CHAPTER 3

ELECTROENCEPHALOGRAPHY AND MILD TRAUMATIC BRAIN INJURY

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Abstract: This chapter is a review and analysis of quantitative EEG (qEEG) for the evaluation of the locations and extent of injury to the brain following rapid acceleration/deceleration trauma, especially in mild traumatic brain injury (TBI). The earliest use of qEEG was by Hans Berger in 1932 and since this time over 1,600 peer reviewed journal articles have been published in which qEEG was used to evaluate traumatic brain injury. Quantitative EEG is a direct measure of the electrical energies of the brain and network dynamics which are disturbed following a traumatic brain injury. The most consistent findings are: 1- reduced power in the higher frequency bands (8 to 40 Hz) which is linearly related to the magnitude of injury to cortical gray matter, 2- increased slow waves in the delta frequency band (1 to 4 Hz) in the more severe cases of TBI which is linearly related to the magnitude of cerebral white matter injury and, 3- changes in EEG coherence and EEG phase delays which are linearly related to the magnitude of injury to both the gray matter and the white matter, especially in frontal and temporal lobes. A review of qEEG reliability and clinical validation studies showed high predictive and content validity as determined by correlations between qEEG and clinical measures such as neuropsychological test performance, Glasgow Coma Scores, length of coma and MRI biophysical measures. Inexpensive and high speed qEEG Neurolmaging methods were also discussed in which the locations of maximal deviations from normal in 3-dimensions were revealed. Evaluation of the sensitivity and specificity of qEEG with a reduced number of EEG channels offers the feasibility of real-time monitoring of the EEG using Blue Tooth technology inside of a football helmet so that immediate evaluation of the severity and extent of brain injury in athletes can be accomplished. Finally, qEEG biofeedback treatment for the amelioration of complaints and symptoms following TBI is discussed.

Keywords: qEEG; Mild traumatic brain injury (MTBI); LORETA; EEG biofeedback; Concussion; Neurolmaging of Concussion; Electrochemistry of EEG; EEG current source localization.

1. INTRODUCTION

When evaluating neuroimaging techniques to measure the effects of traumatic brain injury an important fact to keep in mind is that the brain,
while only constituting approximately 2% of our body weight, consumes approximately 60% of total blood glucose (Tryer, 1988). For example, the approximately two and 1/2 pound brain consumes approximately 20% of the total energy of the body, as much as muscles in active contraction at every moment of time (Tryer, 1988). A pertinent question is how is this disproportionate amount of energy utilized? The answer is that most of the brain’s metabolic energy is transformed into electricity by which the essential perceptual, cognitive, emotive, regulatory and motoric functions are carried out at each moment of time.

The human brain is vulnerable to traumatic injury by the fact that it sits on a hard bony vault. Rapid acceleration/deceleration forces often result in contusions or bruising of the frontal and temporal lobes which are located at the interface between the soft tissues of the brain and the hard bone of the skull. For example, because of physics even blunt impacts to the occipital bone result in frontal and temporal brain injuries (Ommaya, 1986; 1994; Sano et al, 1967). In addition to linear percussion forces, rapid acceleration/deceleration often produces shear forces in which different regions of the brain move at different rates resulting in stretching of axons with effects on the myelin and on conduction velocities. Similarly, rotational forces can also be imparted to the brain and both the shear and rotational forces can damage the cerebral white matter as well as brain stem structures even in whiplash injuries (McLean, 1995; Ommaya and Hirsch, 1971). The duration of reduced brain function following traumatic brain injury can be many years even in the case of mild head injuries in which there is no loss of consciousness (Ommaya, 1995, Barth et al, 1983; Rimel et al, 1981).

2. ELECTROCHEMISTRY AND THE EEG

The electroencephalogram or EEG is typically recorded at the scalp surface with reference to the ear and represents the moment-to-moment electrical activity of the brain. The electroencephalogram or EEG is produced by the summation of synaptic currents that arise on the dendrites and cell bodies of billions of cortical pyramidal cells that are primarily located a few centimeters below the scalp surface. The synaptic currents involve neurotransmitter storage and release which are dependent on the integrity of the sodium/potassium and calcium ionic pumps located in the membranes of each neuron. Metabolic activity is the link between EEG/MEG and PET, SPECT and fMRI which are measures of blood flow dynamics. Glucose regulation and restoration of ionic concentrations occurs many milliseconds and seconds and minutes after electrical impulses and synaptic activity and therefore, blood flow changes are secondary to the