Statistical Analysis of Arterial Blood Pressure (ABP), Central Venous Pressure (CVP), and Intracranial Pressure (ICP)

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Abstract- Traumatic brain injury (TBI) is the leading cause of death for children and young adults in the U.S. Current therapy is targeted towards treating hypertension in ICP after they occur. We investigated the change in the signal characteristics of three simultaneously recorded signals before and after an acute episode of intracranial hypertension. In this paper, we report statistical evidence of change in the signal characteristics of ABP, ICP, and CVP prior to intracranial hypertension compared to the signal characteristics after the hypertension. We found that there were significant changes in the spectral power at the heart rate frequency and the correlations that occur prior to the intracranial hypertension and it may be possible to predict acute episode of hypertension.

Index term- Arterial Blood Pressure (ABP), Central Venous Pressure (CVP), Intracranial Pressure (ICP), Traumatic Brain Injury (TBI)
I. INTRODUCTION

Traumatic brain injury (TBI) is the leading cause of death for children and young adults in the U.S. Increased intracranial pressure following TBI may result in permanent ischemic damage to brain. [1] Current therapy is targeted towards treating hypertension in ICP after they occur.

We hypothesized that there are changes in signals that precede hypertensions in ICP. Accurate detection of these changes prior to hypertension can lead to better therapy that improves patients’ outcome.

There have been few reports that describe the relationship among signals. However, investigators have described relationship between ABP and ICP. Piper et al. suggested that a change in transfer function that relates ABP to ICP may precede elevation. [3] Rosner et al. often observed a short decrease in ABP at beginning of a wave. [4]

Our goal of this study was to find the statistical evidence of change in the signal characteristics of ABP, ICP, and CVP prior to intracranial hypertension compared to the signal characteristics after the hypertension.

II. METHODOLOGY

A. Data Collection

The data contain three set of ABP, CVP, and ICP signal from the Traumatic Brain Injured patient. These signals are sampled at 125Hz. 10 minute data samples are used for the study: The 1 minute segments of the signals prior to the intracranial hypertension were compared to other segments after the intracranial hypertension.

B. Stationary and Ergodicity

For our statistical analysis, we assumed that each segments were statistically independent and locally stationary (WSS). This mean that signal behavior over time can
be considered to be the same on average. Also, the segments could be considered to be ergodic, because we considered one patient’s data.

C. Signal characterizations

Correlation was used in time series analysis to determine whether a substantial linear relation exists and its own lagged values. Auto-correlation function (ACF) gives a profile of the linear correlation at all possible lags and shows which values of lag lead to the best predictability. The output was normalized with autocorrelation at zero lag for all three signals. This normalized plot made it easier to compare the estimates at each lag to one another. Values closer to any of these limits indicate strong correlation. In real application, we can not derive true ACF, because we can only measure limited portion of data. For this reason, we estimated the ACF. Cross-correlation (CCF) was used to show the relationship between signals.

For the spectral analysis, prior to applying the fast fourier transform (FFT), signals were decimated by a factor of 10 and mean values were subtracted from signal. This will be ensured that the power spectrum does not contain high frequencies and DC component. A modified periodogram with a Blackman-Harris window was used to estimate the power spectral density. To reduce the variance, 50% overlap was applied. Zero padding was used to improved frequency resolution.

For joint spectral analysis, the Blackman-Harris window with 50% overlap was also used to estimate the transfer function.

III. Result

In the one second window in Fig. 1, the cardiac cycle is observed in ABP, CVP and ICP signals. The waveforms of three signals are plotted in Fig.2. This figure
illustrated the intracranial hypertension and two 1 minute segments. The biased auto-correlation estimates for the three signals before and after the shock are shown in Fig.3-4. After the shock, there is more strong correlation in the signals. Also, there is phase shift after the shock. Fig.4 shows that shape prior to Hypertension has smaller variances than after shock. There is more strong correlation between ABP and ICP and between ICP-CVP in Fig. 5.

The power spectral density with Blackman-Harris window in Fig. 6 shows that there was change in heart rate frequency. Prior to the shock, heart rate frequency increased. In Fig. 7, the transfer functions of the joint signals verify that there is the power at the cardiac frequency of 2Hz.

IV. Discussion

In the study we found statistical evidence of change in the signal characteristics of ABP, ICP, and CVP prior to intracranial hypertension compared to the signal characteristics after the hypertension. We found that there were changes in the spectral power at the heart rate frequency and the correlations that occur prior to the intracranial hypertension.

V. Conclusions

The results of this study show that there is change in the signal characteristics of three signals. These mean that it may be possible to predict acute episode of hypertension. Further study is necessary to generalize the results.

VI. References


Fig. 1. Simultaneously recorded ABP, CVP, and ICP in one second.

Fig. 2. the waveforms of ABP, ICP, and CVP signal and segmentation
Fig. 3. Autocorrelation of ABP, ICP, and CVP signals

Figure. 4. Autocorrelation of the ABP, ICP, and CVP
Fig. 5. Cross-correlation of three signals

Fig. 6. Power spectral density using Blackman-Harris window with 50% overlap
Fig. 7. Transfer function estimate of the ABP-ICP, ABP-CVP, and ICP-CVP using Blackman-Harris window with 50% overlap.