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Pulse and mean intracranial pressure analysis in pediatric traumatic brain injury*

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Summary

Objective. We investigated the relationship between the intracranial pulse pressure (ICP_{PP}) and the mean intracranial pressure (ICP_M) in pediatric patients with traumatic brain injury (TBI).

Methods. We screened ICP records of 42 patients admitted to the Pediatric Intensive Care Unit at Doernbecher Children's Hospital (OHSU) for segments in which the ICP_M varied at least 5 mmHg. We found 54 ICP segments in 9 pediatric TBI patients (ages 0.2–17.8 years, mean = 9.9). ICP was continuously monitored ($f_s = 125$ Hz). We used an automatic algorithm to detect ICP beat components. We then calculated the ICP_{PP} and ICP_M for each beat and created density plots of ICP_{PP} vs. ICP_M.

Results. The coefficient of linear correlation was $r > 0.70$ in 43/54 segments ($p < 0.01$). We found that an underlying linear relationship exits between ICP_{PP} and ICP_M in most 1-hour records of pediatric patients with TBI. This finding is consistent with the data in adult studies, suggesting that children with TBI demonstrate similar changes in brain compliance. However, density plots revealed that there are also nonlinear ICP_{PP}-ICP_M patterns present that are not captured by linear metrics.

Conclusion. Although there is an underlying linear relationship between ICP_{PP} and ICP_M, nonlinear patterns are also present. Further research is required to determine if specific nonlinear ICP_{PP}-ICP_M patterns correlate with clinically significant information.

Keywords: Intracranial hypertension; intracranial pressure; waveform analysis; pulse pressure.

Introduction

Traumatic brain Injury (TBI) is the leading cause of death and disability in children in the United States [1]. Elevated intracranial pressure (ICP) following TBI may result in secondary injury due to decreased cerebral perfusion pressure (CPP) and cerebral ischemia. ICP monitoring and therapeutic interventions to control elevated ICP (>20 mmHg) have resulted in improved outcomes [9].

Several investigators and research groups have studied the relationship between the ICP pulse pressure (ICP_{PP}) and the mean ICP (ICP_M) in adult patients and dogs. Castel and Cohadon studied the ICP waveform in three groups of neurosurgical patients and noted that a linear relationship exists between ICP_{PP} and ICP_M [4]. Avezatt and Van Eijndoven examined this relationship in dogs and described a linear relationship between ICP_{PP} and ICP_M below a breakpoint where the slope changes, which they attributed to vasoparesis and failure of autoregulation [2]. They proposed to use the ratio ICP_{PP}-ICP_M as an index of brain compliance. The rationale behind this definition is that a change in this relationship during patient monitoring indicates a change either in the volume-pressure relationship or in the net volume change per cardiac cycle. Price defined the *pulse wave index* as the ratio of ICP_{PP} and ICP_M [10]. More recently, the correlation coefficient between ICP_{PP} and ICP_M has been termed the *pressure-volume compensatory reserve index* (RAP). This index measures the degree of correlation between ICP_{PP} and ICP_M over short periods of time, and indicates the relationship between ICP and changes in volume of the intracerebral space. In general, increased ICP_{PP} has been associated with decreasing intracranial compliance [3, 5–7].

Due to the unavailability of automatic ICP component detection algorithms, none of these previous studies calculated ICP_{PP} and ICP_M on a beat-by-beat

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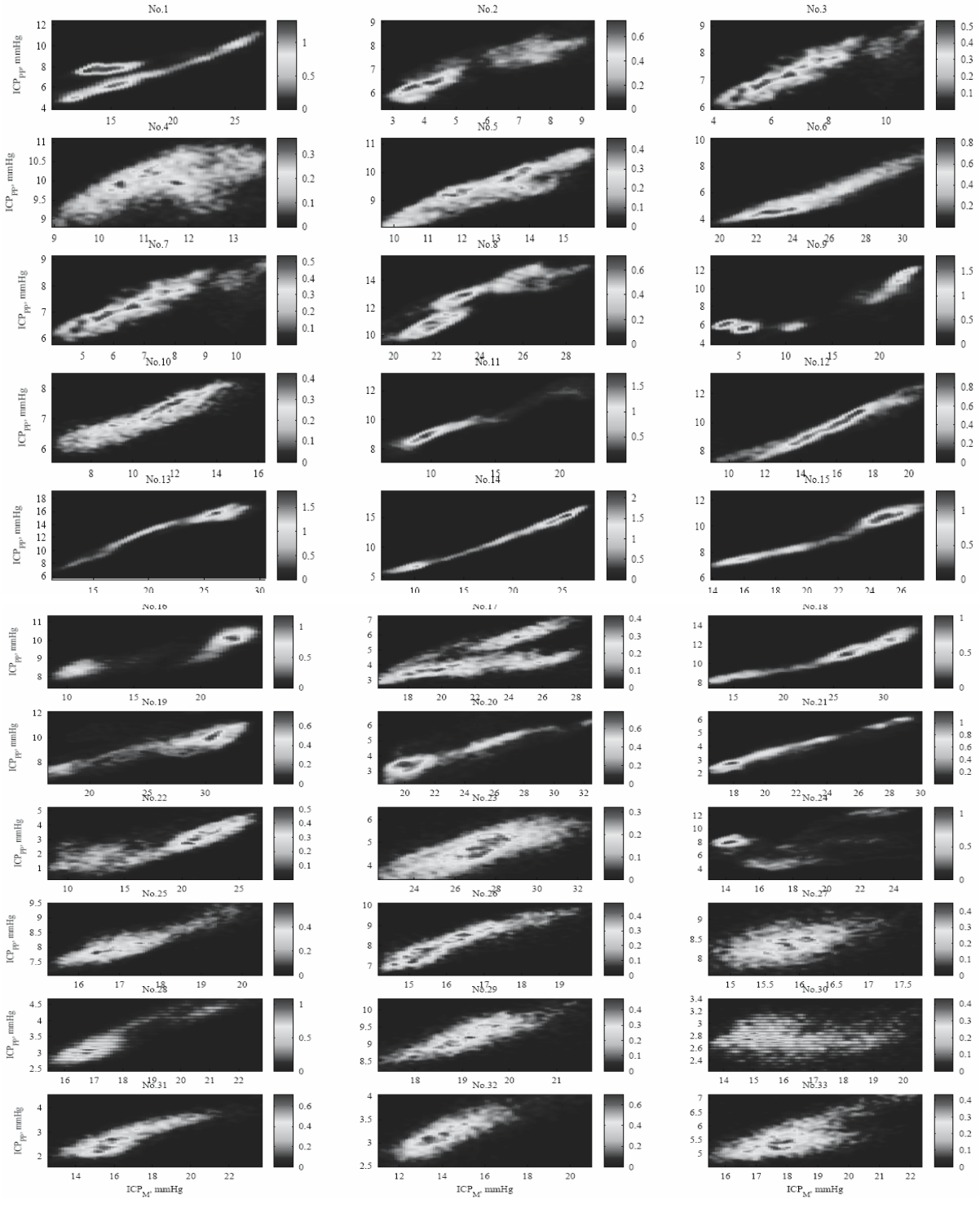

Fig. 1. Density plots showing the relationship between ICP_{PP} and ICP_M for 33 episodes

basis. Instead, ICP_{PP} and ICP_M are often estimated by indirect measures based on moving averages or frequency domain techniques. The most common methodology used to calculate the RAP index, for instance, consists of estimating the ICP_{PP} as the squared root of the power of the fundamental harmonic component, and the ICP_M as the moving average mean ICP over specific time window length [6].