克服。

・适应症

非惊厥性发作的监测。

・脑缺血

大脑皮层对缺血缺氧变化尤为敏感。EEG 作为脑皮层生理状态指标能反映脑血流量降低或神经元损害程度，尤其连续监测其动态变化更有价值。

・急性严重头外伤

・昏迷诊断和预后

・技术方法

・临床案例

・EEG 的定量转换

・应用连续 EEG 监测，评价所进行的治疗

・连续 EEG 监测大脑缺血

・需要进一步拓展和定义的领域

・什么样的 EEG 类形提示积极的干预（如，什么样的波形提示 NCSE）？

・什么监测时段适合某种特殊患者？在一些患者存在一个最小的临床转归点吗？

・CEEG 监测在临床决策上能发挥什么相对重要的作用？

・应该在所有昏迷病人中实施 CEEG 监测吗？

・整体而言，CEEG 监测相对于常规 EEG 监测，定量分析应在对 EEG 解释上起什么作用？

・什么是最好的定量分析技术？

・如何运用整合在 CEEG 监测中的棘波及发作识别程序？

・在记录期间，分析功能在评价出现的有意义的特殊状态起到了什么作用？

・在 ICU 中长程纪录时，如何能使电极保持的最好？

・结论

CEEG 现在可以在昏迷病人的评价和治疗中作为一个强有力的辅助工具。技术的进步已解决了以前数据储存和 EEG 数据快速分析和解释的接近实时处理方面的问题。尽管许多潜在的应用还要进一步的研究，在非惊厥性发作这方面应用的好处，已让这一工具得以广泛认可和应用。

CEEG 监测为危重病人脑功能评价提供了一个临床迫切需求的方法。似乎这一技术的细化将拓展其应用并导致在下一个十年 CEEG 监测在 ICU 中更广泛的应用。

1.2 The EEG in coma.

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The EEG allows insight into thalamocortical function in comatose patients when this is inaccessible clinically. A single EEG can help with broad diagnostic categorization whereas continuous or serial EEG provides monitoring for unstable and potentially treatable conditions and for monitoring the effects of therapy. The EEG plays a supplemental role in establishing the prognosis in disease states that are capable of causing neuronal death. The most prevalent and problematic of these conditions involves survivors of cardiac arrest who are initially in coma with intact brainstem reflexes. In such patients single EEGs are of 100% specificity for no possibility of recovery of consciousness only for essentially complete generalized suppression (<10 microV) after the first day of the arrest. Several other generalized patterns, including less marked suppression, burst-suppression, epileptiform activity, periodic complexes, and alpha-theta coma patterns, usually but not invariably indicate a poor outcome. Serial EEGs, continuous raw and automated "trending," testing of reactivity, and the inclusion of multiple variables hold promise for an improved role in the prognostic determination in

these patients.

[译文摘要]

EEG可以在临床观察有困难的时候了解昏迷病人的丘脑-皮质功能。常规EEG有助于普遍的诊断分类，而连续或系列EEG对不稳定以及潜在的可治疗的状态提供检测，同时可监测治疗的效果。EEG在评价疾病的预后状态(不良的预后可造成神经元的死亡)起到了补充作用。最有优势及问题较多的是涉及心肺复苏存活者的情况，他们先期出现昏迷，但保留完整的脑干反射。在那些经抢救第一天后显示完全的广泛性抑制(<10 microV)的病人中，单次EEGs对无意识恢复的可能性的预判有100%的特异性。其它几种广泛性异常类型，包括程度较轻的抑制，爆发-抑制，epileptiform活动，周期性复合波，α-θ昏迷波型，通常，但不完全提示很差的结局。系列EEGs，连续的原始或自动趋势分析，反应性测查以及多变量分析有希望改善对这类病人的预后判定。

1.3 An EEG Severity Index of Traumatic Brain Injury

Robert W. **Thatcher, Ph.D.**

EEG spectral analyses were conducted from 19 scalp locations for patients with mild (n = 40), moderate (n = 25), and severe (n = 43) traumatic brain injury (TBI), 15 days to 4 years after injury. Severity of TBI was judged by emergency hospital admission records (Glasgow Coma Score and duration of coma and amnesia). Highestloading EEG variables on each factor that differed significantly between severe and mild TBI by univariate t-test were entered into a multivariate discriminant analysis, yielding 16 variables. Discriminant analysis between mild and severe TBI groups showed classification accuracy of 96.39%, sensitivity 95.45%, and specificity 97.44%. The EEG discriminant score also measured intermedi- ate severity in moderate TBI patients. Results were cross-validated in 503 VA patients. Significant correlations between EEG discriminant scores, emergency admission measures, and posttrauma neuropsychological test scores validated the discriminant function as an index of severity of injury and a classifier of the extremes of severity.

(The Journal of Neuropsychiatry and Clinical Neurosciences 2001; 13:77-87)

[译文摘要]

外伤性脑损伤（Traumatic Brain Injury,TBI）

重症监护医学协会推荐：当要决定继续、限定、或终止 ICU 支持时，只要有可能，就要考虑采用能反映疾病情况和预后的客观检查指标（SCCM，1988）。神经影像和神经生理技术提供了对损伤严重程度的客观评价。

采集外伤后 15 天至 4 年内的轻度（n=40）,中度（n=25），重度（n=43）TBI 患者 19 导脑电并进行功率谱分析。TBI 的严重程度依据急诊入院时的纪录（GCS 及昏迷,健忘持续时间）。经 t-检验确定在中度和重度 TBI 之间有明显差别的各个因子，提取 EEG 变量，导入多变量判别分析，得出 16 个变量。中度和重度 TBI 组之间的判别分析显示分级准确率 96.39%，敏感度 95.45%，特异性 97.44%。EEG 判别得分同样用于在中度 TBI 患者中间的严重程度。结果在 VA 医院 503 名患者中交叉验证，EEG 判别分数，急诊入院测查以及外伤后神经心理学测查评分之间存在显著性相关，证实这一判别函数作为外伤严重程度的指数以及严重程度的分级方法的效度。

外伤对大脑的影响机制可由单一或不同因素交互作用引起：出血进入脑实质、硬膜下、蛛网膜下腔；缺血性梗死（血管损伤、动脉痉挛、皮层灌注压下降等引起）；白质内轴索损伤；代谢障碍；缺氧；电解质紊乱及炎症；以及症状性发作。所以 EEG 的异常表现也是多样化的。它们对预后的重要性不仅依赖于损害的严重程度，还取决于其病理机制的可逆程度。

各家学者描述了下列 TBI 的 EEG 异常表现：①θ节律变慢；②δ活动，包括-连续性局灶性失律、弥漫性节律性/失律或间断性节律活动；③癫痫样活动，包括局灶性棘波或发作性放电（临床或仅为 EEG 变现）；④同步周期性慢波爆发；⑤三相波；⑥局部抑制；⑦不对称⑧α，θ，或纺锤昏迷。

考虑到异常类型以及和病原学的关系，临床采取的措施以及与预后等相关的问题，EEG 监测的时机是非常重要的。

在任何阶段监测到的局灶性异常都提示该区域的局灶性损伤。波幅的改变，特别是局限性电压降低，应考虑颅内血肿，但应注意排除相应脑区有无头皮水肿。电生理发作性放电通常反映严重的脑损伤，还有可信的定侧价值。

当描记到连续的节律性活动，包括睡眠现象，频率和波幅出现变化，其预后要比无变化者更好，有反应性也比无反应性要好的多。

1.4 Continuous Quantitative EEG Monitoring in Hemispheric Stroke Patients Using the Brain Symmetry Index

Michel J.A.M. van Putten, MD PhD; Dénes L.J. Tavy, MD

Stroke. 2004;35:2489.

Background and Purpose— There is increased awareness that continuous brain monitoring might benefit neurological patients, because it may allow detection of derangement of brain function in a possible reversible state, allowing early intervention. Here, we explore if quantitative continuous electroencephalography (cEEG) monitoring is technically feasible and possibly clinically relevant in patients with acute ischemic hemispheric stroke.

Materials— Twenty-one consecutive patients with an acute hemispheric stroke were monitored in our stroke unit, using cEEG for 12 to 24 hours on the day of admission. EEGs were quantified using a particular measure for symmetry, the brain symmetry index (BSI). This measure was subsequently correlated with the clinical condition of the patient using the National Institute of Health Stroke Scale (NIHSS).

Results— cEEG was technically feasible. We found a most satisfying positive correlation between the BSI and the NIHSS, with r=0.86 (P<0.01).

Conclusions— Technically, cEEG monitoring posed no major problems. It was found that the BSI correlates satisfactorily with the clinical neurological condition of our stroke patients. This suggests that the BSI can be used as a measure to monitor possible changes of brain function in this patient category.

[译文摘要]

Michel J.A.M 等人应用脑对称指数 BSI 方法对所在医院卒中单元收治的 21 例急性半球缺血性卒中患者进行连续的定量 EEG 监测。探讨 CEEG 用于缺血性卒中重症监测技术上的可能性及临床相关问题。

病人与方法

2002 年底—2003 年初收入卒中单元的 21 例，一例幕上卒中患者，无既往卒中史，住院 24hr 内进行 CEEG 监测，连续 12-24hr，并于入院当天做 NIHSS，定量评价患者的神经功能。

用 BSI 作为缺血损伤的量化测量，选择一个片段的 EEG（如 5min）由 FFT 计算各导联功率谱，从特点的半球双导记录中计算出 EEG 信号功率，在求出 BSI，BSI 数值在 0（完全对称）与 1（最大不对称）之间。

结果

影像学检查所有病人均有不同大脑 A 支配区域的梗死，临床技师每日两次检查 EEG 记录的电极阻抗，分析数据中无明显技术问题，没有护士对病人护理的干扰，NIHSS 评分与 BSI 指数呈非常满意的相关性。R=0.86(P＜0.01＝。还可以从两个病例中看到 BSI 与临床观察之间的关系。

1、大面积右半球梗死，NIHSS=13，平均 BSI=0.18。在第 2 个 24hr 内基本维持不变。

2、轻度的左半球梗死，NIHSS=3，BSI=0.06，在几小时后，有轻微的症状性局灶发作（右侧面肌节律性收缩）。此时，EEG 可见左侧半球发作性活动，BSI=0.20，当发作停止，BSI 降至发作前水平。

讨论

技术上，CEEG 或 LT-EEG 应用于 SU 监测不会遇到问题，作者应用 BSI 这一类分析方法的初衷是要以有限的导联减少应用 EEG 监测所花费的时间，而神经科病房标准的护理工作未对记录产生干扰。

这些分析方法还包括 EEG 谱分析，delta 功率变化，以及非线性分析方法时间相关熵分析。BSI 方法对测查 EEG 不对称性非常敏感，且已被颈 A 内皮切除手术所证实。BSI 给出的指数也容易被没有 EEG 阅读背景的人士所掌握。

BSI 与 NIHSS 之间很好的相关性提示 BSI 可以作为急性半球卒中患者的神经病学损伤的测量指标，BSI 的变化提示对患者再次进行临床检查，而造成 BSI 改变的原因有缺血，局灶性发作以及出血。

两点问题：（1）无特异性（2）实时 BSI 检查的重要性

1.5 Correlation of Quantitative EEG in Acute Ischemic Stroke With 30-Day NIHSS Score

1.5.1 Comparison With Diffusion and Perfusion MRI

Simon P. Finnigan, PhD

(*Stroke*. 2004;35:899.)

Abstract

Background and Purpose— Magnetic resonance imaging (MRI) methods such as diffusion- (DWI) and perfusion-weighted (PWI) imaging have been widely studied as surrogate markers to monitor stroke evolution and predict clinical outcome. The utility of quantitative electroencephalography (qEEG) as such a marker in acute stroke has not been intensively studied. The aim of the present study was to correlate ischemic cortical stroke patients' clinical outcomes with acute qEEG, DWI, and PWI data.

Materials and Methods— DWI and PWI data were acquired from 11 patients within 7 and 16 hours after onset of symptoms. Sixty-four channel EEG data were obtained within 2 hours after the initial MRI scan and 1 hour before the second MRI scan. The acute delta change index (aDCI), a measure of the rate of change of average scalp delta power, was compared with the National Institutes of Health Stroke Scale scores (NIHSSS) at 30 days, as were MRI lesion volumes.

Results— The aDCI was significantly correlated with the 30-day NIHSSS, as was the initial mean transit time (MTT) abnormality volume (=0.80, P<0.01 and =0.79, P<0.01, respectively). Modest correlations were obtained between the 15-hour DWI lesion volume and both the aDCI and 30-day NIHSSS (=0.62, P<0.05 and =0.73, P<0.05, respectively).

Conclusions— In this small sample the significant correlation between 30-day NIHSSS and acute qEEG data (aDCI) was equivalent to that between the former and MTT abnormality volume. Both were greater than the modest correlation between acute DWI lesion volume and 30-day NIHSSS. These preliminary results indicate that acute qEEG data might be used to monitor and predict stroke evolution.

[译文摘要]

Finnigan，SP 等人的工作旨在研究将 EEG 这一相对 MRI 资源节省的方法，作为急性卒中病人的床旁监护，并增加对卒中后大脑病理生理学变化的了解，MRI 能更好地探测和确定缺血半暗带组织，而 EEG 数据的进一步分析，如相关性，发生源推算以及和 MRI 数据对比分析，会对卒中进展过程有新的认识，特别是后一方法更有潜力确定 δ 活动是否是由影像学所显示的弥散/灌注异常脑区产生的 ；有头皮记录的 δ 活动是否与定义为异常的脑组织容积相关。

作者认为急性卒中治疗和研究的一个主要目标是精确识别和预测大脑梗死的进展及临床转归。MRI 在操作层面不适于重症急性卒中后其间的大脑病理生理进展的连续评估。电生理数据可以在床旁连续获取。但现在的情形是，不同于 MRI 检查，临床一直缺乏卒中发病后几个小时内采集 q EEG 数据以及其与临床结局相关性研究。所以本文应用一个通用的，多模式的方法评价急性期 q EEG 监测梗塞进展并预测脑功能转归，进而比较 DWI 和 PWI 的检查结果。

作者选择急性局灶运动神经症状伴有语言损伤或注意障碍或与缺血性皮质卒中相符的认知障碍的病人入组，在卒中发作后 6 小时内，15±3 小时，及 30 天后进行 DWI 和 PWI 检查。在首次 MRI 后 2 小时内及第 2 次 MRI 检查前 1hr 进行 64 导 EEG 监测，检查 30 天的 NIHSS。

在首次 MRI 后及第 2 次 MRI 检查之前尽可能早地采集 EEG 数据。用 FFT 计算由所有头皮电极平均功率导出的平均头颅功能谱。应用急性 Delta 变化指数（acute delta change index ,aDCI）反映卒中后急性期平均大脑 delta 功率的变化程度和方向。aDCI=(Dt2-Dt1)/t

11 例患者，平均首次 MRI 检查 5hr，EEG6.6hr，首次和第 2 次 EEG 监测时间 7.7hr。10 例有包括白质和灰质的急性 DWI 损伤，1 例为脑深部白质损伤；所有人均有扩展到皮质表面的 MTT 异常。所有患者均显示与临床表现相一致的 DWI 异常。

以下图表显示本次研究的主要结果。

这次研究得到一些新的发现，作者论证了卒中急性期 q EEG 的一个重要参量 aDCI 与患者 30 天 NIHSS 很好的相关性。这一相关性等同于 MTT 异常体积和 30 天 NIHSS 之间的相关。上述两个相关性要比尔后的临床结局评分与急性 DWI 损伤容积之间的相关性更大。同时本次研究是首次报告 q EEG 测量与 30 天 NIHSS 之间的相关性。从卒中后 72hr 的监测数据导出的其它 q EEG 变量和 3 个月 CaNS 相关，

作者还进一步证实了在 aDCI 和 15hrDWI 损伤容积之间中等程度的相关，这也是首次报道急性卒中阶段 q EEG 与 MRI 之间的相关性。

图 2，3，4 显示了表现最高功率的电极位置与卒中影响的脑区之间的对应性。然而 aDCI 本身并非严格的定位参量，而是对平均头皮 delta 功率改变的测量。因此，其与 30 天 NIHSS 的相关性要做总体上的评估而不拘泥于皮质卒中的定位。值得指出的是本次小样本数据的研究提示了一定范围的 DWI/PWI 异常体积和分布。

1.6 Cerebral monitoring in the operating room and the intensive care unit: an introductory for the clinician and a guide for the novice wanting to open a window to the brain. Part I: The electroencephalogram.

Freye E, **Levy JV**.

J Clin Monit Comput. 2005 Apr;19(1-2):1-76.

While there is an increasing body of knowledge in regard to central nervous system function and/or the mode of action of centrally active agents on neuronal function, little is done to develop new techniques on how to measure such changes. Also, monitoring of the cardiovascular system in the past has made extensive progress especially when it comes to evaluate the failing heart. In contrast monitoring of the central nervous system is only done in rare cases where operative procedures likely impede nervous function integrity. Since in the past decade the aging population undergoing operation has rise considerably, the risk of cerebral malperfusion or minute signs of degradation of the aging central nervous system (CNS) to anesthetics and agents being used in the operation room (OR) or the intensive care unit (ICU), needs continuous monitoring of an organ which presents the highest vulnerability and is likely to deteriorate faster than the cardiovascular system. In spite the rapid improvement in technology regarding the electroencephalogram (EEG) and evoked potential monitoring, physicians still are reluctant to use a technology on a routine base, which will give them insight information into brain function and activity. Such "windows to the brain" now not just are reserved to specialists working in the area of neurology and/or psychiatry. More so, cerebral monitoring is getting an integrated part in the overall therapy in patients undergoing operation or who need ventilatory support in the ICU as it effects the well-being and the outcome. The present book therefore, is intended for the practitioners who work with the patient, guide the clinician in his decision making and outlining those situations where cerebral monitoring presents an integrated part in the diagnosis and therapy of patient care. Without going too much into the technical details, representative cases underline the potential use of cerebral monitoring in the underlying clinical situation where either the patient presents borderline perfusion of the CNS, undergoes vascular surgery, or where monitoring of cerebral function in the intensive care in a head trauma patients is an integrated part in therapy.The book therefore is meant for all those clinicians who have to deal with the CNS in a day-to-day situation. This may be the anesthesiologist, the surgeon, the intensive care therapist, the nurse anesthetist as well as all other medical personal involved in intensive care therapy. The aim of the book therefore is to outline the possibilities, the limitations, and the options for therapy when the windows to the brain are opened, how to interpret the data in the light of other physiological parameters and aid the user in the technical details of how to avoid artifacts in recording which may have an impact on final decision making. Therefore, emphasis is placed on the electrode placement, artifact and electrical noise reduction, as well as data interpretation so that cerebral function diagnosis can be made on reliable grounds. The following serves as an introduction to and as a reference guide for Cerebral Monitoring in the OR and the ICU: Gives complete coverage of EEG power spectra analysis. Describes in detail the EEG machines available to be used in the OR and ICU setting. Describes in detail the major features of EEG power spectra and evoked potential measurements, including amplifiers, filter setting and microprocessor algorithm for data reduction. Gives suggestions for assessing and improving signal quality, including noise and artifact rejection, which usually are encountered in the operation room and the intensive care unit, both of which can be considered as electrically contaminated. Gives examples of EEG power spectra and evoked potential monitoring related to different types of anesthesia, in coma, after head trauma, and for the detection of ischemic events. In addition, gives complete coverage of those machines being available for the OR and the ICU, including a list of parameters regarding latency and amplitude in evoked potential As an introductory, recommendations are given for the novice to start cerebral monitoring and guide the beginner in setting up cerebral monitoring in the clinical environment.

[译文摘要]

手术室和 ICU 中的脑监测：对临床医师的介绍及对渴望打开大脑之窗的新手的指导。EEG 部分。

有关中枢神经系统功能以及中枢化学成分对神经元功能作用模式的知识已了解得很多，而对开发如何测量这些变化的新技术做得很少。以往心血管系统监测取得了广泛进展，特别是当用于评价心脏衰竭时。然而，中枢神经系统的监测应用的很少，只有个别案例用于术中可能影响了神经功能的完整性时。过去的十年中由于接受手术的老龄人口显著增加，脑灌注不良的风险或老龄化中枢神经系统的退化，影响到在 OR 或 ICU 的麻醉剂及药物的使用，需要对一个比心血管系统更易受损害，更易退化的器官进行连续监测。涉及到 EEG 和 EPs 技术发展很快，医师们还是不愿意将其作为常规技术应用，尽管这些手段能帮助医生深入了解脑功能及活动的内在信息。像这样的“ 大脑之窗”现已不仅限于工作在这一领域的精神病学，神经病学的专家，进而，脑检测正在成为对需要手术及在 ICU 中需要呼吸支持的患者全面治疗的不可分割的部分，特别是评价治疗效果和预后。本书是为工作在这一领域的临床工作者，直到他们在对患者制定整体诊断和治疗方案时，运用脑监测做出决策和规划。在不涉及具体技术细节的基础上，以据有代表性的病例说明脑监测作为应用于 CNS 边缘性灌注，接受血管手术，或是 ICU 中外伤性患者脑功能检测的一个整体治疗的概况。本书适用于所有日复一日和 CNS 打交道的临床医师，如麻醉师，外科大夫，重症监护治疗师以及所有 ICU 的治疗人员。本书的目的是概括出当大脑之窗被打开后，治疗的可能性，局限性和选择，如何解释电生理数据并帮助使用者了解技术细节以避免记录中的伪差影响最终的决策。所以我们强调电极安放，伪差排除以及数据解读。这样可以在可信的基础上对脑功能作出诊断。以下内容作为在 OR 或 ICU 中脑功能检测的简介和指导参考：全面的 EEG 功率谱分析；OR 或 ICU 中 EEG 仪器的详细描述；EEG 功率谱和诱发电位主要特点的描述，包括波幅，滤波，以及数据推导的数学算法；提出改进信号质量的建议，包括常出现于 OR 或 ICU 中的伪差和噪声的排除；给出 EEG 功率谱和诱发电位应用于不同类型的麻醉，昏迷，头部外伤及缺血性事件的监测实例。另外，还有这类仪器用于 OR 或 ICU 的全面说明，包括诱发电位波幅和潜伏期参量。作为一个简介，要给于从事脑监测的新手一些建议，以及对已经在临床工作中开展脑功能检测的人员一些指导。

1.7 Rapid EEG Analysis for Intensive Care Decisions in Status Epilepticus

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Nonconvulsive status epilepticus in intensive care units (ICUs) is common and increases the risk of death. Nonconvulsive status epilepticus treatment delays are associated with poor patient outcomes. Continuous EEG or EEG-video monitoring is used in ICU settings to diagnose subtle seizures and nonconvulsive status epilepticus among at-risk populations including patients with closed head injuries and altered consciousness, stroke, subarachnoid hemorrhage, neonates at-risk for sepsis or hypoxic-ischemic encephalopathy, and children who have undergone surgery for congenital heart disease. However expert EEG interpretation, currently required for accurate diagnosis, often lags behind the real-time recordings by hours or even longer. At most hospitals the numbers of at-risk patients in intensive care units far exceeds the capacity of the available EEG equipment and personnel to perform and interpret EEGs. Seizure-detection software, compressed EEG spectral arrays, and near real-time remote EEG interpretation have brought us closer to the goal of real-time analysis of EEG for intensive care decisions, but even at major tertiary referral centers the vast majority of at-risk ICU patients do not undergo EEG monitoring. Additional technological advances, innovative use of EEG technologists and ICU personnel, and clinical trials of new EEG monitoring technology and associated clinical outcomes are needed to achieve the goal of optimal use of EEG data for intensive care decisions.

[译文摘要]

非惊厥性癫痫持续状态 NCSE 在 ICU 常见并使死亡率增加。非惊厥性癫痫持续状态的治疗延迟与患者的预后差有关， ICU 中 C-EEG /V-EEG 用来对包括闭合性头部外伤，意识改变，卒中，蛛网膜下腔出血，感染或水肿—缺血性脑病的高危新生儿，以及承受先天性心脏病手术的儿童这类细微发作及非惊厥性癫痫持续状态的高危人群进行监测和诊断。然而，对于准确的诊断所需要的熟练的 EEG 解释，经常落后于实时记录几个小时甚至更久。在大多数医院，ICU 中高危患者的人数远远超

过了现有的脑电图仪和操作并对 EEG 解读的人员。发作检测软件，压缩谱阵图，接近实时的远程 EEG 分析是我们接近了为重症监护决策 EEG 实时分析的目标，但即使在三级会诊中心，ICU 高危患者的绝大多数，也未能进行 EEG 监测。今后仍需要有新的技术进展，脑电技师和 ICU 工作人员的创新应用，以及新的 EEG 检测技术及与临床结果的相关性的临床试验，以实现把 EEG 数据用于重症监护决策的目标。

2 国内医院 Solar2000临床应用论文

2.1 长程脑电图监测对评估昏迷患者预后的应用价值

《中华神经科杂志》-2007 年 40 卷 10 期 -667-670 页

CHINESE JOURNAL OF NEUROLOGY

刘旸　王薇薇　吴逊

[摘要]　目的　探讨长程脑电图监测和临床检测指标对评估昏迷患者预后的 应用价值。方法　对 26 例昏迷患者(男 15 例,女 11 例,年龄 17~90 岁)急性 期进行长程脑电图监测、改良 Glasgow 昏迷评分以及半球复杂性的分析,随访患 者至昏迷后 2 个月,并进行 Glasgow 预后评分,将长程脑电图监测和临床检测指 标结果和昏迷患者预后进行相关分析,观察昏迷患者半球复杂性随时间的变化及 其与预后的关系。结果　长程脑电图监测对昏迷患者预后评估的特异度(77.8%)、准确度(92.3%)均较临床检测指标改良 Glasgow 昏迷评分高。脑电图分级与 Glasgow 预后评分进行线性相关分析,相关系数 $r=0.81$, $P<0.01$;改良 Glasgow 昏迷评分和 Glasgow 预后评分进行线性相关分析,相关系数 $r=-0.39$, $P<0.01$。患者病情 变化时,脑电图改变出现在改良 Glasgow 昏迷评分改变之前。所观察的全部 26 例昏迷患者其左、右半球复杂性的熵值差异均无统计学意义,熵值随时间的变化呈 6 种图形,其中 4 种图形的昏迷患者 Glasgow 预后评分指标不良;2 种图形的 患者预后指标良好。结论 对昏迷患者进行长程脑电图监测,在评价脑功能和预测昏迷患者的预后两方面有较好的应用价值。

[关键词]　长程脑电图;改良 Glasgow 评分;昏迷;预后评估

Application of long-time EEG monitoring in comatose patient

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[Abstract] **Objective** To explore the prognostic value of long-time EEG monitoring and clinical examination index in comatose patients.

[Key words] Long-time EEG monitoring; Reformed Glasgow coma scale; Coma; Prognosis

昏迷是临床常见的症状，神经系统疾病或其他各系统疾患导致脑功能受损， 均可使患者处于昏迷状态。虽然昏迷的原因不尽相同，但其脑电图的改变大多相 似。近年来用非线性分析的方法研究脑电信号的复杂性渐渐引起重视,应用复杂 性分析研究各种状态下的脑电活动已成为热点[1]。对昏迷患者的预后进行评估不 仅具有临床意义，还具有一定的社会经济学意义和人类伦理学意义。国内外这一 领域的研究已有不少，均肯定了脑电图的应用价值，但对昏迷患者应用长程脑电 图监测进行预后评估目前尚无确切且被广泛认可的结论[2]，为此，我们对 26 例 昏迷患者在急性期内进行了长程脑电图监测,以进一步研究长程脑电图监测在评 估昏迷患者预后方面的应用价值。

资料和方法

一、临床资料

2006 年 1 月—2006 年 10 月于北京大学第一医院住院的昏迷患者,共 26 例，其中男 15 例，女 11 例，年龄 17~90 岁，平均（70.6±9.8）岁。所有患者符合以 下入组标准：（1）各种原因导致的弥漫性脑功能损害者，如低氧血症、低血压休 克、低血糖昏迷、心肺复苏后等；（2）入组时改良 Glasgow 昏迷评分在 3~13 分 之间（满分 20 分）；（3）排除使用抗癫痫药物或镇静类药物导致昏迷的患者。昏 迷的原因为心肺复苏术后为 16 例，肺性脑病 5 例，脑炎 4 例，电击伤 1 例。

二、研究方法

1、目测脑电图进行脑电图分级：脑电图描记使用北京太阳电子科技有限公司生产的便携式脑电图仪（Solar2000B），时间常数 0.3，高频滤波 40 Hz，走纸速度 3 cm/s，灵敏度 50 μV/5 mm。按国际 10-20 系统放置电极，盘状电极用火棉胶固定于头皮。进行床旁单极 8 导脑电图描记，采样时间为 24~48 h，所有患者均在发病 后 24~48 h 内进行床边描记，脑电图描记时患者均符合上述入组标准，部分患者 因病情恶化而死亡，描记时间短于 24 h。

2、半球复杂性和改良 Glasgow 昏迷评分：脑电图记录的同时每隔 2 h 进行一次 脑电图分级和改良 Glasgow 昏迷评分，记录脑电图分级和改良 Glasgow 昏迷评分 指

标发生变化的时间。脑电图结果分级参照 Young 脑电图分级标准[3]稍作改动。 Ⅰ级：以 θ 波为主，伴少量 α、β 波，纺锤波形；Ⅱ级：多形性 δ 波为主，伴 θ 波； Ⅲ级：单一节律的 δ 波为主，间有少量平坦波（暴发-抑制型），或 α 昏迷、β 昏迷； Ⅳ级：平坦波为主（波幅 10~20 μV），间有少量 θ 波；Ⅴ级：平坦波（波幅<10 μV）。以患者每 2 h 内的主要脑电图波形作为定级标准。

国际上复杂性的定义和算法不尽一致。一般可以用复杂度、李氏指数、相关 维度和近似熵来描述[1, 4]。我们进行熵的计算来描述半球复杂性，熵的取值范围是 0~1。选择与进行临床改良 Glasgow 评分相同的时间点的脑电图进行半球复杂性的计算，观察熵值随时间变化的规律，观察不同变化规律的昏迷患者的预后有何 不同。

Glasgow 预后评分：随访至患者昏迷 2 个月后，进行 Glasgow 预后评分（2 个月内死亡的患者以死亡为观察终点进行 Glasgow 预后评分）。Ⅰ级：良好：成 人恢复工作，学生上学；Ⅱ级：中残：仅能生活自理；Ⅲ级：重残：生活需他人 照顾；Ⅳ级：植物状态；Ⅴ级：死亡。预后判断的终点时间为发病后 2 个月或 2 个月内患者死亡。随访时间：24 h 内死亡 2 例，1 周内死亡 3 例，1 个月内死亡 8 例，随访至昏迷后 2 个月者 13 例。

4、脑电图和临床检测指标对预后评估的价值的计算方法：指标良好且预后良好的患者计为真阴性(TN)；指标良好而预后不良的患者计为假阴性(FN)；指标不 良且预后不良的患者计为真阳性(TP)；指标不良而预后良好的患者计为假阳性(FP)；灵敏度(SE)=[TP/(TP+FN)]×100%，特异度(SP)=[(TN/(TN+FP)]×100%。指 标对预后评估的准确度=（TN+TP）/总人数。其中脑电图Ⅰ级和Ⅱ级为良好,Ⅲ 级、Ⅳ级和 Ⅴ 级为不良；Glasgow 评分 9~13 分为指标良好，3~8 分为指标不良；Glasgow 预后评分Ⅰ~Ⅲ级为预后良好，Ⅳ级和 Ⅴ 级为预后不良。由于同一例患 者的左右半球复杂性可能存在差异，故将半球复杂性的结果单独列出，以观察半 球复杂性随时间变化的规律。

三、统计学方法

对长程脑电图监测及临床检测指标结果和昏迷患者预后用 SPSS10.0 软件进行数据处理，统计学处理用 spearma 相关分析。

结　果

1、不同预后的昏迷患者的改良 Glasgow 评分、Young 氏脑电图分级的比较： 预后

良好的患者（7 例）的 Young 氏脑电图分级在 2.25±0.45，预后不良的患者（19 例）Young 脑 电图分级在 3.92±0.79，两者比较 t=－6.81，P<0.05，差异有统计学意义；预后良 好的患者（7 例）的改良 Glasgow 评分在（12.00±4.57）分，预后不良者（19 例） 的改良 Glasgow 评分在（7.08±4.91）分，两者比较 t=2.61，P<0.05，差异有统计 学意义。

2、临床检查和脑电图检查对昏迷患者预后的评估的比较：脑电图监测指标对 昏迷患者预后的评估的特异性、准确率均较 Glasgow 评分高（分别比后者高出 19.5% 和 11.6%）；在敏感性上同 Glasgow 评分一样，均为 100.0%（表 1）。

表 1 临床检查和脑电图检查对昏迷患者预后的评估的比较

	总例数（例）	TN（例）	FN（例）	TP（例）	FP	敏感度（%）	特异度（%）	准确度（%）
脑电图监测	26	7	2	17	0	100.0	77.8	92.3
Glasgow 评分	26	7	5	14	0	100.0	58.3	80.7

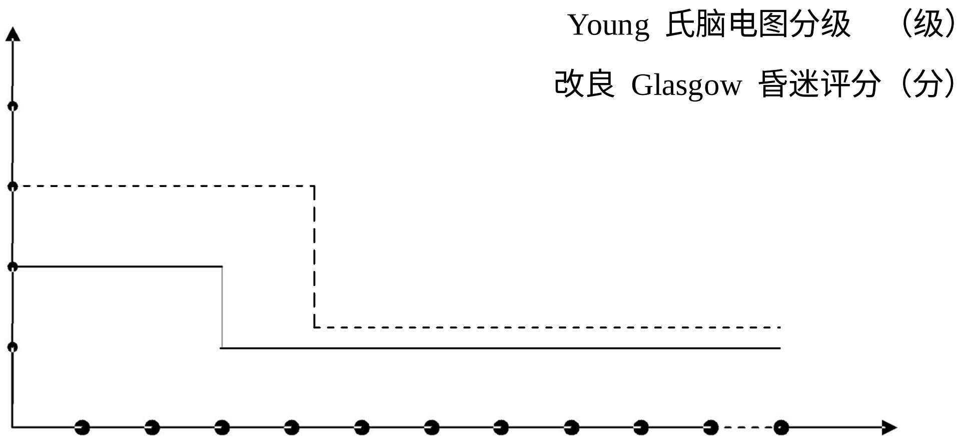
3、脑电图分级、改良 Glasgow 昏迷评分和 Glasgow 预后评分三者之间的关系：

脑电图分级与改良 Glasgow 昏迷评分的相关系数 r=－0.56，P<0.01，说明脑电图 分级与改良 Glasgow 昏迷评分呈负相关。脑电图分级与 Glasgow 预后评分进行线 性相关分析的相关系数 r=0.81，P<0.01，说明脑电图分级与 Glasgow 预后评分呈正相关。改良 Glasgow 昏迷评分和 Glasgow 预后评分进行线性相关分析，相关系 数 r=-0.39，P<0.01，说明改良 Glasgow 昏迷评分与 Glasgo 预后评分呈负相关。结果显示，脑电图分级与改良 Glasgow 预后评分的相关性较 Glasgow 昏迷评分与 Glasgow 预后评分的相关性高。

4、脑电图分级改变、改良 Glasgow 昏迷评分变化和预后的观察：本组共 26 例患者，脑电图分级发生改变者共 8 例：（1）分级改善者 3 例（Ⅱ级→Ⅰ级者 2 例，Ⅲ级→Ⅱ级者 1 例），这 3 例的改良 Glasgow 昏迷评分均在脑电图发生改变 后（2~4 h）也随之好转（分别由 8、8、9 分变为 15、15、19 分），患者的 Glasgow 预后

评分均在Ⅱ级。(2）脑电图分级恶化者 5 例（均为Ⅲ级→Ⅴ级），这 5 例患 者中有 3 例的改良 Glasgow 昏迷评分在脑电图发生改变后（2~4 h）也随之改变。(由 10、8、8 分均变为 3 分)，另 2 例的改良 Glasgow 昏迷评分始终为 4 分，直至观察终点。这 5 例患者的 Glasgow 预后评分均为Ⅴ级。

在本组 26 例患者中改良 Glasgow 昏迷评分发生变化（分别由 8、10、13 分变为 10,8,17 分）而脑电图监测指标无改变（均为Ⅱ级）者 3 例，预后分级均 为Ⅲ级。图 1 所示为 1 例心肺复苏后的昏迷患者（男，70 岁）的 Young 脑电图 分级和 Glasgow 昏迷评分随时间变化图。



0 2 4 6 8 10 12 14 16 18 20 36

时间（h）

图 1、昏迷患者的 Young 氏脑电图分级和改良 Glasgow 昏迷评分随时间变化图

5、昏迷患者半球复杂性随时间的变化及其与预后的关系：对 26 例昏迷患者左右半球复杂性的熵值逐一进行 t 检验，结果显示：所有患者的左右半球复杂性的熵值在统计学上差异均无统计学意义。选择 26 例昏迷患者半球复杂性的熵值为纵轴，时间为横轴作散点图，观察熵值随时间的变化。主要图形包括如图 2 的 6 种。(图略)

图 2、昏迷患者半球复杂性随时间变化图。横坐标为时间(h)，纵坐标为熵值，主要图形如图 2A 的患者共 6 例（23.1%)，Glasgow 预后分级均为Ⅴ级；如图 2B 的 6 例 (23.1%)，有 5 例预后Ⅳ级，1 例预后Ⅴ级；如图 2C 的 2 例（7.7%)， 其中 1 例患者预后为Ⅳ级，1 例患者预后为Ⅴ级；如图 2D 的 2 例（7.7%)，预后 为Ⅴ级；图 2E 的 4 例（15.4%)，3 例预后Ⅱ级，1 例预后Ⅲ级；如图 2F 的 3 例（11.5%)，2 例预后为Ⅱ级，1 例预后Ⅲ级；另有 3 例（11.5%）患者因为在 24 h 内很快死亡，

监测时间短，无法做出图形进行归类。前 4 型图的昏迷患者共 16 例，其 Glasgow 预后评分的指标均不良（Ⅳ级 6 例，Ⅴ级 10 例）；E、F 型图的患者 7 例，预后指标良好（Ⅱ级 5 例，Ⅲ级 2 例）。

讨 论

脑电图能直接反映脑代谢异常，对昏迷患者大脑皮质功能的评价敏感性高，尤其是便携式脑电图检查简单易行，临床应用更为广泛。本组监测数据显示，脑 电图分级和 Glasgow 评分对昏迷患者预后评估的敏感性均为 100.0%，也就是说脑电图分级较差和 Glasgow 评分指标不良的昏迷患者预后均不良，两者在这方面没有表现出差异。在对昏迷患者预后评估的特异性和准确性方面，脑电图分级均比临床指标显示出优势，同时，Young 脑电图分级与预后的相关性也较 Glasgow 评 分高。脑电图分级有多种，我们选择的 Young 脑电图分级标准较其他脑电图分级 标准对于昏迷患者预测的相符性更高[5]。

我们观察到：昏迷程度发生变化时，脑电图最先改变，临床指标的变化滞后。提示预后不良的脑电图征象有：脑电图对外源性刺激缺乏反应性；脑电图无自发性改变；爆发性抑制；α 昏迷；周期性癫痫样放电；普遍抑制[1,6-7]。我们对预后 不良的昏迷患者进行观察，其脑电图多数表现为普遍抑制，无自发性改变，对外 源性刺激缺乏反应性。提示预后良好的脑电图征象有：对外源性刺激有反应性， 有正常的睡眠电位及正常的睡眠周期，在持续的监测中脑电图异常有改善等[9]。 如果能够及时地观察到昏迷患者的脑电图变化，在临床指标变化之前予以干预， 对改善患者预后有一定价值。脑电图与临床资料结合还能提供部分昏迷的病因学 线索，以便于为预后做出准确判断[7]。

从半球复杂性的角度分析，可以将脑电活动理解为一种随时间序列而随机变 化的过程，从头皮不同位点记录的脑电活动组成了一种空间关系，可以大致反映 不同脑区的生理性和病理性活动的情况[1]。吴浩江等[8]用近似熵的方法研究了大 鼠脑缺血前后缺血区域和正常区域脑电信号，结果表明，局灶性缺血发生时，缺 血区域脑电信号近似熵低于正常区域。我们观察了昏迷患者半球复杂性随时间的 变化及其与预后的关系，结果显示：①昏迷患者双侧半球的熵值差异没有统计学 意义；②半球复杂性随时间变化而变化，熵值总体趋势下降的患者预后不良，熵 值总体趋势上升的患者预后良好；③由计算机计算的 26 例昏迷患者脑电图的熵 值，都随时间发生变化，肉眼观察的 26 例患者的 Young 脑电图分级只有 8 例发生变化，证明通过

熵的计算来描述半球复杂性，能够更加敏感地反映昏迷患者的脑功能。

综上，我们对昏迷患者进行长程脑电图监测，发现其在评价脑功能和预测昏迷患者的预后两方面有较高应用价值，在指导昏迷患者的临床治疗方面有一定价值。随着脑电图的计算机分析技术不断发展，如果能将比 Young 脑电图分级更加敏感、准确的定量的分析指标应用到临床工作中，从脑电图检查中获得更多有意义的信息，将为昏迷患者的预后评估和临床治疗带来更大的价值。

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2.2 连续脑电监测在神经科重症监护病房的应用

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2.3　癫痫患者全夜自然睡眠结构的研究

The structure of the spontaneous all night sleep in epileptics

<<中风与神经疾病杂志 >>2003 年 06 期

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[摘要]　目的　观察癫痫患者发作间期全夜自然睡眠结构特点，并评价其与正常对照组睡眠结构的差异；评价发作类型、用药情况及是否记录到发作间电发放对睡眠结构的影响。方法　对 20 名癫痫患者及 11 名对照进行全夜自然睡眠多导监测，并结合患者的发作类型、是否记录到发作间电发放(IIDs)及服用 AEDs 的情况进行分组统计分析，评价各组患者与正常对照间各睡眠参数的差异。结果癫痫患者组，记录到 IIDs 组，及该组患者中部分性发作者和未服 AEDs 者均较正常对照 TRT、RL 显著延长(P＜0.05)。记录到 IIDs 的患者睡眠效率显著下降(P≤0.05)，其中部分性发作者入睡后觉醒次数较全身性发作者显著增多(P＜0.05)。部分性发作者较全身性发作者 NREM 睡眠期转换次数有增高的趋势。不同用药癫痫患者睡眠脑电图较正常对照组睡眠破碎性增加。结论　癫痫患者与正常对照比较 RL 延长；睡眠破碎性增加；记录到 IIDs 的患者睡眠效率降低；部分性发作患者较全身性发作患者有 NREM 期转换次数频繁的趋势；记录到 IIDs 患者中服用 AEDs 的情况对其睡眠结构无显著影响。

关键词： 癫痫，睡眠，脑电图，睡眠-觉醒周期，睡眠结构

3 Solar2000N主要功能特点

3.1 系统设计的目的

- 昏迷和意识状态评估
- 预后评估
- 帮助诊断疾病
- 对病人的状态实时监控,即时反映病人状况
- 协助对疾病的定型和分类
- 对治疗和药效进行评估
- 进行科学研究

3.2 功能简介

- 实时的数据显示和报警
- 长时间数据的保存,回放和管理
- 常规参数趋势图
- 脑电加权趋势分析
- 脑电相对变化分析
- 脑电半球复杂度趋势分析
- 脑电综合评价
- 脑电爆发抑制检测
- 脑功能指数分析
- 脑电地形图
- 数据合并

3.3 关于各种功能指数的计算方法

- 加权趋势分析是脑电频谱分析的加权显示。
- 相对变化提示传统脑电频谱分析中各频段功率的相对变化。这对有脑电概念的人是很有益处的。

- 半球复杂度是以左右半球分别计算，不仅可以观察脑功能随时间的变化，还可考察对称性的变化。
- 综合评价是利用所选择的全部导联数据，经过复杂的数学运算和适当的图形表现脑功能的变化趋势。
- 以上两项功能的设置主要是为了减少阅读 LT_EEG 的难度，以及临床医生和护理人员的困难。这也是监护数据分析的必然趋势。
- 对于遇到的每一个个案，都要从所有这些趋势分析中找到变化的趋势和规律。从而结合临床进行分析。
- 脑电图表现的脑功能的变化一般都比临床和其它检测设备如 CT,MRI 等提前。而在治愈后，脑功能的变化又比较滞后。