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Short communication

THE EEG IN THE DIAGNOSIS OF SUBDURAL EMPYEMA

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Summary The EEG findings in 9 patients with a subdural empyema are reported. In all cases the EEG, recorded before the diagnosis had been established, contained focal zeta waves, extensive unilateral depression of cortical activity and, in all but one, a diffuse slowing of the background activity. This combination has not been reported before in the literature and it is concluded that in its presence the existence of a subdural empyema should be seriously considered. Comparison with CT scan findings in 3 cases indicated that sometimes EEG may be more sensitive than CT scanning in the diagnosis of subdural empyema. The value of EEG and CT scan in the diagnosis of patients presenting with an acute or subacute bacterial meningo-encephalitis is briefly discussed.

Keywords: *subdural empyema – EEG – zeta waves – CT scan – meningo-encephalitis*

Although as early as 1943 EEG findings in a patient with a subdural empyema were described by Kubik and Adams, to the best of our knowledge no specific study of the EEG in subdural empyema has been performed. In clinical series the EEG findings were described as non-specific and non-valuable for the diagnosis of subdural empyema (Hitchcock and Andreadis 1964; Kaufman et al. 1975; Luken and Whelan 1980; Williams 1982). To determine more precisely the value of the EEG in the diagnosis of subdural empyema the EEG records of 9 patients have been reviewed and correlated with the clinical data and, when available, with results of CT scans.

Patients and Methods

The data for this study are derived from a retrospective survey of 103 patients in whom the diagnosis of subdural empyema had been established in the years 1935–1984, collected from the files of the neurosurgical departments of 5 hospitals in The Netherlands (Mauser 1986 thesis). In 43 of these patients EEGs had been recorded prior to operation. In 9 of them the EEGs were still available for further study. The diagnosis of subdural empyema was confirmed at operation (8 cases) or with CT scan (1 case). In 3 of the 9 patients CT scans, performed before the moment of diagnosis, were also available.

The 9 EEG records were interpreted by two of the authors (H.M. and A.H.) without knowledge of the original description. All EEGs had been recorded with montages using the 10-20 system. Special attention was given to technological data (e.g., filter settings and paper speed) and to the presence of characteristic wave forms. The CT scans were also evaluated retrospectively by two of the authors (H.M. and C.T.).

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Results

Clinical data

The clinical data of the 9 patients are summarized in Table I and are in close agreement with the clinical data of the larger series of 103 patients. The patients were diagnosed in the years 1965–1984. There was a preponderance of males (7 out of 9) and all patients but one were in their second or third decade. Paranasal sinusitis was the most common cause (7 patients). The symptoms and signs in all patients fitted the clinical picture of an acute or subacute meningo-encephalitis. Seven patients were somnolent at the time of EEG recording, 1 patient was alert and 1 patient was comatose. Seven patients were hemiparetic and 3 aphasic at the time of EEG examination. Seizures had occurred in 2 patients up to this moment. All patients were seriously ill, had a high temperature and showed nuchal rigidity.

The subdural pus, as determined at operation or with CT scan, was located over the frontal lobe in 4 patients and in 2 of them this accumulation also extended over the parietal or temporal lobe. In 3 patients the pus was located along the falx, in 1 patient over the whole hemisphere and in 1 patient over the parietal and temporal lobes. All patients except one were operated upon and all were treated with antibiotics. Seven patients ultimately made a good recovery, one patient survived severely disabled and one died.

EEG findings

The findings of the last EEG before the diagnosis are presented in Table I and summarized in Table II. All these

TABLE I

Clinical and EEG findings and location of the subdural pus.

Patient no.	Sex	Age (years)	Aetiology	Clinical findings *	EEG findings **				Location subdural pus
					Zeta waves	Depr cort activity	Sl backgr activity	Other findings	
1	M	23	sinusitis	somnolent hemiparesis l hemianopsia l	r frontal	r hemisphere	moderate r ≳ l	FIRDA	r hemisphere
2	M	57	otitis	somnolent hemiparesis r aphasia	l frontal	anterior part l hemisphere	mild		l frontal
3	F	23	sinusitis	somnolent hemiparesis r	l frontal	l frontal	no		l frontal
4	M	17	lung infection	somnolent aphasia	l frontal	l hemisphere	mild l ≳ r		l frontal l temporal l parietal
5	M	30	sinusitis	somnolent hemiparesis r	l frontal l temporal	l hemisphere	moderate	FIRDA	l frontal l temporal
6	F	25	sinusitis	comatose hemiparesis l focal seizures	r frontal	r hemisphere	severe	FIRDA focal epileptiform activity	r temporal r parietal
7	M	14	sinusitis	somnolent paresis r leg aphasia	l frontal	anterior part l hemisphere	moderate l ≳ r		along l side falx
8	M	21	sinusitis	somnolent seizures	l frontal l temporal	l hemisphere	mild l ≳ r		along l side falx
9	M	11	sinusitis	normal paresis l leg	r frontal	r hemisphere	severe r ≳ l	focal epileptiform activity	along r side falx

* Clinical findings at the moment of EEG examination.

** Last EEG before diagnosis.

Depr cort activity, depression of cortical activity; sl backgr activity, slowing of the background activity; M, male; F, female; r, right; l, left.

EEGs except one (patient no. 4) were performed within 7 days after the first neurological sign presented. A subdural empyema was diagnosed in all cases within 5 days after this recording.

Conspicuous focal delta waves with a duration of up to 2 sec were found in all 9 EEGs. The delta waves had an amplitude of up to 300 μV and occurred intermittently, isolated or in short trains. In all records many delta waves displayed the characteristics of zeta waves (Fig. 1a), as described by Van der Holst and Magnus (1972a, b). These zeta waves consist of 3 parts. The first part is negative, the second positive, going far beyond the baseline, and the last part shows a slow return to the base line. The duration is 1.5–3 sec and the amplitude up to 400 μV. Extensive unilateral depression of cortical activity was also present in all 9 records (Fig. 1b). This depression extended in all but one patient over a much larger area than that in which the focal delta activity was present. Slowing of the background activity (decrease of alpha frequency and increased amount of slow activity) was present in 8 cases. In 5 of these cases the slowing was more pronounced in the hemisphere in which the zeta waves and the depression of cortical activity were present. The slowing was mild in 3 cases,

TABLE II

EEG abnormalities in 9 patients with subdural empyema.

Focal zeta waves	9
Unilateral depression of cortical activity	9
Slowing of background activity	8
Frontal intermittent rhythmic delta activity (FIRDA)	3
Focal epileptiform activity	2

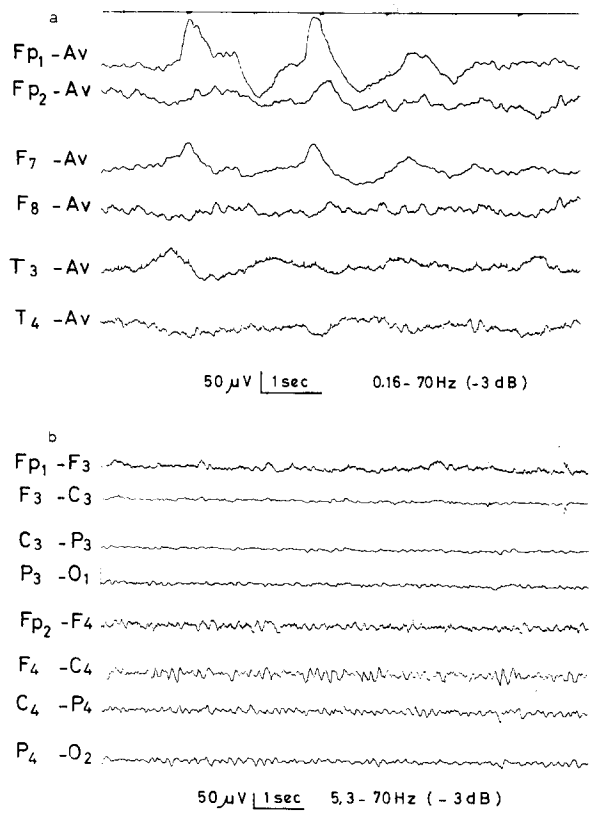

Fig. 1. a: zeta waves over the left frontal area (patient no. 4). TC: 1.0 sec (− 3 dB; 0.16 Hz); with this time constant the slow activity is clearly shown. Av, common average reference. b: depression of cortical activity over the left hemisphere (same patient as in a). TC: 0.03 sec (− 3 dB; 5.3 Hz); due to this filter setting activity below 5 Hz can no longer be seen.

moderate in 3 and severe in 2. Frontal intermittent rhythmic delta activity (FIRDA) was present in 3 patients. Focal epileptiform activity was seen in 2 records. In one patient sharp waves and spike-and-wave variants occurred intermittently and in the other a train of sharp waves was accompanied by a contralateral focal seizure.

In 2 patients (nos. 4 and 9) more than 1 EEG was recorded prior to the establishment of the diagnosis. The first EEG of patient no. 4, performed 2 days after he had presented with headache and fever, was normal. The neurological examination at this moment revealed no abnormalities except nuchal rigidity. Three weeks later a second EEG showed conspicuous focal zeta waves, extensive unilateral depression of cortical activity and slowing of the background activity. The patient was somnolent and aphasic at this time. The next day the diagnosis of subdural empyema was established at operation. The second patient will be described more extensively.

Case report (patient no. 9). An 11-year-old boy was admitted because of an acute impairment of consciousness, 14 days after he had contracted a paranasal sinusitis. At neurological examination he was found to be stuporose and to have a mild left-sided hemiparesis, nuchal rigidity and fever. The EEG at admission showed conspicuous focal zeta waves over the right frontal region, extensive depression of cortical activity over the right hemisphere, a severe slowing of the background activity and focal epileptiform activity. CT scan at admission was normal. Haematological investigation revealed a leucocytosis with a shift to the left and a raised sedimentation rate. The cerebrospinal fluid contained 53 cells/mm^3 (nearly all polymorphonuclear leucocytes) and 0.22 g protein/l. A tentative diagnosis of bacterial meningo-encephalitis was made and the patient was treated with antibiotics.

The next day he was alert and the mild hemiparesis had disappeared. Fever and nuchal rigidity persisted. This rapid amelioration of the clinical picture and the epileptiform activity in the EEG led to the hypothesis that the impairment of consciousness and the hemiparesis might have been the result of an unobserved seizure. On the third day a second EEG showed the same abnormalities as the previous one apart from a slight increase of the number of zeta waves. A second CT scan on the same day was normal again. On the fifth day the patient acutely developed a paresis of the left leg. Another EEG revealed the same abnormalities as the second, but CT scan now revealed abnormalities consistent with an accumulation of subdural pus along the right side of the falx. Two days later the diagnosis of subdural empyema was confirmed at operation. After surgery the antibiotics were continued for several weeks. The patient made a full recovery.

This patient presented clinically with an acute meningo-encephalitis. Although the CT scan findings were consistent with a leptomeningitis, the EEG, demonstrating severe focal abnormalities, rendered this very unlikely. The CSF findings were not informative because the patient had already been treated with antibiotics for several days. Yet, only a third CT scan on the fifth day after admission showed a subdural pus accumulation, after a focal deficit had developed and a second EEG on the third day had already suggested a progression of the focal cerebral lesion.

Correlation between EEG findings and clinical findings

The last EEG record before the diagnosis was established indicated a severe focal cerebral lesion in all cases. In 8 of these patients a focal neurological deficit was present. In one of them (patient no. 9) a previous EEG had already demonstrated a severe focal abnormality, although clinically no focal deficit was present at that moment. One patient had no focal deficit at all (patient no. 8), but presented with generalized seizures. The EEG in this patient did not show epileptiform activity. Focal epileptiform activity was present in two cases whereas in only 1 of these were seizures observed.

In all cases the focal EEG abnormalities were located over the cerebral area adjacent to the subdural pus accumulation. The spread of the depression of cortical activity, however, was often more extensive than the subdural pus accumulation, as determined at operation or by CT scan, could account for. Slowing of the background activity was present in 8 cases. In the only patient with normal background activity conscious-

ness was slightly impaired at the time of recording. The patients with mild (3 cases) or moderate slowing (3 cases) had a slight impairment of consciousness at the time of the recording. In 2 cases a severe slowing was present. One of these 2 patients was comatose during the examination; the other, however, had no impairment of consciousness at that time. This patient had been stuporose 5 days earlier, possibly resulting from unobserved seizure. Three records demonstrated FIRDA. This was found in combination with a moderate slowing of the background activity and a slight impairment of consciousness in 2 cases and with severe slowing and coma in the other case.

Correlation between EEG and CT scan findings

In 3 cases EEG findings could be correlated with results of CT scan investigations (patients no. 7, 8 and 9). In all these the first EEG, performed before the diagnosis had been established, indicated a severe focal cerebral lesion in contrast to the CT scan, performed on the same day as the EEG.

In 2 of these cases the first CT scan before the diagnosis showed an accumulation of material along the falx consistent with subdural pus. One of these patients (no. 7) was immediately operated upon and was treated with antibiotics. The other patient (no. 8), who has been reported in detail elsewhere (Mauser et al. 1985), was treated non-surgically. After the start of the antibiotic treatment he improved considerably in a few days. A second EEG, performed 7 days after the first, indicated a decrease of the focal abnormalities corresponding with the clinical improvement, whereas a second CT scan, performed that same day, indicated a small left fronto-temporal lesion, consistent with a cerebritis, and a slight increase of the subdural pus accumulation. These CT scan findings suggested a progression of the disease in contrast to the clinical picture and the EEG findings. Antibiotic treatment was continued and the patient made a full recovery. Follow-up CT scan, 4 weeks later, demonstrated that these abnormalities had disappeared.

In the third case (patient no. 9, see also the case report) the first CT scan did not show any abnormality, whereas the EEG on the same day was highly suggestive of a severe focal cerebral lesion. A third CT scan, 5 days later, indicated subdural pus along the falx, after the focal EEG abnormalities had increased and a focal neurological deficit had developed.

Discussion

In the current investigation the EEG showed in all cases conspicuous focal delta activity and extensive unilateral depression of cortical activity and also, in all cases but one, a slowing of background activity, ranging from mild to severe. FIRDA was present in 3 cases and focal epileptiform activity in 2 cases.

The focal delta waves occurred intermittently and never showed a tendency to periodicity, as reported by Le Beau and Dondey (1959). In each patient numerous delta waves displayed the characteristics of zeta waves, indicating the presence of an acute focal cerebral lesion (Van der Holst and Magnus 1972a,b). According to these authors the zeta waves were recorded before as well as after operation in patients with the following diagnoses: astrocytoma, meningioma, aneurysm, intracerebral haematoma, cerebral contusion and subdural haematoma. In their series no mention of patients with focal intracranial infections was made. Ischaemic lesions in the subcortical white matter have been reported to be present in acute subdural empyema (Geraghty 1936; Kubik and Adams 1943). However, it is unlikely that these ischaemic lesions are the cause of the zeta waves, because these waves have not been identified in the presence of ischaemic lesions (Van der Holst and Magnus 1972a,b). Probably toxic and infectious factors deriving from the pachymeningitis interna may play a role in their origin. In the current study the zeta waves were always found in the frontal or fronto-temporal region, in accordance with the location of the subdural empyema. In the study of Van der Holst and Magnus (1972a,b) they were also but not exclusively found in the fronto-temporal region. The question of whether these zeta waves show a preference for the anterior region remains open.

The extensive unilateral depression of cortical activity, present in all cases (comparable with the depression found in subdural haematoma), might be attributed to the presence of the pus in the subdural space. However, the simultaneous presence of depression of cortical activity and the absence of subdural pus according to the CT scan, as found in 1 case in this study, suggest that the depression is the result of involvement of the cortex itself. The observation that in many cases the depression of cortical activity was more extensive than the subdural pus accumulation is also in favour of the assumption that cortical involvement is the cause of the depression. Cortical ischaemic lesions, as reported in an autopsy series (Kubik and Adams 1943) and in a study concerning the CT scan findings in subdural empyema (Zimmerman et al. 1984) might be held responsible for the cortical involvement, giving rise to the depression of EEG activity.

The diffuse slowing of background activity, present in 8 cases and asymmetric in 5 of them, may be the result of toxic factors deriving from the pachymeningitis interna. Toxic factors, interfering with the cellular metabolism, are also thought to account for the diffuse cerebral dysfunction in purulent leptomeningitis (Weil 1980). Increased intracranial pressure, frequently encountered in subdural empyema (Mauser 1986 thesis), might cause slowing of the background activity. It did not correlate with the level of consciousness at the time of recording in all cases; one patient with severe slowing had no impairment of consciousness at this time.

This combination of EEG findings (numerous focal zeta waves, extensive unilateral depression of cortical activity and slowing of the background activity) has not been reported before in the literature. The results of this study indicate that in the presence of this combination the existence of a subdural empyema should be seriously considered. Further study in acute focal cerebral lesions should be done before questions concerning the specificity can be answered.

Comparison of the current data with those of other studies is difficult, because no specific study concerning EEG findings

in subdural empyema has been reported. In clinical studies it has been reported that the EEG showed diffuse slowing of background activity, focal delta waves, depression of cortical activity and focal epileptiform activity, without mentioning further details (Kubik and Adams 1943; Gurdjian and Webster 1948; Hitchcock and Andreadis 1964; Kaufman et al. 1975; Luken and Whelan 1980; Williams 1982) except for the study of Gaches and Lérique-Koechlin (1977), who described abnormalities that reflect according to them 'a large irritative cortical encephalitic focus.' The findings were considered to be non-specific and not valuable for diagnosis. The fact that zeta waves as such have not been reported before in subdural empyema may be due to the unfamiliarity with this specific type of delta wave, but also to the use of a time constant of less than 0.6 sec. It should be noted that especially the slowly rising parts of zeta waves cannot be recognized when using a short time constant (see Fig. 1a).

The results of this study also provide data concerning the significance of the EEG in the differential diagnosis of patients presenting with an acute or subacute bacterial meningo-encephalitis. The absence of focal EEG abnormalities in a patient with a meningo-encephalitis makes a cerebral abscess or subdural empyema very unlikely. In an uncomplicated leptomeningitis the EEG does not show focal abnormalities (Gaches and Lérique-Koechlin 1977). In cerebral abscesses focal EEG abnormalities (very slow polymorphic delta waves) are always present, except in the very early stage in some cases (Gaches and Lérique-Koechlin 1977; Michel et al. 1979). In subdural empyema focal EEG abnormalities were present in all cases studied in the current series. Furthermore the presence of focal zeta waves and an extensive unilateral depression of cortical activity makes a subdural empyema more likely than a cerebral abscess. Focal zeta waves have not been described with cerebral abscesses. Depression of cortical activity has been reported in some cases of cerebral abscess (Pine et al. 1952; Vignaeandra et al. 1975), but this depression was clearly related to the location of the abscess and not as extensive as in subdural empyema.

The comparison of EEG and CT scan findings in 3 patients revealed that the EEG may be a more sensitive diagnostic procedure than CT scan. In 1 of the 3 patients the CT scan on admission was normal, whereas the EEG at that time already suggested the presence of a subdural empyema. This is an important consideration because a normal CT scan in the first stage of a subdural empyema has been repeatedly described (Luken and Whelan 1980; Williams 1982; Kaufman et al. 1983; Zimmerman et al. 1984). Comparison of EEG and CT scan findings also revealed that in all 3 cases the CT scan did not show any focal cerebral abnormality, whereas the EEG contained severe focal abnormalities. In 1 of these 3 cases follow-up CT scanning showed a focal cerebral lesion consistent with cerebritis. This observation suggests that, although CT scan is considered to be the preferred diagnostic test (Britt and Enzmann 1983; Garvey 1983), the EEG may indicate a focal cerebral infection at an earlier stage.

These observations suggest that in patients presenting with an acute or subacute bacterial meningo-encephalitis both EEG and CT scan have diagnostic significance and that these methods, when combined, appear of additive value.

Résumé

Utilisation de l'EEG pour le diagnostic de l'empyème sous-dural

On décrit les résultats d'études électroencéphalographiques chez 9 malades atteints d'un empyème sous-dural. Dans tous les cas on constate dans l'EEG, enregistré avant qu'on ait pu porter un diagnostic, l'existence d'ondes zêta locales, d'une dépression d'activité corticale unilatérale et dans tous les cas sauf un, d'un ralentissement du rythme de fond d'extension diffuse. Cette combinaison de résultats électroencéphalographiques n'a pas été communiquée avant et on conclue qu'en présence d'une telle combinaison il faut considérer sérieusement l'existence d'un empyème sous-dural. En comparant les résultats d'études T.A.C. avec les résultats d'examen EEG chez 3 patients, on peut conclure que l'EEG dans certains cas paraît être une méthode de diagnostic plus sensible. La valeur diagnostique de l'EEG et du T.A.C. chez des malades, présentants des signes d'une méningo-encéphalite aiguë ou subaiguë, est discutée.

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