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Invasive and Non-Invasive Ways of Measuring Intracranial Pressure and Its Importance in an Intensive Care Unit

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ABSTRACT

Introduction: Intracranial pressure (ICP) monitoring has been used for decades in neurosurgery and neurology. There are both invasive and non-invasive techniques. This article aims to provide an overview of the advantages and disadvantages of the most common and well-known methods. Objective: To carry out a literature review, based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, on the main invasive and non-invasive methods of measuring Intracranial Pressure. Methodology: After individually evaluating each article, analyzing the title and abstract of the study and applying the inclusion and exclusion criteria, 23 articles were selected. Final considerations: ICP monitoring techniques are diverse. However, before choosing the technique to apply in intensive care, several factors need to be taken into account: the accuracy of the measurements made, the cost of the device, as well as the possible complications and mechanical problems associated with each of the techniques.

Key words: Intracranial pressure; invasive and non-invasive measurement of ICP.

INTRODUCTION

Intracranial hypertension is characterized by increased pressure inside the skull (ABAY et.al, 2022).

According to Cucciolini et.al (2023), Intracranial (ICP) means inside the skull and hypertension means high fluid pressure. A condition of intracranial hypertension means that the pressure of the fluid surrounding the brain (cerebrospinal fluid or CSF) is too high.

ICP monitoring is important in various clinical conditions where there is intracranial hypertension (ICH), and is an important tool in clinical practice for monitoring intracranial pressure and compliance (DHAESE et.al, 2021).

Currently, there are several methods for monitoring ICP and these can be invasive, minimally invasive or non-invasive. Since none of the methodologies is considered perfect, it is important to know the applicability and the advantages and disadvantages of each one, in order to use the one that best suits the patient (ABAY et.al, 2022).

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Dhar et.al (2020), describes that in most cases, increased intracranial pressure can be due to an increase in the amount of cerebrospinal fluid (the fluid that surrounds the brain and spinal cord) in the spaces around the brain.

Increased intracranial pressure can also be due to an increase in pressure within the brain itself. This can be caused by a mass (such as a tumor), by bleeding in the brain or fluid around the brain, or by swelling within the brain itself (DHAESE et.al, 2021; ABAY et.al, 2022).

Many conditions can increase intracranial pressure. Common causes include: Ruptured aneurysm and subarachnoid hemorrhage; Brain tumor; Encephalitis, irritation and swelling or inflammation of the brain; Head injury; Hydrocephalus (increased fluid around the brain); Brain hemorrhage; Meningitis (infection of the membranes covering the brain and spinal cord); Bruising of the brain; Seizure (DHAESE et.al, 2021; ABAY et.al, 2022; EVENSEN et.al, 2018; BEZERRA et.al, 2018).

For Evensen et.al (2018), the most common symptom is usually an unbearably painful or frequent headache, sometimes associated with nausea and vomiting that is not relieved by medication. The headache often awakens the patient from sleep. Some patients are seen in the emergency room, where a lumbar puncture is performed as a last resort to temporarily relieve the headache.

Other common symptoms include transient altered vision, particularly on movement or bending, intracranial noise (synchronized pulse tinnitus), neck stiffness, back and arm pain, pain behind the eye, exercise intolerance and memory difficulties (FANELLI et.al, 2019).

An increase in intracranial pressure is a serious and life-threatening medical problem. The pressure can damage the brain or spinal cord, putting pressure on important structures and restricting blood flow to the brain (DHAESE et.al, 2021; ABAY et.al, 2022; EVENSEN et.al, 2018).

Hassett et.al (2022), cites that the doctor will try to find out the cause of the increased ICP. This includes a physical examination, assessment of your symptoms and a neurological examination. These examinations also check mental state and coordination, including muscle function, senses and reflexes.

Tests carried out if an increase in ICP is suspected may include: Computed tomography of the head; Magnetic resonance imaging of the head; Lumbar puncture (HASSET et.al, 2022).

There are usually three ways of measuring intracranial pressure. The first is by placing a sensor inside the skull, which is only done in critically ill patients. The other is through lumbar puncture, when the doctor connects a pressure gauge to the needle at the time of the puncture. The third is via a non-invasive sensor. This article aims to conceptualize these three ways, presenting their advantages and disadvantages, as well as their importance in an Intensive Care Unit.

GENERAL OBJECTIVE

To carry out a systematic review, based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, of the main invasive and non-invasive methods of measuring Intracranial Pressure.

METHODOLOGY

This article is a systematic review, based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, which seeks to identify methods of measuring Intracranial Pressure by analyzing pre-performed studies. A search strategy was developed based on the evaluation of an objective on the subject in question, which forms the basis of the study.

The search descriptors were selected from the Descriptors in Health Sciences (DeCS) website and then combined with the Boolean operator "AND". The databases used for the search were: PubMed and the Virtual Health Library (VHL), which evaluated cross-sectional, cohort and case-control studies from 2018 to 2023, in Portuguese, English and Spanish.

In all, the result of the search in the databases using the descriptors, but without the application of filters, resulted in 167 articles available. After applying the following filters, PubMed: search periods between 2018 and 2023, Portuguese, English and Spanish language and type of literature being a cross-sectional study. VHL: search periods between 2018 and 2023, Portuguese, English and Spanish language and type of literature being an observational study, a total of 65 articles were selected.

The divergence pointed out in relation to the type of literature filter, which could lead to selection bias, was resolved by selecting only cross-sectional articles in the inclusion criteria. After evaluating each article individually, analyzing the title and abstract of the study and applying the inclusion and exclusion criteria, 23 articles were selected.

After selecting the articles, a research protocol was created which clearly illustrated the objective of the study, the data collection process and the criteria involved in including the articles.

DISCUSSION

Since none of the methodologies is considered "ideal", it is important to know the applicability and the advantages and disadvantages of each one, in order to use the one that best suits the patient. The normal ICP curves and standards can be seen in FIGURE 1.

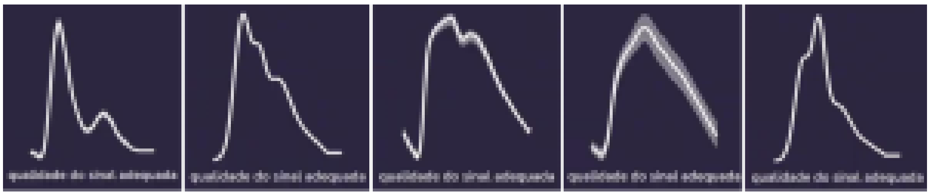

Figure 1. Characteristic wave patterns of intracranial pressure obtained correctly.

INVASIVE VS. NON-INVASIVE METHODS OF MEASURING INTRACRANIAL PRESSURE

Invasive method

In general, invasive ICP monitoring methodologies consist of inserting a catheter, which varies in intracranial location and pressure transduction method (HELDT et.al, 2019).

Kazimierska et.al (2021) cites that the ICP monitoring systems most commonly used in clinical practice today are still invasive, usually through the implantation of intracerebral sensors. Invasive ICP monitoring methodologies consist of inserting a catheter (FIGURE 1), which varies in intracranial location and pressure transduction method. With regard to anatomical locations, the devices can be inserted in the following regions: intraventricular, intraparenchymal, epidural, subdural and subarachnoid.

In addition to measuring ICP, this technique can also be used for CSF drainage and intrathecal drug administration, for example, the administration of antibiotics in cases of ventriculitis (HELDT et.al, 2019).

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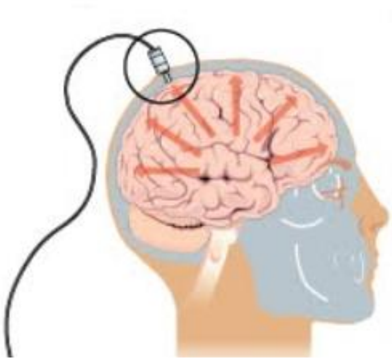

Figure 2. Invasive ICP monitoring methodologies with catheter insertion.

During prolonged CSF drainage, compression of the ventricular system can occur due to the formation of progressive edema, blocking proper drainage of the brain (HELDT et.al, 2019).

RISKS, ADVANTAGES AND DISADVANTAGES OF THE INVASIVE METHOD

When it comes to the accuracy of measuring exact ICP values, invasive methods are considered the gold standard, closely followed by microtransducers, which measure ICP with almost the same precision. Non-invasive techniques have their greatest shortcomings in this field (OCAMOTO et.al, 2021).

Post-operative bleeding" is common when inserting an invasive catheter to measure ICP. Another complication is bacterial colonization of the catheter with subsequent retrograde infection. This encompasses a wide range of conditions, from benign skin infections to ventriculitis, meningitis and fatal septicemia (HELDT et.al, 2019).

Factors predisposing to a higher infection rate include: prolonged treatment time of more than five days, frequent CSF sampling rate, intraventricular or subarachnoid hemorrhage, skull fracture with CSF leak and non-sterile insertion. The main factor contributing to a lower infection rate was subcutaneous tunneling (HELDT et.al, 2019).

Another factor contributing to the increased infection rate is incorrect catheter placement or a defective catheter. Recent studies have found through retrospective review of a patient population that catheters were misplaced, both intraparenchymal and extraventricular. This, in turn, resulted in reoperation in several cases; a factor that contributes to a higher infection rate. These misplacements can also result in lesions of important brain structures, for example, basal ganglia, thalamus, internal capsule and even penetration into the floor of the third ventricle (DHAESE et.al, 2021; ABAY et.al, 2022; EVENSEN et.al, 2018).

Non-invasive method

Zhang et.al (2020), cites that the proposal for a non-invasive method of measuring ICP is captivating, since the complications observed in relation to invasive methods of measuring ICP, i.e. hemorrhage and infection, are avoidable.

With this in mind, a group of Brazilian researchers have developed a non-invasive technique for measuring intracranial pressure. The technology consists of a mechanical sensor, positioned on the patient's scalp, in the fronto-temporal region, capable of picking up nanometric changes resulting from pulses of intracranial pressure. The sensor captures and sends signals from the patient (intracranial pulses) to a mobile device via Bluetooth pairing (FRIGIERI et.al, 2018).

The brain4care's technology from Brazil was cleared for commercial use in the United States by the Food and Drug Administration (FDA) in December 2021. The company's managers expect the commercial launch to take place in 2023. The FDA has authorized the use of the device with restrictions. It cannot be used by children under 18, people with skull defects or patients who have undergone surgery involving the removal of part of the skull bone (decompressive craniectomy or craniotomy). The sensor, a wearable device positioned on the patient's head with a fixation band, is connected via the internet to an analytical platform, which generates data available in real time on tablets or cell phones. As the device does not collect numerical pressure data recorded in millimeters of mercury, it does not replace invasive sensors.

The application displays the waves and sends the signals to the cloud platform. Algorithms, using artificial intelligence, process the signals and issue automated analytical reports showing the intracranial pulse waves and their P2/P1 ratio and TTP parameters. The recommended location for positioning the sensor is in the center of the frontotemporal region, two inches (5 - 6 cm) perpendicularly above the entrance to the external auditory canal in the coronal plane, as shown in FIGURE 3 (FRIGIERI et.al, 2018).

Either side of the head will work for sensor placement.

Figure 3. Non-invasive ICP monitoring methods.

The test can be carried out in two ways: Static test: where the patient is positioned in the supine position, keeping the head in a neutral position and aligned with the sternum bone, without any clothing or accessories that could lead to an increase in abdominal and/or thoracic pressure. The aim of this test is to assess changes in intracranial compliance that are suggestive of intracranial hypertension. Dynamic examination: after the static examination, the patient is placed in the orthostatic position to assess the results of venous and cerebrospinal fluid return on compliance and intracranial pressure. If the orthostatic position is not possible, the patient should be positioned between 45º and 75º, avoiding a sitting position at 0º as this can lead to an increase in abdominal pressure. The aim of this test is to assess, for example, the functioning of hydrocephalus valves. The patient should also remain in the second position for 5 minutes (FRIGIERI et.al, 2018; IMADUDDIN et.al, 2019; MLÁDEK et.al, 2019).

If the patient is wearing a mask that increases the concentration of CO_2, such as N95 or others, they should be asked to remove the mask or replace it with a conventional surgical mask (FRIGIERI et.al, 2018).

Two others models of wireless intracranial pressure sensors are now available on the global market. One was developed by the German company Raumedic AG and the other by the American company Branchpoint Technologies. The current equipment, however, does not have a Wi-Fi connection and uses a dedicated device that depends on getting close to the patient's skull in order to obtain the data captured by the implanted sensor.

RISKS, ADVANTAGES AND DISADVANTAGES OF THE INVASIVE METHOD

At its current stage of development, this method is able to provide direct absolute ICP values, and a complete ICP waveform with all its characteristic peaks can be obtained. In addition, the method allows continuous monitoring with no risk of infection. The disadvantage is still access to this equipment, as many hospitals still don't have or haven't adopted this method.

IMPORTANCE OF MONITORING PIC IN THE INTENSIVE CARE UNIT

Patients with suspected altered intracranial compliance are all those with neurological symptoms, regardless of whether these symptoms have a non-neurological origin (CZOSNYKA et.al, 2020).

In any of the clinical pictures, the symptoms listed below are indicative of attention and suggest ICP monitoring: Headache; Visual changes; Gait alteration; Dizziness, nausea and vomiting; Rhythm deviation; BP difficult to control; Reduction in the Glasgow scale; Lowering of the level of consciousness; Delirium; Difficult awakening; Seizure crisis; Pupil changes (NASSIF, C. & FRIGIERI, 2023).

According to Rickli et. al (2021), the assessment of patients with these symptoms can be carried out in emergency medical settings, emergency rooms, doctors' surgeries, clinics, laboratories or in cases of clinical worsening in hospitalized patients.

Non-neurological patients with conditions that lead to hepatic, renal, cardiac and respiratory alterations should also be assessed for the need to monitor intracranial compliance, as these alterations can also compromise it. Early detection of these alterations makes it possible to treat them more quickly, with an impact on clinical outcomes (RUESCH et.al, 2020).

Patients at risk are those who already have a diagnosis that can lead to altered intracranial compliance, such as nephropathies, liver diseases, difficult-to-control hypertension, obesity, respiratory impairment, pseudotumor cerebri, hydrocephalus, cranial alterations, sepsis, among others. These patients should be monitored preventively and frequently, or as a screening for the appearance of neurological symptoms (OCAMOTO et.al, 2021).

Patients with proven changes in compliance and intracranial pressure, such as those with head trauma, strokes, hydrocephalus, intracranial tumors and meningitis, should be monitored frequently, or even continuously, to assess whether the therapeutic procedures are resulting in an improvement in this condition (RUESCH et.al, 2020).

Interpreting the result

The interpretation of intracranial compliance monitoring should be carried out by analyzing the morphology of the ICP pulse, using the parameters P2/P1 ratio and time to peak (TTP). These figures make it possible to quantitatively assess changes, which may indicate altered intracranial compliance and suggest intracranial hypertension (DHAESE et.al, 2021; ABAY et.al, 2022; EVENSEN et.al, 2018).

The results should be assessed dynamically over time, the longer the time and the greater the intensity of the alteration, the worse the patient's clinical condition (EVENSEN et.al, 2018).

If the orthostatic position has led to an improvement in an already altered value of the indices, the result is indicative of intracranial hypertension; if orthostatism has led to a worsening of the values, the suggestion is intracranial hypotension (DHAESE et.al, 2021).

Intracranial compliance can also help to define therapeutic blood pressure targets, since it is related to cerebral autoregulation (ABAY et.al, 2022).

FINAL CONSIDERATIONS

ICP monitoring techniques are diverse. However, before choosing which technique to use in intensive care, several factors need to be taken into account: the accuracy of the measurements taken, the cost of the device, as well as the possible complications and mechanical problems associated with each technique.

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