경막혈종및 뇌내압 증가에 따른 청각 유발전위의 분석

임 재 중
인제대학교 보건대학 의용공학과

EVALUATION OF AUDITORY EVOKED POTENTIALS IN WHITE NEW ZEALAND RABBITS WITH SIMULATED SUBDURAL HEMATOMA AND INCREASED INTRACRANIAL PRESSURE

Im, Jae Joong
Department of Biomedical Engineering, Inje University

ABSTRACT

Development of a noninvasive intensive care system calls for the use of evoked potentials (EPs), as a means of diagnosing traumatic head-injured patients. The experiment entails surgically placing two subarachnoid bolts and a subdural balloon through the skull to simulate a subdural hematoma. Using various levels of intracranial pressure (ICP) and/or different sizes of balloons, auditory evoked potentials (AEPs) were recorded from a rabbit. Six positive peak latencies (P_1-P_6) and five negative peak latencies (N_1-N_5) were extracted from an averaged AEP waveform. Multiple regression analyses were performed for determining a relationship between the ICP and AEP peak latencies. The results indicate that a major correlation of changes on AEP peak latencies is due to mechanical forces of a mass (inflated balloon simulating a hematoma) in the distortion of the brain matter rather than increased ICP.

INTRODUCTION

Head injury, a serious health problem in all industrial nations, is a significant factor in more than half of all death related to trauma. Intracranial hypertension, the most frequent cause of death related to head injury, must be detected and controlled. Trauma induced changes in the brain, cerebrospinal fluid (CSF), or blood supply (such as, cerebral contusion and subdural hematoma) will cause a change in the ICP. An ICP of greater than 20 mmHg is considered abnormal, resulting in neurological dysfunction and impairment of the brain's electrical activity, as the increased pressure limits the cerebral blood flow[1],[2]. Several major disadvantages are associated with current methods of monitoring, such as the invasive methods which poses a risk of infection to the patient, technical problems in determining reliable ICPs, requirement for surgery, and the availability of monitoring equipment at the site of injury[3]. If a noninvasive means of measuring ICPs were developed and found to have a linear relationship with the ICP, the noninvasive method would be preferred for use on all traumatic head-injured and hydrocephalic patients[4],[5].

The Objective of this experiment is to evaluate the specifications and develop a noninvasive, quantitative, intensive care system for the traumatic head-injured patients by establishing a relationship between the ICP and parameters of the AEPs from an experimental animal group. Several indices will be extracted from the AEP waveform as an electrical manifestation of the brain's reception of and response to an auditory stimulus.

EXPERIMENTAL DESIGN AND METHODS

Experimental Design

The experiment was devised with twelve rabbits divided into three groups. Group 1 and 2 (two rabbits for each group) were used to establish the control for examining the effects of anesthesia and sham surgery, respectively. Group 3 (8 rabbits) was used as an experimental group to study the changes in the AEP's parameters under various experimental conditions.

An ipsilateral recording of the AEP was performed by placing an earphone in the left ear canal. The other earphone was placed in the contralateral (right) ear for white noise generation. The rabbit's auditory system was stimulated by clicks (0.12 milliseconds pulse

duration) with a repetition rate of 5 clicks per second. Once the program performed data collection with 500 clicks, those AEPs were averaged, and an averaged AEP file was saved.

The experimental conditions were generated by surgically placing two subarachnoid bolts and a subdural balloon through the skull. One bolt was used to incrementally raise the ICP by continuously infusing lactated ringers solution (LRS) into the subarachnoid space to maintain four predetermined levels of ICP (15, 20, 25, and 30 mmHg). The second bolt was attached to a pressure transducer to continuously monitor and record the ICP. A balloon was placed in the subdural space and inflated with a known volume of LRS (0.2, 0.4, and 0.6 ml) to simulate a subdural hematoma condition.

Data Collection

Five signals were acquired from each subject, i.e., AEP, electroencephalogram (EEG), electrocardiogram (ECG), arterial blood pressure (ABP), and ICP. The overall equipment setup for the experiment is shown in Fig.1. Each signal was input to a 12-bit analog-to-digital (A/D) converter, and digitized at a specific sampling rate. The EEG, ECG, ABP, and ICP data were sampled at a sampling rate of 128 samples per second for the duration of 16 seconds. The AEP data were sampled at a sampling rate of 25,600 samples per second for the duration of 10 milliseconds. After each trial of data collection, the data were transfered to an IBM PS/2 and stored on the hard disk for further processing and analysis.

Data Processing and Analysis

After the program has stored the averaged AEP, several indices of measures were extracted from averaged AEP waveform peaks as measurements of absolute latencies in milliseconds (ms). The parameters extracted include the first six positive peak latencies (P_1 through P_6) and the first five negative peak latencies (N_1 through N_5) of the waveform. Interpeak latencies, P_1-P_3, P_1-P_5, and P_3-P_5 were also calculated from the waveform as a measure of central conduction time (CCT).

Multiple regression analyses were performed to determine a relationship between the ICP and regressor variables: positive/negative peak latencies. An R-square value was obtained as a measure which indicates the portion of the total variation that is attributed to the fit.

RESULTS AND DISCUSSION

Damage along the eighth nerve or brainstem pathway impedes the neural ability to conduct electrical impulses. One indication of neurological dysfunction revealed in the AEP trace is prolonged peak latencies. The abnormality may be localized to a more precise area of the brainstem depending on whether the time delay exists between any combination of waves, from which clear peak latencies can be drawn.

In the first statistical study, the effects of anesthesia and/or sham surgery (without either increasing ICP or inflating balloon) were evaluated with Group 1 and Group 2. Two groups showed no significant

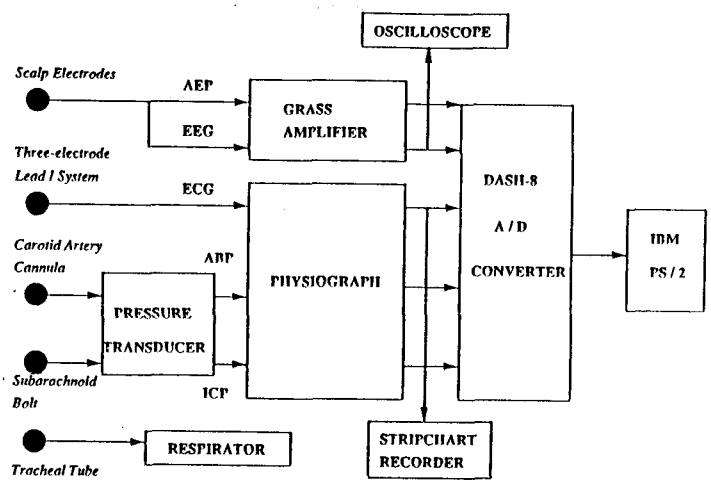

Fig.1. The overall equipment setup for the experiment.

changes at a 0.05 significant level on the mean differences of the AEP parameters. This infers that there is no significant adverse effect caused by anesthesia and/or surgery.

For the experimental group, Fig.2 shows the AEP waveforms at baseline ICP and at four increased levels of ICP with 0.6 ml of balloon inflation. Vertical lines at P_3, P_4, and P_6 illustrate the latency prolongation in AEP waveforms at increased ICP levels. Fig.3 and Fig.4 compare the changes on AEP parameters under combined experimental conditions. In Fig.3, mean differences increase rapidly as the size of the balloon is varied while maintaining the ICP constant, but there are no definite increase in mean differences between ICP levels. On the other hand, Fig.4 shows the mean differences increase gradually between different sizes of the balloons. There are no fluctuations in the mean differences between different sizes of the balloon.

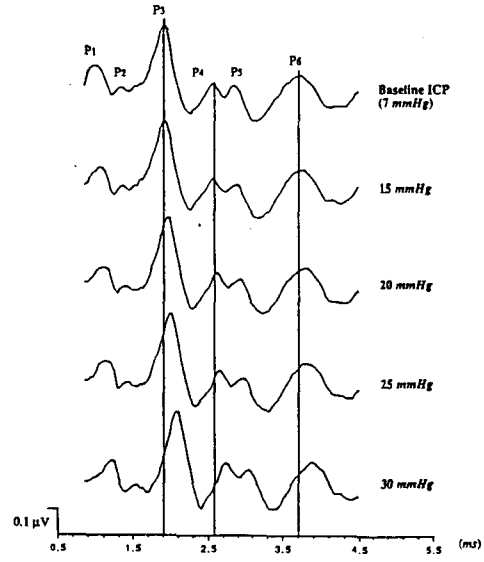

Fig.2. The AEP waveforms at baseline ICP and at four increased levels of ICP with 0.6 ml of balloon.

Based on the best subset of variables selected for each experimental treatment, Table I summarizes the R^2 values for each experimental treatment. At a balloon inflation of 0.2 ml and 0.4 ml, AEP parameters are correlated to the various ICP levels with the R^2 values of 0.329 and 0.389, respectively. The experimental treatment in which the ICP is varied while maintaining the balloon size at 0.6 ml had the highest R^2 value of

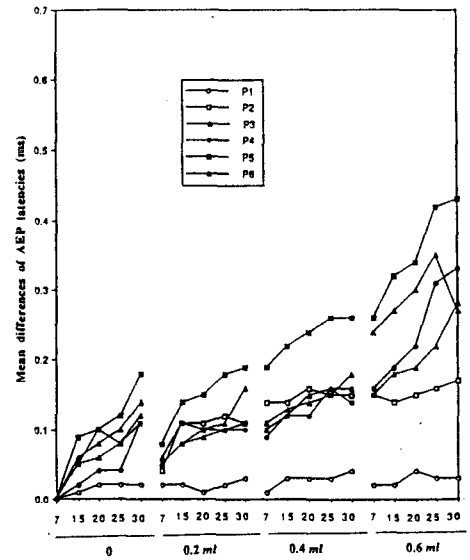

Fig.3. Changes on AEP peak latencies (P_1-P_6). The ICP levels are varied while holding the balloon size constant.

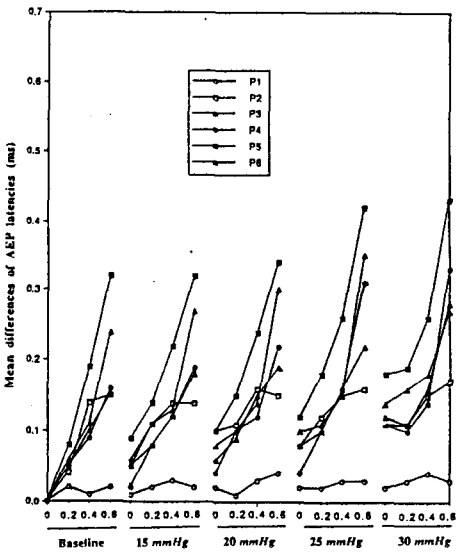

Fig.4. Changes on AEP peak latencies (P_1-P_6). The balloon sizes are varied while holding the ICP level constant.

0.608. On the other hand, varying the balloon size while maintaining the ICP level constant does not provide much variation.

CONCLUSION

The conclusion drawn from multiple regression analyses results are: (1) a major correlation of changes on AEP peak latencies is due to mechanical forces of a mass (inflated balloon simulating a hematoma) in the

distortion of the brain matter rather than increased ICP. (2) AEP parameters have higher predictability on ICP changes with bigger size of the balloon simulating a hematoma.

TABLE I
SUMMARY OF MULTIPLE REGRESSION RESULTS FOR EACH EXPERIMENTAL TREATMENTS

Experimental Treatment..	Prob > F	R-square
Variation of ICP without balloon inflation	0.1079	0.225
Variation of ICP with 0.2 *ml* of balloon	0.0148	0.329
Variation of ICP with 0.4 *ml* of balloon	0.0038	0.389
Variation of ICP with 0.6 *ml* of balloon	0.0001	0.608
Variation of balloon size at baseline ICP	0.0028	0.440
Variation of balloon size at 15 *mmHg*	0.0255	0.224
Variation of balloon size at 20 *mmHg*	0.0027	0.336
Variation of balloon size at 25*mmHg*	0.0255	0.224
Variation of balloon size at 30 *mmHg*	0.0173	0.244

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