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RECENT ADVANCES IN DIAGNOSTIC, THERAPEUTIC AND PROGNOSTIC STRATEGIES FOR TRAUMATIC BRAIN INJURY

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Abstract: Objective: To explore the latest diagnostic, therapeutic and prognostic strategies for the management of patients with Traumatic Brain Injury. Methodology: Using the PubMed - MEDLINE database with specific terms such as "Traumatic brain injury", "TBI", and "Recent advances", a rigorous selection of literature was carried out, resulting in 16 articles pertinent to the topic. Review: Advances in intracranial pressure monitoring and imaging technologies such as Positron Emission Tomography (PET), along with the development of new biomarkers, have significantly improved the early diagnosis of LTCs. This has a positive impact on the prognosis. The implementation of multimodal monitoring, which includes technologies such as Brain Tissue Oxygen Tension Monitoring (PetO2), Pressure Reactivity Index (PRx) and Continuous Electroencephalography (cEEG), has enriched the management of Traumatic Brain Injury (TBI). Final Considerations: Brain microdialysis is crucial for identifying post-trauma biochemical and metabolic changes, allowing for more personalized therapies. Furthermore, pharmacological research is vital to develop more effective treatments for moderate to severe cases of TBI, aiming to improve clinical outcomes and quality of life for patients.
Keywords: Traumatic brain injuries; Advanced diagnosis; Innovative treatment.

INTRODUCTION

TBIs are characterized by severe head injuries caused by violent, non-penetrating impacts that result in brain contusions. These injuries not only affect individuals' cognition, coordination, and emotions, but can also cause secondary injuries, such as hypoxia, and increase the risk of neurodegenerative diseases, such as Parkinson's and Alzheimer's (Lkaijzel et al., 2017; Needham et al., 2019). TBI constitute a significant challenge for

public health, being the main cause of death and disability among the young population. Globally, such injuries negatively impact the economically active population, generating considerable economic implications (Dasic et al., 2022; Lkaijzel et al., 2017; Needham et al., 2019).

In this context, advancement in understanding and treatment strategies for these injuries has become a priority in contemporary medical and scientific research. With more than 10 million people affected annually worldwide, resulting in hospitalization or mortality, TBI is also a leading cause of disability and death in individuals under the age of 45 in the United States, contributing to approximately 30% of all deaths from injuries (Lkaijzel et al., 2017).

Given this, critical questions emerge about the most recent advances in the diagnosis, treatment and prognosis of traumatic brain injuries. Current scientific literature suggests that despite advances in the management of these conditions — including studies on anticonvulsant prophylaxis and emerging therapies — there is still a lack of research that not only develops new strategies, but also evaluates the long-term benefits or disadvantages of current approaches (Stein; Feather; Napolitano, 2017).

These gaps in the literature highlight the need for further investigation, especially considering that despite the creation and common use of the Glasgow scale, protocols and guidelines for the management of TBIs may not be entirely clear regarding their effectiveness and applicability in practice. clinic (Lkaijzel et al., 2017). Future research could therefore develop new strategies to evaluate the long-term benefits and drawbacks of current approaches (Stein; Feather; Napolitano, 2017).

The aim of this review is to provide a comprehensive overview of the most up-to-date diagnostic, therapeutic and prognostic strategies, thereby contributing to improved TBI patient care and guiding future research in this vital area of medicine.

METHODOLOGY

The narrative bibliographic review carried out for this research was structured based on the PVO methodology, which encompasses the analysis of Population or research problem, Variables of interest and Outcomes. This approach was applied to answer the guiding question: "What are the most recent advances in the diagnosis, treatment, and prognosis of traumatic brain injuries as evidenced by current scientific literature?"

For data collection, a systematic search was used in the PubMed - MEDLINE (Medical Literature Analysis and Retrieval System Online) databases. Search terms were selected to capture the breadth and specificity of the topic and included: "Traumatic brain injury", "TBI", "Recent advances", "Recent developments", "Diagnosis", "Diagnostic methods", "Diagnostic techniques", "Treatment", "Therapy" and "Interventions". These terms were combined using the Boolean operators "AND" and "OR", aiming to optimize the search results.

Initially, the search resulted in the identification of 44 relevant articles. After applying the selection criteria, the number was refined. The inclusion criteria adopted were: articles written in English; published between 2014 and 2024; that directly addressed the issues of diagnosis, treatment and prognosis of traumatic brain injuries; and available in full. Review studies, meta-analyses, observational and experimental studies were considered for inclusion. On the other hand, the exclusion criteria eliminated duplicate articles, publications only in abstract

format, and works that did not directly answer the research question or that did not meet the other inclusion criteria.

After meticulous application of the inclusion and exclusion criteria, 16 articles were selected to form the basis of this study. These articles were then analyzed and discussed to map recent advances and substantiate the study's conclusions about the diagnosis, treatment, and prognosis of traumatic brain injuries.

This methodological process allowed for a comprehensive and updated review, essential for understanding innovations and progress in the area of traumatic neuroscience, as evidenced by the most recent scientific literature.

DISCUSSION

INNOVATIONS IN TRAUMATIC BRAIN INJURY DIAGNOSIS

Traumatic brain injury (TBI) is a clinical condition resulting from direct trauma to the head region, with possible temporary or permanent effects. Recent studies indicate a significant increase in the incidence of subarachnoid hemorrhages associated with TBI over the past 25 years, although it remains uncertain whether this increase is due to diagnostic improvements or changes in medical practices. Additionally, research in the United States comparing TBI patients treated without intracranial pressure (ICP) monitoring versus those undergoing monitoring and targeted therapy showed a 12% reduction in mortality and a 6% increase in favorable outcomes, suggesting a positive impact of monitoring patient prognosis (Gómez et al., 2017).

Recently, the CREVICE consensus-based management protocol for severe TBI has been discussed. Randomized trials have found no differences in outcomes between groups undergoing induced temperature control (ICE) and groups managed based on ICP monitoring. However, the ICP monitoring group required 50% more interventions and had a 1.4 day longer intensive care stay (Chesnut et al., 2020).

Furthermore, Chesnut et al. (2020) report that in low- and middle-income countries, there is a shortage of evidence-based guidelines for the treatment of TBI, which can adversely affect patients' prognosis. When ICP monitoring is employed, the decision to use it is often not based on early clinical or radiographic predictors of intracranial hypertension, but rather on the physician's level of clinical suspicion. Indicators for monitoring include neurological worsening, no improvement or deterioration on CT scan, and lack of response to initial treatment.

Factors determining outcome in patients with severe TBI include age, Glasgow Coma Scale (GCS) score on admission, Rotterdam score, and maximum recorded intracranial pressure. ICP monitoring facilitates targeted patient management, with the aim of preventing, early diagnosing and treating secondary brain injuries, such as ischemia, herniation, infection and cerebral edema, thus improving the patient's prognosis. It is essential to preserve cerebral perfusion within normal parameters to prevent ischemia and irreversible brain damage (Khalili et al., 2016).

Recent advances in imaging technology, such as Positron Emission Tomography (PET), have been fundamental in identifying neurological dysfunctions and underlying pathologies in cases of Traumatic Brain Injury (TBI), especially mild ones. PET stands out for its high sensitivity in detecting metabolic changes in brain regions affected by TBI. Future and prospective studies are essential to better understand how these functional regions are affected and to determine the characteristics of blood flow and metabolic

changes in the injured areas, aiming to optimize the management and clinical outcomes of patients with mild TBI (Huang et al., 2022).

In the field of immunology, the study of the responses of microglial cells and other myeloid cells after TBI is crucial for the development of rapid and accurate diagnoses. Currently, the challenge is to identify specific and sensitive biomarkers that can reflect the complex heterogeneity of the immune response to trauma. Genetic analysis of these cells can help determine the severity of TBI at different stages and differentiate between types of injury. These findings could lead to the development of biomarkers for early diagnosis, severity stratification, and prognosis, enabling more targeted and effective therapies (Jassam et al., 2017).

Raman Spectroscopy, an emerging technology, shows potential as a non-invasive tool to detect neuroinflammatory signals. Integration of established biomarkers such as S100B, GFAP, and NAA with Raman spectroscopy could facilitate the creation of a database for clinical applications, including ocular use. However, challenges such as the intense light in surgical environments and the presence of large blood volumes still need to be overcome for the effective implementation of this technique in a clinical context (Harris et al., 2022).

Furthermore, monitoring of Intracranial Pressure (ICP) has been a cornerstone in the treatment of severe TBI, but isolated control of ICP is not sufficient to optimize clinical outcomes and prevent secondary injuries and adverse biological processes, such as excitotoxic injury. Studies indicate that, in patients not monitored for ICP, there is a tendency towards increased use of hyperosmolar therapies and hyperventilation, suggesting a possible overestimation of ICP based on clinical and radiographic findings alone. Close clinical observation without direct ICP monitoring can achieve results similar to direct monitoring, especially in terms of therapy delivery (Abraham et al., 2017).

Age also plays a significant role in complications related to ICP monitoring. In adults, monitoring is associated with complications such as Deep Vein Thrombosis, Pulmonary Embolism and pneumonia associated with mechanical ventilation, in addition to increasing the length of hospital stay and the use of mechanical ventilation. However, in pediatric populations, ICP monitoring is associated with a reduction in mortality without an increase in the aforementioned complication rates (Chopko et al., 2024).

EMERGING THERAPEUTIC STRATEGIES AND FUTURE PERSPECTIVES IN THE DIAGNOSIS OF TRAUMATIC BRAIN INJURY

The management of Traumatic Brain Injury (TBI) has advanced considerably, driven by the adoption of neuromultimodal monitoring. This approach allows for more individualized therapeutic decisions, aiming to optimize the prevention of secondary ischemic brain injuries. Traditionally, monitoring of patients with TBI has relied on clinical assessments, neuroimaging, and intracranial pressure (ICP) monitoring. However, these methods were limited, not adequately addressing lesion heterogeneity and failing to provide a holistic assessment of brain physiology (Makarenko; Griesdale; Gooderham; Sekhon, 2016).

The integration of technologies such as Brain Tissue Oxygen Tension Monitoring (PbtO2), the assessment of cerebral autoregulation through the Pressure Reactivity Index (PRx) and Continuous Electroencephalography (cEEG) to invasive ICP monitoring provides significant advantages. This set of techniques,

known as neuromultimodal monitoring, is essential for the early detection of cerebral ischemia and for identifying signs of acute deterioration in neurological function (Makarenko; Griesdale; Gooderham; Sekhon, 2016).

At the same time, cerebral microdialysis has emerged as an essential tool in the management of TBI. This invasive method, which allows the sampling of cerebral extracellular fluid for metabolite analysis, offers precise monitoring of post-trauma biochemical and metabolic disorders, providing valuable data for personalized patient treatment (Khellaf; Khan; Helmy, 2019).

In the pharmacological sphere, research continues in the search for effective therapies to improve clinical results in cases of moderate to severe TBI. Amantadine hydrochloride, for example, has shown promise in improving cognitive function and accelerating post-traumatic functional recovery (El-Swaify et al., 2022). Furthermore, tranexamic acid (TXA), when administered early after trauma, has been associated with reduced mortality, according to evidence from the CRASH-2 study (Khellaf; Khan; Helmy, 2019).

Recent investigations are also exploring innovative therapies, such as the use of MAP kinase inhibitors and the nanotechnological delivery of Methylene Blue, aimed at neuroprotection and mitigation of brain damage after TBI. These new approaches have shown promising results and may represent future therapeutic strategies for the treatment of TBI (Sharma et al., 2020).

FINAL CONSIDERATIONS

Emerging techniques such as PET and Raman Spectroscopy are improving the understanding of neurophysiological changes, facilitating the monitoring of metabolic and inflammatory signals. Brain Microdialysis has been fundamental in monitoring biochemical and metabolic disorders after trauma. Advances in pharmacology, including the use of Amantadine Hydrochloride and Tranexamic Acid, have shown positive results, with new therapies such as MAP kinase inhibitors and nanotechnology being explored. The technical challenges and the need for more studies to develop specific biomarkers and evaluate new pharmacological interventions are crucial to improve the management of patients with TBI, aiming for better prognostic results and directly impacting the young, economically active population.

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