

## THE NIMHANS MODEL ECT INSTRUMENT: A TECHNICAL REPORT

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### SUMMARY

The importance of electrical dose measurement ("dosimetry") during electroconvulsive therapy (ECT) has been gaining recognition. There is a need to explicitly provide full details of the electrical stimulus used during ECT. The conventional sinewave ECT stimulators in use in our country suffer from some limitations in this regard. To overcome these, a new model of ECT instrument was designed to deliver unmodified, bidirectional sinewave stimuli, with facilities for measuring the electrical dose incorporated into the instrument. The report outlines the features of this model of ECT instrument, and describes the dosimetric observations carried out in preclinical and clinical settings.

### Introduction

This year completes five decades of extensive clinical application of electroconvulsive therapy (ECT). Since its introduction in 1938, the efficacy of ECT has been established in different psychiatric disorders (Gangadhar et al. 1982 and 1985a; Janakiramaiah et al. 1982; Janakiramaiah 1985; Khanna et al. 1988). Refinements and variations in the treatment procedure have been introduced - these include modified versus unmodified ECT, unilateral versus bilateral electrode placement, ECT administered under different time schedules, sinewave versus pulse ECT, and electrical dosimetric variations (Andrade et al. 1988a & b; Fink. 1979; McAllister et al. 1987; Maletzky. 1979; Robin and de Tissera 1982; Sackeim et al. 1987).

Attention in ECT research has most recently turned to electrical dosimetric practice - the precise controlling and monitoring of electrical variables during treatment. The assumption that the electrical stimulus is no more than one of the means for producing a generalized convulsion is now being questioned. Just as the dose of electrical stimulus has been said to influence the adverse effects of ECT, so too has it been suggested to influence the therapeutic potency (Andrade et al. 1988a & b; Fink 1979; Malitz et al, 1986; Robin and de Tissera, 1982). Investigations have examined the role of different waveforms of the electrical stimulus, different doses of stimulus, and have even attempted titrating the electrical dose (Andrade et al. 1988a & b; Malitz et al. 1986; Robin and de Tissera. 1982; Sackeim et al. 1987). Such

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research calls for the exercising of rigorous control over the electrical stimulus parameters and has led to the introduction of a second generation of ECT instruments (Weaver and Williams 1987). Notably, the need for furnishing the details of electrical dosimetry in ECT research communications has recently received emphasis (Weiner et al. 1988).

The most commonly employed forms of electrical stimulus used in ECT practice are the unmodified sinusoidal waveform and brief square wave pulses (Gordon 1981 & 1982). The electrical doses required by these two stimulus waveforms to elicit a seizure are different (Weaver and Williams 1982). The electrical dose delivered during ECT is expressed as either coulombs of charge (current in amperes  $\times$  duration in seconds) traversing the tissue or as watt-seconds of energy (current in amperes  $\times$  voltage in volts  $\times$  duration in seconds) dissipated across the electrodes (Gordon 1981). Weaver and Williams (1982) have suggested yet another unit - joules per second. It has been recommended, however, that details such as waveform, frequency, voltage, current and duration of stimulus are all furnished as all three suggested measures of electrical dosimetry carry certain limitations (Gordon 1981; Weaver and Williams 1982; Weiner et al. 1988).

ECT instruments are primarily of two types-constant current and constant voltage stimulus generators. The former instrument permits electrical dosimetric monitoring in the units of coulombs of charge; if the interelectrode impedance is measurable, the watt-seconds of energy dissipated between the electrodes can also be calculated. The latter instrument is the conventional constant voltage sinewave apparatus wherein the electrical dose deli-

vered is expressed only in terms of voltage and stimulus duration if a current measuring device is not incorporated. However, if the interelectrode impedance is relatively constant, the charge or the energy of the electrical dose can be calculated. It has however been observed that the interelectrode impedance varies widely across patients and even in the same patient across time (Gangadhar et al. 1985b; Gordon 1982). Procedures to measure impedance by passing a small voltage calibration current can yield erroneous results as it has been observed that the impedance is influenced by the applied voltage (Gangadhar et al. 1985b; Gordon 1982). Hence, it is necessary to calculate the interelectrode impedance to the actually administered ECT stimulus in order to accurately determine the other electrical stimulus parameters.

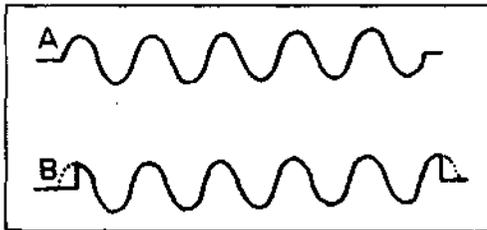
Considering the extent of practice and the relevance of ECT (Reddy 1988; Shukla 1981) and in view of the importance presently attached to the electrical stimulus parameters, we designed an ECT instrument with facilities for such precise electrical dosimetric measurements.

### *The Instrument*

The instrument designed is a constant voltage sinewave stimulator. The block diagram (Fig.) summarizes the salient features of the apparatus.

The 50 Hz mains supply of 220 volts is stepped down using an isolated tapped transformer. The secondary side has tapings from 90 to 190 volts (RMS) which can be selected in steps of 10 volts and set manually. The voltage which is selected and administered is monitored on a three figure digital display as the mains voltage fluctuation can influence the output at the secondary side.

A digital circuit for selecting the stimulus duration offers the choice of settings from 0.1 to 2.0 secs. in steps of 0.1 sec. As the frequency of the stimulus wave is constant (50 cycles per second), the duration of stimulus train is derived from the cycle length; i.e., five cycles give a duration of 0.1 seconds, ten cycles give 0.2 seconds etc. The timer clock is synchronized with the mains frequency so that the solid state relay circuit operates from the zero-crossing of the sinewave. This facilitates undistorted waveform representation unlike the distortion which can occur if the starting and closing of the stimulus occurs randomly (inset). In addition to this timer circuit, another electromagnetic relay is incorporated in series, which breaks the circuit after two seconds. This adds to patient safety in that no patient will receive a stimulus of duration longer than two seconds in the unlikely event that the first relay fails.



Unmodified 50 Hz sinusoidal wave train 0.1 sec duration. A. With timer synchronization. B. without timer synchronization, demonstrating distortion of the waveform.

The primary objective of the design of this instrument was to obtain full details of the electrical parameters during ECT. Hence, another circuit to measure the actual delivered current is incorporated. The current in milliamperes (RMS) is displayed in a three figure display unit, and the display is stored until the instrument is reset for the next stimulus.

As the instrument displays the actual voltage and current delivered during the

treatment session, precise electric dosimetric calculation is feasible in terms of both coulombs of charge as well as watt-seconds of energy.

After completing the assembly, the instrument was carefully tested in the biomedical engineering laboratory at our institute for accuracy of calibrations. The operational safety was examined by applying it on laboratory animals. After confirming the required safety as well as electrical standards, the instrument was put to use for patient care services and other academic purposes (Andrade 1986; Andrade et al. 1988a, b, c, d, Gangadhar et al. 1987 and 1988; Jain et al. 1986; Swaminath 1986).

### Observations

As the introduction of the facility for measurement of current - and hence the electrical dose - was the important feature of this instrument, observations made on this parameter are presented.

The stimulus dose for electroconvulsive shocks (ECS) was measured in 64 male Wistar rats. A stimulus of 150 volts was delivered for one second using saline-soaked earclip electrodes to elicit a generalized tonic-clonic convulsion. The current delivered on the first occasion varied from 29-54 (38 + 9.1)mA. Rats received 8-10 ECS, one per day on consecutive days. Within each rat too the current received was noticed to vary across occasions. The variation was, on average,  $\pm 5.32$ mA from the median value for each rat.

Stimulus parameters were also measured in 16 patients who received modified ECT (after providing informed consent) for endogenous depression (n=11), schizophrenia (n=4) or mania (n=1). There were 10 males and 6 females with

ages ranging from 24 to 55 years. The occurrence and duration of the seizure was monitored by the 'cuff' method. After pre-medication (thiopentone sodium 150-200 mgm, atropine 0.6 mgm and succinylcholine 20-40 mgm), patients received 140 volts of stimulus for 0.6 secs. ECT was administered on alternate days and patients received 3-11 treatments (mean=6.4). Excepting four patients, none received subconvulsive stimuli on any occasion. These four patients who received one subconvulsive stimulus on one occasion each were successfully treated with an increase in stimulus duration by 0.1 sec.

At 140 volts (RMS) of electrical stimulus, constant for all patients, the patients received a current ranging from 290 to 622 (496.8 + 108.2)mA (RMS) on the first treatment occasion. The current delivered in the first six ECT sessions was examined in the 10 patients who received six or more ECTs using repeat-measures analysis of variance. The mean current received by these ten patients did not change significantly across six sessions ( $F=1.11$ ,  $df$  5,45,  $p > 0.05$ ) whereas the mean current value in six sessions for these ten patients was significantly different ( $F=3.94$ ,  $df$  9,45,  $p < 0.001$ ). In the four patients who received a restimulation in the same treatment session at the same stimulus voltage, the current delivered varied marginally (mean=3.5 mA).

### Discussion

This instrument is essentially a 50 Hz sinewave stimulator. Although this waveform delivers a higher dose of stimulus than other waveforms, the therapeutic superiority of this type of stimulus seems apparent (Andrade 1986, Andrade et al. 1988a, Robin and de Tissera 1982). The claim that higher electrical stimulus dose leads to increased cognitive

side effects (Fink 1979, Sackeim et al. 1987) has not been supported (Swaminath 1986), thus justifying the development of a sinewave ECT instrument. In the wake of progress made in microprocessor technology, we argue that instruments with greater sophistication and flexibility required for safer use and progress in research on ECT. This report briefly outlines the model of a sinewave ECT instrument developed to permit precise stimulus dosimetry.

It may be noted here that while ECT is one of the potent treatment modalities extensively used in psychiatric practice (Reddy 1988), safety standards as well as legislatively established norms for instrumentation are yet to be introduced in the country. Further work should be directed to develop and recommend standard norms for ECT instrumentation which can be formally implemented at the national level for clinical practice and research.

### References

- ANDRADE, C. (1986) Outcome of endogenous depression following electroconvulsive therapy (ECT) assessed along different ECT parameters, Thesis submitted to Bangalore University.
- ANDRADE, C., GANGADHAR, B.N. & CHAN-NABASAVANNA, S.M. (1988a) A double-blind comparison of sinusoidal wave and brief-pulse electroconvulsive therapy in endogenous depression, *Convulsive Therapy* in Press.
- ANDRADE, C., GANGADHAR, B.N. & CHAN-NABASAVANNA, S.M. (1988b) Does ECT stimulus waveform influence rate of recovery in endogenous depression? *NIMHANS Journal*, 6, 121-126.
- ANDRADE, C., GANGADHAR, B.N., SWAMINATH, G. & CHAN-NABASAVANNA, S.M. (1988c) Mania as a side effect of electroconvulsive therapy, *Convulsive Therapy*, 4, 81-83.
- ANDRADE, C., GANGADHAR, B.N., SWAMINATH, G. & CHANNA-

- BASAVANNA, S.M. (1988d) Predicting the outcome of endogenous depression following electroconvulsive therapy. *Convulsive Therapy* (in press).
- FINK, M. (1979) *Convulsive Therapy: Theory and Practice*. New York: Raven Press.
- GANGADHAR, B.N., KAPUR, R.L. & KALYANASUNDARAM, S. (1982) Comparison of electroconvulsive therapy with imipramine in endogenous depression: a double blind study. *British Journal of Psychiatry*, 141, 367-371.
- GANGADHAR, B.N., KAPUR, R.L. & KALYANASUNDARAM, S. (1985a) Effect of ECT in endogenous depression: a double blind comparison with imipramine. *NIMHANS Journal*, 3, 7-12.
- GANGADHAR, B.N., LAXMANNA, G., SUBBAKRISHNA, D.K. & CHANNABASAVANNA, S.M. (1985b) Impedance measurements during electroconvulsive therapy. *NIMHANS Journal*, 3, 135-139.
- GANGADHAR, B.N., PRADHAN, N. & MAYANIL, C.S.K. (1987) Dopamine autoreceptor down regulation following electroconvulsive shocks. *Indian Journal of Medical Research*, 86, 787-791.
- GANGADHAR, B.N., RAMADEVI, G., ANDRADE, C. & PRADHAN, N. (1988) Dopaminergic effects of repeated electroconvulsive shocks. *Convulsive Therapy* (in press).
- GORDON, D. (1981) The electrical and radiological aspects of ECT. In Palmer, R.C. (ed.) *Electroconvulsive Therapy: An Appraisal*, Oxford: Oxford University Press, 79-96.
- GORDON, D. (1982) Electroconvulsive therapy with minimum hazard. *British Journal of Psychiatry*, 141, 12-18.
- JAIN, S., SESHADRI, S. & GANGADHAR, B.N. (1986) Seizure duration with pulse and sinusoidal waveform stimuli. Paper presented at the 39th Annual Conference of the Indian Psychiatric Society, Calcutta.
- JANAKIRAMAIAH, N. (1985) Lithium and post-lithium developments at NIMHANS in the somatotherapy of mania. In Channabasavanna, S.M. and Shah, S.A. (eds.) *Affective Disorders: Recent Research and Related Developments*. Proceedings of the INDO-US Symposium on Affective Disorders held at NIMHANS, Bangalore, 119-132.
- JANAKIRAMAIAH, N., CHANNABASAVANNA, S.M. & NARAYANA MURTHY, N.S. (1982) ECT-chlorpromazine combination versus chlorpromazine alone in acutely schizophrenic patients. *Acta Psychiatrica Scandinavica*, 66, 464-467.
- KHANNA, S., GANGADHAR, B.N., SINHA, V., RAJENDRA, P.N. & CHANNABASAVANNA, S.M. (1988) Electroconvulsive therapy in obsessive compulsive disorder. *Convulsive Therapy* (in press).
- MALITZ, S., SACKEIM, H.A., DECINA, P., KANZLER, M. & KERR, B. (1986) The efficacy of ECT dose-response interaction with modality. In Malitz, S. and Sackeim, H.A. (eds.) *Electroconvulsive Therapy: Clinical and Basic Research Issues*. *Annals of the New York Academy of Sciences*, 462, 56-64.
- McALLISTER, D.A., PERRI, G.M., JORDAN, R.C., RAUSCHER, F.P. & SATTIN, A. (1987) Effects of ECT given two versus three times weekly. *Psychiatric Research*, 21, 63-69.
- MALETZKY, B.M. (1981) *Multiple-monitored electroconvulsive therapy*, Boca Raton FL: CRC Press.
- REDDY, G.N.N. (1988) From asylums to the community. *Health for the Millions*, 16, 2-6.
- ROBIN, A.A. & de TISSERA, S. (1982) A double-blind comparison of the therapeutic effects of low and high energy electroconvulsive therapy. *British Journal of Psychiatry*, 141, 357-366.
- SACKEIM, H.A., DECINA, P., KANZLER, M., KERR, B. & MALITZ, S. (1987) Effects of electrode placement on the efficacy of titrated low-dose ECT. *American Journal of Psychiatry*, 144, 1449-1455.
- SHUKLA, G.D. (1981) ECT in a rural teaching hospital in India. *British Journal of Psychiatry*, 139, 69-79.
- SWAMINATH, G. (1986) Effect of stimulus energy parameters on memory following electroconvulsive therapy. Thesis submitted to Bangalore University.
- WEAVER, L.A. & WILLIAMS, R.W. (1982) The electroconvulsive therapy stimulus. In Abrams, R. and Essman, W.B. (eds.) *Electroconvulsive Therapy: Biological Foundations and Clinical Applications*. Lancaster: MTP Press Limited, 129-156.
- WEAVER, L.A. & WILLIAMS, R.W. (1987) ECT second generation instruments. *Biological Psychiatry*, 22, 1181-1182.
- WEINER, R.D., WEAVER, L.A. & SACKEIM, H.A. (1988) Reporting of technical parameters in ECT publications: recommendations for authors. *Convulsive Therapy*, 4, 88-91.