Effect of Electroencephalogram Neurofeedback Training on Quality of Life in Patients with Traumatic Brain Injury: In Context of Spontaneous Recovery

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Abstract

Introduction Quality of life (QOL) is strongly affected following traumatic brain injury (TBI). There is a strong need to explore the use of new developments in neuropsychological rehabilitation such as electroencephalogram (EEG) neurofeedback training (NFT) on QOL in TBI patients.

Objective The objective was to study the effect of EEG NFT on QOL in TBI patients in the context of spontaneous recovery.

Methodology A sample of 60 TBI patients was assigned to an NFT group (n = 30) and a treatment as usual (TAU) group (n = 30). Twenty sessions of α/θ NFT at the occipital 1 and 2 scalp locations were given to the NFT group. The NFT protocol used was dependent on (4–7 Hz) θ and (8–12 Hz) α activity with the aim of decreasing the θ/α ratio. Pre- and postassessments of QOL were recorded on the World Health Organization quality of life questionnaire (WHOQOL)–BREF.

Results This study results indicate significant enhancement of QOL in the NFT group as compared with the TAU group. The improvement scores indicate that the 12- to 18-month postinjury NFT group had significantly less improvement on QOL as compared with the < 6-month NFT group.

Conclusion EEG NFT helps improve QOL in TBI patients. Early intervention is more effective in improving QOL than later intervention.

Keywords
- neurofeedback
- electroencephalogram
- brain injury
- traumatic brain injury
- quality of life
- neurorehabilitation
- spontaneous recovery

Introduction

Individuals who sustain head injury present with a series of symptoms. Once the primary complaints are addressed, there are a host of secondary issues that have a deleterious effect on the individual's well-being. Cognitive, emotional and behavioral ramifications are imminent. While functional outcome has been a major measure of outcome following head injury so has quality of life (QOL). Traumatic brain injury (TBI) is one of the foremost causes of death and disability, and it affects health-related QOL (HRQOL).

The relationships between chronic stress, fatigue-related QOL (F-QOL) and associated covariates after mild to moderate TBI have been examined. Studies indicate that F-QOL in community-dwelling individuals with mild to moderate TBI is associated with chronic stress and somatic symptoms. Management of symptoms may therefore require training in stress management to decrease fatigue, burden, and enhance

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QOL.[1] In a related study, HRQOL in 358 TBI patients was examined 2 years after TBI. At the 2-year follow-up examination, there were 312 (87.2%) survivors. Patients with injury had significantly lower scores in every domain than the control group 2 years after discharge. However, HRQOL of TBI patients improved during the 2 years after discharge. Age, sex, and severity of the head injury were found to be significantly associated with physical or mental HRQOL following discharge.[2]

Neuropsychological rehabilitation is based on the principle of plasticity. The concept of neural plasticity goes hand in hand with that of spontaneous recovery. Parker (1990) describes recovery as the process of healing and outcome as the TBI patient's condition once they have stabilized at a plateau. Spontaneous recovery generally occurs within the first 3 months after the injury. Some other factors that affect recovery include the type of brain injury (location of damage, extent of damage, laterality, etc.), premorbid levels of intelligence, premorbid personality attributes, social support from family and significant others, motivation to recover, ability to communicate (receptive and expressive), professional support, and victim's age and occupation. The significance of each factor of course is debatable. Some residual difficulties that may remain with the patient include emotional disturbances, cognitive difficulties, memory problems, language impairment, and alteration of sexual behavior.[3] It is important to make some attempt to understand neural plasticity in the context of spontaneous recovery, as the basic assumption of spontaneous recovery or any recovery for that matter is the ability for the brain to adapt and heal.

Cutting-edge research in the area of neuropsychological rehabilitation has led to the development of a new advancement in technology. Electroencephalogram (EEG) neurofeedback training (NFT) has been used to modify amplitude, frequency, and even coherency of an individual's brain waves using operant conditioning methods.[4] Raw signals are further analyzed before feedback is given. Both single- and two-channel systems are typically used in EEG training systems. Two-channel training systems are often preferred because they are more flexible and can be used to train two scalp locations concurrently.

α/θ training is used for therapeutic purposes. Especially the Peniston and Kulkosky brain wave neurotherapy (PKBNT) was found to be effective in the treatment of alcoholics and posttraumatic stress disorder (PTSD).[5] Patients with these disorders showed a significant improvement in their disease pattern, compared with controls that were not treated with the PKBNT. Anxiety disorders are also treated with NFT. Results of these studies showed that α increases, and that most of the time, anxiety scores dropped. Thus, neurofeedback can help in initiating a relaxed state, but it is not completely clear whether it is more effective than other relaxation methods.

Need and Scope of This Study

In India, millions require hospitalization and thousands suffer from disabilities. Large-scale population-based surveys in Bangalore indicate that the ratio of deaths, hospitalizations, and injuries is 1:20:40.[6] In India, pedestrians, two-wheeler occupants, and bicyclists are at greater risk for motor vehicle accidents.[6] Nearly 70% of these injuries were among men aged 15 to 44 years, and 80% of the injuries were in rural areas.[6] These figures have serious implications for the economy and political system of the country. Though survival rates are on the increase with improved medical attention, the burden of the disabilities escalates. However, despite the increase in prevalence of cognitive, emotional, and behavioral disability in India, not much attention has been paid to their neuropsychological remediation. It then becomes vital for neuropsychological rehabilitation professionals to develop efficacious preventive and intervention programs to deal with this seemingly interminable predicament. This study will examine the use of neurofeedback intervention in a spontaneous and a nonspontaneous recovery groups on QOL.

Methodology

Aim

The aim was to study the effectiveness of EEG NFT on QOL in TBI patients within the context of spontaneous recovery.

Operational Definitions

TBI (within recovery): Those who classify for a diagnosis of TBI within 6 months of the injury.

TBI (in the plateau phase): Those who classify for a diagnosis of TBI 12 to 18 months after the injury.

Design

It was an experimental longitudinal design with pre–post comparison.

Sample

The sample comprised two groups of patients.

1. Thirty TBI patients in the NFT group
2. Thirty TBI patients in the treatment as usual (TAU) group

Traumatic brain injury patients following road traffic accidents (RTAs) were referred from the inpatient and outpatient services of the Department of Neurosurgery, the National Institute of Mental Health and Neurosciences (NIMHANS). They were assigned to an intervention (NFT) or TAU control group. The sample was divided into two halves. Group 1 consisted of those within 6 months of injury and group 2 consisted of patients within 12 to 18 months of injury. This classification was made to account for the effect of spontaneous recovery ►**Table 1**.

Based on Glasgow coma scale (GCS) score, in the NFT group, 28.6% of the group fell in the mild category, 35.7% was

Table 1 Sample distribution to account for the effect of spontaneous recovery

Sample	NFT Group	TAU Group
Within 6 mo of injury	15	15
12–18 mo of injury	15	15
Total	30	30

Abbreviations: NFT, neurofeedback training; TAU, treatment as usual.

moderate, and 35.7% fell into the severe category. In the TAU group, 44.4% of the group had a mild head injury, 33.3% had a moderate injury, and 22.2% had a severe injury. However, the differences between the two groups at baseline on GSC score was not significant (p = 0.415, chi-square test).

Inclusion Criteria

- Individuals with diagnosis of TBI
- Mechanism of injury: RTA
- Age range: 18 to 50 years
- Normal or corrected vision and hearing
- Right handed

Exclusion Criteria

- TBI patients with any other mechanism of injury than road traffic–related injuries, such as injuries sustained due to falls, assaults, etc. (This was to create homogeneity in the group regarding mechanism, as RTA-related injuries are susceptible to shearing, rotational, acceleration, deceleration forces not commonly seen in other injuries).
- History of comorbid psychiatric or other neurologic conditions, mental retardation, or substance dependence.
- History of medical conditions such as hypertension, diabetes mellitus.
- Exposure to any form of neuropsychological rehabilitation (other than NFT) or psychotherapy.

Measure

The World Health Organization QOL questionnaire (WHOQOL)–BREF (World Health Organization, 2004).[7]

The WHOQOL-100 assessment comprises 100 items. It was developed by the WHOQOL group with the intention of developing a QOL assessment that could be used across different cultures. The study was conducted on 15 international field centers simultaneously. The WHOQOL-BREF is an abbreviated version of the WHOQOL-100. It was developed by the WHO in 1996. It comprises 26 items, which measure the following broad domains of psychological health, physical health, social relationships, and environment. This brief measure was developed for its convenience in larger research studies or clinical trials. The higher the score, the greater the estimation of QOL.

Procedure

After procuring ethical clearance from the ethics committee of NIMHANS, a written informed consent was taken from each participant. Completers of EEG NFT were defined as those who completed 80% of the specified number of sessions (i.e., 16–20 sessions).

Preintervention Assessment

Sixty patients who fulfilled the inclusion and exclusion criteria of the study were recruited. The assignment into intervention and TAU groups was made by convenient sampling techniques. The treatment group obtained routine treatment as well as EEG NFT. The routine treatment included surgical procedures such as craniotomy and craniectomy, antiedema measures and antiepileptic medication. When required, patients were referred for physiotherapy, speech therapy, and other rehabilitation services. WHOQOL-BREF was then administered.

Intervention

Electroencephalogram NFT was performed in a quiet, dimly lit room. The protocol used was α/θ training. The process and the objectives were explained to the patient before beginning the session, and the nature of the program was also explained. The rewards were set to be given through visual feedback as well as an increase in the score that was displayed during the task. Each session was 40-minute duration, with three sessions per week.

Postintervention Assessment

Postassessment was performed on completion of sessions in the intervention group. In the case of the TAU group postassessment was performed between 45 and 60 days following preassessment. Postassessment using the WHOQOL-BREF was then performed.

Analysis

Analysis was performed using SPSS version 16 (SPSS Inc.). The following analyses were made.

- Descriptive statistics: Mean, standard deviation (SD), percentage
- Shapiro-Wilk test for normality of distribution
- Mann-Whitney U test for continuous variables (two independent groups)
- Wilcoxon signed rank test for continuous variables (two dependent groups)

Results

The results obtained were analyzed using SPSS version 16.

As the data did not follow a normal distribution (p < 0.200), as evidenced by the Shapiro-Wilk test, nonparametric statistical methods were used for inferential statistics.

Tests Comparing Neurofeedback and Treatment as Usual Groups at Baseline

►**Table 2** indicates that there was a significant difference on WHOQOL-BREF between the NFT and TAU groups at baseline. The NFT group had significantly poorer QOL.

Table 2 Mann-Whitney U test results for testing difference between the NFT and TAU groups on WHOQOL-BREF at baseline

Variable	NFT mean	NFT SD	TAU mean	TAU SD	*p*
WHOQOL-BREF	71.39	15.08	86.12	18.82	**0.003****

Abbreviations: NFT, neurofeedback training; SD, standard deviation; TAU, treatment as usual; WHOQOL, World Health Organization quality of life questionnaire.
** $p \leq 0.01$

Table 3 Wilcoxon signed rank test results for testing difference between the NFT and TAU groups' pre- to postassessment on WHOQOL-BREF

Variable	NFT pre-mean	NFT pre-SD	NFT post-mean	NFT post-SD	*p*	TAU pre-mean	TAU pre-SD	TAU post-mean	TAU post-SD	*p*
WHOQOL-BREF	71.39	15.08	103.37	15.01	**0.000*****	86.12	18.82	86.69	19.72	0.409

Abbreviations: NFT, neurofeedback training; SD, standard deviation; TAU, treatment as usual; WHOQOL, World Health Organization quality of life questionnaire.
***$p \leq 0.001$

Tests Comparing Neurofeedback and Treatment as Usual Groups

Within Group Comparison

►**Table 3** indicates that significant differences were seen within the NFT group ($p = 0.000$). No significant differences were seen within the TAU group on WHOQOL-BREF.

Between Group Comparisons (Difference Scores Used: Post-Pre Assessment)

►**Table 4** indicates that significant differences were seen between the NFT and TAU groups ($p = 0.000$) on improvement on the WHOQOL-BREF.

►**Tables 5** and **6** indicate significant improvements seen in the NFT group in comparison with the TAU groups on WHOQOL-BREF in the < 6 and 12- to 18-month groups ($p = 0.000$).

►**Table 7** indicates that the NFT 12- to 18-month group showed significantly less improvement than the NFT < 6-month group on QOL.

►**Table 8** indicates that there are no significant differences between the TAU (< 6- and 12–18 month) groups.

To summarize, this study results indicate significant enhancement in QOL in the NFT group as compared with the TAU group (►**Table 4**).

Subgroup analyses of the < 6 months from injury group and 12 to 18 months from injury group indicate that both the groups improved significantly as compared with their TAU counterparts (►**Tables 5**, **6**). The improvement scores indicate that the 12- to 18-month NFT group had significantly less improvement on the QOL measure as compared with the < 6-month NFT group (►**Table 7**). On the other hand, there was no significant change between the two TAU subgroups (►**Table 8**). This indicates that during the normal course of recovery, without NFT intervention, the amount of improvement in terms of QOL is no different between the < 6- and 12- to 18-month TAU groups.

Effect size was calculated using Cohen's *d*. Large effect size were seen on QOL (Cohen's $d = 2.58$).

Discussion

Differences between the Neurofeedback and Treatment as Usual Groups at Baseline

At baseline, the fact that the NFT group had significantly poorer QOL was addressed in the analyses. When the two groups are similar in all aspects except for the presence of the independent variable (in this case NFT), they are compared at postassessment to ascertain difference in outcome. As the two groups varied at the baseline on these measures, the change from pre- to postassessment scores were used in the analysis (i.e., a new score was created subtracting performance at baseline from the performance at postassessment). This new score reflected the amount of improvement in both groups. The variations in baseline between the two groups were therefore controlled for while addressing the main objectives.

Table 4 Mann-Whitney U test results for testing difference between the NFT and TAU groups' pre- to postdifference scores on WHOQOL-BREF

Variable	NFT mean	NFT SD	TAU mean	TAU SD	*p*
WHOQOL-BREF	31.30	14.97	0.58	7.76	**0.000*****

Abbreviations: NFT, neurofeedback training; SD, standard deviation; TAU, treatment as usual; WHOQOL, World Health Organization quality of life questionnaire.
***$p \leq 0.001$

Effectiveness of Electroencephalogram Neurofeedback Training on Quality of Life in Patients with Traumatic Brain Injury

The importance of remediating residual symptoms of TBI victims cannot be overemphasized. Reduction in posttraumatic stress has been often found to be associated with a reduction in postconcussive symptoms.[8] A positive and significant relationship is commonly found between postinjury symptom frequency and tension/anxiety, anger/hostility, and perceived chronic stress.[9] Even while controlling for age, time elapsed from injury as well as the mechanism of injury, TBI severity continues to be significantly related to postconcussion complaints on the neurobehavioral symptom inventory, which indicates that much of the symptom complaints in mild TBI patients may be due to emotional distress.[10] Therefore, the identification of postconcussive symptoms and stress is indicated in directing and prioritizing clinical interventions.

Comparison of Neurofeedback Training and Treatment as Usual Groups

This study results indicate significant enhancement in QOL in the NFT group as compared with the TAU group (►**Table 4**, ►**Fig. 1**).

Subgroup analyses of the < 6 months from injury group and 12 to 18 months from injury group indicate that both the groups improved significantly as compared with the TAU groups (►**Tables 5**, **6**).

Table 5 Mann-Whitney U test results for testing difference between the NFT group's pre- to postdifference scores (< 6 months) and TAU group (< 6 months) on WHOQOL-BREF

Variable	NFT (< 6 mo) mean	NFT (< 6 mo) SD	TAU (< 6 mo) mean	TAU (< 6 mo) SD	*p*
WHOQOL-BREF	37.93	14.78	1.00	11.02	**0.000*****

Abbreviations: NFT, neurofeedback training; SD, standard deviation; TAU, treatment as usual; WHOQOL, World Health Organization quality of life questionnaire.
***$p \leq 0.001$

Table 6 Mann-Whitney U test results for testing difference between the NFT group's pre- to postdifference scores (12–18 months) and TAU group (12–18 months) on WHOQOL-BREF

Variable	NFT (12–18 mo) mean	NFT (12–18 mo) SD	TAU (12–18 mo) mean	TAU (12–18 mo) SD	*p*
WHOQOL-BREF	24.15	11.94	0.15	1.91	**0.000*****

Abbreviations: NFT, neurofeedback training; SD, standard deviation; TAU, treatment as usual; WHOQOL, World Health Organization quality of life questionnaire.
***$p \leq 0.001$

Table 7 Mann-Whitney U test results for testing difference between the NFT pre- to postdifference scores comparing the < 6- and 12- to 18-month groups on WHOQOL-BREF

Variable	NFT (< 6 mo) mean	NFT (< 6 mo) SD	NFT (12–18 mo) 0.mean	NFT (12–18 mo) SD	*p*
WHOQOL-BREF	37.93	14.78	24.15	11.94	**0.029***

Abbreviations: NFT, neurofeedback training; SD, standard deviation; TAU, treatment as usual; WHOQOL, World Health Organization quality of life questionnaire.
*$p \leq 0.05$

Table 8 Mann-Whitney U test results for testing difference between the TAU pre- to postdifference scores comparing the < 6 and 12- to 18-month group on WHOQOL-BREF

S. No.	Variable	TAU (< 6 mo) mean	TAU (< 6 mo) SD	TAU (12–18 mo) mean	TAU (12–18 mo) SD	*p*
1.	WHOQOL-BREF	1.00	11.02	0.15	1.91	0.390

Abbreviations: NFT, neurofeedback training; SD, standard deviation; TAU, treatment as usual; WHOQOL, World Health Organization quality of life questionnaire.

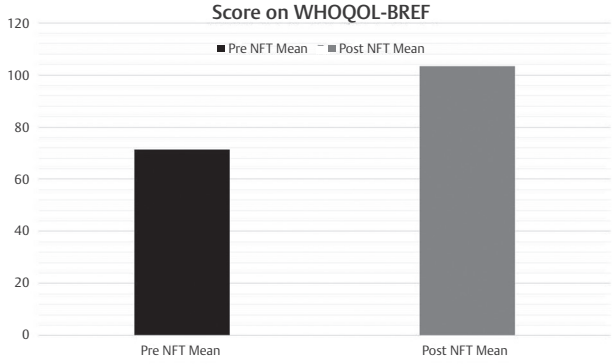

Fig. 1 Bar graph showing significant (*** $p = 0.000$) difference between pre- and postassessment scores on the WHOQOL–BREF in the NFT group. NFT, neurofeedback training. WHOQOL, World Health Organization quality of life questionnaire.

The Influence of Spontaneous Recovery

At postassessment, the 12- to 18-month NFT group had significantly less improvement on the QOL measure as compared with the < 6-month NFT group (►**Table 7**). On the other hand, there was no significant change between the two TAU subgroups (►**Table 8**). This indicates that during the normal course of recovery, without NFT intervention, the amount of improvement in QOL is no different between the < 6- and 12- to 18-month TAU groups. This in itself is a revelation, given the fact that several studies indicate that maximum recovery happens within 6 months and this recovery is not expected to be as significant (and tends to plateau) as we move further from the date of injury.[3] However, it is clear that with neurofeedback, early intervention is more effective in improving QOL in TBI patients.

Limitations of This Study

- The study would have to be replicated in a larger sample.
- The influence of therapist variables could not be accounted for.

Future Directions of This Study

This study results indicate that NFT helps in the improvement of QOL. This study has implications for spontaneous recovery. Future studies could include assessments of cognitive and clinical symptoms and research on electrophysiologic mechanisms of α and θ activity as well as biochemical mechanisms. Future research would require studies on the

structural, functional, electrophysiologic, biochemical, and qualitative ramifications of the intervention.

Declaration of Conflicting Interests
The author(s) declared no conflicts of interest in the research, authorship, and/or publication of this article.

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