METHODOLOGY FOR NON-INVASIVE MONITORING OF INTRACRANIAL PRESSURE WAVES IN DOGS WITH TRAUMATIC BRAIN INJURY USING THE BRAIN4CARE® BCMM/2000 MONITOR

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ABSTRACT

Invasive intracranial pressure (ICP) monitoring is performed in humans to identify and manage intracranial hypertension (ICH) early. However, its use in veterinary medicine remains limited due to the cost and risk of complications, prompting ongoing research to non-invasive alternatives. Recently, a non-invasive ICP monitoring device (PIC-Ni) was released on the market and has already been used in humans, rats and dogs. Although the technique has been described in dogs, there are some difficulties in carrying out the procedure. Thus, this study aims to detail the methodology employed in monitoring ICP-Ni using the Brain4care® BcMM2000 monitor in dogs with traumatic brain injury. Conducted as a prospective case series at a Veterinary Teaching Hospital between May 2019 and December 2020, the study involved 11 dogs with cranioencephalic trauma. Efforts were made to ensure a calm environment. Unlike in humans, in which the sensor is placed on the head with an adjustable band, in dogs the sensor is used with the aid of a stereotaxic support, thus requiring patients to remain still for a few minutes. Although successful ICP-Ni waveform monitoring was achieved in all cases using this methodology, eight dogs required procedure repetition due to artifacts, and five dogs needed sedation. Despite positive outcomes, the encountered challenges suggest the need for device modification by the company to enhance its usability in dogs.

Keywords: intracranial hypertension, intracranial pressure waves, traumatic brain injury, dogs.

METODOLOGIA APLICADA NO MONITORAMENTO NÃO INVASIVO DAS ONDAS DE PRESSÃO INTRACRANIANA EM CÃES COM TRAUMATISMO CRANIOENCEFÁLICO UTILIZANDO O MONITOR BRAIN4CARE® BCMM/2000

RESUMO

A monitoração invasiva da pressão intracraniana (PIC) é realizada em seres humanos para detectar e tratar precocemente a hipertensão intracraniana (HIC). Na medicina veterinária o método é pouco utilizado devido ao custo e risco de complicações, assim há pesquisas sobre técnicas alternativas. Recentemente, um dispositivo de monitoramento não invasivo da PIC (PIC-Ni) foi lançado no mercado e já foi usado em seres humanos, ratos e cães. Embora a técnica tenha sido descrita em cães, há algumas dificuldades na realização do procedimento. Assim, o objetivo do presente estudo é relatar a metodologia empregada no monitoramento da PIC-Ni com o monitor Brain4care® BcMM2000, em cães com traumatismo cranioencefálico (TCE). O estudo foi do tipo série de casos prospectivo, e incluiu 11 cães atendidos em um Hospital Veterinário Escola entre maio de 2019 e dezembro de 2020, com histórico de trauma cranioencefálico. Para garantir um ambiente silencioso foram adotados cuidados específicos no manejo do ambiente. Ao contrário de seres humanos, nos quais o sensor é colocado na cabeça com uma banda ajustável, em cães o sensor é utilizado com auxílio de um suporte estereotáxico,

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assim necessita-se que os pacientes permaneçam imóveis por alguns minutos. Foi possível monitorar as ondas da PIC-Ni em todos os casos, mas em oito cães o procedimento teve que ser repetido devido à ocorrência de artefatos e sedação foi necessária em cinco casos. Embora tenha havido bons resultados com a metodologia empregada, devido a algumas dificuldades encontradas, recomenda-se que a empresa realize adaptações no aparelho para minimizar esses desafios na utilização do equipamento em cães.

Palavras-chave: hipertensão intracraniana, ondas da pressão intracraniana, trauma cranioencefálico, cães.

METODOLOGÍA APLICADA EM LA MONITORIZACIÓN NO INVASIVA DE LAS ONDAS DE PRESIÓN INTRACRANEAL EM PERROS COM TRAUMATISMO CRANEOENCEFÁLICO COM EL MONITOR BRAIN4CARE ® BCMM/2000

RESUMEN

La monitorización invasiva de la presión intracraneal (PIC) se realiza en humanos para detectar y tratar la hipertensión intracraneal (HIC) de manera temprana. En medicina veterinaria el método es poco utilizado debido al costo y riesgo de complicaciones, por lo que se investigan técnicas alternativas. Recientemente, se lanzó al mercado un dispositivo de monitorización de la PIC no invasivo (PIC-Ni) que ya se ha utilizado en humanos, ratas y perros. Aunque la técnica ha sido descrita en perros, existen algunas dificultades para realizar el procedimiento. Por lo tanto, el objetivo del presente estudio es informar la metodología utilizada en el monitoreo de la PIC-Ni con el monitor Brain4care® BcMM2000, en perros con lesión cerebral traumática (TCE). El estudio fue una serie de casos prospectivos e incluyó a 11 perros tratados en un Hospital Universitario Veterinario entre mayo de 2019 y diciembre de 2020, con antecedentes de lesión cerebral traumática. Para garantizar un entorno silencioso, se tuvo especial cuidado en la gestión del medio ambiente. A diferencia de los humanos, en los que el sensor se coloca en la cabeza con una banda ajustable, en los perros el sensor se utiliza con la ayuda de un soporte estereotáxico, por lo que se requiere que los pacientes permanezcan quietos durante unos minutos. Fue posible monitorear las ondas ICP-Ni en todos los casos, pero en ocho perros se tuvo que repetir el procedimiento debido a la aparición de artefactos y en cinco casos fue necesaria la sedación. Si bien hubo buenos resultados con la metodología utilizada, debido a algunas dificultades encontradas, se recomienda que la empresa realice adaptaciones al dispositivo para minimizar estos desafíos al utilizar el equipo en perros.

Palabras-clave: hipertensión intracraneal, ondas de presión intracraneal, traumatismo craneoencefálico, perros.

INTRODUCTION

The invasive monitoring of intracranial pressure (ICP) by inserting an intraventricular catheter stands as the gold standard in the managing neurocritical human patients (1). In dogs, this invasive ICP monitoring is seldom performed, due to challenges in keeping patients in intensive care units (ICU), equipment and supply costs, and risk like hemorrhage and infection (2). To mitigate potential complications in both humans and animals, various studies have explored non-invasive ICP monitoring methods, such as transcranial Doppler to assess blood velocity in the middle cerebral artery and measuring optic nerve diameter via ultrasound or magnetic resonance (3).

Brain4care®, a Brazilin company, recently developed a non-invasive method for monitoring ICP waves (ICP-Ni) known as the BCMM/2000 monitor. This method has been used to record ICP-Ni wave dynamics in humans (4-6), as well as in rats and dogs (1,2). A study involving 72 humans with brain injuries, demonstrated a strong correlation between information obtained through non-invasive monitoring using this method and invasive ICP monitoring (7).

The monitor operates using a strain gauge sensor to measure cranial bone deformation based on principles from material engineering for tension and compression. For ICP wave monitor, the sensor sits on the skin surface of the skull, gauging bone deformation due to increased cranium pressure, recording changes as ICP waves. The sensor is positioned on a pin that rests on the skin of the skull, detecting movements ≤ 0.2 micrometers, and converting them into electrical signals. These signals are then amplified, filtered, and digitized by a device before being transmitted. The data is sent online to a software application (LabView®) for interpretation (5). Although this method does not offer calibrated pressure values in mmHg, it provides insight into ICP wave morphology and the P2 to P1 amplitude ratio (6). The company considers waveform characteristics indicating and ICP increase are independent of absolute pressure values (Brain4care®).

In humans, the sensor is secured with an elastic strap, around the skull, even with awake patients, and usually recording is performed for 5–10 minutes. However, a study involving 18 patients with stroke, showed an average monitoring time of 45 min (8). In rats and dogs, the sensor requires contact with the skull skin using a stereotactic device. Animals need to lie down, sedated or anesthetized, to prevent patient movement that could cause reading errors or sensor damage (1,2,9).

For instance, in a study of six dogs having spinal cord disorders, monitoring during and after subarachnoid contrast injection lasted 1 minute for anesthetized dogs at each stage (10). In rat experimental, monitoring spanned up to 1 h (9). However, a preliminary study involving eight dogs without neurological disorders and 10 with such issues, showed monitoring times ranging from 2–5 min. In this study, 10 dogs without neurological disorders and four with such problems were anesthetized; among the remaining six dogs with intracranial problems, five were not anesthetized or sedated (2).

Given the limited information on conducting ICP-NI monitoring in dogs, this study aims to outline the methodology for using Brain4care® BcM2000 monitor in dogs with traumatic brain injury (TBI), highlighting limitations and procedural challenges.

MATERIAL AND METHODS

This study was approved by the Committee on Ethics in Animal Use, protocol number 8266.2015.10. It constituted a prospective case series involving 11 dogs treated at a Veterinary Teaching Hospital between May 2019 and December 2020. All dogs had a history of TBI and underwent ICP-Ni monitoring with the Brain4care® BcMM2000 monitor.

All patients were hospitalized and underwent a comprehensive clinical evaluation, systolic blood pressure measurement using the Doppler method, and neurological examination. Venous catheterization was performed for intravenous crystalloid fluid administration and pain management based on pain intensity. Pain management included tramadol hydrochloride (3–5 mg/kg, SC or IM/TID), methadone (0.1–0 .2 mg/kg, SC or IM), or continuous fentanyl infusion (2–5 μg/kg/h).

Furthermore, patients were positioned in lateral recumbency with a 30° head elevation, received oxygen therapy through a simple face mask, and underwent chest radiography and abdominal ultrasonography as necessary. Blood samples were collected for a complete blood count, serum biochemical profile, blood gas analysis, and lactate assessment. Alongside the neurological examination, evaluation was conducted using the Modified Glasgow Coma Scale (MGCS) (11). Subsequently, non-invasive ICP monitoring was performed. The time interval between initial care and monitoring ranged 1–4 h.

The sensor used is highly sensitive to patient head and body movements, necessitating complete immobilization of the animal throughout the procedure. Monitoring was conducted in a quiet, dimply-lit room maintaining a room temperature of 25°C with the aid of an air conditioning device.

Two veterinarians were responsible for patient management. The dogs were brought into a room and positioned in lateral recumbency on a table, with the stereotactic apparatus base in place. Subsequently, the environment was kept quiet, with cotton placed inside the auditory canals to manage noise, and eye coverage with a dressing was applied as needed to reduce visual stimuli, for each case. Once the patients became relaxed and still, the sensor was positioned on the parietal skin without the need for shaving, aligning with methods outlined in another study (2) and ICP-Ni recording commenced (Figure 1). In cases where initial monitoring was disrupted by head movement or agitation, sedatives were administered, enabling successful monitoring sessions. The durations of ICP-Ni recording varied from 2–5 min.

Figure 1. A dog with TBI underwent non-invasive monitoring of intracranial pressure (ICP-Ni) using the Brain4care® monitor. The patient was positioned in right lateral recumbency, and the sensor was placed on the parietal region with the assistance of the Brain4care® stereotactic apparatus.

Immediately after the non-invasive monitoring was completed, the acquired data were transmitted via the internet to the analytical platform of the Brain4care® company for assessment using LabView® software. The software conducted a blind analysis, comprising waveform recording, mean ICP pulses, and P2/P1 ratio (Figure 2). A P2/P1 ratio ≥ 0.8, defined as the ratio between the heights of P2 and P1 waves, is likely associated with alterations in cerebral compliance and increased ICP (12).

RESULTS AND DISCUSSION

This study comprised eleven dogs of varied ages, sexes, breeds, and body weights. Among them, were six males (54.54%) and five females, with an average age of 5.6 years (ranging 3 months – 13 years) and average weight of 9.53 kg (ranging 2.4–23 kg). Initial post-care monitoring revealed P2/P1 ratio ranging from 0.57 to 2.65, with a mean value of 1.24. This ratio indicated intracranial hypertension (ICH) in eight cases, whereas remaining within normal levels in three cases.

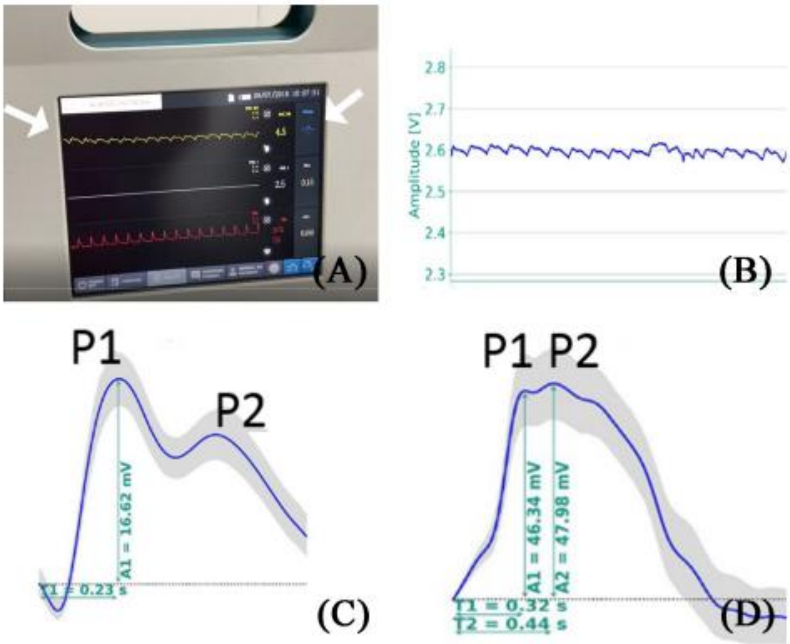

Figure 2. Image (A) depicts the Brain4care® BcMM2000 monitor with yellow waves (indicated by white arrows) representing the tracing along side the obtained pulses. A graph is shown in (B) following the digitization of recorded signals. (C) Non-invasive ICP waveform graph indicating P1 > P2, normal brain compliance. Lastly, in (D) and ICP non-invasive waveform graph exhibits P2 > P1, suggesting a probable change in cerebral compliance.

To mitigate dog movements, extra measures were necessary. Eye covering was required for four patients, and cotton was inserted into the ear canals of seven patients to facilitate ICP-Ni monitoring. Despite these efforts, maintaining stillness in five of the 11 patients for the required efforts duration posed challenge. Sedation was administered in these cases, using diazepam at a dose of 1 mg/kg/IV in three dogs, and midazolam 0.4 mg/Kg /IV in two dogs. These drugs induced cooperation for monitoring.

Benzodiazepines were chosen for sedation, due to their minimal impact on cardiovascular and respiratory functions, as well as ICP. They reduce cerebral blood flow, lower brain oxygen consumption, and protect against brain hypoxia through this mechanism (13). However, a human case report showed an increase in the P2/P1 ratio during non-invasive monitoring under moderate sedation with midazolam for an upper digestive endoscopy. However, definitively attributing this increase to the drug remained uncertain (14).

Despite described procedures, record failures or artifact occurred (Figure 3). In most cases (eight dogs), repeating the procedure was necessary for satisfactory records. A study involving children with hydrocephalus, using the same device for non-invasive ICP monitoring, faced similar artifacts due to patient movement. Similar to dogs, children tended to be restless, resulting in data loss in 28 out of 56 children with hydrocephalus and 2 out of 30 children without hydrocephalus in the control group. The monitoring duration, 3 min, was relatively short, akin to the duration used in this study. The authors suggested potential technical improvements for better usability in children (4).

In a study involving 75 humans with acute brain injury, 10 min recordings were conducted, but data from three patients were excluded because of poor recording quality (7). Another study, published after this one, monitored ICP-Ni in 24 adult humans with acute brain injury from strokes. Due to artifacts after placing the sensor on the skull skin, recordings began after 20 min, lasting 20–40 min. However, 87.5% of patients were sedated due to needing mechanical ventilation (15). The same device was used in a study involving 29 adult women having migraines, and the results were compared to those of 29 women without migraines. The monitoring lasted 20 min without the use of consciousness-depressing agent and no data loss from movement artifacts was reported (16).

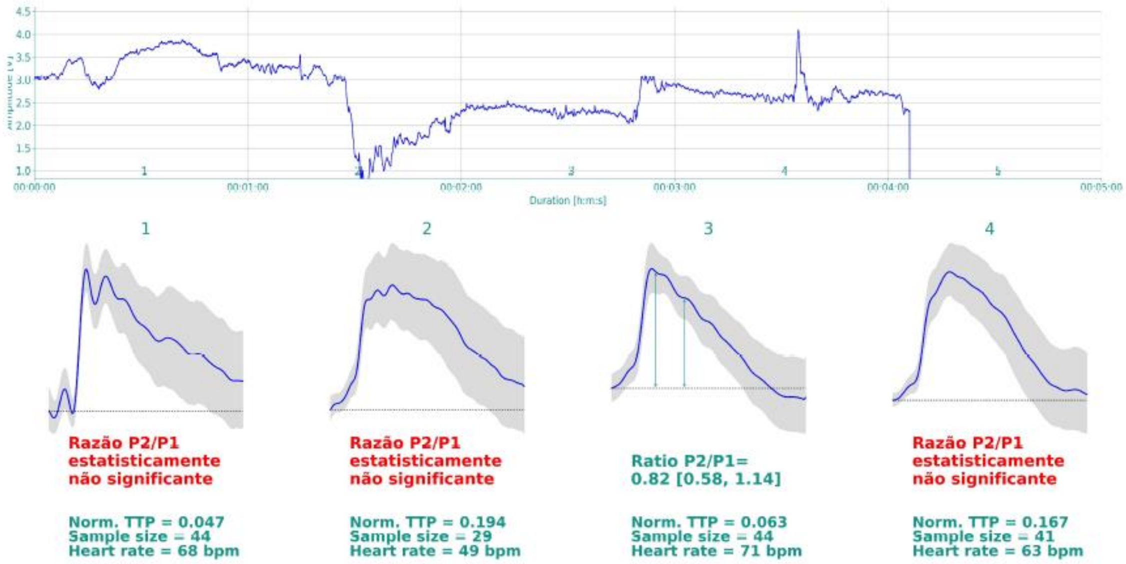

Figure 3. Intracranial pressure waveforms tracing in a dog with TBI, with inadequate recordings (in red: P2/P1 ratio not statistically significant).

In Veterinary Medicine, managing conditions causing increased intracranial pressure (ICH) ideally involves ICP monitoring, commonly done in human medicine. However, invasive ICP monitoring is rare in dogs owing to certain limitations. Non-invasive techniques developed for humans are increasingly researched; their application in veterinary medicine could benefit conditions such as meningoencephalitis, hydrocephalus, brain neoplasms, and TBI, aiding in treatment assessment.

In this study, the original plan was to conduct additional ICP-Ni monitoring after initial treatment to improve patient condition. However, due to the need for new sedation or anesthesia for patient stillness, the procedure was only performed in six of the 11 cases. Consequently, the P2/P1 ratio could not be determined in all the cases with positive clinical outcomes.

CONCLUSION

In this study, we effectively monitored non-invasive ICP waves (ICP-Ni) in dogs with TBI using the Brain4care® BcMM2000 monitor. Specific precautions were taken to control the environment and ensure patient stillness for reliable signal capture. However, similar to human studies, we encountered limitations with the equipment. These constraints involve the lack of consensus on ideal monitoring duration and occasional disruptions due to artifacts affecting data collection.

Furthermore, when adapting the device for animal use, the company replaced the elastic band with stereotaxic support, necessitating complete patient immobility. This requirement makes it impractical to perform the examination in cases where sedation or anesthesia is contraindicated. Future modifications to the sensor could address these challenges when using the equipment in animals.

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