ELECTROCONVULSIVE THERAPY SEIZURE GENERATION. CASE IN CHILDREN

Juanjo Solano
School of Electrical and Electronic Engineering
University of Manchester, UK
28th April 2009

Abstract—Mainly being a treatment for adults with affective disorders, Electroconvulsive Therapy (ECT) has a long history. However, ECT has not been widely used with children and adolescents, and no empirical studies or controlled evaluations have been conducted. In this study, we are trying to find if ECT could be performed in the same way on children than it is on adults. ECT parameters vary between the reports and several studies analyzed, and some findings are got in this document, regarding the assumption of the best setting choice for our future work.

Index Terms—ECT, children, bilateral, unilateral, constant current, brief pulse, sine wave

I. INTRODUCTION

Since 1950s electroconvulsive therapy in children was applied, but was unusual and not many records have being obtained. This is the reason why some findings are needed in regard to the suitability of this treatment upon non-completely developed brains, considering risks and side effects.

In comparison with the treatment in adults, it is quite similar and some interesting safety consideration should be accounted for.

Among several studies in regard to ECT treatment, it is necessary to review in depth which stimulus parameters and characteristics are the most suitable and safe to be used, and the aim of this report is to reason an appropriated choice.

II. ECT WITH CHILDREN

A. History

In the 1950s, in spite of the literature on ECT with minors was sparse, some children and young adults were included in treatment populations.

In 1970s, some practitioners emphasized the inadvisability of ECT with children or adolescents, or to persons with neurotic/addictive behaviour problems. “Administration of ECT to children who have not yet reached puberty has no established usefulness and that therefore such treatment on a routine basis cannot be justified” (Frankel, 1973) [1].

ECT with children and adolescents generally was viewed during the 1970s as an unusual but not exceptional treatment. It was available as a treatment option to “control an acute psychotic or depressive illness” and was considered “if all drug treatments have failed after proper and prolonged use to control the illness” (Frommer, 1972) [2].

In the 1980s it was still noted the comparative rarity of the use of ECT with children. Although ECT has been used with adolescents, it has seldom been used to treat disorders occurring before puberty.

B. Introduction

There is a long history in children and adolescent psychiatry of using treatments shown to be effective and safe in adults, but without adequate empirical research in young people (Laughren, 1996) [2]. It is clear now that, in the absence of such information, adult data about efficacy or safety should not be generalised to younger age groups.

At the same time, it should be noted that the young have received ECT for more than half a century (Heuyer, Bour and Feld, 1942) [2], and that clinical experience suggest even “life-saving” (National Health and Medical Research Council, 1977) for a variety of severe conditions in this population.

About 1% of patients aged 13 to 18 years is ECT administered when admitting to hospital with a mental illness [2].

Research on the use of ECT with children and adolescents consist mainly of single-case reports and uncontrolled studies (Baldwin and Oxlad, 1996). Although some other texts have identified ECT as an option in the treatment of childhood schizophrenia (e.g., Freedman et.al., 1972, Redlich and Freedman, 1966). Others have been less positive (Kanner, 1966) [1]. The literature with children and adolescents offers no controlled studies, no reliably applied criteria, and no valid assessment scales (Black, Wicox, and Stuart, 1985).

C. Electroconvulsive Therapy in children. Indications and effectiveness

In children, bilateral ECT was used traditionally, but unilateral ECT is today apply by many clinicians with the objective of reducing memory problems and post-ECT confusion, among other side effects.

Although the mechanism of action is still obscure, there is convincing evidence that convulsive therapy is effective in the treatment of a variety of disorders and is safe, even in elderly, frail, or physically ill patients (American Psychiatric Association, 1990: Devanand, Dwork, Hutchinson, Bolwing and Sackeim, 1994) [2].

ECT in young appears to be similar to adults in indications, effectiveness and side effects (American Psychiatric Association, 1990; Freeman, 1995), but this must be qualified because
The primary indication for ECT in adolescents is the treatment of severe mood symptoms, depressive or manic. Mood symptoms in the course of major depression, psychotic depression, bipolar disorder, organic mood disorders schizophrenia and schizoaffective disorder respond well to ECT. In Fig. 1 are presented the rates of improvement in cases reported in the literature, that appears to be comparable with those in adult patients [2].

D. The effects of ECT on developing brain

The side effects are similar in type and frequency to those described for adults, which are mild and transient. The most common are headache, generalised muscle aches, nausea, subjective memory problems and confusion. No fatalities attributable to ECT have been reported in young persons.

Moreover, there is currently no evidence to suggest that ECT causes structural damage in a young person’s brain or adversely affects brain development. However, it is noted that there are differences in structure between adult and adolescence brain, and perhaps vulnerability.

Table 1
ECT in ADOLESCENTS

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Patients with remission or marked improvement of symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Depression</td>
<td>67</td>
</tr>
<tr>
<td>Major depression</td>
<td>52</td>
</tr>
<tr>
<td>Psychotic depression</td>
<td>35</td>
</tr>
<tr>
<td>Manic episodes</td>
<td>26</td>
</tr>
<tr>
<td>Bipolar disorder</td>
<td>70</td>
</tr>
<tr>
<td>Schizophrenia</td>
<td>41</td>
</tr>
<tr>
<td>Schizoaffective</td>
<td>6</td>
</tr>
<tr>
<td>Cataract</td>
<td>29</td>
</tr>
<tr>
<td>Neurotic malignant syndrome</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>224</td>
</tr>
</tbody>
</table>

![therapy/table1child.jpg](http://home/juanjo/Electroconvulsive therapy/ECTCH1.pdf)

Fig. 1. Electroconvulsive therapy in adolescents. Path: /home/juanjo/Electroconvulsive therapy/ECTCH1.pdf

![therapy/table2child.jpg](http://www.psych.med.umich.edu/ECT/how-does-ECT-work.asp)

E. Findings of ECT in children

The decision to recommend ECT involves a variety of elements of which diagnosis, illness severity and response to other treatments are three of them. In Fig. 2 some of these factors are listed.

In a recent survey of 26 patients who received ECT in adolescence and 28 parents, it was found that overall ECT was viewed favorably. A very small minority (8%) were very strongly negative. About half of patients and parents believed that ECT had been helpful [2].

Stimulus parameters in children are included in the following sections in which seizure generation characteristics are discussed in adults as well. There have been assertions (e.g. Hill, Courvoisie, Dawkins, Nofal and Thomas, 1997) that young people require more ECT treatments in a course than adults [2]. ECT should be continued until the patient no longer seems to be improving. In practical terms, this means that the patient’s mental state is reviewed after each treatment and that the patient’s last 2 to 3 ECT treatments have not been followed by further positive change. A patient must be said to be resistant to ECT if there is no response to 12 ECT treatments, 6 of which are bilateral.

III. SEIZURE GENERATION

A. Unilateral or Bilateral ECT?

Electrodes were traditionally placed on both temples (“bilateral ECT”). Today many clinicians apply the electrodes to the temporal and parietal regions of the non-dominant hemisphere (“unilateral ECT”) with the aim of reducing side effects, including memory problems and post-ECT confusion.

In recent years, it has been recognized that with unilateral ECT, effective treatment requires doses of electricity to be higher in relation to the seizure threshold than with bilateral ECT. Just-above or moderately suprathreshold (i.e. 50% - 100% above seizure threshold) dosing is effective for bilateral
ECT, but unilateral ECT requires electrical doses of at least 2 – 2.5 times threshold (“high-dose” ECT) [2].

With the appropriate electrical doses described earlier, unilateral ECT is probably as effective as bilateral ECT, and may be associated with fewer side effects, as just one hemisphere of the brain is being stimulated. Bilateral ECT may, however, have a faster onset of action and is possibly the electrode placement of choice in adolescents in whom a rapid response is required.

Electrode position should be changed from bilateral to unilateral if the adolescent becomes confused, or from unilateral to bilateral if after 6 to 8 treatments there is no improvement.

Bilateral ECT (see Fig. 3) was administered in several studies, like in [3] and [4]. In the first one, treatment was given using the standard method of applying the electrodes across the temples, but in the second one, asymmetrical bilateral stimuli was applied due to it was thought to have advantages over traditional bitemporal placement.

Many studies, including [5], reveal that unilateral non-dominant ECT is as effective in relieving depression as bilateral ECT, though progress may be less rapid. This observation holds true only for the reactive depressives. Endogenous depressives benefit more from bilateral ECT. Caution is advised against the administration of unilateral dominant ECT, since this group does not respond to treatment as well as the other two.

In [6] bilateral ECT with electrodes in the bitemporal position is applied as well, suggesting this electrodes position to be the correct one in order to perform the ECT treatment in a proper and efficient way.

B. Duration?

Each pulse is typically 0.5 to 1 ms duration. Electrical silence between pulses typically lasts for 6 to 16 ms, about 10 times longes than the pulse [7]. A typical ECT stimulus has 100 to 1,000 pulses and is one to three times as long as the minimum that would generate a seizure, so a single pulse is not strong enough to induce a seizure by itself. The ECT seizures generated by rapid kindling mechanism, consist of 2 to 5 waves per second lasting 20 to 60 seconds [7].

In other reports different stimulus duration are found. In [8], the Constant Voltage (CV) method had a duration of the administration of 1.7s (85 pulses). On the other hand, Constant Current (CC) lasted 4s (160 pulses) with 1.25ms pulse. A course treatment consists of 6 ECT administrations, but some had as few as 3 and one as many as 10.

In the CC with rectangular pulse method applied for finding the efficiency of the stimulus characteristics of ECT [9], pulses of 0.75 and 1.25 ms/sec widths were delivered, with a greater failure rate for the latter. Greater efficiency was observed for the 0.5 ms/sec stimulus pulse width than for the 1 ms/sec pulse width in the frequency ranges measured (30Hz and 60Hz). No study has compared sine wave and square wave stimuli of equal phase width; therefore, attributions of difference in efficiency and side effects to differences in shape are unproved.

This results complement those of several other reports. Similarly, seizure thresholds were lower width 0.5ms/sec pulse width than 1 – 2ms/sec pulse widths at the first sessions of the right unilateral and bilateral ECT. [9]. The stimulus dose was set by the half-age method: the charge was 2.27 times the patient’s age rounded up to the nearest multiple of 25.2mC. The half-age strategy is more successful with 0.5msec pulse width than with the 1msec pulse width. An overall seizure induction rate of 92% for the 0.5msec pulse width stimulus confirms that the half-age strategy for the first bilateral ECT remains successful for ECT.

In other study [6], in CV ECT stimulus took 3s sine-wave at 50Hz). Voltages varies with impedances, but electrical energy was 2 – 4 times CC stimulus. In CC method, stimulus was 5s at 800mA using pulses of 1.25ms wide at a frequency of 55Hz, equivalent to 275mC.

C. Constant Voltage or Constant Current?

As mentioned in the previous report (Juano Solano, ect,txt) [10], risks from electricity comes from temperatures increases that correspond to the rate of heat liberation. In this way, constant current (CC) is safer than constant voltage (CV).

In that report we argue that keeping impedance down is essential, whose value must be in an ordinary range of 100 to 320Ω [7], with a typical average of 22Ω. A higher dynamic impedance would indicate poor connection.

These findings about impedance values, are consistent with other one’s obtained from different studies. In [3] no wide variation in inter-electrode resistance was seen. Using CV in 10 patients, a minimum impedance of 200Ω was observed, and the maximum value was encountered at 320Ω. In CC method, similar results were got, with impedance ranging from 235Ω to 380Ω, but these differences between both stimulating ways (8%) were consider to be due to systematics errors in the measurements of the voltage and current.

As the DHSS (Department of Health and Social Security, 1982) recommends, CC instruments for delivering the electrical energy required are better than other one’s, due to it is a safer way, as was view in our previous report [10]. In some other reports, like in [3] this statement made by the DHSS was mentioned, suggesting us that the electrical energy delivered by the CC device would vary depending on the impedance encountered.

In the last study mentioned above, CV devices produced a biphasic truncated sine wave, with the following features: amplitude = 170V, frequency = 50Hz and duration = 1.7s (85 pulses).

On the other hand, the CC machine produced a square wave with: amplitude = 800mA, frequency = 40Hz and duration = 4s (160 pulses).

Regarding the previous values, and what results are obtained in each stimulation, a equation of the energy delivered to the brain, related with peak voltage and current, were assumed: For CV:

\[ E = 0.25 \cdot Vp \cdot Ip \cdot 1.7 \]

The results were : 51J with 25Ω and 700mA. For CC:
The results in this latter case were: 37J with 274Ω.

Main source of electrical resistance is the contact resistance between the electrodes and the skin of the scalp. Wide variation in resistance can be accounted for by variations in the application technique.

The mean energy delivered by the CV device is 30% higher than the mean energy delivered by the CC device, but the range of energies delivered is comparable in the two cases. These results show that with consistent application of the electrodes, the advantages of the CC device over the CV device are not realised, in terms of variation of energy delivered.

However, although most of the energy delivered by either device is dissipated in the electrodes, proportionately more energy is delivered to the brain by the CV machine than by the CC machine.

In Fig. 4 we can see the effect that changes in inter-electrode resistance causes, obtained by placing resistors of known value between the electrodes. With CV, it can be observed that increasing the value of resistance the energy delivered decreases. In the CC case, more energy is delivered until the constant current characteristic cannot be maintained (above 450Ω).

So, CC machine is less dependent on variations in electrode application, since it will compensate the variations in the constant resistance of the electrodes.

With consistent techniques of electrode application, there appears to be little advantage in either the CV or CC ECT machine, but it may be desirable to reduce the energy delivered by the CV machine. Where consistency cannot be achieved, the CC machine offers some advantages.

Constant current method was used in several studies (like in [9]), as it’s a safer procedure for stimulating the brain than constant voltage one’s.

It is of importance to mention some useful findings we can extract from [6] in which CC and CV treatments were studied. The CC ECT was a stimulus of 5s at a current of 800mA using pulses 1.25ms wide at a frequency of 55Hz (equivalent to 275 mC). The standard setting for a CV ECT was a stimulus of 3s of a uniphase modified sine wave at a frequency of 50Hz (peak output voltage varies with impedance, but the intensity of electrical energy supplied was about 2 to 4 times that of the CC stimulus).

\[ E = 0.25 \cdot V_p \cdot I_p \cdot 4 \]

The major findings of this last study was that the treatment using a modern CC brief-pulse ECT machine with bilateral electrode placement, was as clinically efficacious as that of using a traditional ECT machine.

Although no difference was found between the two policies in terms of clinical efficacy, it is likely that CV ECT was associated with more confusion and memory impairment after treatment.

Several of the reports concerning the inferior efficacy of brief-pulse ECT involve unilateral ECT, and this study [6] was limited to bilateral ECT.

The side-effects of traditional ECT are substantially greater than these modern ECT. The DHSS stated that the traditional ECT machine should be phased out.

D. Brief-pulse, Rectangular pulse or Sine wave?

Sine-wave machines are obsolete and should not be used because the side effects are too pronounced. Brief-pulse machines should be used.

Because, above all young people have low seizures thresholds, they need to be treated with machines capable of delivering low doses of electricity. Unfortunately, some brief-pulse machines produce 25 mC as the lowest energy level, which may be excessive for young people.

The modern ECT stimulus consist of a series of electron pulses flowing between 2 electrodes (the brief-pulse stimulus). The pulse strictly alternate in direction. This electrode flow is called “bidirectional” or “alternating” current, see Fig. 5.

In [7], some equation are obtained in relation to the stimulus dose in different stimulus cases:

1) Brief pulse stimulus dose:

\[ \text{BilateralDose} = 1.327 \cdot \text{Charge(mC)} \cdot \text{Current(A)}^3 \]

\[ \text{UnilateralDose} = 1.372 \cdot \text{Charge(mC)} \cdot \text{Current(A)}^{2.5} \]

2) Sine wave stimulus dose is more complex to express because its current and voltage constantly vary:

\[ \text{Foranentiresine} = 3/8 \cdot \text{T} \cdot A^4 \]

A is the peak current and, T is the sine-wave stimulation duration.
Sine-wave devices deliver far higher maximum stimulus doses than present brief-pulse devices do. The problem with sine-wave stimuli was inefficiency. Inefficiency is why sine wave stimuli need high doses to succeed, and it is presumably why they also produce substantially greater side effects than do brief-pulse stimuli.

The greater efficiency closely follows lower charge rate and might follow lower pulse width. Failure rates were 5% and 50% with bilateral stimuli of 0.75 msec and 1.25 msec pulse widths and 72 and 144 mC/sec charge rate, respectively, with rectangular pulse using CC. In [9] it is investigated the clinical efficacy of a contemporary Ectron CC brief-pulse ECT (introduced in 1985) with that of a traditional, CV sine-wave machine (first developed in 1950). The amount of electrical energy supplied by modern ECT machines is preset by the treating doctor (hence the “CC”), whereas the electrical energy supplied to the patient’s head in traditional ECT varies with the impedance between the electrodes. This is not an optimal situation for a scientific comparison between the 2 types of treatment. We can only compare both in clinical efficacy (rate and degree of improvement) of symptoms of depression, number of treatments required and the likelihood of eventual recovery. Bilateral placement was recommended by the ECT Sub-Committe (1989).

IV. PROPOSAL OF RESEARCHING APPROACH

After analysing all the studies and reports in depth, and taking into account the information explained above, we suggest the following parameters and characteristics for electroconvulsive treatment:

1) BILATERAL ECT

It is more effective than unilateral electrodes placement and less doses are needed to elicit seizure in the brain. It is recommended as well by some committees and organizations, which suggest us to be a safety way. Although it is supposed to be more dangerous than unilateral ECT, due to brain is being stimulate from side to side rather than just one hemisphere, less doses in comparasion with the seizure threshold make this option to be more advisable from our point of view.

2) CONSTANT CURRENT BRIEF-PULSE

As mentioned above, constant current is safer than constant voltage in heat liberation rate, recommended by the DHSS.

From our point of view, one choice is like in Fig. 5 a CC brief-pulse stimulus.

Since CC machine is less dependant on variations in electrode application, and it will compensate the variations resistance of the electrodes as mentioned above, just we must assured to have a dynamic impedance between 200 and 320Ω.

Taking into account the previous findings, we can consider a CC brief-pulse ECT with bilateral electrode placement a safer method than those with CV. We should also assumed the bilateral brief-pulse stimulus dose equation displayed at subsection D in Seizure Generation section.

Pulse width should be set to 0.5 msec stimulus pulse width due to it was more efficient in the studies mentioned above, with lower seizure threshold.

We also assumed the typical ECT stimulus to have 100 to 1,000 pulses, at a frequency of $50 - 55 \text{Hz}$ and a stimulus amplitude of $800 \text{mA}$.

With all this useful findings, it is needed a way to implement that, using input data of electrical characteristics of the brain and programming its heat distribution, taking into account the delivered stimulus doses.

V. CONCLUSION

Despite the emergence of many new psychotropic drugs in recent years and campaigns to prohibit its use, ECT has retained a role as a safe and effective treatment of severe psychiatric disorder, both in adolescents and adults. Although the precise mechanism of action of ECT remains unknown, the technical aspects of its administration have continued to evolve since the treatment was introduced.

In the case of children, it could be noticed that the stimulus characteristics are almost the same as in adults, in the same way that occurs with side effects. Nonetheless, each case must be consider separately before applying ECT in non completely developed brains, since the most important thing in the technic is the guarantee of success and safety.

REFERENCES