Brit. J. Psychiat. (1968), 114, 989–996

A Comparison of Techniques in Electro-Convulsive Therapy

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Introduction

Electroconvulsive therapy, modified by intravenous anaesthesia and muscle relaxants, has long been accepted as a satisfactory form of treatment. Relatively simple and safe, and effective in selected cases, the technique has undergone little change in recent years and seems almost in danger of becoming fixed indefinitely in its present form.

However, the technique is not altogether free from defects. Side-effects in the form of post-treatment headache are not uncommon, though generally brief; more important is the amnesia which affects most patients to a degree, and some severely. Indeed, the use of electro-convulsive therapy (E.C.T.) is usually postponed or avoided in patients where memory impairment would be a serious handicap. Such amnesia as occurs in the course of therapy is usually regarded as a side-effect, and there is no firm indication that it is an essential component of the treatment. A recent investigation (12) disclosed a 90 per cent. incidence of side-effects; it is evident, therefore, that there is room for improvement in the orthodox technique, which should not be complacently accepted as perfect. The memory loss in E.C.T. consists of islets of amnesia, and fortunately there does not appear to be any extending disability in the sense that future retentive powers are impaired. A patient with marked E.C.T. amnesia is likely to have substantial memory loss for the sequence of events immediately prior to treatment, and also a very partial and scattered amnesia, particularly for names, people and events, extending backwards in time for perhaps many months. The fragmentary nature of this amnesia is striking, some areas of experiential memory being quite unimpaired, others totally lost, though often capable of recall on stimulation. It does not exactly resemble other types of amnesia, but perhaps bears some kinship to "post-concussional" amnesia.

The production of E.C.T. amnesia is related to the number and frequency of applications, which tend to have a cumulative effect. Continued daily treatments may be well tolerated for the first few applications, but in most individuals when a critical number (variable from person to person) is exceeded there is liable to be an explosive cumulative effect, with the rapid production of confusion and amnesia. On the other hand, if treatments are spaced widely, at the rate of, say, once per week, the incidence of amnesic side-effects becomes very much lower, but the cumulative therapeutic effect may fail to build up. For these reasons, the most widely-used rate of application of treatments is twice per week.

The amnesic side-effects of E.C.T. were described by "a practising psychiatrist" (1) who underwent a course of five applications. He noted that recent events were most severely affected, that he experienced a good deal of topographical disorganization, but that the memory gaps closed completely within two months. A patient (11) who received at another hospital a course of seven E.C.T. applications within twelve days also described a considerable memory loss for at least a month before treatment and also for several days after the course was completed. Her memory deficit was most marked for people, but also affected her memories of her daily life, routine and environment. She lost all recollection of psychotherapeutic interviews during the previous three months; much of the work she had been studying had also been forgotten, and she could not remember having used or owned the textbooks she employed in her studies. Some of these memories slowly returned, not so much spontaneously as under the stimulation of discovering reminders of the past.

Amnesic side-effects are also related to the wave-form of the current used to induce the convulsion, and to the manner of the placement of the electrodes. Many E.C.T. machines

https://doi.org/10.1192/bjp.114.513.989 Published online by Cambridge University Press

employ a diphasic sinusoidal waveform with peak voltage of the order of 200-300 volts (i.e. a slightly modified form of mains current) applied across the temporo-frontal areas for a period of up to several seconds, perhaps not precisely timed. Most of this considerable amount of electrical power is dissipated in the tissues; certainly only a minute fraction of the power output is necessary to induce a convulsion. In the early days of E.C.T. it was usual to employ heavy currents; Hemphill and Walter (6) mention ratings of up to one ampere. Later, experimental variations with different types of current led to modifications of technique. Brief-stimulus therapy was pioneered in America by Liberson (10), but the technique was considered by Kalinowsky and Hoch (8) to be less reliable and apt to cause apprehension, although this impression related to treatment unmodified by intravenous anaesthesia and muscle relaxant. Kalinowsky and Hoch were not, in fact, convinced that any current or any machine gave superior results compared to others.

The advisability of subjecting the brain to large quantities of electrical power is therefore open to question. Similarly it may be asked whether it is necessary or desirable to irradiate a large part of the brain with electric current, as occurs with the orthodox bilateral technique. The unilateral technique, perhaps first mentioned in 1942, was in 1957 re-investigated by Frost (4) and by Lancaster, Steinert and Frost (9), who found that there was less memory disturbance with this method. Zamora and Kaelbling (15) confirmed this finding and also showed that stimulation of the non-dominant hemisphere was essential for full success with the unilateral technique; Cannicott (2, 3) found the method of non-dominant unilateral stimulation to be the preferred technique.

Variables in the Experiment

Of these variable factors in E.C.T. the purpose of the present study is to compare two types of stimulator waveform, one with a high output and the other with a low output; and also to compare two techniques of application of electrodes, the bilateral technique and the unilateral technique.

The two types of E.C.T. stimulators to be compared were, first, the Ectron A.C. Mains model apparatus, delivering a diphasic sinusoidal waveform with peak about 260 volts. The duration of the passage of the current through the brain is often not precisely timed, but in this investigation the duration was one second. The waveform appears to be similar to that of mains current, with only minor differences due to its passage through a transformer. The other stimulator is the Ectonus Mark 3 apparatus, delivering brief pulses of current, passed through the brain for five seconds. The applied waveform here is totally different from the A.C. Mains type; it consisted of bidirectional spikes of very short duration, only about 1/2,000 of a second, and although the voltage is higher the total amount of current employed is infinitesimal as compared with the A.C. Mains type of electro-shock. The output of the pulse current machine is illustrated in Fig. 1.

The two types of electrode placement technique to be compared were, first, the orthodox bi-temporofrontal placement (see Fig. 2), and, second, unilateral placement over the non-dominant hemisphere (see Fig. 3). These two types of stimulator output, together with the two types of electrode placement technique, constituted a four-cell "block" (see Fig. 4) to which depressed patients were randomly assigned for treatment after categorizing for sex and age.

Measurement of post-E.C.T. confusion and memory disturbance will indicate, therefore, the amount of side-effect associated with each combination of waveform and electrode placement. On the expectation that minimal stimulation power, applied with minimal topographical irradiation of the brain, is least damaging, the least side-effects would be predicted for the combination of pulse current with unilateral electrode placement.

Design of the Experiment

The criteria for selection for the trial were, first, a state of depression judged clinically to merit a course of E.C.T., and, second, no physical abnormalities liable to influence the outcome.

Each section of the "block" (Fig. 4) was subdivided into male and female divisions, and each of these was subdivided into three age

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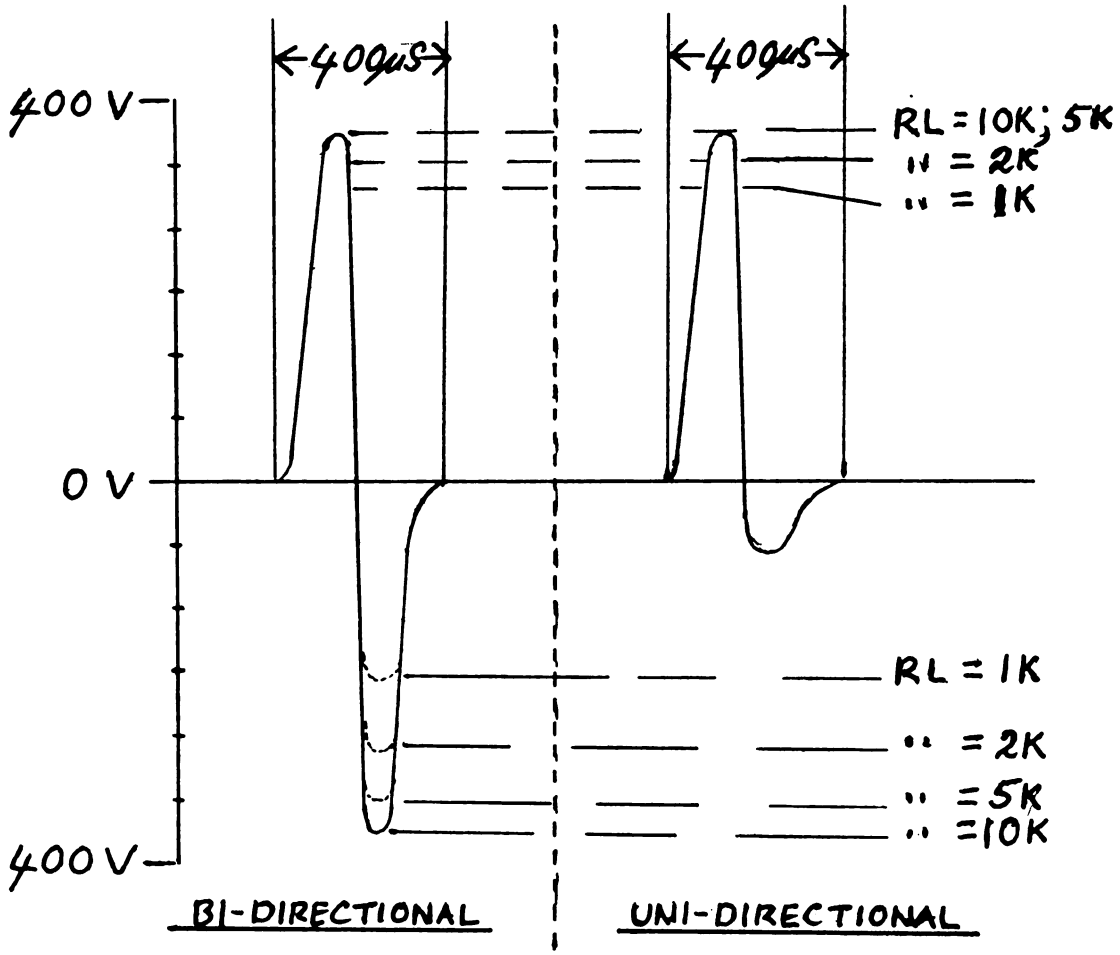


FIG. 1.—The Ectonus Mark 3 apparatus delivers bi-directional pulses of 750 volts peak-to-peak at a repetition rate of 21·5 cycles per second. The effective duration of each cycle is less than 400 microseconds; uni-directional pulses lasting less than 200 microseconds are also available.

Artificial resistive loads (RL) of 5,000 ohms upwards did not change amplitude or appearance significantly, but lower loads produced progressive asymmetry. Capacitative loads of up to 0·02 microfarads produced little change.

Measurements were made with an E.M.I. Solid State Oscilloscope, Type 101.

ranges—20 to 39 years; 40 to 59 years; and 60 to 79 years. This ensured matching the patients for sex and age; it was impracticable, and probably unnecessary, to match the groups further for intelligence, social class, etc.

After being assigned to the trial, patients were further examined as follows: (*i*) a pre-E.C.T. electroencephalogram was carried out, with analysis of both temporal channels, (*ii*) a pre-E.C.T. Depressive State Rating Scale was estimated by two clinicians, the Hamilton (5) scale items 1 to 17 being employed, and (*iii*) cerebral dominance was assessed by the Department of Clinical Psychology, using the Humphrey Questionnaire (7) for hand-preference—a finger-tapping test, three tests of foot dominance and tests of ocular dominance.

For estimation of post-E.C.T. confusion and memory disturbance, the technique used was as follows: (*i*) Ten minutes before treatment, the patient was asked to commit to memory a list of five "paired associates". Three of those were

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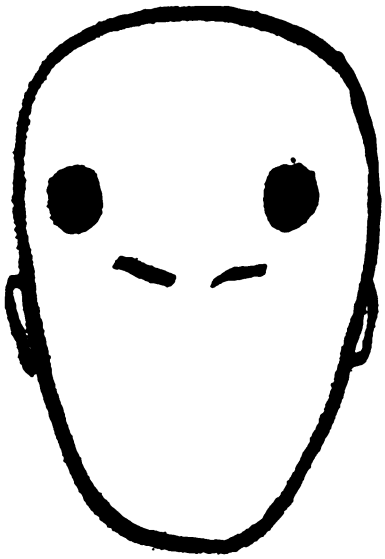


FIG. 2.—In the conventional bi-temporofrontal method of electrode placement, the current is passed across the anterior portions of the cerebral hemispheres.



FIG. 3.—In the unilateral method of electrode placement, the non-dominant hemisphere is selected and the current is passed between the electrodes positioned as illustrated. The lower electrode is placed 4 cm. above the eye-ear line (lateral angle of orbit to external auditory meatus). The upper electrode is 8 cm. distant at an angle of 70°.

"easy" e.g. "DOG–BARKS" and two were difficult, e.g. "CABBAGE–PEN" and required new learning; a different set of words was used each time the patient was tested. (*ii*) It was also ascertained that the patient, prior to treatment, was fully orientated. (*iii*) The passage of the electric current was taken as zero time and a stop-watch was set in motion. The time of the first spontaneous respiration was noted, also the time of recovery of consciousness, as estimated by eye-opening and spontaneous movements. (*iv*) As soon as the patient became conscious, the time was noted, and next the times were noted when he became re-orientated in person, place and time. (*v*) He was then given the stimulus-words of the paired associates, and asked "What goes with . . . ?" etc. Points were awarded on the basis of one point for the recall of an "easy" word and 2 points for the recall of a "difficult" one.

All these measurements were made on the occasion of the first, third and fifth treatments, and these constituted the basis of Table I. When the course of E.C.T. was completed, as judged on clinical grounds, the patient was referred for a post-E.C.T. electroencephalogram, and the Depressive State Rating Scale was also estimated again to obtain the post-E.C.T. score. An independent estimation was made by a clinician who did not know which form of treatment had been used. It was intended that any estimates showing considerable discrepancy should be discarded, but in the event agreement between different estimators was very close, and none of the subjects had to be discarded on these grounds.

Unilateral Electrodes and Pulse Current	Unilateral Electrodes and Sinusoidal Current	Bilateral Electrodes and Pulse Current	Bilateral Electrodes and Sinusoidal Current

FIG. 4.—The two types of current, and the two methods of electrode placement make up a four-cell "block" of variables. If other relevant factors are controlled, significant differences pertaining to these variables may appear if patients are randomly assigned to each cell.

Technique of Treatments

Treatments were given twice weekly initially,

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sometimes tapering off to once weekly towards the end of the course. No set number of treatments was administered, and the duration of the course depended on the patient's response.

Premedication with atropine was used, 0·6 mg. being given intramuscularly half an hour before treatment. The convulsion was modified by intravenous thiopentone 250 mg. followed by intravenous suxethonium bromide 60 mg. (of the cation).

The scalp underlying the electrodes was cleaned with 25 per cent. Teepol in spirit; the electrodes, covered with gauze pads, were soaked in "Ectronolyte" solution before use.

The unilateral treatments were administered with a pair of electrodes mounted on a perspex holder, contoured to fit the head. The electrodes were 3 cm. in diameter and 8 cm. apart, between centres. It is important that a low-resistance contact is made, and that the electrodes are kept firmly applied against the scalp for the duration of the stimulus-current. In all cases mentioned as receiving unilateral treatment, it should be understood that the electrodes were applied to the non-dominant side.

Results

The recovery times observed in the four treatment groups are set out in Table I, which shows the medians and geometric means for the variables under study, and is based on results in 72 treatments. It is noted that spontaneous respiration recommences more quickly in both of the techniques using unilateral electrodes, and it is also notable that those patients treated by unilateral pulse current start breathing in less than half the time taken by patients treated with the bilateral sinusoidal technique. This suggests that the unilateral pulse technique constitutes less of a "physiological insult" to the vital centres.

Recovery of consciousness is also much quicker in the patients treated by the unilateral pulse current method; they recover consciousness in less than one-quarter of the time needed by the sinusoidal-bilateral group. The unilateral sinusoidal current cases, and the bilateral pulse current cases, lie about midway between the others.

Once the patient recognized his own identity, his knowledge of place and orientation in time was also accessible in the unilateral groups; in the bilateral groups however, these facts were recovered more slowly, and this was particularly the case in the bilateral-sinusoidal group. Perhaps the most effective comparison is to consider how long it took patients in the different groups to recall what day it was. The unilateral

Table I

Recovery Times for First Spontaneous Respiration, Time of Regaining Consciousness, and Time of Regaining Orientation, after E.C.T.

	Spontaneous Respiration	Recovery of Consciousness	Orientation				
			Person	Place	Year	Time Month	Day
Unilateral Pulse Current.. ..	45″	1′ 45″	2′ 2″	2′ 15″	2′ 17″	2′ 25″	2′ 30″
	41″	1′ 37″	2′ 2″	2′ 15″	2′ 42″	2′ 49″	3′ 4″
Unilateral Sinusoidal Current ..	45″	4′ 0″	6′ 25″	6′ 33″	7′ 10″	8′ 3″	7′ 31″
	50″	3′ 39″	5′ 33″	6′ 13″	6′ 44″	7′ 23″	7′ 35″
Bilateral Pulse Current	1′ 15″	2′ 30″	4′ 0″	4′ 50″	5′ 10″	4′ 50″	8′ 0″
	1′ 12″	2′ 46″	4′ 54″	5′ 39″	6′ 19″	7′ 42″	8′ 31″
Bilateral Sinusoidal Current ..	1′ 38″	8′ 0″	9′ 31″	14′ 30″	20′ 8″	27′ 20″	30′ 0″
	1′ 27″	7′ 33″	11′ 3″	13′ 55″	29′ 31″	37′ 33″	37′ 56″

In each instance the upper figure is the median and the lower figure is the geometric mean. The table is based on results in the first 24 patients treated; as treatments 1, 3 and 5 were measured in each patient, the total number of treatments measured was 72.

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pulse current patients knew the day of the week within a median time of *2½ minutes after the shock*, whereas the bilateral sinusoidal group did not recover this knowledge until after the lapse of *30 minutes from the time of treatment*. Again, the two other techniques fell into an intermediate grouping of 7 to 8 minutes, not significantly differing from each other.

The concussive effect of the bilateral sinusoidal technique was also shown by the "paired associates" test, by evaluating how many word associates, learned just before treatment, could be recollected after the shock; a perfect score was represented by 7 points before treatment and 7 points after treatment, with net loss of zero points. The mean decrement (i.e. loss of points for failure to retain recently learned paired associates) per patient per treatment in the four groups was as follows:

Unilateral Pulse Current	0·22
Unilateral Sinusoidal Current	0·36
Bilateral Pulse Current	0·28
Bilateral Sinusoidal Current	1·87

Again we find least disturbance with the unilateral pulse technique, by far the most disturbance with the bilateral sinusoidal technique, and the others intermediate.

Comparison of the before-and-after Depressive Rating scores, on the other hand, showed no significant differences among variances or means. The mean reduction in score (which corresponds to the degree of clinical improvement) did not vary much from group to group; the figures for the four treatment groups were 12·25, 11·20, 13·60 and 11·67. In so far as initial improvement under E.C.T. is concerned, therefore, no substantial differences were observed.

The number of treatments given did not differ significantly between the unilateral and bilateral groups. The mean number of treatments given in the unilateral cases was 7·2, and the corresponding figure for the bilateral group was 8·8.

Statistically, the recovery times fall into three classes which do not overlap with each other:

(1) unilateral pulse current;
(2) (*a*) unilateral sinusoidal current;
    (*b*) bilateral pulse current;
(3) bilateral sinusoidal current.

As these results appear to fall into distinct "populations" without overlapping, tests of statistical significance are scarcely applicable. Class (1) is distinct from class (2), and class (2) is as far from class (3). The two techniques of class (2) however are not significantly different in terms of recovery times.

Discussion

The prediction of post-E.C.T. confusion being related to the strength and type of the stimulus and to the area and type of brain tissue involved appears to be borne out in the event. The pulse current applied unilaterally produces by far the least side-effects, and the sinusoidal current applied bilaterally produces by far the greatest. Between these two techniques lies a middle group consisting of the two intermediate methods—the powerful sinusoidal current applied unilaterally, and the mild pulse current applied bilaterally. There is no consistent or considerable difference between these two. In order to obtain the reduction of side-effects, it is important to stimulate the non-dominant side when using the unilateral technique. Stimulation of the dominant hemisphere is likely to give results more nearly approximating to those of the bilateral method, at least in the case of sinusoidal current.

Satisfactory convulsions were obtained with the pulse current, except in one case, a man of 69 who failed to develop a fit with the unilateral pulse technique. He also failed with the bilateral pulse technique, but later had a satisfactory course of treatment with the bilateral sinusoidal method. The fits produced by unilateral stimulation are usually symmetrically bilateral. In some patients, and then on some occasions only, flushing of the face was observed only on the side stimulated. This involved the forehead, pinna, conjunctiva and the lower face; the mid-line demarcation was sometimes strikingly accurate.

Patients who had previously had a course of bilateral sinusoidal E.C.T. were pleasantly surprised by the lighter side-effects of unilateral treatment, and particularly so in the case of the pulse-current technique. The nursing staff also found the recovery phase easier to handle in the cases treated by the unilateral pulse technique.

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After the first 36 patients had been treated, the difference in the recovery times in the various groups were so clear that this part of the investigation was terminated. The long-term stability of therapeutic results is still being studied, also the selection of the most suitable types of case for these forms of treatment.

Addendum on EEG Findings

We are indebted to Dr. P. K. G. Warren for the data leading to the following observations on the EEG changes. EEG studies were completed in 23 patients in the series, with re-examination about 10 days after the course of E.C.T. was concluded.

Adverse changes were noted in the form of increased temporal theta activity in 12 cases, symmetrical in 8 and asymmetrical in 4. The four asymmetrical records were all from patients having had unilateral E.C.T., but in two the slow activity was more prominent on the side the current was applied, and in the other two it was on the opposite side. There was no delta activity, nor was there any paroxysmal activity; the only changes in the alpha band consisted of three cases showing an alteration of plus or minus one cycle per second.

In three cases the EEG showed an improvement after the course of E.C.T. All these cases had been treated by pulse current (1 unilateral, 2 bilateral), but they had also received small doses of sedative or tranquillizing medications.

From a review of the literature, the proportion of cases in this study showing adverse changes after E.C.T. is similar to those reported elsewhere, i.e. between 50 per cent. and 60 per cent. However, the degree of abnormality in the present study appears to be much less than previously reported; for example, neither delta nor paroxysmal activity was noted to occur. A possible reason for this diminished incidence of the more severe forms of abnormality is that earlier studies referred to unmodified E.C.T., whereas in the present investigation the electroplexy was modified by intravenous barbiturate anaesthesia and relaxant. If this hypothesis is correct, it suggests that the barbiturate anaesthesia of modified E.C.T. may exert a "protective" effect on the brain, preventing the development of the more serious forms of transitory EEG abnormality.

Summary

In a controlled study of electro-convulsive therapy, a comparison was made between two types of stimulating current—a pulse current of very low power and a sinusoidal current approximating to the domestic type. Also compared were two types of electrode placement—unilateral on the non-dominant side, and bilateral.

Therapeutically, no considerable differences were noted between the groups, but post-shock confusion, malaise and memory disturbance were significantly reduced by use of the unilateral technique and by the use of pulse current. These two in combination produced almost complete freedom from side-effects. Study is continuing on the stability of therapeutic results, and on selection of the most suitable cases for these forms of treatment.

Acknowledgments

Our thanks are due to Mr. G. M. Clark (formerly of the Long Ashton Research Station, University of Bristol) for assistance in the design of the experiment and assessment of the results; and to Mr. W. Webber (Electronic Technician, Barrow Hospital) for the graph of the pulse current output in Fig. 1.

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(*Received 30 June, 1967*)

https://doi.org/10.1192/bjp.114.513.989 Published online by Cambridge University Press