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Would Monitoring by Electroencephalogram Improve the Practice of Electroconvulsive Therapy?

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Estimates of seizure length made by the treating psychiatrist were compared with estimates made by six-channel EEG in 100 electroconvulsive treatments in 22 depressed patients. In 70 treatments the doctor observed a fit which was shorter than 25 seconds. No doctor restimulated a patient in such a case and on only three occasions was the electrical stimulus increased at the next treatment. EEG monitoring revealed that only 30 of the treatments resulted in a seizure of less than 25 seconds, and this was detected in almost all cases by the treating doctor. The potential value of EEG monitoring was to identify patients whose visible seizure was short but where cerebral seizure length was satisfactory. Trainee psychiatrists often mismanage patients who have short seizures.

"A shameful state of affairs." Such was the description of the practice of electroconvulsive therapy (ECT) in an editorial (*Lancet*, 1981) after the publication of "Electroconvulsive treatment in Great Britain" by Pippard & Ellam (1981). Many improvements have taken place in the regulation and administration of ECT in the United Kingdom since the publication of these disturbing findings (Pippard, 1986), but Pippard & West (1987) warned recently that British standards of ECT practice may be in decline. The rate of incomplete or missed seizures in contemporary ECT practice may be unacceptably high (Snaith & Simpson, 1987; Bhatnagar, 1987), which may be the result of the wider use of brief-pulse ECT machines (Fink, 1987).

Pippard & Ellam (1981) saw ECT treatment sessions where few patients had a seizure and this was not recognised by the medical staff. Several methods have been suggested to confirm that a cerebral seizure has occurred, including the cuff technique to block the distribution of muscle relaxant to a limb (Addersley & Hamilton, 1953), the portable electromyograph (Ives *et al*, 1976), measurement of ECT-induced tachycardia (Larson *et al*, 1984), or changes in the electrodermal response (Watkins-Pitchford & Reynolds, 1984), and the measurement of seizure activity itself by electroencephalogram (EEG) (Christensen & Koldbaek, 1982).

EEG monitoring is widely used in the USA where the MECTA ECT machine is manufactured. This machine has a built-in single-channel EEG which records from two electrodes applied to the forehead. Brumback (1983) found that MECTA recordings of brain activity from bifrontal electrodes did not correlate with standard EEG tracings and were particularly susceptible to muscle and eye movement artefacts. Ries (1985) found a low inter-rater concordance in the estimation of seizure duration from MECTA EEG tracings, although this has been disputed (Warmflash *et al*, 1987). A serious limitation of single-channel EEG recording is that it cannot detect focal seizures, nor can it estimate seizure generalisation which may be an important influence on the antidepressant efficacy of induced seizures (Daniel, 1983).

The main aim of this preliminary study was to develop a reliable method of multiple-channel EEG monitoring of ECT capable of estimating seizure generalisation, and to assess the value of such a system in the routine practice of ECT.

Method

Patients

Twenty-two depressed patients from those routinely referred to receive ECT for the treatment of depressive illness at the Royal Edinburgh Hospital took part in the study. The sample consisted of 18 women (mean age 48 years) and four men (mean age 60 years). Three Research Diagnostic Criteria (RDC; Spitzer *et al*, 1978) categories were represented in the sample; probable major depressive disorder (one patient), definite major depressive disorder (18), and definite major depressive disorder, psychotic subtype (3). All patients received concomitant psychotropic drug therapy, although no patients received a benzodiazepine drug. None had received ECT within the previous three months.

Procedure

This is a study of 100 consecutive EEG recordings of ECT treatments. In all patients, EEG recording was carried out at the first or second treatment and towards the end of the course. Additional recordings were carried out throughout

the course of ECT, depending on the ability of individual patients to tolerate the procedure. Eight patients were sufficiently co-operative to allow recording of each treatment.

ECT treatment was given by a rota of 20 psychiatric senior house officers (including general practice trainees) and registrars. In attendance were two designated treatment nurses, and the anaesthetic service was provided by a rota of senior house officers and registrars in anaesthetics. All patients had a hospital ECT chart which detailed the indications for ECT and provided information about physical and mental health. Each treatment session was prescribed by the referring psychiatrist and there was a space for the treating psychiatrist and anaesthetist to record the treatment procedure and make any additional comments. The treating psychiatrist was expected to time the length of the seizure by a stop-watch.

The EEG recordings were made by an independent researcher who was not responsible for treating patients. Unknown to the treating psychiatrist, the ECT charts were reviewed and the doctor's estimate of seizure length, treatment details and any comments were recorded by the researcher. The EEG machine was at the opposite end of the ECT treatment room and the tracing could not be seen by the treating doctor. The treating doctor was not permitted to study the EEG record.

ECT

ECT was given between 09.15 and 10.15 hours after an overnight fast. Anaesthesia was induced by thiopentone sodium (76 treatments) or methohexitone sodium (24 treatments), and followed by suxamethonium (100 treatments) to produce muscle relaxation. No regular anaesthetic premedication was prescribed. ECT treatment was given either by an Ectron CCX Series 3 machine (brief pulse, constant current) or by an Ectron Mark 3 machine (unidirectional, modified sine wave, constant voltage) on the instruction of the referring psychiatrist. Bilateral ECT was given with the electrodes in the bitemporal position. Unilateral ECT was given with the electrodes in the d'Elia position (temporoparietal). A course of ECT consisted of 3 to 14 (mean = 6.9) treatments as directed by the referring psychiatrist.

EEG monitoring

Seizure activity was measured on six channels (pF1-Cz, pF2-Cz, F3-Cz, F4-Cz, C3-Cz, C4-Cz) of a portable EEG machine made by Specialised Laboratory Equipment (model 100P). The University Department of Medical Physics and Engineering developed an electronic relay triggered by the ECT stimulus which isolated the EEG machine for the duration of the stimulus. Satisfactory recordings were obtained about two seconds after the end of the treatment stimulus.

Measures of seizure duration

In all cases the treating psychiatrist measured seizure duration with a stop-watch, by clinical observation alone. A sphygmomanometer suitable for use in the cuff technique was available but was never used. All doctors included the length of the treatment stimulus in their estimate.

Three measures of seizure duration were made, using the 6-channel EEG record. Total seizure length was the time from the end of electrical stimulation to the end of any paroxysmal seizure activity. Spike wave activity was timed to the end of bilateral spike waves and also to the last spike wave in any channel. The seizure lengths were estimated by an independent EEG rater who was blind to treatment details and read all 100 records. The first 20 records were also shown to three other independent raters who had a special interest in neurology or electrophysiology.

Statistics

The inter-rater agreement in EEG seizure length was estimated by a Pearson correlation matrix. The effects of clinical variables, ECT machine and treatment laterality were assessed by independent sample t-tests or χ^2-tests. All P values quoted are two-tailed.

Results

Table I shows the clinical characteristics of the patients cross-classified with the type of ECT machine used and treatment laterality.

Table II shows the correlation between the main EEG rater and the three other EEG raters in their estimations of seizure length for the first 20 treatments. There is a close agreement among the raters. Recommendations about the

TABLE I
Patient characteristics and ECT machine and treatment laterality

	Ectron CCX		*Ectron Mark 3*	
	Unilateral treatment (n = 8)	*Bilateral treatment (n = 8)*	*Unilateral treatment (n = 1)*	*Bilateral treatment (n = 5)*
Sex	6F 2M	7F 1M	1M	5F
Mean age	50	47	63	52
RDC category[1]				
PMDD-P	1	0	0	0
DMDD	5	7	1	5
DMDD-P	2	1	0	0

1. PMDD-P = probable major depressive disorder, psychotic subtype; DMDD = definite major depressive disorder; DMDD-P = definite major depressive disorder, psychotic subtype.

TABLE II
Pearson correlations between main rater and three other independent raters in estimations of seizure length (20 treatments)

Measure	*Rater 2*	*Rater 3*	*Rater 4*
Bilateral spike waves	0.88	0.99	0.94
Last spike wave	0.89	0.99	0.95
Total seizure length	0.94	0.95	0.98

$P < 0.001$ for all correlations.

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minimum requirements of a therapeutic seizure are concerned with total seizure length. Although we can assess the amount of spike wave activity reliably, in this preliminary report the following results are concerned only with total seizure length.

Table III shows the distribution of total seizure lengths as estimated by the treating psychiatrist and as measured by the EEG. The table also shows on how many occasions the doctor's estimate was confirmed by EEG and on how many occasions the short fits on the EEG were detectable by the treating doctor.

The taskforce on ECT of the American Psychiatric Association (1978) and Fink (1987) have recommended a minimum of 25 seconds for the length of the induced seizure; however, d'Elia *et al* (1983) have recommended a mimimum of 30 seconds. Table III shows that 70 of the treatments (70%) were less than 25 seconds as measured by the treating doctor, although in only 30 of these treatments was the seizure less than 25 seconds as measured by EEG. Eighty-six of the treatments (86%) were less than 30 seconds as estimated by the doctor, although only 45 of these treatments were under 30 seconds as measured by EEG. Table III also shows that in 34 of the treatments (34%) the seizure lasted less than 25 seconds as measured by the EEG, and that in almost all cases (32/34) this was detected by the treating doctor. Forty-eight of the treatments (48%) were less than 30 seconds as measured by EEG, and in all but one case this was detected by the treating doctor.

On no occasion did the treating doctor restimulate a patient. There were only two occasions when the treating doctor made a written comment that a seizure was too short and recommended a greater stimulus on the next occasion. These recommendations were carried out, and on one further occasion a treating doctor gave a patient an increased electrical stimulus because of a short fit at the previous treatment. These findings are surprising because there were two patients in the study who had a series of short fits and were not getting better. For example, a 32-year-old woman required a course of 14 right unilateral treatments and in 10 of these treatments the observed fit was less than 20 seconds. On only two occasions – and only after the sixth treatment – was any attempt made to increase the electrical stimulus. A 68-year-old woman required 11 bilateral treatments and she had a series of 10 fits lasting less than 20 seconds on clinical observation. It was only after the fifth treatment that the electrical stimulus was increased.

TABLE III

Cumulative distribution of total seizure lengths in 100 treatments as estimated by treating doctor and by EEG

Total seizure length (seconds)	*Doctor's estimate (number of treatments)*	*EEG estimate (number of treatments)*
10>	4 (0[1])	0
15>	19 (3)	5 (3[2])
20>	41 (10)	13 (11)
25>	70 (30)	34 (32)
30>	86 (45)	48 (47)
35>	88 (61)	64 (63)
35⩽	12 (11)	36 (11)

1. Although the treating doctor estimated that four fits were shorter than 10 seconds, none of these four fits was shorter than 10 seconds on EEG.

2. Although five seizures were shorter than 15 seconds on EEG, this was apparent to the treating doctor in only three of these treatments.

There was a highly significant correlation between the estimate of seizure duration made by the treating doctor and that based on the EEG ($r=0.56$, d.f. 98, $P<0.001$). There was no correlation between the doctor's estimate of seizure length and age. There was a non-significant tendency for short seizures on EEG to be associated with older patients. There were four patients in whom the average EEG-measured seizure length was less than 25 seconds and 18 patients in whom average EEG-measured seizure length was greater than 25 seconds. The mean age of the patients who experienced short seizures was 59.7 compared with a mean age of 47.7 years in those patients whose average seizure length was greater than 25 seconds; this difference was not statistically significant. There was a non-significant negative correlation ($r=-0.34$, d.f. 20, NSS) betweeen age and average EEG-measured seizure length. In this small sample there was no association between an average fit length less than 25 seconds and sex, laterality of treatment or type of ECT machine. As noted above there were two patients who had a series of short fits and they required 11 and 14 treatments.

Discussion

We have developed a reliable method of multi-channel EEG monitoring of ECT which revealed that in 40 of the 70 treatments where the treating doctor estimated that the induced seizure had lasted less than 25 seconds, it had in fact lasted longer. These 40 patients would have been at risk of unnecessary restimulation or increased electrical stimulation at the next treatment, but this was only a theoretical risk because these remedial steps were rarely carried out. In those treatments in which the EEG revealed that the induced seizure lasted less than 25 seconds, this was apparent to the treating doctor on almost all occasions (32/34). Thus EEG monitoring contributed little to the identification of treatments where the induced seizure was too short. The potential value of EEG monitoring was to identify those patients in whom the observed seizure was short and cerebral seizure activity was satisfactory.

A limitation of this study is that time alone was used to define the minimum requirements for a therapeutic seizure. Although there is a general belief "that convulsive activity in the brain is the crucial ingredient" of ECT (Kendell, 1981), there

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is no general agreement about the minimum length of a satisfactory cerebral seizure. However, the recommendations of what constitutes a satisfactory tonic clonic seizure may vary with the methods used to monitor seizure activity, namely 30 seconds of generalised muscle activity (d'Elia *et al*, 1983), 25 seconds of muscle activity in the tourniquet method (Fink, 1979) or 30 seconds of epileptic activity on EEG (Fink, 1979). The American Psychiatric Association (1978) recommended that a seizure lasting less than 25 seconds may not be adequate; observation alone, the tourniquet method and EEG monitoring were all practical methods of ensuring that seizures were adequate.

There is only circumstantial support for these definitions. Although Ottosson (1962) believed that the grand mal seizure was an essential component of successful ECT, he found that the duration of the grand mal seizure had no significant relationship to therapeutic efficiency. Maletzky (1978) and Kramer (1983) found that there was a relation between cumulative seizure duration and clinical improvement, but neither of these studies controlled for treatment number. Later studies have supported Ottosson's belief that there is no relation between individual seizure length (as measured by observation or EEG) and clinical change during a course of ECT (Weiner *et al*, 1983; Rich & Black, 1985; Zorumski *et al*, 1986). The practical importance of these findings is that seizures lasting less than 25 seconds may be effective if they are grand mal in type and sufficiently generalised. On the other hand, the two patients who experienced the greatest number of short fits also required the greatest number of treatments. The minimum requirements for a therapeutic seizure were not investigated and merit further investigation.

It was these difficulties that prompted us to develop a method of measuring seizure length by multi-channel EEG recording. This permitted reliable measurement of the length of spike wave activity, which is the "signature of a seizure" (Martin, 1985). It is the spatial distribution of spike wave activity that distinguishes focal seizures from those that become generalised. We now plan to study the relation between clinical improvement and spike wave activity and also the influence of treatment laterality and ECT stimulus on the generation of spike wave activity. Until these studies are complete, it would be premature to recommend the adoption of this measure in clinical practice.

The minimum requirements for a therapeutic seizure are not fully defined. Until this is achieved, we may conclude from our findings that multi-channel EEG monitoring is not necessary for all patients. We suggest that such EEG monitoring may be of value in the assessment of patients who are observed to have short fits. We also conclude, however, that a major problem in contemporary ECT practice is how short fits are managed by the trainee psychiatrists who administer ECT. All the treating doctors had received instruction in the practice of ECT by the consultant psychiatrist responsible for ECT. This included advice that observed seizures should last 25 seconds or more. Despite this, most of the doctors took no remedial steps when treatment resulted in short seizures. In the course of our study, we noted that with a large rota of junior doctors, an individual doctor will treat patients only about once a month. The ECT duty usually competes with ward work and is seen by some as a nuisance. Several doctors appeared to lack confidence in their abilities at first and there was little opportunity for them to gain much experience or expertise. The designated ECT suite nurses were experienced, but took a secondary role to that of the treating doctor.

Fink (1987) has urged the American Psychiatric Association to examine training practices in ECT and has suggested that competence in the administration of ECT should be a necessary preliminary for certification in psychiatry. Our findings suggest that we in the United Kingdom should also be concerned about the training and competence of psychiatrists who administer ECT.

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