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Clinical Neurophysiology 118 (2007) 2149–2155

www.elsevier.com/locate/clinph

Emergent EEG in clinical practice

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Accepted 4 July 2007
Available online 20 August 2007

Abstract

Objective: Emergency situations require a rapid and precise diagnostic approach. However, the exact role and value of the electroencephalogram (EEG) in emergent conditions have yet to be clearly defined. Our objective was to determine why clinicians order an emergency EEG, to assess to what extent it helps establish a correct diagnosis and to evaluate the result it has on subsequent patient management.
Methods: We studied all successive emergency EEGs ordered during a 3-month period in our institution. We analyzed the reasons why each EEG was ordered and interviewed the prescribing clinicians in order to determine the impact the result of the EEG had on the diagnosis and subsequent therapeutic management.
Results: We prospectively studied a total of 111 consecutive recordings. The main reasons for ordering an emergent EEG were: suspected cerebral death (21%), non-convulsive status epilepticus (19.7%), subtle status epilepticus (14%) and follow-up of convulsive status epilepticus (11.2%). In 77.5% of the cases the clinicians considered that the EEG contributed to making the diagnosis and that it helped confirm a clinically-suspected diagnosis in 36% of the cases. When subtle status epilepticus (SSE) or non-convulsive status epilepticus (NCSE) was suspected, the diagnosis was confirmed in 45% and 43.3% of the cases, respectively. In 22.2% of the requests involving follow-up of convulsive status epilepticus after initial treatment, the EEG demonstrated persistent status epilepticus. It resulted in a change in patient treatment in 37.8% of all the cases. When the EEG helped establish the diagnosis, patient treatment was subsequently modified in 46.6% of the cases.
Conclusions: This prospective study confirms the value of an emergent EEG in certain specific clinical contexts: the management of convulsive status epilepticus following initial treatment or to rule out subtle status epilepticus. An emergent EEG can also be ordered if one suspects the existence of non-convulsive status epilepticus when a patient presents with mental confusion or altered wakefulness after first looking for the specific signs suggesting this diagnostic hypothesis.
Significance: After 50 years of development and use in daily practice, the EEG remains a dependable, inexpensive and useful diagnostic tool in a number of clearly-defined emergency situations.
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Keywords: EEG; Emergency; Epilepsy; Diagnosis; Status epilepticus; Confusion; Coma

1. Introduction

Electroencephalography is a technique that has been routinely used for nearly 50 years for the functional exploration of the brain. The recent development of newer methods of anatomic and functional imagery has limited its clinical indications. Nevertheless, the electroencephalogram (EEG) remains essential for assessing cerebral maturation, for determining a patient's physiological (awakening and sleep) and pathological (comas) level of wakefulness and in epileptology. The term "emergency" denotes a pathological condition which is life-threatening or which can lead to organ failure requiring prompt treatment in order to avoid severe worsening and/or severe

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doi:10.1016/j.clinph.2007.07.003

sequels (Conférence de consensus, 1998). An EEG can be required in several emergent conditions such as seizure, status epilepticus (including non-convulsive status epilepticus) or confusional state. In 1996, a meeting of French experts established a set of guidelines based on a review of the available literature (Conférence de consensus, 1998). Nevertheless, the value of the EEG for diagnostic evaluation of the EEG in emergent clinical situations has yet to be clearly defined.

Emergent EEG is available 24 h a day in our institution. Outside of normal hospital hours (6 p.m. to 8:30 a.m. and Saturdays, Sundays and holidays), a technician is always on-call to respond to a physician's request for an EEG for a patient considered to be in an emergency situation. This study was designed to identify the reasons physicians prescribed an emergent EEG in daily medical practice, to assess the therapeutic benefits which could be expected and to determine the consequences of the EEG results on subsequent patient management.

2. Methods

We studied all emergent EEG recordings ordered between January 15, 2004 and April 15, 2004. Each attending physician determined the presence of a medical emergency by using the accepted definition (see above). Ruling in or out non-convulsive status was considered an emergency. All EEGs were performed within the hour following their prescription. We excluded requests for a second EEG when organ harvest was considered in cases of cerebral death.

Each EEG was recorded during a minimum of 20 minutes by using a Digital EEG Acquisition system. We placed 20 electrodes on each patient's scalp according to the International 10–20 system. When a bedside recording was performed, we sometimes used only eight electrodes (F3, F4, C3, C4, T3, T4, O1, O2). Each EEG included standard activation procedures when the patient's clinical state permitted. In every case, a simultaneous ECG was recorded. Responses to pain and noise were recorded when the patient had an alteration in wakefulness.

Information containing the patient's age and gender, the reason for ordering the procedure, the clinical context, the patient's present treatment and where the patient was hospitalized were included on each EEG request form or obtained from the ordering physician by telephone. For the EEG interpretation, we used a pragmatic approach: the EEG criteria for non-convulsive status epilepticus consisted of discrete electroencephalographic seizures, continuous spike and wave activity, or rhythmic recurrent epileptiform activity (Towne et al., 2000). Periodic discharges were always considered seizures if they occurred following a generalized tonic–clonic seizure in a comatose patient. In other situations, a case by case interpretation was performed according to both clinical context (the reason for ordering the procedure) and EEG pattern.

Table 1
Questions we asked the physicians who ordered an emergent EEG

1 – Did the EEG result help establish the diagnosis?
2 – If yes, did it confirm or invalidate your clinical diagnosis?
3 – What was the final diagnosis?
4 – Did the EEG result change your therapeutic management?

The EEG interpretation was immediately telephoned to the attending physician by an electroencephalographist (present in the hospital) and, later, a written interpretation was sent. To provide homogeneous, complete and clear results, by the following morning each EEG recording was also interpreted by another practitioner qualified in electroencephalography and if the interpretation was different, it too was sent to the physician who originally ordered it.

Twenty-four to 48 h later, the attending physician was asked if the results of the emergency EEG in any way modified, confirmed or ruled out the suspected clinical diagnosis and if it changed the patient's subsequent therapeutic management (see Table 1). This procedure was repeated until the patient left the hospital.

3. Results

We enrolled a total of one-hundred and eleven consecutive EEG recordings into this prospective study. Requests for emergent EEGs represented 8.9% of all the EEGs performed during the study-period. The patients were either children ($n = 16$; 4 girls, 12 boys; average age: 3.4 years $\pm$ 53.4 months) or adults ($n = 95$; 61 females, 34 males; average age: 53 ± 17.2 years) (Fig. 1). The majority of the EEG requests came from intensive care units (Fig. 2). Sixty-three percent of the requests were made during normal hospital hours and 37% during on-call coverage. Bedside recordings using eight electrodes were performed on 39 patients (Table 2). A second interpretation was provided for 19 recordings because the first result was affected in its structure (but not in content) as it did not fulfil defined criteria for homogeneous interpretation.

The clinical situations requiring emergent EEG requests were classified into different categories and order of frequency and are shown in Fig. 3. The 2 requests listed in the ''other'' category were related to one case of neonatal distress and another case involving the initial assessment of a premature infant (32 weeks post-amenorrhea).

In 77.5% of the cases, the clinician considered the EEG had contributed to the diagnosis. In 36% of the cases, it contributed to establishing a diagnosis which was clinically suspected (40/111 recordings) and ruled it out in the remaining 64%. When cerebral death or non-convulsive status epilepticus (NCSE) was suspected, the EEG was always contributory and the diagnosis was confirmed in 43.3% and 20% of the cases, respectively. When subtle status epilepticus (SSE) was suspected, the procedure was always contributory and confirmed the diagnosis in 45%

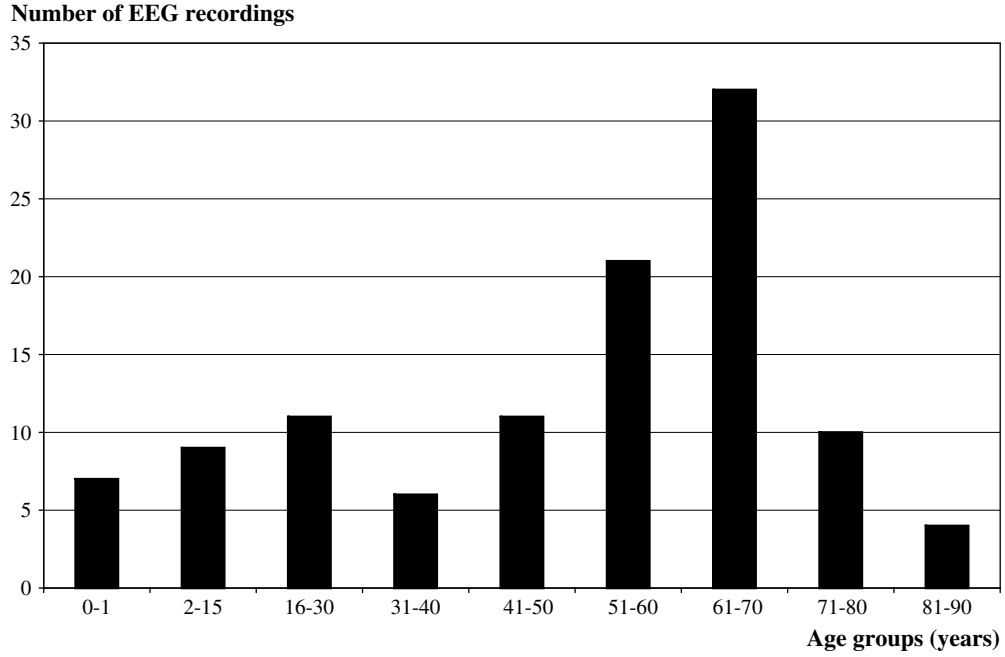

Fig. 1. EEG recordings by age groups.

of the cases. In 22.2% of the requests involving follow-up of convulsive status epilepticus after initial treatment, the EEG demonstrated persistent status epilepticus. The procedure ruled out one case of suspected myoclonic status epilepticus and resulted in the discontinuation of a treatment with benzodiazepines. The attending physicians considered the EEG as non-contributory in four suspected cases of partial status epilepticus. The EEG was contributory by demonstrating generalized spike discharges in one case of an inaugural tonic–clonic seizure. When an EEG was requested for suspected encephalitis, one out of two recordings illustrated elements in favor of the diagnosis.

If the clinical categories for which the EEG was always contributory by our definition (brain death and all forms of status epilepticus) were excluded, the EEG results helped the attending physician in 14.8% (4/27 recordings) of the cases.

Overall, the EEG resulted in a modification in treatment in 37.8% of the cases (42 recordings). When the EEG was contributory to the final diagnosis (88 recordings), the

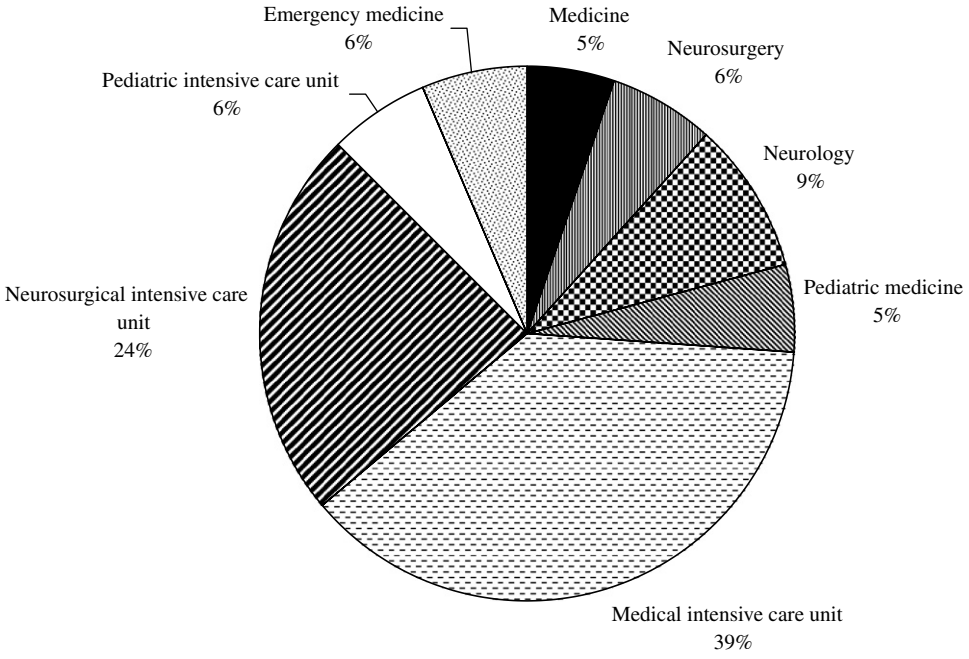

Fig. 2. Distribution of EEG recordings according to the type of medical or surgical unit requesting the procedure.

Table 2
Placement of the 8 bedside EEG electrodes according to the type of medical or surgical unit requesting the procedure and the clinical context of the patient

Unit	Indication	Number
Medical intensive care unit	Cerebral death	9
	Subtle epilepticus status	4
	Convulsive epilepticus status after treatment	3
	Non-convulsive epilepticus status	1
Neurosurgical intensive care unit	Cerebral death	15
	Non-convulsive epilepticus status	1
Pediatric intensive care unit	First generalized tonic–clonic seizure	2
	Others	2
	Cranial damage	1
	Cerebral death	1

patient's treatment was modified in 46.6% (41 recordings) of the cases. When the EEG recording was contributory to diagnosing NCSE, SSE, an epileptic syndrome following a first convulsive seizure or viral encephalitis, the patient's treatment was modified in every case. When the EEG ruled out a clinically-suspected diagnosis (57 recordings), the treatment was modified in 38.6% (22 recordings) of the cases (in each case, the treatment was discontinued). When the EEG was non-contributory to the final diagnosis, the patient's therapeutic management remained unchanged.

4. Discussion

The EEG, a technique used for the functional assessment of the brain, is a readily available procedure in our institution. The value of the EEG in emergency situations was demonstrated by the high percentage (8.9%) of emergent EEGs among all the EEGs performed during the study-period. The percentage we found was higher than those published in a multicentric North American study (Quigg et al., 2001) involving 46 Canadian and American institutions performing electroencephalography. These researchers found that only 37 centers provided 24 h-a-day emergency EEG. In addition, emergent EEGs represented an average of $4.4 \pm 3.6\%$ of the annual total although this percentage needs to be tempered by the fact that 80% of the institutions studied required a neurologist's opinion before performing the procedure. The percentage of emergent EEGs was higher (12.8%) in an American institution which retrospectively reviewed their emergency EEG requests (which they defined as a procedure performed within one hour of the formal request) over a 4-year period (Varelas et al., 2003).

To date, no prospective study has fully assessed the role and value of the EEG in the management of emergency patients. We chose to allow the attending physician to assess the ultimate diagnostic yield. Indeed, the opinion of the clinical practitioner who is faced with an emergency situation and who is responsible for patient management is

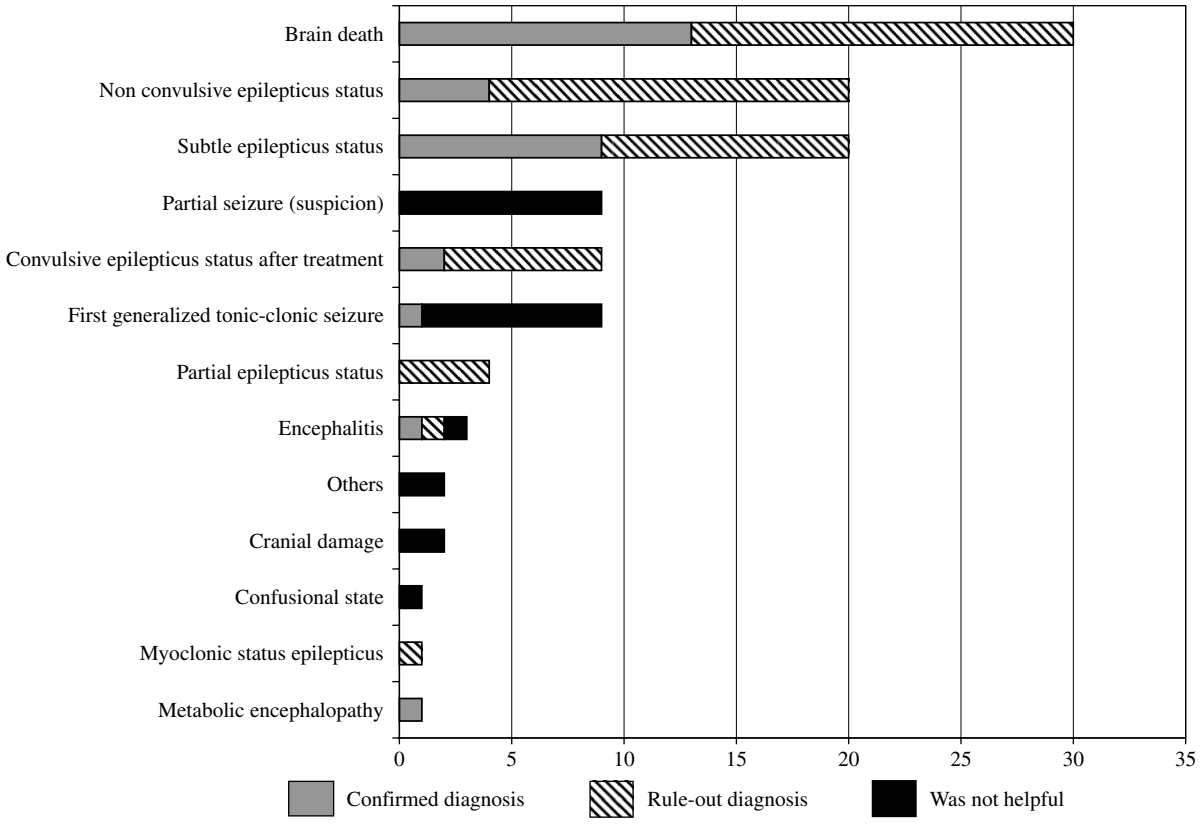

Fig. 3. Clinical situations and diagnostic yield of the EEG.

essential. The rough EEG results and the electroencephalographic interpretation are not the only objective assessment criteria which need to be considered.

Our study mainly concerned in-hospital emergent EEG requests and included all age-groups. Requests were more numerous in patients between the ages of 50 and 70 years, an age-group especially exposed to neurological disorders and acute medical problems. In addition, in nearly two-thirds of the cases, the requests came from intensive care or emergency units, places where acute medical problems are habitually encountered. The use of 8 electrodes for some bedside recordings conceivably only provides partial results; nevertheless it corresponds to our usual practice and complies with published recommendations for emergency recordings (Conférence de consensus, 1998; Fischer, 1997).

Emergent EEGs were mainly ordered for the following disorders: determination of cerebral death (21%), non-convulsive status epilepticus (19.7%), subtle status epilepticus (14%) and follow-up of convulsive status epilepticus after initial treatment (11.2%). These are the same indications most often found in earlier studies (Quigg et al., 2001; Varelas et al., 2003; Praline et al., 2004). In children, emergency requests were for the same disorders as in adults although they mainly concerned diagnostic problems in epilepsy as has been noted in other studies (Navelet et al., 1998; Alehan et al., 2001; Kothare et al., 2005). We excluded follow-up after convulsive status epilepticus in children from our study since continuous EEG monitoring can easily be performed in our pediatric hospital.

When cerebral death is clinically established, the EEG constitutes a simple, atraumatic and inexpensive procedure for confirming the absence of cerebral activity. Nevertheless, it alone is not sufficient for diagnosing cerebral death with certainty and a functional assessment of the brainstem using evoked potentials (early auditory and/or somesthesic) should also be performed (Fischer, 1997). In France, two EEGs (the second performed 4 h after the first) are legally required before organ harvest for transplant. Our series included thirty requests in this context and all were considered contributory. Emergency cerebral angiography is not routinely performed before organ harvest in our institution. This fact probably explains why we had so many requests for emergent EEGs when cerebral death was diagnosed. About one-half of the emergent EEGs for this request did not confirm electrocerebral inactivity. We did not assess whether or not standard, reliable clinical procedures used for determination of clinical brain death, including lack of all brainstem reflexes during exam, cold calorics and an apnea test, were followed prior to ordering the EEG. However, the high rate of brain activity found in our EEG studies suggests that this clinical determination of brain death, as performed in our institution, was often inaccurate.

Suspected NCSE was the second most frequent reason for ordering this procedure. Four out of 20 recordings confirmed the presence of status epilepticus. Privitera and Strawsburg (1994) found NCSE in 37% of 198 patients who presented with altered consciousness. These results suggest that NCSE is common and that an emergent EEG is justified in patients with and unexplained alteration in consciousness. In two of the four cases, the disturbance in vigilance was associated with other signs suggesting the diagnosis: clonic movements of the chin or face. Another patient was receiving treatment for epilepsy which had already been diagnosed. The last-mentioned patient presented unexplained somnolence which had appeared a few days after surgery for a frontal cavernoma and was already receiving anti-epileptic medications. Clonic movements of the chin or face and a past history of seizures are more specific clinical elements which were more frequently encountered in previously published series (Thomas, 2000; Khan et al., 2001). We never encountered them in requests for which the EEG failed to demonstrate any paroxysmal activity. Since the EEG is indispensable for the diagnosis of NCSE, it is not surprising that clinicians felt that it was particularly contributory in every case especially when one considers that the symptoms of NCSE can vary from mental confusion and simple subjective slowing in intellectual efficiency to catatonic stupor (Gastaut, 1983). In addition, it is frequently important to accurately define the underlying diagnostic syndrome with an EEG, particularly in children, since the treatment needs to be adapted as a function of the particular epileptic syndrome present. Furthermore, some anti-epileptic medications can aggravate certain forms of epilepsy (Chiron et al., 2004).

An EEG is not indicated in CSE before appropriate treatment has been instituted and the clinical manifestations have ceased (Thomas, 1997). The diagnosis of CSE is mainly based on the clinical presentation. Nevertheless, an EEG may be useful when atypical signs, suggesting a non-epileptic event, are present (Conférence de consensus, 1998). The EEG is thus particularly useful after appropriate treatment has been instituted in order to verify the absence of any persistent paroxysmal activity (electromechanic dissociation or subtle status epilepticus) which can affect the prognosis (Fagan and Lee, 1990; DeLorenzo et al., 1998). Prolonged and continuous EEG monitoring has also been suggested in this context (DeLorenzo et al., 1998; Treiman, 1999; Thomas, 2000; Claassen et al., 2004; Pandian et al., 2004) and is indeed used in our pediatric hospital.

We deliberately distinguished requests concerning the secondary management of CSE and suspected cases of SSE. In the first-mentioned, the procedure was ordered a few hours after well-adapted and appropriate treatment had been instituted. EEG requests during SSE mainly concerned patients who initially had an effective treatment in whom a non-convulsive clinical modification suggested the recurrence of paroxysmal activity. Clinicians felt the EEG results were contributory in both circumstances. These two indications alone (CSE and SSE) justify the availability of emergency EEG 24-h a day and 7 days a

week. Indeed, it has been shown that when latent or persistent spike activity is not promptly detected, the patient's prognosis can be affected since prolonged paroxysmal activity and delay to diagnosis are associated with increased mortality (Towne et al., 1994; Young et al., 1996; DeLorenzo et al., 1998).

Emergent EEG was considered contributory in the four patients suspected of having simple partial status epilepticus. As the EEG did not show any epileptic discharges, the attending clinicians reached a diagnosis of non-epileptic cause. It is important to recognize that the clinical assessment remains essential since a scalp EEG often does not show any spike activity in cases of simple partial seizure or status epilepticus (Devinsky et al., 1988). In two cases, the EEG results resulted in the cancellation of anti-epileptic treatment. Clinical suspicion was based on worsening of a preexisting neurological deficit or fluctuating focal neurological symptoms without any change in the level of consciousness. Both can suggest simple partial status epilepticus but can also be related to a vascular or inflammatory disorder. It has already been shown that the appearance of a focal neurological deficit does not justify an emergent EEG (De Toffol et al., 1997).

An emergent EEG following a first generalized seizure was contributory in only one case; it demonstrated discharges of spikes leading to the diagnosis of idiopathic generalized epilepsy. In the eight other cases and in the nine EEG recordings performed following the clinical suspicion of partial seizures, the procedure showed non-specific abnormalities and was thus non-contributory. Spike discharges are not always present during the interictal period and consequently, a normal EEG does not rule out an epileptic seizure. The diagnosis remains largely clinical (Vespignani et al., 1997). Even though it increases the chances of demonstrating interictal spikes (Gotman and Koffler, 1989; King et al., 1998), an emergent EEG is not justified for a first seizure (Dunn et al., 2005).

We were not able to draw any particular conclusions for the limited number of cases we had involving other clinical situations. Nevertheless, they did illustrate that an emergent EEG is not particularly useful in these circumstances. In cases suggesting encephalitis, only one EEG recording showed periodic lateralized temporal activity. These specific anomalies appear between the second and third day of the clinical course and this typical pattern of herpes encephalitis, while not pathognomonic, is very suggestive of the disorder (De Toffol et al., 1997). Therefore, an emergent EEG can help establish the diagnosis during the initial phase, especially when the time of onset of the disorder is not clear and can also help determine the prognosis (De Toffol et al., 1997). While waiting for the EEG, the clinician should also order other appropriate diagnostic procedures and initiate effective treatment. The two patients who had head trauma did not show any seizure activity or alteration in consciousness. Non-convulsive seizures are rather common in moderate-severe head trauma (Vespa et al., 1999) but as our two cases of head trauma were mild with no impairment of consciousness, an emergent EEG was not indicated.

The results of emergent EEG modified the patient's therapeutic management. An effect on treatment was more likely if the EEG was considered contributory. Although we have shown that treatment is altered, this does not necessarily translate to improved outcomes, which we did not assess.

The results of this study show the importance of the emergent EEG in certain clearly-defined clinical situations. The retrospective study by Firosh Khan et al. already demonstrated that the value of the EEG varies according to the clinical context. The EEG helps clinical decision-making in patients with epileptic disorders, hypoxic encephalopathies and cerebral death (Firosh Khan et al., 2005). Nevertheless, the precise diagnostic yield of the EEG remains difficult to assess. Varelas et al. (2003) evaluated the diagnostic benefits of the EEG by considering the number of cases of status epilepticus they discovered. In their large retrospective series of 261 emergent EEG recordings, they discovered status epilepticus in 10.7% of the cases. In our cohort, 15 recordings (or 13.5%) showed continuous paroxysmal activity. In order to be representative, this percentage needs to be compared to the diagnostic yield of the emergent brain scan (12%) in similar conditions (Chen et al., 1996). At any rate, it seems difficult to imagine that the diagnostic yield of a given procedure can simply be defined by the number of positive diagnoses it discovers. We used a different approach. We elected to study the clinical benefits of emergent EEGs in daily practice by asking the attending physicians who ordered the procedures how it influenced their case management. This method allowed us to study the benefits of the EEG in what can be termed "ecological conditions". Nevertheless, the answers to closed questions for the sake of clarity do not always reflect the reality of daily practice. In addition, in certain indications (NCSE, cerebral death) in which the results are extremely clear, prescribing clinicians may consider EEGs beneficial as soon as they suggest a diagnostic possibility. In spite of that, this demonstrates that the EEG in these indications remains indispensable.

Consequently, just like in all daily medical practice, the emergent EEG should be considered part of an overall clinical approach based on sound medical reasoning. It should rarely be used to rule out a single diagnosis and should be based on the overall findings of the patient's medical history and clinical presentation. Follow-up of convulsive status epilepticus represents a well-defined situation in which the EEG plays a vital role although the same is not true in confused patients or those who manifest impaired vigilance or consciousness. In this clinical context, NCSE is not the most likely diagnosis and the diagnostic approach should be based on the specific clinical signs which have been previously described in the literature (Thomas, 2000; Khan et al., 2001; Husain et al., 2003). Nevertheless, the EEG remains the only diagnostic test for NSCE in patients presenting with an unexplained alteration in consciousness.

In a patient who has lost consciousness, the diagnosis of a generalized seizure is mainly based on clinical arguments and the EEG, while it may help define the precise epileptic syndrome involved, can be differed (Dunn et al., 2005). In addition, a number of paroxysmal anomalies discovered immediately after syncope can mistakenly suggest a generalized seizure (Davis and Freemon, 1990).

5. Conclusion

Emergent situations require a prompt diagnostic approach leading to appropriate therapeutic management. After 50 years of development and use in daily practice, the EEG remains a dependable, inexpensive and useful diagnostic tool in a number of clearly-defined emergency situations. It is indispensable for the emergency management of convulsive status epilepticus following initial treatment and for ruling out subtle or non-convulsive status epilepticus. Since it is the only test available for the diagnosis of non-convulsive status epilepticus, it is always indicated in cases of unexplained confusion states or altered consciousness, conditions which require a logical clinical approach.

Acknowledgments

The authors thank the EEG technicians who performed the EEGs and all the physicians who participated in this study, particularly the neurologists who provided the emergency EEG interpretations. (Dr. I. Bonnaud, Dr. AM. Guennoc, Dr. K. Mondon, Dr. S. Rimbaux, Dr. D. Saudeau).

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