

Efficiency of the Stimulus Characteristics of ECT

Conrad M. Swartz, Ph.D., M.D.

David T. Manly, M.D.

Objective: Greater ECT stimulus efficiency allows for a lower stimulus dose and should diminish the side effects of ECT.

Method: Four different ECT stimuli of identical charge (average $mC=2.5$ times age) with pulse widths of 0.5 msec and 1 msec and frequencies of 30 Hz and 60 Hz, respectively, were compared for efficiency. The stimuli were applied in a balanced order to each of 24 subjects. Asymmetric bilateral electrode placement was used.

Results: Peak heart rates were higher with the 0.5-msec pulse width than the 1-msec pulse width. Seizure induction was more successful with the 0.5-msec pulse width than the 1-msec pulse width. Stimulus frequency had no effect on heart rate or seizure induction.

Conclusions: The pulse width of 0.5 msec is more efficient than the 1-msec pulse width. The “half-age” dose for the first bilateral ECT treatment is usually successful for subsequent ECTs when the 0.5-msec pulse width is used.

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There are two qualitatively different aspects to the selection of an ECT stimulus: electrical charge dose and waveform characteristics. The characteristics of rectangular-pulse, constant-current ECT are pulse width, frequency, charge rate, and current. These characteristics affect the ability of the stimulus of a given charge to induce a seizure—that is, its efficiency. Any waveform aspects that diminish efficiency—that is, do not promote the development of seizures—stand to increase side effects without additional benefit. Accordingly, it is clinically desirable to identify and use the most efficient values of the waveform characteristics.

Previous measurements suggest that greater efficiency closely follows lower charge rate and might follow lower pulse width (1, 2). Failure rates were 5% and 50% with bilateral stimuli of 0.75-msec and 1.5-msec pulse widths and 72 and 144 mC/second charge rates, respectively. A 10% failure rate for 1.5-msec pulses at 72 mC/second was also found (1, 2). The present study aimed to determine if still-lower pulse widths and charge rates would increase efficiency further.

Method

The protocol for the study was approved by the university's institutional review board. The subjects were 24 consecutively admitted adult patients on a teaching ward who gave written informed consent after the procedures had been fully explained. Exclusionary criteria were coarse brain disease, substance abuse, ECT within 3 months of the study, pulmonary disease, or medication that affected the development of seizures. Subjects were maintained free of such medication, such as benzodiazepines. The subjects were seven men and 17 women aged 19–74 years (mean=50.0 years, SD=15.0). One patient had been diagnosed with atypical psychosis, and 23 met the DSM-IV criteria for major depression; of these, seven were both melancholic and catatonic, nine were melancholic alone, and one was catatonic alone.

Three ECT sessions were given weekly, as described in an associated study (3); heart rate and motor measurements were taken, as described in that report. One stimulus electrode was placed over the right temple (per standard bitemporal placement), and the other was placed on the forehead above the left eye, per Swartz and Evans (4). This asymmetrical bilateral placement was used because it was thought to have advantages over traditional bitemporal placement. The methohexital anesthesia dose was held constant across study sessions. All ratings and measurements were made by one investigator (C.M.S.) who was blind to stimuli and motor durations. The peak rate submaximality was

calculated as the highest peak heart rate during the subject's course, less the peak heart rate during the treatment (5).

The protocol began with the second ECT seizure; the first ECT seizure was excluded from study because it is unusually vigorous (6, 7). The 30-Hz, 0.5-msec stimulus was selected as the lowest charge rate available. The other stimuli were 30 Hz, 1 msec; 60 Hz, 0.5 msec; and 60 Hz, 1 msec. The corresponding charge rates were 27, 54, 54, and 108 mC/second. There are 24 permutations of the four stimuli; these were assigned to the 24 subjects randomly. This method compensates for progressive changes in seizure threshold and duration along the course of ECT treatment (6). The stimulus dose was set by the half-age method (8); the charge (in millicoulombs) was 2.27 times the patient's age rounded up to the nearest multiple of 25.2 mC.

Results

Three considerations indicated the superiority of the 0.5-msec stimuli: peak heart rate, seizure failure rate, and sequence of failure. Two-factor repeated measures analysis of variance (ANOVA) of peak heart rate showed the superiority of the 0.5-msec stimuli ($F=4.76$, $df=1, 23$, $p=0.04$), no effect of frequency ($F=0.72$, $df=1, 23$, $p=0.41$), and no interaction between frequency and pulse width ($F=0.42$, $df=1, 23$, $p=0.52$). Peak heart rates were 148.8 bpm (SD=20.3), 148.4 bpm (SD=25.4), 141.5 bpm (SD=23.9), and 138.2 bpm (SD=25.8) for the 30 Hz/0.5 msec, 60 Hz/0.5 msec, 30 Hz/1 msec, and 60 Hz/1 msec stimuli, respectively. Analyses of peak rate submaximality provided the same results. The mean peak rate submaximalities were 10.7 bpm (SD=10.4), 11.0 bpm (SD=14.4), 18.0 bpm (SD=22.6), and 21.3 (SD=26.4); higher peak heart rate corresponds to lower peak rate submaximality.

The incidences of inadequate (abortive or failed) motor seizures were 25%, 21%, 8%, and 8% with 60 Hz/1 msec, 30 Hz/1 msec, 60 Hz/0.5 msec, and 30 Hz/0.5 msec stimuli, respectively. Only one ECT was abortive (9 seconds in duration). Seven subjects experienced at least one inadequate seizure; none of these included both 0.5-msec trials, but five included both 1-msec trials. Defining high success as seizure induction after failure on a previous trial, two-factor repeated measures ANOVAs on 3-point ratings (failure, success, high success) showed the superiority of the 0.5-msec stimuli ($F=5.28$, $df=1, 23$, $p=0.03$), no effect of frequency ($F=0.59$, $df=1, 23$, $p=0.45$), and no interaction between frequency and pulse width ($F=0.09$, $df=1, 23$, $p=0.77$).

Concerning sequence, adequate seizures occurred all four times that the 0.5-msec pulse width stimulus followed one inadequate seizure. In contrast, inadequate seizures resulted all four times that the 1-msec pulse width stimulus followed one seizure failure. Five of seven initial occurrences of inadequate seizures were with the 1-msec stimulus.

Another effect difference is that longer motor seizures produced higher peak heart rates with the 0.5-msec stimulus but not with the 1-msec stimulus; this might reflect the quality of generalization of seizures throughout the brain. Excluding motor seizures under 20 seconds list-

wise, the Pearson's correlation coefficients between motor duration and peak rate submaximality were -0.60 , -0.40 , -0.19 , and 0.17 for the 30 Hz/0.5 msec, 60 Hz/0.5 msec, 30 Hz/1 msec, and 60 Hz/1 msec stimuli, respectively. These correlation coefficients differed significantly between the 60 Hz/1 msec stimulus and the two 0.5-msec stimuli ($z=2.49$, $p=0.006$, and $z=1.71$, $p=0.044$, for 30 Hz and 60 Hz, respectively).

Discussion

All measures were in the direction of greater efficiency for the 0.5-msec stimulus pulse width than for the 1-msec pulse width in the frequency ranges measured. The lack of effect by frequency indicated that any variation of efficiency with charge rate or stimulus duration was attributable to pulse width.

Previous results suggest that the range of frequencies, pulse widths, and charge rates in the present study were more efficient than stimuli of higher frequency, pulse width, or charge rate (1, 2). Although narrowing the pulse width below 0.5 msec might improve efficiency further with stimuli of low charge, it might not be practical with higher charges. This is because the particularly high frequency necessary to deliver the charge within 8 seconds should degrade efficiency by "stimulus crowding" (9). For example, a 378-mC/second, 900-mA, 0.25-msec, 8-second ("75% energy") stimulus has a frequency of 105 Hz. At 1-msec pulse width, 30 Hz stimuli were more efficient than higher frequencies (9).

The greater efficiency of stimuli with narrower pulse widths seen here is consistent with the greater efficiency of 0.75–2-msec square-wave stimuli than of sine-wave stimuli of phase width 8 msec (10, 11). No study has compared sine wave and square wave stimuli of equal phase width; therefore, attributions of differences in efficiency and cognitive side effects to differences in shape (11, 12) are unproved.

The present results complement those of several other reports. With stimuli of 0.5 msec and 30 Hz, the mean threshold for seizure occurrence for the first right unilateral ECT was 48.9 mC; this is qualitatively lower than thresholds reported by others using higher pulse widths and higher frequencies (13). Similarly, seizure thresholds were lower with 0.5 msec pulse widths than with 1–2-msec pulse widths at the first sessions of right unilateral and bilateral ECT (14).

An overall seizure induction rate of 92% for the 0.5-msec pulse width stimulus confirms that the half-age dose strategy for the first bilateral ECT remains successful for subsequent ECTs. For the first ECT, 100% success was reported (8), but characteristics of the stimuli were not considered. According to the present results, the half-age strategy is more successful with the 0.5-msec pulse width than with the 1-msec pulse width.

BRIEF REPORTS

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Received June 17, 1999; revisions received Nov. 1, 1999, and Jan. 19, 2000; accepted March 2, 2000. From the Department of Psychiatry, School of Medicine, Southern Illinois University; and the Department of Psychiatric Medicine, East Carolina University, Greenville, NC. Address reprint requests to Dr. Swartz, Department of Psychiatry, Southern Illinois University, P.O. Box 19642, Springfield, IL 62794-9642; ectdoc@pol.net (e-mail).

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References

1. Swartz CM, Larson G: ECT stimulus duration and its efficacy. *Ann Clin Psychiatry* 1989; 1:147–152
2. Swartz CM: ECT stimulus charge rate and its efficacy. *Ann Clin Psychiatry* 1994; 6:205–206
3. Swartz CM, Manly DT: Endpoint of ECT-induced elevation in heart rate. *J ECT* 1999; 15:125–128
4. Swartz CM, Evans CM: Beyond bitemporal and right unilateral electrode placements. *Psychiatr Annals* 1996; 26:705–708
5. Swartz CM: Variations of peak and baseline heart rates. *J ECT* 1999; 15:222–225
6. Malitz S, Sackeim HA, Decina P, Kanzler M, Portnoy S, Prohovnik I, Hopkins N, Kahn D, Kerr B, Lee C, Mukherjee S, Neeley P, Yudofsky SC: Low dosage ECT: electrode placement and acute physiological and cognitive effects. *Am J Soc Psychiatry* 1984; 4:47–53
7. Krystal AD, Weiner RD, Coffey CE, McCall WV: Effect of ECT treatment number on the ictal EEG. *Psychiatry Res* 1996; 62:179–189
8. Petrides G, Fink M: The “half-age” stimulation strategy for ECT dosing. *Convuls Ther* 1996; 12:138–146
9. Devanand DP, Lisanby SH, Nobler MS, Sackeim HA: The relative efficiency of altering pulse frequency or train duration when determining seizure threshold. *J ECT* 1998; 14:227–235
10. Weaver LA, Ives JO, Williams R, Nies A: A comparison of standard alternating current and low-energy brief-pulse electrotherapy. *Biol Psychiatry* 1977; 12:525–543
11. Weiner RD: ECT and seizure threshold: effects of stimulus wave form and electrode placement. *Biol Psychiatry* 1980; 15:225–241
12. Weiner RD, Rogers JH, Davidson JRT, Squire LR: Effects of stimulus parameters on cognitive side effects. *Ann NY Acad Sci* 1986; 462:315–325
13. Rasmussen KG, Zorumski CF, Jarvis MR: Possible impact of stimulus duration on seizure threshold in ECT. *Convuls Ther* 1994; 10:177–180
14. Isenberg KE, Dinwiddie SH, Heath AC, Jarvis M, Zorumski CF: Effect of stimulus parameters on seizure threshold and duration (abstract). *Convuls Ther* 1996; 12:68