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Case Report

Use of intracranial compliance to assist arterial blood pressure adjustment in critical patients: Short report and review of the literature

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ABSTRACT

Background: Blood pressure management is extremely important to prevent cerebral hypoxia and influence the outcome of critically ill patients. In medicine, precise instruments are essential to increase patient safety in the intensive care unit (ICU), including intracranial compliance (ICC) monitoring. A new technology developed by Brain4care, makes it possible to analyze the waveform of intracranial pressure (ICP) non-invasively associated with ICC, and this instrument was used in the patient for monitoring.

Case Description: A 40-year-old male underwent aortic endocarditis surgery involving 182-min extracorporeal circulation and 9-min aortic clamping. Post-surgery, he exhibited a seizure bilateral mydriasis, followed by isochoric pupils and rapid foot movements. Neuroprotection measures were applied in the ICU, with non-invasive ICC monitoring initiated to assess intervention effectiveness.

Conclusion: The non-invasive measurement of ICP can help clinical decision-making regarding the optimization of adapted protocols for neuroprotection in the ICU.

Keywords: Arterial blood pressure, Critical patients, Intracranial compliance, Intracranial pressure, Monitoring

INTRODUCTION

The assessment to maintain adequate cerebral perfusion can be a challenge for patients with heart disease in an intensive care unit (ICU). The adjustment of arterial blood pressure (ABP) to supply the brain with adequate blood requires individualized analysis. Tools that allow precision performance medicine are essential to increase patient safety in the ICU. This report presents the use of a non-invasive technology for intracranial compliance (ICC) monitoring[2] in the management of ABP by adjusting sedation and vasoactive drugs. This same method showed efficiency in reduced ICC detection during an increase in ABP and the effect of antihypertensive drugs on this important clinical parameter.[4] A case using this technology for the management of ABP with a focus on determining the ABP target with the best result for the ICC will be presented here.

The intracranial pressure waveform (ICPwf) as a patient analysis mode offers more interesting data than just the intracranial pressure (ICP) cutoff value. The ICPwf is composed of 3 elements: P1 (cardiac systole), P2 (pulse wave in the blood), and P3 (venous return and diastole), and this waveform has been associated with cerebral compliance.[4,6,9,10] Such a non-invasive technique to measure cerebral compliance related to ICP has the following advantages: efficiency, accessibility, and simple and practical handling.[5]

CASE REPORT

A male, 40 years old, admitted to the hospital with aortic endocarditis, was submitted to a valved conduit exchange and coronary artery reimplantation. During the surgical procedure, he was maintained at extracorporeal circulation for 182 min, and the aorta was clamped for 9 min after 112 min from the beginning of surgery. This procedure has been associated with marked decreases in cerebral blood flow, stroke, and brain hypoxia.[11] After the surgery, the patient was transferred to the ICU and maintained on sedation, mechanical ventilation, and managed with vasoactive drugs. On the same day, the patient had a single episode of tonic clonic seizure and bilateral mydriasis during this episode. After seizure cessation, pupils remained isochoric, and rapid foot movements were present. Non-invasive ICC monitoring was requested to follow up on the effectiveness of the neuroprotection measures in place.

Methods

The patient was monitored with the non-invasive brain4care technology, which allows the analysis of the ICPwf, related to ICC.[1,3] The technology was used 4 times, starting just after the seizure episode and in the subsequent days. The ICPwf was monitored using the P2/P1 ratio[2] and the information was used for the analysis presented in the Figure 1 (normal values between 0.65 and 1).

ICP measure technique

The use of ICPwf as a method for assessment and patient monitoring provides more detailed information than simply a fixed value of ICP. The ICPwf comprises three distinct components: P1, which is associated with cardiac systole; P2, which represents the pulse wave within the skull; and P3, related to venous return and diastole. Mosso[7] first recorded this waveform in 1875 using a pioneering invasive method. Subsequently, this waveform was linked to cerebral compliance. In 2017, Ballestero *et al.* introduced the use of the P2/P1 ratio as a marker in hydrocephalus studies, employing the non-invasive monitoring method developed by Braincare Corp. This method involves a strain gauge attached to a mechanical device that contacts the scalp surface in the lateral frontoparietal region up to the sagittal suture, detecting small variations in skull dimensions resulting from changes in internal pressure, without the need for surgical intervention or scalp shaving. The electronic system correlates cranial deformation with the detection of changes in ICP.[5,8,10,11]

RESULTS AND DISCUSSION

Immediately, post-seizure monitoring: indication of altered ICC with averaged ICPwf showing P2 > P1 (P2/P1 ratio = 1.29). Brain computed tomography showed diffuse cerebral edema, and electroencephalogram revealed diffuse disorganization. Transcranial Doppler assessments of the middle cerebral arteries (MCAs) revealed normal mean cerebral blood flow velocities (CBFVs) (98 cm/s and 78 cm/s for the right and left-brain hemispheres, respectively), without indication of microemboli or clear signs of intracranial hypertension but with varying mean CBFV in the MCAs which could be related to cerebral autoregulation impairment. To overcome the potential detrimental implications of dysfunctional autoregulation in cerebral perfusion pressure, we targeted systolic blood pressure at 140 mmHg and mean ABP at 100 mmHg. Medical management was characterized by sedation increase protocol and secondary cerebral ischemia prevention using vasoactive drugs to keep systolic blood pressure above 140 mmHg.

The second monitoring was made in 24 h after the first monitoring indicating ICC changed with P2 > P1, with marginal improvement of the P2/P1 ratio (P2/P1 = 1.21). Transcranial Doppler assessments of the cerebral arteries revealed different mean CBFVs. Medical management was the maintenance of sedation protocol and vasoactive drugs for neuroprotection. Blood pressure targets were established according to transcranial Doppler.

The third monitoring showed 24 h after the second monitoring indicated that ICC was improving, with a P2/P1 ratio under 1.0 (P2/P1 = 0.95). Medical management was maintenance sedation and vasoactive drugs. Another non-invasive ICP monitoring was requested after 48 hours.

The fourth monitoring was done after the third monitoring. The patient responded well to the neuroprotection management without any signs of intracranial edema on the tomography exam performed on the same day. The non-invasive ICP waveform normalized (P2/P1 = 0.88) and transcranial Doppler revealed normal mean CBFVs reaffirming that the clinical management by non-invasive monitorization might help physicians in decision-making in ICU.

The patient was extubated on the 5th day post-surgery without neurological symptoms.

In the prospective study conducted by Okon *et al.*,[9], 18 individuals diagnosed with idiopathic intracranial hypertension (IIH) according to the Modified Dandy Criteria were recruited to investigate new approaches in disease management. The study developed a technique to assess craniospinal compliance during lumbar puncture, analyzing cerebrospinal fluid (CSF) pressure waveform and pressure-volume response. Results showed a decrease in CSF pressure pulse amplitude with passive drainage and a positive correlation between this amplitude and CSF pressure in IIH patients. This indicates that analyzing CSF pressure waveform and pressure-volume response is valuable for managing IIH and tailoring treatment to each patient.

Fernandes *et al.*[4] investigated the effects of 2K1C renovascular hypertension in Holtzman and Wistar rats. They induced hypertension by partial occlusion of the renal artery and monitored ICP. Significant increases in ICP and the P2/P1 ratio were observed at weeks 4 and 6. Treatment with losartan partially reduced these increases, unlike hydralazine. In addition, there was a disruption of the blood-brain barrier (BBB) in critical areas. The study concluded that Angiotensin II and activation of the AT1R receptor elevate ICP during 2K1C hypertension, exacerbated by BBB disruption.

Kazimierska *et al.*[6] conducted an original study on CSF circulation in 36 patients with normal pressure hydrocephalus. Using infusion tests with simultaneous recording of ICP and CBFV, the study assessed CSF space compliance. Results showed significant decreases in the amplitudes of P1 and P2 peaks of the ICP pulse wave during infusion tests, indicating changes in CSF compliance. The study concluded that indirect assessment methods, such as analyzing peak amplitudes of the pulse wave, correlate well with direct methods of compliance assessment, allowing continuous monitoring of changes in CSF compliance.

At last, Westhout *et al.*[12] studied patients with traumatic brain injury, analyzing ICPwfs. They observed that the slope of the waveforms was higher during inspiration compared to expiration ($P < 0.0001$ for 5 subjects and $P < 0.03$ for 1 subject). In addition, they found a strong positive correlation between waveform slope and simultaneous ICP ($P < 0.0001$ for all 6 cases). These findings suggest that variation in the slope of ICPwfs may indicate loss of ICC in patients with traumatic brain injury.

The reviewed studies reveal important neuroprotective factors in various neurological conditions. In IIH, analysis of craniospinal compliance and CSF pressure waveform can guide management strategies. In renovascular hypertension, Angiotensin II and the AT1R receptor have been linked to increased ICP and disruption of the BBB. For normal pressure hydrocephalus, analysis of ICPwf amplitudes provides an effective method for monitoring CSF compliance. In traumatic brain injury, variations in ICPwf slope may indicate ICC loss, suggesting potential targets for neuroprotective interventions.

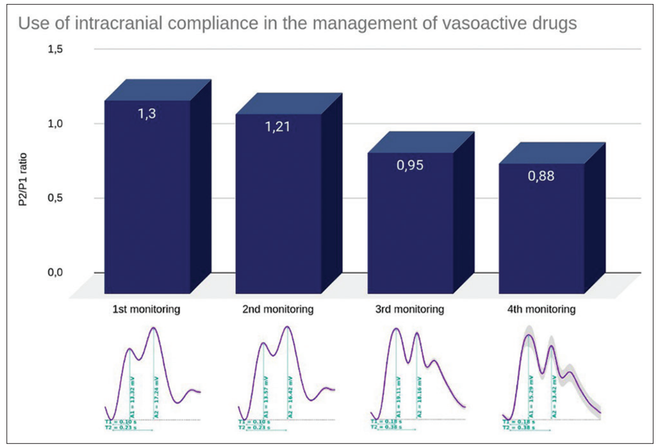

Figure 1: Evolution of intracranial compliance.

CONCLUSION

Cardiac surgeries are associated with intermittent brain hypoxia, which could lead to eventual cerebral edema and increased intracranial volume with consequent derangement of ICC. The technology used to monitor the ICC identified morphological changes in the ICPwf post-surgery and throughout the patient management in the ICU. The method could assist in clinical decision-making regarding the optimization of the protocols adapted for neuroprotection. Moreover, it is a non-invasive method to monitor the intracranial pressure (ICP) of patients with criteria and not mandatory, in a cheap, easy, and efficient way for diagnosis and treatment, whether in clinics or hospitals. Therefore, it is an innovative device that has a high capacity to reach many people because it is cheap and can positively impact the health and lives of many people.

Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

Patient's consent was not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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