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Case Report

Influence of hemodialysis on intracranial compliance in a chronic renal patience assessed non-invasively: a case report

Influência da hemodiálise na complacência intracraniana em doente renal crônico observada de forma não invasiva: relato de caso

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ABSTRACT: Chronic kidney disease (CKD) has been increasing globally, with hemodialysis (HD) being the most commonly used treatment. However, HD can lead to episodes of hypotension, affecting cerebral perfusion and intracranial pressure (ICP), potentially compromising cerebral compliance. In this context, non-invasive ICP monitoring becomes a valuable tool for the early detection of such changes. This report describes a 58-year-old patient on HD for three years, whose cerebral compliance was assessed before and after dialysis sessions. A significant reduction in systolic blood pressure (SBP) was observed, possibly influencing ICP dynamics and the P2/P1 ratio. Since HD can cause osmotic imbalances and cardiovascular effects that impact cerebral perfusion, continuous ICP monitoring using non-invasive methods may enhance clinical management and reduce neurological risks in individuals with CKD.

KEY WORDS: Chronic kidney disease; Hemodialysis; Intracranial pressure; Hypotension.

RESUMO: A doença renal crônica (DRC) tem aumentado globalmente, sendo a hemodiálise (HD) o tratamento mais utilizado. Contudo, a HD pode provocar episódios de hipotensão, afetando a perfusão cerebral e a pressão intracraniana (PIC), o que pode comprometer a complacência cerebral. Nesse contexto, a monitorização não invasiva da PIC torna-se uma ferramenta valiosa para a detecção precoce dessas alterações. Este relato descreve um paciente de 58 anos em HD há três anos, cuja complacência cerebral foi avaliada antes e depois das sessões dialíticas. Observou-se uma redução significativa na pressão arterial sistólica (PAS), potencialmente influenciando a dinâmica da PIC e a relação P2/P1. Como a HD pode gerar desequilíbrios osmóticos e repercussões cardiovasculares que impactam a perfusão cerebral, o monitoramento contínuo da PIC por métodos não invasivos pode aprimorar o manejo clínico e minimizar riscos neurológicos em indivíduos com DRC.

PALAVRAS-CHAVE: Doença renal crônica; Hemodiálise; Pressão intracraniana; Hipotensão.

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INTRODUCTION

Chronic kidney disease (CKD) is characterized as a group of diseases that impair renal structure and function for more than three months, and its prevalence has been growing worldwide[1]. "According to the Brazilian Dialysis Census, as of July 1, 2023, there were 157,357 patients on dialysis, of whom 51,153 initiated treatment that year. The prevalence rate was 696 patients per million population (pmp), whereas the prevalence and incidence rates were estimated at 771 and 251 pmp, respectively. This corresponds to an estimated 771 dialysis patients per million inhabitants (prevalence) and 251 new cases per million (incidence)"[2].

Hemodialysis (HD) is the most frequently used treatment for patients with CKD; however, it may lead to dialysis disequilibrium syndrome (DDS), resulting in cerebral edema and increased intracranial pressure (ICP)[3]. Thus, DDS may be associated with impacts on cerebral compliance. Consequently, methods for ICP analysis have been developed, one of which involves non-invasive assessment of cerebral compliance through intracranial pressure pulse waveforms[3].

The non-invasive Brain4care® method evaluates intracranial pressure by measuring cranial expansion when its adaptive capacity is exceeded by an increase in one of its components (blood, cerebrospinal fluid, or parenchyma). The analysis of the ICP waveform provides information on cerebral compliance and its relationship with pressure values[4]. As ICP rises, a cranial motion sensor captures minute cranial bone deformations (<0.2 micrometers) The device filters, amplifies, and scans the sensor signal before transmitting the data to a mobile device[5]. With elevated ICP, compliance decreases, resulting in significant waveform changes[4].

Thus, real-time monitoring is made possible by a sensor placed on the cranium that detects small deformations caused by pressure waves. These variations are recorded, converted into numerical values, and presented graphically to facilitate clinical interpretation[4], aiding healthcare professionals in making more confident decisions. This approach enables continuous ICP monitoring, enhancing patient condition assessment.

In this context, this study aimed to report a case that evaluated the cerebral compliance of a hemodialysis patient non-invasively. We obtained the patient's clinical parameters from electronic medical records, and cerebral compliance was assessed non-invasively via the Brain4care® method.

METHODS

This case report is linked to the research project "Monitoring Chronic Kidney Disease Patients on Hemodialysis Through Non-invasive Intracranial Pressure Monitoring," supervised by Professor Cristiane Rickli Barbosa, PhD. The study received approval from the Research Ethics Committee at the State University of Ponta Grossa (UEPG), Brazil, via the *Plataforma Brasil* system (approval number 1,834,627).

Following the signing of an Informed Consent Form (ICF), the patient's clinical parameters were obtained from electronic medical records, and cerebral compliance was evaluated non-invasively using the Brain4care® method over six months, three times per week, before and after each dialysis session. During the procedure, the patient was instructed to remain still for 1–2 minutes while a sensor, secured by a strap, was placed on the parietal region of the skull.

This method evaluates the volumetric expansion of the skull when its adaptive capacity is exceeded due to increases in one of its components (blood, cerebrospinal fluid, or parenchyma). Analysis of ICP pulse waveform morphology provides the P2/P1 ratio and Time to Peak (TTP)[4]

The ICP waveform morphology comprises three main peaks: P1, P2, and P3. The P1 peak, also called the percussion wave, reflects arterial pressure transmission into the intracranial system and is directly linked to arterial compliance. The P2 peak, termed the compliance wave, is associated with brain parenchyma elasticity, whereas the P3 peak reflects the venous component of intracranial circulation[3].

Under normal conditions, these peaks follow a descending sequence (P1 > P2 > P3). However, when cerebral compliance is reduced, P2 rises above P1 (P2/P1 > 1.0), indicating increased resistance to intracranial flow and potential deterioration in the brain's adaptive capacity[3,6].

Mean ICP alone is not a precise indicator of disproportionate increases in intracranial pressure. However, the elevation of the P2 peak and the resulting rounding of the ICP waveform may indicate reduced cranial adaptive capacity and compromised intracranial dynamics[6].

The TTP measures the time from the onset of the ICP curve to its highest peak (P1 or P2). Non-invasive cerebral compliance assessment can detect changes in ICP waveform morphology before and after dialysis. Studies suggest that this analysis provides key data on intracranial dynamics, aiding in the evaluation of cerebral adaptation and blood flow regulation, thus contributing to clinical monitoring of patients[3].

The non-invasive method for assessing cerebral compliance has been applied in various pathological and non-pathological scenarios, including hydrocephalus, epilepsy, hemorrhagic stroke, traumatic brain injury, looping maneuvers in pilots, and experiments involving subarachnoid space infusion in pigs. This underscores the method's utility and relevance, providing additional diagnostic information without subjecting patients to invasive procedures, thereby enhancing patient safety[3]. When compared to invasive sensors, non-invasive systems show a strong correlation in monitoring and demonstrate excellent consistency in detecting intracranial hypertension (ICP ≥ 20 mmHg)[3].

DATA ANALYSIS METHODOLOGY

Data were analyzed using inferential statistics through the SPSS 17.0® statistical software (Chicago, USA). Specific statistical tests were selected based on the study objectives, following data tabulation. A significance level of $p < 0.05$ was set for all tests. Results were presented in the form of graphs and tables.

DISCUSSION

This case involves a 58-year-old male patient with CKD

of multifactorial etiology, on hemodialysis for three years. The patient also presented other comorbidities such as hypertension, diabetes, and cardiovascular problems. His pharmacological regimen during the study included clopidogrel, carvedilol, simvastatin, calcium carbonate, sevelamer, acetylsalicylic acid, erythropoietin, iron hydroxide, fluoxetine, clonazepam, and NPH insulin. He received three HD sessions per week.

After signing the ICF, the patient's clinical parameters were obtained from the electronic medical record, and his cerebral compliance was evaluated non-invasively using the Brain4care® system over six months, three times a week, before and after dialysis. The patient was instructed to remain still during the procedure for 1–2 minutes while a sensor attached with a strap was placed on the parietal region of the skull.

During the patient's third weekly dialysis session, a substantial drop in systolic blood pressure (SBP) was observed, from 113/47 mmHg pre-dialysis at 1:30 PM to 73/35 mmHg post-dialysis at 3:30 PM. This marked reduction may impact cerebral perfusion and, consequently, cranial compliance, as evidenced by changes in the P2/P1 ratio of ICP.

Measuring ICP allows for the assessment of cerebral perfusion pressure, which represents the pressure gradient that promotes cerebral blood flow (CBF), which supplies oxygen to the brain. Cerebral compliance (CC) is the relationship between CBF and the balance between the production and absorption of cerebrospinal fluid (CSF).

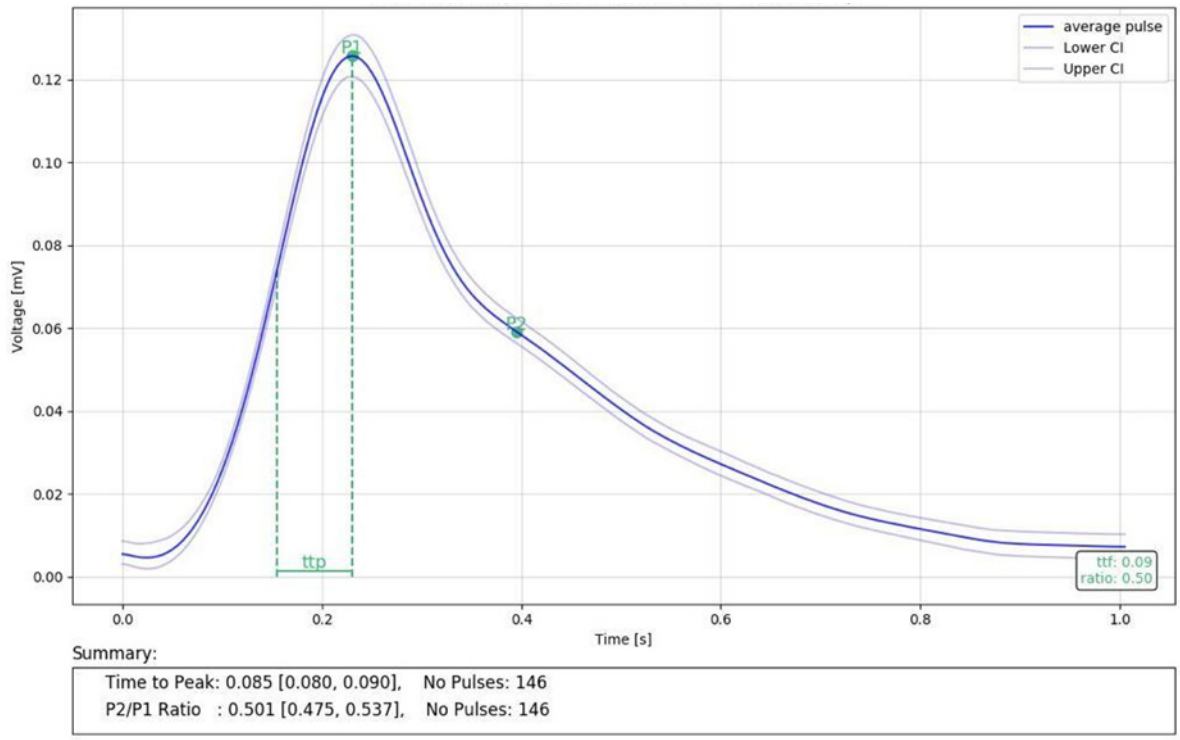
Under normal conditions, cerebral volume is typically static. CC determines the ability of the intracranial compartment to accommodate an increase in volume without a significant rise in ICP. Variations in CC can be observed through the pressure-volume curve[7,8].

Given that systemic blood pressure and fluctuations in ICP are interrelated, marked changes in SBP can directly influence cerebral compliance and ICP dynamics. Blood pressure plays a crucial role in cerebral perfusion, which in turn affects ICP dynamics. CPP, the difference between mean arterial pressure (MAP) and ICP, is essential for ensuring adequate cerebral blood flow to maintain brain function[9].

In this specific case, the observed P2/P1 ratio was 0.500 pre-dialysis (Figure 1) and 0.489 post-dialysis (Figure 2), which is below the expected values. Such a result is somewhat atypical, given that reduced cerebral compliance typically corresponds to a P2/P1 ratio greater than 1.0. The pronounced drop in SBP could have contributed to this outcome by reducing cerebral perfusion pressure and compromising cerebral compliance. This finding may indicate increased cerebral stiffness or an inadequate cerebral response to volume changes, possibly due to decreased perfusion.

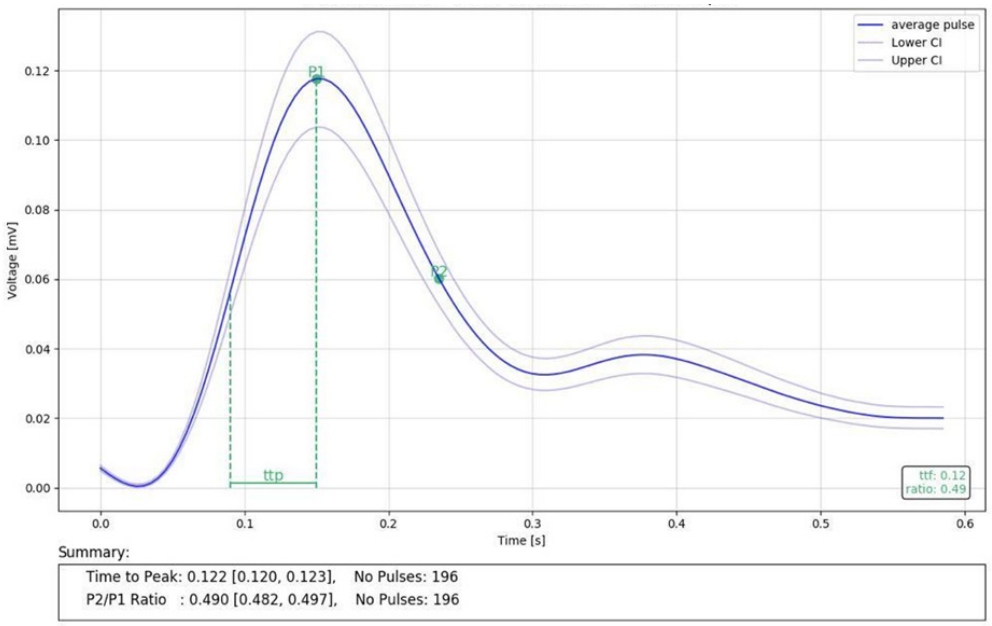
It is also noteworthy that analyzing ICP waveform representation enables assessment of the intracranial capacity to adapt to varying pressure conditions, providing insights into intracranial dynamics and reflecting cerebrovascular adaptability, which supports clinical management[10].

FIGURE 1 - ICP waveform morphology before dialysis



Source: Authors

FIGURE 2 - ICP waveform morphology after dialysis



Source: Authors

Although HD offers many benefits, it is not without complications. The literature describes cramps, pruritus, and headaches as the most frequent issues. Less common complications include abdominal pain, hypotension, hypertension, vomiting, sudden weight gain, and constipation, while more severe incidents such as seizures, numbness, and shortness of breath have also been reported[11].

Temporary imbalances in cellular compartments, coupled with the rapid removal of osmotically active substances, may lead to a transient reduction in plasma osmolality and potential episodes of hypotension. Furthermore, fluctuations in electrolyte levels, particularly those affecting cardiac activity, influence repolarization processes, predisposing patients to cardiac arrhythmias[11].

Hypotension is often considered a secondary complication, triggered by the cardiovascular compensatory mechanism when the ultrafiltration rate exceeds vascular refilling capacity. The swift removal of active osmotic elements, coupled with delayed intracellular equilibration, results in a momentary decrease in plasma osmolarity, leading to hypotension[11]. This phenomenon may partly explain the unusual findings in this patient, with a P2/P1 ratio of 0.500 pre-dialysis and 0.489 post-dialysis.

FINAL CONSIDERATIONS

Non-invasive intracranial pressure (ICP) monitoring can be a valuable tool in tracking how the brain adapts to HD-induced changes, offering a deeper understanding of the interplay between cerebral compliance and the physiological effects of HD. In the present case, the P2/P1 ratio showed atypical values (0.500 before dialysis and 0.489 afterward), possibly reflecting patient-specific responses to the procedure. Other studies have also demonstrated improvements in ICP wave morphology after dialysis, suggesting more typical patterns in certain patients[3].

Thus, continuous monitoring of ICP waveform morphology may be critical for early detection of cerebral compliance changes, aiding clinical decision-making and enhancing the management of hemodialysis patients. Non-invasive methods like Brain4care® enable real-time evaluation and could become a key resource in managing conditions affecting intracranial dynamics, offering new perspectives for personalized patient care.

Additional clinical research is needed to further elucidate the behavior of ICP and its waveform morphology in patients with CKD on HD. Even so, the advantages of non-invasive ICP monitoring include real-time evaluation of ICP and cerebral compliance, proving essential for detecting early changes and refining therapeutic approaches. As it requires no invasive interventions or costly devices, this method may be more cost-effective, facilitating ongoing monitoring, particularly in intensive care units, emergency departments, and during hemodialysis sessions.

AUTHORS CONTRIBUTIONS : The authors contributed to the article as follows: Flávia Polatto Pepece was the principal author and responsible for writing the main manuscript. Vinicius Gonçalves Olioze also contributed to the writing of the main manuscript. Camille Romero Cunha worked on writing the manuscript in accordance with submission guidelines and performed revisions. Ana Beatriz Mendes Castanha was responsible for writing the main manuscript, contributed to writing the manuscript following submission guidelines, as well as revising and translating it. Raquel Teston Furlan was responsible for writing the manuscript according to submission guidelines. Cristiane Rickli contributed to data collection, article planning, supervision, and revision. José Carlos Rebuglio Vellosa served as a co-supervisor.

REFERENCES

1. Gouvêa ECDP, Szwarcwald CL, Damacena GN, Moura L. Self-report of medical diagnosis of chronic kidney disease: prevalence and characteristics in the Brazilian adult population, National Health Survey 2013 and 2019. Epidemiol Serv Saude. 2022;31(spe1):e2021385. Doi: 10.1590/SS2237-9622202200017. especial.
2. Nerbass FB, Lima HN, Strogoff-de-Matos JP, Zawadzki B, Moura-Neto JA, Lugon JR, Sesso R. Brazilian Dialysis Survey 2023. Braz J Nephrol. 2025;47(1):e20240081.
3. Rickli C, Koch MS, Bueno BF, Vellosa JCR. Efeito da hemodiálise na complacência cerebral avaliada de forma não invasiva: relato de caso/ Effect of hemodialysis on cerebral compliance assessed in a non-invase way: case report. Brazilian J Develop. 2021 ;7(1), 10169-77. Doi : https://doi.org/10.34117/bjdv7n1-689.
4. Nucci CG, Bonis P, Mangiola A, Santini P, Sciandrone M, Risi A, et al. Intracranial pressure wave morphological classification: automated analysis and clinical validation. Acta Neurochirurg. 2016 ;158(3) :581-8. Doi : https://doi.org/10.1007/s00701-015-2672-5
5. Brasil S, Solla DJF, Nogueira RdC, Teixeira MJ, Malbouisson LMS, Paiva WdS. A Novel Noninvasive Technique for Intracranial Pressure Waveform Monitoring in Critical Care. J Personal Med. 2021 ;11(12) :1302–2. Doi : https://doi.org/10.3390/jpm11121302
6. Souza JCA. Morfologia da onda de pulso da pressão intracraniana avaliada de modo não invasivo em indivíduos ativos e saudáveis após exercício de agachamento realizado com auxílio da fita de suspensão. 2023. Dissertação (Mestrado em Ciências Fisiológicas) – Universidade Federal de São Carlos, São Carlos, 2023. https://repositorio.ufscar.br/handle/20.500.14289/17997.
7. Beaumont A. Physiology of the cerebrospinal fluid and intracranial pressure. In: Winn HR, Youmans JR (ed.). Youmans and Winn neurological surgery. Filadélfia: Elsevier/Saunders, 2017, cap. 52, p. 417-423.
8. Kirkness CJ, Mitchell PH, Burr RL, March KS, Newell DW. Intracranial Pressure Waveform Analysis: Clinical and Research Implications. J Neurosc Nurs. 2000 ;32(5) :271-7. https://journals.lww.com/jnnonline/abstract/2000/10000/intracranial_pressure_waveform_analysis__clinical.7.aspx
9. Fernandes MVS, Melo M, Mowry FE, Gabriela Maria Lucera, Mariana Ruiz Lauar, Frigieri G, et al. Intracranial Pressure During the Development of Renovascular Hypertension. Hypertension. 2021 ;77(4):1311-22. Doi : https://doi.org/10.1161/HYPERTENSIONAHA.120.16217
10. Davies S, Lindley A. Monitoring the Injured Brain. In: Adams JP, Bell D, Mckinlay J. (ed.). Neurocritical Care: A Guide to Practical Management, Nova Iorque: Springer London. 2010, p.9-18. Doi : https://doi.org/10.1007/978-1-84882-070-8_2
11. Tinôco JDS, De Paiva MGMN, Lúcio KDB, Pinheiro RL, De Macedo BM, Lira ALBC. Complicações em pacientes renais crônicos submetidos à hemodiálise.. Cogitare Enf. 2017 ;22(4). Doi : https://doi.org/10.5380/ce.v22i4.52907
12. Mascarenhas S, Vilela GHF, Carlotti C, Damiano LEG, Selugue W, Colli B, et al. The New ICP Minimally Invasive Method Shows That the Monro–Kellie Doctrine Is Not Valid. In: Schuhmann, M., Czosnyka, M. (eds) Intracranial Pressure and Brain Monitoring XIV. Acta Neurochirur Suppl. 2012 ;114. Doi : https://doi.org/10.1007/978-3-7091-0956-4_21
13. Czosnyka M, Czosnyka Z. Origin of Intracranial pressure pulse waveform. Acta Neurochir. 2020 ;162(8) :1815-7. Doi : https://doi.org/10.1007/s00701-020-04424-4
14. Cardoso ER, Rowan JO, Galbraith S. Analysis of the cerebrospinal fluid pulse wave in intracranial pressure. J Neurosurg. 1983 ;59(5) :817-21. Doi : https://doi.org/10.3171/jns.1983.59.5.0817
15. Moreira JM, Matta SM, Kummer AM, Barbosa IG, Teixeira AL, Silva ACS. Transtornos neuropsiquiátricos e doenças renais: uma atualização. Braz J Nephrol. 2014 :36(3) :396–400. Doi : https://doi.org/10.5935/0101-2800.20140056

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