Maximum Fractal Dimension of Cerebral Seizure Remains Constant through the Course of Electroconvulsive Therapy

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Introduction and background

- In the practice of electroconvulsive therapy(ECT) a seizure is induced to produce clinical effects.
- ECT-induced EEG measures have been used to study their association with different the clinical effects:
  - Higher amplitude of mid-seizure EEG and greater post-seizure EEG suppression have been shown to be associated with better antidepressant effect (1, 2).
  - Fractal Dimension (FD) as a geometrical measure of post-ictal amplitude during 2nd ECT was sensitive to differentiate ECT responders (3)
- There is no literature on how EEG response to ECT changes through a course of ECT.
  - In this study we examined this issue by analyzing ECT-induced EEG data of patients who were involved in a study comparing bitemporal and bifrontal electrode placements in schizophrenia (4)
- This is a part of the continuing efforts of NIMHANS in collaboration with National Institute of Quality and Reliability (NIQR), for arriving at standards in ECT practice and instrumentation.

Aims

To study : 1) The changes in highest mid seizure FD over a course of ECT spanning over 6 session
2) To compare the highest mid seizure FD between bi-temporal and bi-frontal ECT.

Methodology

• Consenting 114 patients with schizophrenia took part in a study comparing the efficacy of bi-frontal and bi-temporal electrode placements during ECT.

•EEG was recorded over frontal pole leads during all ECT sessions.

•FD was calculated as shown in the adjacent box. Figure-1 shows a typical ECT-EEG record; it also shows FD corresponding to this EEG

•We selected artefact-free EEGs recorded during the first 6 ECT sessions. 40 patients had such EEGs (240); 21 received bi-frontal ECT and 19 received bi-temporal ECT.

•For each session, 5 highest FDs were noted by visually scanning the FD graph (figure-1). The average of these 5 for each seizure EEG was used for comparison across ECT sessions and between 2 electrode placements.

- In 16 randomly chosen EEGs 2 researchers calculated this average independently. The inter-rater reliability was excellent (ICC=0.87; P<0.001)

•The changes in this value over a course of 6 ECT's was analysed using repeated measures ANOVA.

A comparison between the fractal dimensions of bi-frontal and bi-temporal ECT was also done.

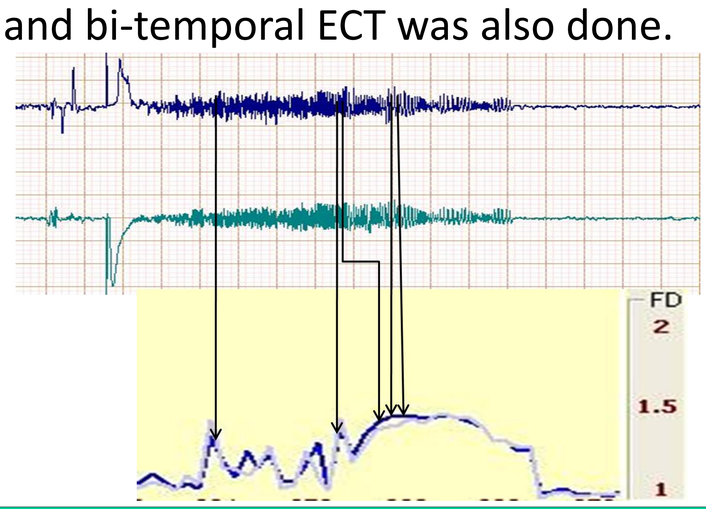

Figure-1A: 2-channel EEG for the complete ECT session.

Figure-1B Corresponding FD graph.

THEORY OF OPERATION:

The fractal dimension of the waveform (F) (As defined by Katz and approximated as D):

$$\Phi \approx D = 1 + \frac{\ln(L)}{\ln(2 \times N')}$$

where L is the length of the curve in the unit square and N'=N-1. The fractal dimension is a parameter that characterizes chaotic systems, and the analysis of time series is one of the most common means to find the fractal dimension from observables. The simple algorithm developed quickly calculates the FD taking the pixel-to-pixel distance between adjacent points. The FD value calculated by this algorithm provides a quick geometric measure of EEG during ECT seizure.

FD calculation is based on the EEG waveform study of 4-second screen visual. It is to be noted that the FD value change according to the zoom value set and this was constant for all records.

FD Analysis can be done for individual channels and thus can be used as a measure of phase cohesion between various regions of the hemisphere of the brain like Fp1, Fp2, T1, T2, etc.

Figure-1A shows 2-channel EEG (frontal) for the complete ECT session (X-axis compressed screen). Figure-1B shows the FD graph for the corresponding 2-channels (Ch#1: Dark blue; Ch#2: Light blue).

References

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Results

The average highest FD remained virtually unchanged across the 6 ECT sessions (Figure-2; Table-1). (F=0.5, p=0.75). Similar results were found in both bi-frontal (F=1.2, p=0.31) and bi-temporal(F=1.2, p=0.32) electrode placements.

Figure-2: Line graph showing the mean average maximum FD across 6 ECT sessions with bi-frontal and bi-temporal placements.

Table-1: shows mean and SD of the average maximum FD for each session.

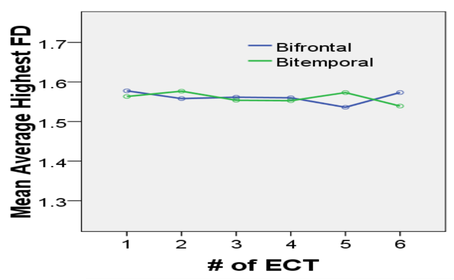

Figure-2 **Table-1 →**

Session	BF (n=21)		BT (n=19)	
	Mean	SD	mean	SD
1	1.5777	0.08846	1.5767	0.06075
2	1.558	0.06741	1.5538	0.07091
3	1.5615	0.06055	1.5527	0.07016
4	1.56	0.05411	1.5732	0.05412
5	1.5361	0.08062	1.5391	0.07089
6	1.5734	0.06131	1.5634	0.05895

Discussion

- The geometric measure of FD obtained in this study compares well with the measures obtained in an earlier study (3)
- Seizures are known to be shorter in duration over successive ECT sessions indicating 'anticonvulsant' action of ECT.
- Absence of differences in FD over sessions and across electrode placements suggests that EEG morphology shows stable pattern across sessions and electrode placements. This may be because of the fact that once generalized, the seizures would follow a pattern that shows little variation, suggesting 'all-or-none' behavior of seizures with regard to their morphology.
- The differential effect of bi-frontal and bi-temporal electrode placements could be due to the 'origin' of the seizures – frontally generated seizures are known to generalize better (5).