Quantitative Electroencephalogram (QEEG) Based Assessment and Treatment in Psychiatry

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Assessment in Psychiatry
Current Standards

- Psychiatry is a specialty dedicated to assessing and treating emotional and cognitive disturbances caused by brain dysfunction.
- The treatment for mental disorders **differs from treatment of all other medical specialties**.
- Modern medicine has embraced imaging technology in almost every field.
- Psychiatrists typically do not use objective measures to guide treatment.
- Psychiatric diagnosis is based on symptoms assessment and management is an “anti-symptom” treatment.

Schematic representation of brain circuitry involved in the mood regulation

Imaging of complex human emotions and behavior poses a challenge.
Neuroimaging in psychiatry

- **Structural brain imaging**
  - CT scan
  - MRI
  - DTI

- **Functional brain imaging**
  - fMRI
  - SPECT/PET
  - QEEG

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**Structural Brain Imaging**

- Evaluates the organization and coherence of white matter fiber tracts
- Gives advantage of conventional MRI techniques – poor visualization of fiber tract direction and organization
**Structural Brain Imaging**

Fiber tracking using DTI techniques

38-year-old patient with TBI 2 weeks after the initial trauma

DTI shows discontinuity of WM tracts within forceps minor

**Functional Brain Imaging**

fMRI signal is related to neuronal activity

Signal intensity in fMRI image is dependent on the local balance between oxygenated and deoxygenated hemoglobin. -> blood oxygenation level-depndency (BOLD) response
Functional Brain Imaging

fMRI Brain While Reading

PET
Positron Emission Tomography

SPECT
Single-Photon Emission Computed Tomography

Healthy Individual

Typical PET imaging results for healthy individuals and a pattern that is common in Alzheimer’s disease.
An epileptic focus can be visualized either in the presence of seizure activity (when blood flow will be increased in the focus) or in its absence (when blood flow will be decreased in the focus).

Functional Brain Imaging

Different patterns of activity seen in depressed patients

Quantitative EEG

- QEEG refers to quantitative signal analysis of the digitized electroencephalogram.
- EEG (electroencephalography) is a measurement of the brain electrical activity generated by pyramidal neurons (postsynaptic potentials) in cerebral cortex.
- EEG (electroencephalography) has been widely used in clinical practice since 1935 (Gibbs et al. 1935).
- Classically, EEG frequency bands are divided into:
  - Gamma: >30 Hz
  - Beta: 12-30 Hz
  - Alpha: 8-12 Hz
  - Theta: 4-8 Hz
  - Delta: 0.5-4 Hz

References: Neuropsychiatry and Quantitative Electroencephalography in the 21st Century. 2011
EEG in psychiatry

- Historically, visually recognized EEG patterns were used to discern etiological aspects of the brain dysfunction related to psychiatric disorders (e.g., temporal seizures in aggressive patients, absence seizures as a differential for ADHD).

QEEG in psychiatry

- However, in the absence of seizures, in psychiatry there are no specific waveforms seen that could distinguish between different neuropsychiatric disorders.
- Electrophysiological differentiation of patients however may be obtained by demonstrating a quantitative difference between the patient’s and a normal brain.
- The early works on quantification of EEG go back to 1938 (Grass et al., 1938).
- Since 1980s, QEEG has evolved into a neuroimaging technique that accurately quantifies the three-dimensional current sources of the electroencephalogram (Thatcher et al., 1994).
Life span Normative EEG database

- Number of normative databases were developed: first one by Matousek and Peterson in 1973, and later by John, Duffy, Thatcher and Congedo and Lubin.

- Subsequent replication of different qEEG normative databases demonstrated the statistical stability and value of using reference NC to aid in identifying deviant EEG features and in linking the location of findings to symptoms.

- Life span Normative EEG database meets criteria for a clinical normative database:
  - 1. Full disclosure of the demographics, sampling procedures and technical details of the database
  - 2. Representative demographic sampling and certainty that only normal or non-clinically compromised subjects are included
  - 3. Large enough sample size at different ages to measure properly any non-invariances in development
  - 4. Non-artifact EEG samples with proper amplifier and digital sampling procedures
  - 5. Correct statistical properties of the database sample to ensure interpretable parametric statistical analysis.


Life span Normative EEG database

- Total sample size N = 900 and spans the age range from 2 months to 82 years. The largest number of subjects are in the younger ages 1-6 years to reflect EEG changes related to brain development.

- Database constitutes a representative sample of the general population of neurologically and clinically normal individuals
  - Neurological history
  - Developmental history
  - Prenatal history
  - Family history
  - Physical examination
  - No history of neurological, mental, emotional, or other nature.
  - No abnormal exam with regards to mental and physical development.

- The database was fit to a Gaussian distribution and cross-validated by independent researchers and the results published in various journals.


Value of Quantitative EEG

- QEEG is distinguish from regular EEG with the latter showing low reliability (0.2 to 0.29) and poor inter-rater agreement for non-epilepsy evaluation.

- In contrast, QEEG is greater than 0.9 reliable and remains stable with high test-retest reliability over many weeks and even years: 1-3 years.

- QEEG reveals “…a level of specificity and sensitivity that is comparable to sonograms, blood tests, MRI’s and other diagnostic measures commonly used in clinical practice.”

(Thatcher, R., Nelson, D., John, A., Duffy, P., et al., 1995)
Quantitative EEG

• The scientific literature demonstrates significant correlation between QEEG and independent measures: MRI, SPECT, and PET.

Quantitative EEG

• QEEG studies help with:
  1. Evaluation and differential diagnosis
     • Different psychiatric disorders show EEG maps that differ statistically both from each other and from normal controls.
  2. Treatment selection and evaluation of treatment efficacy:
     • Pharmaco-EEG
     • Challenge studies

Evaluation of mTBI
Quantitative EEG- mTBI

- Measures of EEG spectral analyses were obtained from a total of 608 mild head trauma patients
- The independent cross validations of the discriminant function yielded accuracy between 92.3 and 96.2%
- The discriminating EEG power spectral analyses indicated 3 classes of neurophysiological variables which are attributable to mechanical injury:
  - 1. increased coherence and decreased phase in the frontal and frontal-temporal regions
  - 2. decreased power differences between anterior and posterior cortical regions
  - 3. reduced alpha power in the posterior cortical regions.


### Table 1

<table>
<thead>
<tr>
<th>Neurophysiologic Disorder</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Disorders, Attention Deficit Disorder</td>
<td></td>
</tr>
<tr>
<td>ADHD/ADHD vs control</td>
<td>82</td>
</tr>
<tr>
<td>ALT vs control</td>
<td>95</td>
</tr>
<tr>
<td>LD vs control</td>
<td>74</td>
</tr>
<tr>
<td>SLT vs control</td>
<td>96</td>
</tr>
<tr>
<td>ADHD/ADHD vs LD</td>
<td>93</td>
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<tr>
<td>ALT vs SLT</td>
<td>69</td>
</tr>
<tr>
<td>Dementing Disorders</td>
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<tr>
<td>Dementia AD, MCI, FTD vs control</td>
<td>80</td>
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<tr>
<td>AD vs MCI</td>
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<tr>
<td>AD vs FTD</td>
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<tr>
<td>Vascular vs nonvascular dementia</td>
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<tr>
<td>Dementia vs depression</td>
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<tr>
<td>Mood Disorders</td>
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<tr>
<td>Depressed vs control</td>
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<tr>
<td>Depression vs dementia</td>
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<tr>
<td>Unipolar vs bipolar depression</td>
<td>85</td>
</tr>
<tr>
<td>Depression vs schizophrenia</td>
<td>86</td>
</tr>
</tbody>
</table>

qEEG: quantitative electroencephalography; AD: Alzheimer’s disease; ADD, attention deficit disorder; ADHD, attention deficit-hyperactivity disorder; MCI, minimally demented not meeting criteria for ADHD or ADHD, FTD, frontotemporal dementia; LID, learning disability; MCI, minimally demented; SLT, speech and language development disability. Adapted from Chabot et al. 2005.

Quantitative EEG studies of ADHD

Adults with ADHD show 2 types of brain patterns specific to ADHD:
- Subtype 1: increased theta absolute and relative power
- Subtype 2: reduced relative theta and increased relative beta power

Children with ADHD showed 3 different types of brain patterns specific to ADHD:
- Subtype 1: increased total power, increased relative theta, and decreased relative delta and beta waves
- Subtype 2: increased relative theta and decreased relative alpha and increased central/posterior relative delta
- Subtype 3: increased relative beta and decreased relative alpha activity.

Chabot, Michele and Prichep. Role of qEEG in child and adolescent psychiatric disorders. 2005

The value of qEEG in diagnosing ADHD was recognized by The U.S. Food and Drug Administration - July 15, 2011.
Quantitative EEG

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Pharmaco-EEG
ADHD - challenge studies

After 20mg of Ritalin
Stable on stimulant

After 20mg of Ritalin
Stable on antiseizure medication

Pharmaco-EEG
Key-Lock principle

Representative drugs of the main psychopharmacological classes induce significant and typical changes to normal human brain function, which in many variables are opposite to the changes in the brain function induced by different psychiatric disorders.
Role of Brodmann area 25 in depression

Nuclear medicine studies

Quantitative EEG

Published studies reported correlation between a patient’s pre-treatment qEEG features and medication outcome, without regard to DSM disorder.

• The subgroup with features including alpha frequency excess responded favorably to antidepressants
• The subgroup with theta frequency excess responded favorably to stimulants
• The subgroup with features including coherence deviation responded to lithium and anticonvulsants

Suffin S.C. and Ininary W.H. 1995

Is clinical presentation alone sufficient to guide a treatment?

• Case 1:
  – 14 yo girl with clinical presentation of MDD of 3 weeks duration.
  – FHx - depression, eating disorder
• Case 2:
  – 19 yo college student with clinical symptoms of MDD of 2 months duration
  – FHx - bipolar disorder
• Case 3:
  – 36yo female with life long history of depression. She failed trials of: Prozac, Zoloft, Effexor, Wellbutrin, Ritalin, Concerta
  – FHx - none
Case 1
The pt is stable on antiseizure medication

Case 2
The pt is stable on SSRI

Case 3
The pt is stable on antipsychotic mediation

**Value of Brain Imaging in psychiatric treatment—Case presentation**

- Case of 42 yo Caucasian male with history of
  - Seizure (on Neurontin 900mg bid and 1500mg qhs) sec. to abscess which was removed 3 yrs prior
  - Depression (on Effexor XR 150mg qam)
  - Violent behavior

Pt was brought by his sister to Hines ER. Pt was arrested after he attacked his wife. Pt was taken to jail where he attempted suicide by cutting his veins with a staple. Pt was discharged several days prior to this visit. He is staying with his sister since his wife has an order of protection against him.

• Aggressive behavior was resolved after stopping Effexor.

• The patient returned home however, he continued to feel depressed

• *Depression resolved after phenobarbital was started*


QEEG in Psychiatry

The objective brain imaging techniques do not substitute for neuropsychiatric evaluation, however...

• the brain studies may aid in evaluation, differential diagnosis and treatment selection

• Initial quantitative EEG profiles may distinguish among patients with the same DSM diagnosis who will respond preferentially to different medications or who will display different evolution of illness.

• Medication efficacy can be improved and side effects minimized through the use of QEEG techniques to guide the prescription

Q&A