PATIENT INFORMATION

Name: ME/CFS Patient
Age: 51.37
Gender: F
Handedness: R
Eyes: Closed

RECORDING

Date: 12/21/2018
Test Site: Chicago, IL
Analysis Length: 02:52
Ave. SH Reliability: 0.97
Ave. TRT Reliability: 0.93

MEDICATIONS: Acyclovir, Sulfasalazine
- Acyclovir stops viral replication but does not kill the virus(es)
- Sulfasalazine is a DMARD (Disease-Modifying Anti-rheumatic Drug) which decreases neural inflammation.

HISTORY: This 51 year-old ME/CFS patient was diagnosed with a brain infection in 2007. This infection became chronic, which then became Myalgic Encephalitis.

SUMMARY: The quantitative EEG (qEEG) analyses were deviant from normal, indicating dysregulation in the bilateral frontal lobes, bilateral temporal lobes especially in the right temporal lobe, bilateral parietal lobes especially in the right parietal lobe and bilateral occipital lobes, especially in the right occipital lobe. Standardized weighted low-resolution electromagnetic tomography (swLORETA) analyses revealed dysregulation in the left posterior insula, the left retrosplenial cortex and right parahippocampal gyrus.

The frontal lobes are involved in executive functioning, abstract thinking, expressive language, sequential planning, mood control and social skills. The temporal lobes are involved in auditory information processing, short-term memory, receptive language on the left and face recognition on the right. The parietal lobes are involved in visual-spatial information processing, short-term memory, executive attention, receptive language on the left and empathy control and awareness of emotional expression in others on the right (e.g., prosody). The occipital lobes are involved in the visual processing of color, form, movement, visual perception and spatial processing. The posterior insular cortex is involved in autonomic system regulation and interoceptive representation of the physiological condition of the body. The parahippocampal gyrus is involved in the creation of new memories, retrieval of short-term memory and attention control, and the retrosplenial cortex is involved with spatial navigation, episodic memory, navigation, imaging future (expected) events and overall spatial working memory. To the extent there is deviation from normal electrical patterns in these structures, then sub-optimal functioning is expected.

There was significant deviation in the retrosplenia cortex (6-8 standard deviations from normal), which indicates increased errors of omission. The retrosplenial cortex is especially involved with response conflict, such as Stroop items. It supports cognition through extensive hippocampal connections and frontal lobe connections.
swLORETA connectivity analyses revealed significant deviations from normal across all frequency bands, involving most Brodmann areas of the brain. At the inception of EEG in 1929, Hans Berger (Finger, 2000) observed the oscillatory nature of the human EEG and subsequent research has found that different rhythmic attributes (frequency bands) have dissimilar physiological significances and mental states as well as different temporal patterns related to brain function.

**Delta activity (~1 – 3 Hz),** for example, is produced by cortico-cortical and cortico-thalamic networks and is involved in basic homeostatic processing, restorative sleep, salience recognition, and language. 1-3 Hz is also involved in slowing of EEG background activity, which has been associated with many neuroinflammatory conditions and neurotropic virus infections. Increases in delta activity have been implicated in studies of Alzheimer’s disease and may demonstrate a link between brain states, arousal, and efficiency, with decrements in information processing speed, which is typically found in ME/CFS.

The **theta frequency band (~4 – 7 Hz)** originates in the thalamus and limbic system and is associated with a variety of cognitive functions, especially memory retrieval and new learning. Theta is known to arise from synchronized neurons (pacemakers) in the limbic system, including the cingulate gyrus and the parahippocampal cortex. It is considered important for a variety of cognitive functions including memory consolidation, spatial navigation, working memory and memory encoding.

**Alpha rhythms** are divided into two parts, **low alpha (8 – 10 Hz) and high alpha (10 – 12 Hz).** There is a large body of evidence indicating that alpha amplitude is associated with the level of cortical activation, especially in perception and attention. High alpha is strongly associated with accuracy in forming cognitive representations of various physiological states, which is known as “being in the zone.” Encouraging this state is usually a core element in optimal performance training.

**Beta rhythms (13-30 Hz)** are hypothesized to be generated in the cortex and appear to be related to movement activity, both planned and actual movement. Beta activity is often subdivided into several bands. Beta-1 (13 – 18 Hz), is associated with problem-solving and forming accurate mental representations. Physiologically, it is also associated with tense muscles and tends to occur when sensory-motor loops are interrupted. Beta-2 (19 – 21 Hz) is also associated with problem-solving and representations but more associated with attention and higher cognitive functions. Beta-3 (22 – 30 Hz) is strongly related to worry and rumination, including other cognitive distortions and general feelings of being “stressed.”

**Dr. Mark Zinn and Dr. Marcie Zinn**
DETAILED NARRATIVE

**LINKED EARS:** The Linked Ears power spectral analyses were deviant from normal with excessive power in the bilateral frontal regions at 9 Hz, excessive power was present in bilateral temporal regions especially in the right temporal region from 3 - 4 Hz and 8 - 9 Hz, excessive power was present in bilateral parietal regions especially in the midline parietal region at 7 Hz and excessive power was also present in bilateral occipital regions especially in the right occipital region at 4 Hz and 7 - 9 Hz. *Excessive power may indicate compensatory mechanisms (when the brain uses an alternate brain region to do the work of another similar region which is deregulated).*

**SURFACE LAPLACIAN:** The Laplacian power spectral analyses were deviant from normal with excessive power in midline frontal regions at 9 Hz, excessive power was present in the left temporal region at 9 Hz and excessive power was also present in the right occipital region at 4 Hz. *The Laplacian montage is useful because it ignores medication effects and other environmental effects.*

**CONNECTIVITY ANALYSES, EEG:** EEG amplitude asymmetry, coherence and EEG phase were deviant from normal, especially in frontal, temporal, parietal and occipital relations. Elevated coherence was present in frontal, temporal and occipital regions which indicates reduced functional differentiation. Reduced coherence was present in frontal, temporal, parietal and occipital regions which indicates reduced functional connectivity. Both conditions are often related to reduced speed and efficiency of information processing.

**EEG BIOFEEDBACK RECOMMENDATIONS:** The following implications for neurotherapy are offered based upon the clinical evaluation of the patient as well as the reference database results. These suggestions for neurotherapy should be evaluated with caution and should only be considered as possible strategies that the clinician may have considered in his/her evaluation. If the patient is depressed, then the clinician should consider treating this condition first through alpha frequency enhancement or some other biofeedback protocol that may reduce depression. If depression or poor mood and/or motivation is not a problem then the clinician may consider using one or more strategies with the priority of treatment in the order presented below.

**Linked Ears Z Score biofeedback:**

1- Suppress toward Z = 0 frequency activity 4 Hz at O2.
2- Suppress toward Z = 0 frequency activity 3 - 4 Hz at T6.
3- Reinforce EEG coherence toward Z = 0 at 8 - 10 Hz between F3 and Pz.

**LORETA Z Score biofeedback:**

1- Suppress toward Z = 0 at 4 Hz, Right Brodmann area 30.
2- Suppress toward Z = 0 at 9 Hz, Left Brodmann area 13.
Conventional EEG Samples and Quantitative EEG Analyses

Example of Linked Ears EEG and Absolute Power - Eyes Closed Condition

Example of Laplacian EEG and Absolute Power - Eyes Closed Condition
Results of the qEEG data: The data in this report is given in Z-scores. Z-scores allow direct comparison with all the scores in this document. If the Z score is either less than -1.96 or more than 1.96, the result is significant at the .05 level.
Electrical Neuroimaging
SwLORETA Connectivity Analyses

**NEUROIMAGING:** SwLORETA 3-dimensional source analyses were consistent with the scalp surface qEEG and indicated excessive current sources in right and left Parahippocampal Gyri with a maxima at 4 Hz in most Brodmann areas. There was dysregulation in most Brodmann areas, especially BA30 (retrosplenial cortex), 27 & 35. Elevated swLORETA current source also were present in the left Posterior Insula with a maximum at 9 Hz (Brodmann areas 13, 29 & 40).

Linking a patient's symptoms and complaints to functional systems in the brain is important in evaluating the health and efficiency of cognitive and perceptual functions. The electrical rhythms in the EEG arise from many sources but approximately 50% of the power arises directly beneath each recording electrode. Electrical neuroimaging uses a mathematical method called an "Inverse Solution" to accurately estimate the sources of the scalp EEG (Pascual-Marqui et al, 1994; Pascual-Marqui, 1999). Below is a Brodmann map of anatomical brain regions that lie near to each 10/20 scalp electrode with associated functions as evidenced by fMRI, EEG/MEG and PET neuroimaging modalities.
swLORETA CONNECTIVITY ANALYSIS: both significantly reduced (blue & dark blue) and significantly elevated (yellow & red) lagged coherence and phase differences were present in frontal, temporal, parietal and occipital regions, indicating reduced information flow, processing speed and less functional differentiation in nearly all brain networks. These effects were present in frontal, temporal, parietal and occipital regions, including the Central Autonomic Network, which is part of the autonomic nervous system (ANS). These conditions are often related to significantly slowed speed and efficiency of information processing, and dysfunction in the Central Autonomic Network is associated with severe fatigue and energy loss, as well as many other autonomic symptoms.

You can find various Brodmann areas in the maps below:
BRAIN BRODMANN REGIONS

FRONTAL BRODMANN AREAS

TEMPORAL BRODMANN AREAS

PARietAL BRODMANN AREAS

OCCIPITAL BRODMANN AREAS

LEFT  RIGHT
swLORETA Z Score connectivity analyses at 1-3 Hz and 4-7 Hz, all networks.

<table>
<thead>
<tr>
<th>All networks, 1-3 Hz, Lagged Coherence</th>
<th>All networks, 4-7 Hz, Lagged Coherence</th>
</tr>
</thead>
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swLORETA Z Score connectivity analyses at 1-3 Hz and 4-7 Hz, Dorsal and Ventral attention networks.

<table>
<thead>
<tr>
<th>1-3 Hz, Lagged Coherence</th>
<th>4-7 Hz, Lagged Coherence</th>
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<tr>
<td>Dorsal Attention Network, Ventral Attention Network</td>
<td>Dorsal Attention Network, Ventral Attention Network</td>
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</table>
swLORETA Z Score connectivity analyses at 1-3 Hz and 4-7 Hz, Default Mode Network, Executive Network, Language Network and Pain Network.

- **The Default Mode Network** relates to one’s internal narrative or the ‘autobiographical self’ during rest and when not engaged in a task. **The DMN is not related to attention** (is orthogonal to attention) and includes episodic memory and ‘theory of mind.’ It is the most extensive network known and one of the first networks mapped in the human brain. It helps to understand that the DMN is not the result of environmental events around us; it is solely our own internal mentation, remaining active during loss of consciousness.

- **The Executive Network** performs functions such as judgement, decision-making, self-monitoring, organizing, behavioral inhibition, memory formation, planning, etc. When dysregulated (as here), the result is poor working memory and distractibility. This person has issues surrounding memory.

- **The Language Network** comprises both expressive functions (what you say or think) and receptive functions (understanding what is said). This network encompasses word-finding issues, common in neurological disorders. This person has word-finding problems and often has halting speech.

- **The Pain Network** mediates pain. It is interesting to know that “pain is in the brain.” When one has pain, it is being produced by the brain in response to something wrong in the body. Something happens, such as hitting your knee accidentally on a door jamb. The pain then is sent to your brain, and you feel the pain, localized in the knee. The actual pain is not produced in the knee, but in your brain.
swLORETA Z Score connectivity analyses at 1-3 Hz and 4-7 Hz, Salience Network, Tinnitus Network, Central Autonomic Network and Face, Object Recognition Network.

- **The Salience Network** is involved in switching between the Executive Network and the Default Mode Network. Our research indicated that this process is compromised in ME/CFS in that the switching is not complete. In the Salience Network, sensory and limbic inputs are processed by the anterior insula which processes attended-to events. It is also very involved in the maintenance of homeostasis. Dysregulation in this network can cause symptoms of depression.

- **The Tinnitus Network** is the perception of auditory noise or ringing in one’s ears. It is not a primary symptom itself, but is instead a symptom of a neurological disorder.

- **The Central Autonomic Network** is the cortical portion of the autonomic nervous system (ANS). The ANS regulates homeostasis and damage in the ANS results in much disability or even death. The ANS produces a wide variety of symptoms and can be managed using Biofeedback.

- **Face and Object Recognition** is what it sounds like.
These are all known symptoms of ME/CFS as well as most neurological disorders. Your diagnosis made by your physician is ME/CFS and this report confirms that diagnosis.

There are other symptoms we can display which are not seen here. However, this report is very thorough and when combined with other types of evidence that you likely have from other providers, a picture emerges that confirms your diagnosis.
Here is a “neuro-typical” person (someone without a neurological disorder):

Lagged Coherence, 1-3 Hz (delta)  Lagged Coherence, 4-30 Hz
An Addendum to NeuroGuide qEEG Report

Important Disclaimer:

QEEG tests are ancillary tests similar to blood tests, that are not intended to provide a diagnosis by themselves, but are used to evaluate the nature and severity of dysregulation in the brain such as in ME/CFS or in any of the other 600+ neurological disorders. The QEEG tests provide a quantitative assessment of areas of brain dysfunction and information regarding impaired conduction and connectivity between different regional neural networks in the brain. The assessment of impaired connectivity is based on abnormal measurements of Coherence and Phase. The diagnosis of MTBI is a clinical one and is not based on any one test. A diagnosis is performed by the clinician, who integrates the medical history, clinical symptoms, neurocognitive tests with the abovementioned brain function tests as well as other information to render a diagnosis. The information on impaired brain connectivity is derived primarily from abnormal measurements of Coherence and Phase. Assessments of regional abnormality rely also on abnormal amplitude (power) distribution across the spectrum of EEG frequencies as compared to the normative database.

Artifact Rejection:

NeuroGuide uses the standard deletion of artifact method to only select artifact free EEG data for analyses. The entire EEG record must be viewed by clicking end and page down and page up and home and by arrow keys and by moving the wiper at the bottom of the screen. A careful visual examination of the EEG record is necessary to detect gross pathology as well as to identify artifacts. The goal is to avoid selecting any artifact and instead to only select artifact free segments of EEG.

View the Test Re-Test reliability which must be at least 0.90. Scan the EEG record and select real and valid EEG and avoid selecting artifact. Splice discontinuities are removed by filtering and exercises to prove no distortion due to splicing are available in the Handbook of QEEG and EEG Biofeedback. Pattern recognition routines are used to identify likely eye movement (EOG), drowsiness and muscle (EMG) artifact in the record and thereby mark these suspected segments and disallow them to be included in subsequent analyses. The pattern recognition routines are based on physics and physiology of artifact. For example, all electrical sources decrement with distance and in the case of eye movement detection is by the presence of an electrical field gradient in the delta frequency band from Fp1/2 > F3/4 > C3/4 and/or 120 degrees or higher of inverse phase between F7 and F8. EMG electrical gradients at > 10 Hz from T3/4 > C3/4 and/or Fp1/2 > F3/4 > C3/4 and/or O1/2 > P3/4. Drowsiness occurs when the locus coeruleus reduces inhibition on the hypothalamic sleep centers resulting in 2 - 4 Hz action potential bursting that projects to the ventral posterior thalamic relay nuclei. Drowsiness pattern detection involves elevated slow waves in the EEG maximal in Cz and Fz as well as alpha slowing. NeuroGuide does not use any regression methods to allegedly remove artifact such as ICA/PCA or Blind Source or unpublished methods like SARA that distort Phase and Coherence and other aspects of the Power Spectrum. Details and tutorials demonstrating how the ICA and regression methods distort Phase and Coherence are available at: https://www.appliedneuroscience.com/PDFs/Tutorial_Adulteration_Phase_Relations_when_using_ICA.pdf.

Split Half and Test Re-Test Reliability:

Split-Half (SH) reliability is the ratio of variance between the even and odd seconds of the time series of selected digital EEG (variance = sum of the square of the deviation of each time point from the mean of the time points). Examine the average reliability and the reliability of each channel as you increase the length of the sample and manually select different segments. Selection of artifact free EEG should have a reliability > 0.95 and a sample length of edited EEG > 60 seconds. Test Re-Test (TRT) reliability is the ratio of variance between the first half vs. the second half of the selected EEG segments (variance = sum of the square of the deviation of each time point from the mean of the time points). Test Re-Test reliability > 0.90 and a sample length of edited EEG > 60 seconds is commonly published in the scientific literature. Test Re-Test reliability is an excellent statistic to compare Brain state changes such as drowsiness as well as the consistency of a measure independent of changes in brain state.
This record supports the following reliability estimates:

<table>
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<tr>
<th>Montage: LinkEars</th>
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<tbody>
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<tr>
<td>Edit Length: 02:52</td>
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<tr>
<td>C3</td>
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| Sampling Rate: 256 |
| Collection Hardware: BrainMaster Discovery |
Description of the NeuroGuide Normative Database:

The NeuroGuide normative database in versions 1.0 to 2.4.6 included a total of 678 carefully screened individual subjects ranging in age from 2 months to 82 years. NG 2.6.8 involved the addition of 49 adult subjects ranging in age from 18.3 years to 72.6 years resulting in a normative database of 727 subjects. The inclusion/exclusion criteria, demographics, neuropsychological tests, Gaussian distribution tests and cross-validation tests are described in several peer-reviewed publications (Thatcher et al, 1983; 1987; 2003). Two year means were computed using a sliding average with 6 month overlap of subjects. This produced a stable and higher age resolution normative database with a total of 21 different age groups. The 21 age groups and age ranges and number of subjects per age group is shown in the bar graph in Appendix F figure 2 in the NeuroGuide Manual (click Help > NeuroGuide Help).

The individuals used to create the normative database met specific clinical standards of no history of neurological disorders, no history of behavioral disorders, performed at grade level in school, etc. Most of the subjects in the normative database were given extensive neuropsychological tests. Details of the normative database are published at: Thatcher, R.W., Walker, R.A. and Guidice, S. Human cerebral hemispheres develop at different rates and ages. Science, 236: 1110-1113, 1987 and Thatcher R.W., Biver, C.L., North, D., Curtin, R. and Walker, R.W. Quantitative EEG Normative Databases: Validation and Clinical Correlation. Journal of Neurotherapy, 2003, 7(3-4): 87-121. You can download a description of the normative database by going to https://appliedneuroscience.com/scientific-articles/ and clicking on Article #5.

Is there a normative database for different montages including bipolar montages?

Yes. The raw digital data from the same group of normal subjects is analyzed using different montages such as Average Reference, Laplacian current source density, a common reference based on all 19 channels of the 10/20 system and standard clinical bipolar montages (e.g., longitudinal, circular, transverse). Users can create any montage that they wish and there will be a normative reference database comparison available for both eyes closed and eyes open conditions.

Age range of the swLORETA Current Density and Source Correlation Normative Databases

The swLORETA current density and source correlation norms use the same subjects as are used for the surface EEG norms and the age range is 2 months to 82 years. The computational details of the LORETA current density norms are published at: Thatcher, R.W., North, D., Biver, C. EEG inverse solutions and parametric vs. non-parametric statistics of Low Resolution Electromagnetic Tomography (LORETA). Clin. EEG and Neuroscience, 36(1): 1-9, 2005 and Thatcher, R.W., North, D., Biver, C. Evaluation and Validity of a LORETA normative EEG database. Clin. EEG and Neuroscience, 2005, 36(2): 116-122. Copies of these publications are available to download from https://appliedneuroscience.com/scientific-articles/ by clicking on article nos. 11 and 12.

Implementation of swLORETA measurement in NeuroGuide

The neuro-navigator swLORETA viewer (Applied Neuroscience, Inc., 2019) can be launched by a single mouse click in the NeuroGuide window. NeuroGuide exports frequency domain and time domain edits of 19 channel x 256 point digital EEG in microvolts (or uv^2) in the Lexicor electrode order as the standard input to the Key Institute T-Matrix. Rows are 256 microvolt time points and the columns are 19 channels at a sample rate of 128 thus producing 0.5 Hz resolution from 1 to 30 Hz. 1 Hz increments in the swLORETA viewer are computed as the sum of adjacent 0.5 Hz bins and thus the ‘Time Frame’ control in the LORETA Viewer is frequency from 1 to 30 Hz. (see Pascual-Marqui RD, Michel CM, Lehmann D., 1994. Low resolution electromagnetic tomography: a new method for localizing electrical activity in the brain. International J. of Psychophysiology, 18:49-65. For computational details see: Pascual-Marqui. R.D., 1999. Review of Methods for Solving the EEG Inverse Problem. International J. of Bioelectromagnetism, 1(1): 75-86. Pascual-Margui, R.D., 2004.)
Amplifier Matching is Necessary

This stems from the fact that amplifiers have different frequency gain characteristics. The matching of amplifiers to the NeuroGuide database amplifier was done by injecting microvolt calibration signals of different amplitudes and frequencies into the input of the respective EEG machines and then computing correction curves to exactly match the amplifier characteristics of the norms and discriminant functions. The units of comparison are in microvolts and a match within 3% is generally achieved. The NeuroGuide research team double checked the amplifier match by computing FFT and digital spectral analyses on calibration signals used to acquire the norms with the calibration signals used to evaluate a given manufacturers amplifiers.

History of the Scientific Standards of QEEG Normative Databases


References


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