Godoy *et al. Critical Care* (2024) 28:311
https://doi.org/10.1186/s13054-024-04974-4

Critical Care

CORRESPONDENCE

Open Access

Further support for the intracranial compartmental syndrome concept

Daniel Agustin Godoy[1,4*], Sergio Brasil[2,4] and Andres M. Rubiano[2,3,4]

To the editor

The current approach to severe neuro-injury monitoring, especially traumatic brain injury (TBI), has experienced paradigm shifts that open a broad outlook for the future [1]. On one hand, advances in pathophysiological knowledge have made possible establishing today that intracranial pressure (ICP) control is just one more epiphenomenon within other serious events that occur simultaneously such as tissue hypoxia, metabolic crises and cerebral energy dysfunction [1]. On the other hand, the advent of new monitoring techniques (invasive and noninvasive) have allowed a deeper analysis in real time of what is happening in the injured brain [1]. One of the most important advancements in neuromonitoring was the recent popularization of the analysis of the ICP wave (ICPw) morphology. Current studies pointed the changes in ICPw as reliable markers of cerebrospinal compliance and to be followed in clinical environments. In this regard, ICPw was considered the pillar of the intracranial compartmental syndrome (ICCS) concept [2]. So, *"ICCS occurs when the compliance of the intracranial system is compromised as a result of the exhaustion of the compensating mechanisms that try to keep it within normal limits". ''Perfusion, oxygenation and energy utilization compromise are its consequences"* [2].

Further enlightenments raised from the recent study of Kazimierska et al., which evaluated a series of 130 patients who were victims of severe TBI from the CENTER-TBI database. Those authors analyzed the relationship between parameters obtained from the neuroimaging Computed Tomography (CT) scan upon admission and variables collected from invasive ICP monitoring [3]. Injury mass volume, degree of midline shift, Marshall's and Rotterdam classifications were the data provided by the CT scans, while mean ICP values, wave amplitude and indices derived from the analysis of ICP recordings. A neural network model (previously tested with 93% accuracy) was applied in order to automatically group ICP waveforms into 4 classes [3]. As a main finding, the pulse shape index—PSI was strongly correlated with the analyzed tomographic parameters ($p=0.001$), while mean ICP was correlated with ICPw amplitude, indicating that the morphology of the ICP pulse wave reflects a decrease in the cerebrospinal compensatory reserve therefore of cerebral compliance [3].

ICP waveform is a result of complex interaction between volumes (blood, brain and cerebrospinal fluid) restrained by meninges and the bony skull box, interacting with dynamic phenomena as blood viscosity, cardiac and respiratory cycles per example [1]. Therefore, several are the ways of exploring and translating ICPw into parameters readable at the bedside to assess compensatory reserve status. Prior to PSI, the compensatory reserve index (RAP) was described by Czosnyka et al. as the moving correlation between ICP values and ICP pulse amplitude variation [4]. Both the

*Correspondence:
Daniel Agustin Godoy
dagodoytorres@yahoo.com.ar
[1] Neurointensive Care Unit, Sanatorio Pasteur, Chacabuco 675, 4700 Catamarca, Argentina
[2] LIM 62, Department of Neurology, University of São Paulo Medical School, Sao Paulo, Brazil
[3] Professor of Neurosciences and Neurosurgery, Universidad El Bosque, Bogotá, Colombia
[4] Medical and Research Director, MEDITECH Foundation, Cali, Colombia

PSI and RAP can be assessed imputing ICP and further variables to the ICM+software (Cambridge Enterprise Ltd., Cambridge, UK). More recently, based on ICP waveform peak relationship changes following cerebral compliance status, Brasil et al. observed the P2/P1 ratio (the second peak amplitude elevation) and time-to-peak (the time length from pulse triggering to its highest peak amplitude) variations following an induced mild ICP variation in neurocritical patients, demonstrating that these parameters may also translate the pressure/volume intracranial relationship [5]. The latter parameters acquisition and assessment are available by means of noninvasive hardware, with potential to widening intracranial compliance applications beyond severe acute brain injuries.

With the infinite contribution which newer hardware and software offer in data acquisition and analysis, we reach assessment options to support the ICCS hypothesis, raising the foundations for developing multicenter prospective clinical studies and validate the concept on a large scale.

Abbreviations

TBI	Traumatic brain injury
ICP	Intracranial pressure
CT	Computed tomography
ICCS	Intracranial compartmental syndrome
PSI	Pulse shape index
RAP	Compensatory reserve index
ICM	Intensive care monitor

Acknowledgements
None.

Author contributions
All author's contribute equally

Funding
Not applicable.

Availability of data and materials
Not applicable.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
All authors give the consent to publish.

Competing interests
DAG and AMR claim no competing interest or conflict of interest. SB serves as a scientific advisor for brain4care.

Received: 11 March 2024 Accepted: 27 May 2024
Published online: 18 September 2024

References

1. Lazaridis C, Foreman B. Management strategies based on multi-modality neuromonitoring in severe traumatic brain injury. Neurotherapeutics. 2023;20(6):1457–71. https://doi.org/10.1007/s13311-023-01411-2.
2. Godoy DA, Brasil S, Iaccarino C, et al. The intracranial compartmental syndrome: a proposed model for acute brain injury monitoring and management. Crit Care. 2023;27:137. https://doi.org/10.1186/s13054-023-04427-4.
3. Kazimierska A, Uryga A, Mataczyński C, et al. Relationship between the shape of intracranial pressure pulse waveform and computed tomography characteristics in patients after traumatic brain injury. Crit Care. 2023;27:447. https://doi.org/10.1186/s13054-023-04731-z.
4. Czosnyka M, Smielewski P, Timofeev I, Lavinio A, Guazzo E, Hutchinson P, et al. Intracranial pressure: more than a number. Neurosurg Focus. 2007;22(5):E10. https://doi.org/10.3171/foc.2007.22.5.11.
5. Brasil S, Solla DJF, Nogueira RC, Teixeira MJ, Malbouisson LMS, Paiva WDS. A novel noninvasive technique for intracranial pressure waveform monitoring in critical care. J Pers Med. 2021;11(12):1302. https://doi.org/10.3390/jpm11121302.

Publisher's Note