Revista de Ciencias Médicas de Pinar del Río

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(S2): e7017

REVIEW ARTICLE

Using the Bootstrap technological tool in the management of traumatic brain injury in pediatric patients

Piedad Elizabeth Acurio-Padilla[1], María Fernanda Latorre-Barragán[1], Paco Israel Zapata-Quishpe[1]

[1]Autonomous Regional University of the Andes "UNIANDES". Ambato, Ecuador.

Received: December 23, 2025
Accepted: December 25, 2025
Published: December 30, 2025

Citar como: Acurio-Padilla PE, Latorre-Barragán MF, Zapata-Quishpe PI. Utilización de la herramienta tecnológica Bootstrap en la gestión del traumatismo craneoencefálico en pacientes pediátricos. Rev Ciencias Médicas [Internet]. 2025 [citado: fecha de acceso]; 29(S2): e7017. Disponible en: http://revcmpinar.sld.cu/index.php/publicaciones/article/view/7017

ABSTRACT

Introduction: pediatric traumatic brain injury is one of the leading causes of childhood morbidity and mortality, which demands rapid diagnoses and standardized protocols supported by accessible technological tools.
Objective: to analyze the usefulness of the technological tool Bootstrap in the implementation of medical protocols for the management of traumatic brain injury in pediatric patients.
Methods: a bibliographic review was conducted following the PRISMA methodology. The search was carried out in different databases using an appropriate search algorithm, which allowed the identification of sources addressing the topic. Compliance with inclusion and exclusion criteria enabled access to those sources that met the selection requirements, followed by an analysis of those with adequate relevance and timeliness.
Development: Bootstrap, as an open-source framework, facilitates the creation of responsive applications that integrate clinical protocols into mobile and desktop devices. Its potential lies in guiding the initial assessment, supporting decision-making, and standardizing the management of pediatric patients with traumatic brain injury. Furthermore, it is necessary to distinguish Bootstrap as a technological tool from other homonymous protocols, highlighting its capacity to optimize interaction between medical teams and digital systems.
Conclusions: Bootstrap emerges as an effective resource for integrating clinical protocols in pediatric neurosurgery, promoting rapid and safe interventions. Its application contributes to reducing diagnostic errors, improving interdisciplinary coordination, and strengthening evidence-based care.

Keywords: Neurosurgery; Pediatrics; Software; Diagnostic Techniques and Procedures; Biomedical Technology; Craniocerebral Trauma.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(S2): e7017

INTRODUCTION

Bootstrap is a technological tool that enables the implementation of previously validated clinical protocols on mobile and desktop devices, facilitating rapid and structured patient assessment. Its front-end–oriented design allows for the development of adaptive, intuitive, and accessible applications, thereby enhancing comprehension and management of complex clinical processes and supporting evidence-based decision-making.[1,2]

Among the most complex conditions is traumatic brain injury (TBI), defined as a physical injury causing structural and functional brain damage with temporary or permanent consequences. The most widely used classification is the Glasgow Coma Scale (GCS), which evaluates eye opening, verbal response, and motor response, allowing TBI to be categorized as mild, moderate, or severe—each with specific clinical, prognostic, and therapeutic implications that determine the need for imaging studies, hospitalization, or intensive care admission.[3,4]

Severe pediatric TBI represents a significant public health problem, being one of the leading causes of morbidity and mortality among children and adolescents, with a sustained increase in incidence.[5] In Ecuador, it ranks as the fifth cause of pediatric hospital discharge according to the National Institute of Statistics and Censuses (INEC), with etiologies varying by age group—primarily traffic accidents, falls, child abuse, and sports-related trauma.[6,7]

From a pathophysiological perspective, pediatric TBI begins with a primary injury caused by direct impact, followed by a secondary injury mediated by inflammatory, vascular, and ischemic processes that exacerbate cerebral damage.[5] Additionally, tertiary and quaternary injuries occur, involving neuroinflammatory cascades, ionic imbalances, apoptosis, and subacute and chronic neurodegenerative processes that contribute to increased intracranial pressure and progressive neurological deterioration.[8]

Given the above, timely and appropriate management of this condition is vital. Therefore, this study aims to analyze the utility of the Bootstrap technological tool in implementing medical protocols for the management of traumatic brain injury in pediatric patients.

METHODS

This study constitutes a systematic literature review conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The methodological design aimed to identify, analyze, and synthesize available scientific evidence on the use of the Bootstrap technological tool in the clinical management of traumatic brain injury, with emphasis on the pediatric population. The search period spanned from January 2010 to June 2024 to ensure inclusion of current and relevant literature.

Information sources included recognized biomedical and academic databases: PubMed/MEDLINE, SciELO, ScienceDirect, Google Scholar, LILACS, and the Virtual Health Library (VHL). Additionally, a manual review of reference lists from selected articles was performed to identify potentially eligible secondary studies. Grey literature, such as technical documents and clinical guidelines, was also considered provided it met established quality and thematic relevance criteria.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(S2): e7017

The search strategy employed a structured algorithm combining controlled descriptors and free-text keywords using Boolean operators AND and OR. Terms included: "Bootstrap," "technological tool," "traumatic brain injury," "pediatrics," "clinical protocols," and "health technology." Searches were adapted to the specific syntax of each database. Publications in Spanish, English, and Portuguese were included to broaden regional and international coverage.

Inclusion criteria encompassed articles published within the defined timeframe, original studies, systematic reviews, and relevant documents directly related to the research topic with full-text availability. Duplicates, studies without full-text access, publications outside the established period, and those unrelated to technological tools or clinical protocols in TBI management were excluded. The selection process occurred in three phases: title screening, abstract review, and full-text evaluation. Standardized data extraction matrices were used, and a qualitative synthesis of results was performed; no meta-analysis was conducted due to methodological heterogeneity among included studies.

DEVELOPMENT

Bootstrap is regarded by several authors as a library of open-source tools designed to optimize the design of websites and web applications. It is built using HTML (HyperText Markup Language) and CSS (Cascading Style Sheets) and includes a wide range of design elements such as forms, buttons, and menus that adapt to different screen sizes.[9,10]

The primary objective of this tool is to create dynamic, responsive web protocols with mobile-first orientation and rapid accessibility, ensuring all implemented elements function correctly across devices—from smartphones and tablets to desktop and laptop computers. It also features user-friendly components such as navigation bars, a grid system, image carousels, and interactive buttons, along with functionalities that support user learning.[11]

Its extensive library of tools and components enables users to customize and enhance any project, largely facilitated by jQuery—a JavaScript library that includes three main files:[12]
- Bootstrap.css: contains styles for various Bootstrap elements, allowing users to apply and modify them as needed.
- Bootstrap.js: contains the framework's execution logic and manages user interaction and screen-size adaptation.
- Glyphicons: provides a gallery of icons to improve user interaction.

Bootstrap installation is simple and practical; however, to fully leverage its potential, programming knowledge is required to effectively implement and execute clinical protocols. Thus, a team of developers is essential to meet this need, working collaboratively with medical personnel knowledgeable in TBI to optimize content and develop a tool that facilitates TBI management.

Due to homonymy, it is crucial to clarify that when referring to the Bootstrap technological tool, we do not mean the BOOTStraP protocol for adult TBI management. However, this technological framework could be highly useful in collaboration with the authors of the BOOTStraP protocol to develop a digital system based on its database, guiding diagnosis and management in pediatric TBI cases.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(S2): e7017

Importance of TBI in Pediatrics

TBI has a high incidence in the pediatric population. Although most cases are mild, TBI remains the leading cause of death and disability in children over one year of age. Prognosis has improved over time due to advances in monitoring and therapeutic technologies. Nevertheless, TBI poses a significant challenge for pediatricians, as it is difficult to identify cases at risk of intracranial injury even with detailed physical examination, complete clinical history, and complementary tests.[13]

As previously mentioned, TBI mechanisms vary widely. The most challenging to assess are cases of child abuse, as caregivers often conceal signs. Therefore, obtaining reliable information about how, where, and when the injury occurred—and who witnessed it—is critical. Primary care pediatricians must identify high-risk TBI cases requiring referral to higher-level hospitals equipped for proper evaluation, diagnosis, and treatment. Simultaneously, they must stabilize vital functions to prevent secondary brain injury.[8,11]

According to INEC data from Ecuador, males are more affected by pediatric TBI (60,72 %), with the highest incidence occurring between 2 and 5 years of age (32,28 %). Falls account for 65,49 % of cases—the most common cause—followed by traffic accidents (22,68 %). Most cases originate in urban areas (84,34 %).[7] In developed countries, TBI is the leading cause of mortality in children over one year old and a major contributor to intellectual disability, epilepsy, and physical impairment.[14]

Risk factors for pediatric TBI include:[7]
- Lack of parental or caregiver supervision
- Child abuse
- Age: peak incidence at 2 years (onset of walking) and 15 years (engagement in extreme sports, driving, or delinquency)

A common form of child abuse is shaken baby syndrome, wherein an infant or young child is violently shaken, causing whiplash-like injury characterized by cervical spine damage and frontal/occipital brain injury. Damage results from abrupt acceleration-deceleration forces. Diagnosis is challenging due to absence of external trauma; identification relies on imaging findings (e.g., subdural hematoma) or clinical signs such as retinal hemorrhages.[13]

As explained in the pathophysiology of TBI, physical force causes brain parenchyma damage. However, impacts may also affect other organ systems, leading to systemic complications—such as hypotension, low cardiac output, hypoxemia, hypercapnia, or anemia—that exacerbate cerebral injury. In severe TBI, loss of cerebral autoregulation limits cerebral blood flow, causing cerebral hypotension. Initial management must therefore focus on optimizing vital functions through fluid resuscitation, electrolyte correction, blood transfusion if needed, oxygen delivery via mask, and securing airway and venous/parenteral access.[11,14]

"In TBI, time is brain." Macroscopic changes are uncommon immediately post-impact; instead, neuronal microtubule disruption and neurotransmitter alterations (e.g., acetylcholine, glutamate, aspartate) occur. Within 30 minutes, vascular congestion leads to cerebral edema. By 24 hours, hemorrhages and parenchymal congestion become evident. Between days 7–10, coagulative necrosis and liquefaction of brain tissue occur, accompanied by macrophage proliferation. Glial reactions become prominent by days 10–14 and may persist for months or years.[15]

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(S2): e7017

Early identification of TBI-associated injuries and timely treatment are essential. Imaging studies are crucial but must be ordered according to established protocols. While most pediatric TBIs are mild and benign, the main challenge lies in recognizing moderate-to-severe cases, where comprehensive clinical assessment, detailed history, and complementary tests are decisive. Initial TBI classification should follow the ATLS primary survey (XABCDE): exsanguinating hemorrhage, airway, breathing, circulation, disability (including GCS), and exposure/environmental control. In polytrauma, FAST ultrasound is valuable for detecting occult internal injuries.[13]

Once hemodynamically stable, a thorough secondary survey must be performed, including systemic and neurological evaluation to identify skull base fracture signs—Battle's sign (retroauricular ecchymosis), periorbital ecchymosis ("raccoon eyes"), otorhinorrhea, otorrhea, hemotympanum, or facial nerve palsy. When present, neuroimaging—primarily computed tomography (CT) or magnetic resonance imaging (MRI)—is indicated to confirm intracranial lesions and guide management.[13] CT interpretation should follow the ABCDE method: assessing structural asymmetries, hematoma volumes, basal cistern compression, midline shift, and additional findings in soft tissues, skull bones, or intracerebral structures—key criteria for therapeutic and surgical decisions.[16]

In moderate-to-severe pediatric TBI, imaging reveals diverse intracranial lesions: skull fractures, epidural/subdural hematomas, subarachnoid/intraparenchymal/intraventricular hemorrhage, cerebral contusions, and focal/diffuse axonal injury with cerebral edema. Integration with basic laboratory tests (complete blood count, blood gas analysis, hemoglobin, glucose) enables comprehensive clinical assessment and detection of complications—particularly elevated intracranial pressure and cerebral herniation, which can be immediately life-threatening.[17,18.19,20]

The above is based on the BOOTStraP protocol, designed for severe TBI in Latin American populations and serving as the foundation for developing an easily accessible, user-friendly digital application for all healthcare personnel using the Bootstrap technological framework. This endeavor requires a multidisciplinary team comprising systems engineers, programmers, graphic designers, software architects, and medical professionals—including general physicians, emergency physicians, pediatricians, neurologists, and neuroradiologists—to collaboratively develop a high-utility tool for pediatric TBI management, with formal approval from the BOOTStraP protocol authors.[12,21]

Bootstrap has diverse applications; globally recognized companies such as Google, Airbnb, and Dell use it for web development. In medicine, it has primarily been applied to statistical data management, enabling reliable, stable, interactive, and dynamic databases adaptable to research evolution. Currently, it is used to generate medical presentation templates for hospital, clinical, or individual use, as well as for advanced research applications such as stratified sampling estimation.[22,23,24]

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(S2): e7017

CONCLUSIONS

The Bootstrap framework presents itself as a versatile technological tool adaptable to any mobile or desktop device, enabling the deployment of responsive applications that integrate pre-designed, specialist-validated clinical protocols. In pediatric TBI, its implementation is particularly relevant, as timely management of moderate and severe cases can prevent secondary, tertiary, and quaternary injuries that are difficult to treat. In this context, it is recommended to advance toward incorporating new technologies that optimize TBI assessment and management in pediatric patients. Specifically, the development of a digital program based on the BOOTStraP Protocol is proposed to support comprehensive, rapid, safe, and evidence-based diagnosis and treatment.

BIBLIOGRAPHIC REFERENCES

1. Bootstrap: guía para principiantes de qué es, por qué y cómo usarlo [Internet]. Rock Content - ES. Rock Content; 2020 [citado 31/07/2024]. Disponible en: https://pingback.com/es/resources/bootstrap/

2. Morales Camachoa JW, Plata Ortiz JE, Plata Ortiz S. La importancia del abordaje y categorización del paciente pediátrico. PEDIATR [Internet].2019[citado 31/07/2024]; 52(3). Disponible en: https://www.researchgate.net/profile/William-Morales-Camacho/publication.

3. TCE - Traumatismo craneoencefálico Pan American Health Organization / World Health Organization [Internet]; 2018 [citado 31/07/2024]. Disponible en: https://www3.paho.org/relacsis/index.php/es/foros-relacsis/foro-becker-fci-oms/61-foros/consultas-becker/938-tce-traumatismo-craneoencefalico/

4. Esparragosa I, Navarro D. Traumatismo Craneoencefálico. Guías de Actuación en Urgencias Clínica Universidad de Navarra [Internet]. 2018 [citado el 31/07/2024]. Disponible en: https://www.studocu.com/es-mx/document/instituto-mexico-de-ciudad-juarez/medicina-legal/guia-actuacion-tce-guia/34730927

5. Hernández Umaña V, Rodríguez Rufino CD, Montero Castillo I, Echeverría Miranda M. Trauma craneoencefálico severo en pediatría: una revisión bibliográfica. Traumatología [Internet]. 2024 [citado el 31/07/2024]; XIX(3) Disponible en: https://www.revista-portalesmedicos.com/revista-medica/trauma-craneoencefalico-severo-en-pediatria-una-revision-bibliografica/

6. González Balenciaga M. PROTOCOLOS DIAGNÓSTICOS Y TERAPÉUTICOS EN URGENCIAS DE PEDIATRÍA. Traumatismo craneal. Sociedad Española de Urgencias de Pediatría (SEUP). 4ta Ed [Internet]; 2024 [citado 31/07/2024]. Disponible en: https://seup.org/wp-content/uploads/2024/04/18_Trauma_craneal_4ed.pdf.

7. Martínez Astudillo, A, López Ochoa E, Lapo Córdova N, Tipán Barros T, Escalante Canto P, Córdova-Neira F. Trauma cráneo-encefálico en niños. Rev Med Ateneo [Internet].2017 [citado 31/07/2024]; 19(2): 131-145. Disponible en: file:///C:/Users/User/Downloads/12-Texto%20del%20art%C3%ADculo-23-1-10-20190501.pdf

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(S2): e7017

8. Godoy DA, Murillo-Cabezas F. Conceptualización evolutiva de los mecanismos lesionales en el traumatismo craneoencefálico. Med Intensiva [Internet]. 2022[citado 31/07/2024]; 46(2): 90–3. Disponible en: http://dx.doi.org/10.1016/j.medin.2020.02.003

9. Londoño P. Qué es Bootstrap, para qué sirve y cómo funciona [Internet]. Hubspot.es; 2023 [citado 31/07/2024]. Disponible en: https://blog.hubspot.es/website/que-es-bootstrap

10. ¿Qué es CSS y cómo funciona en el desarrollo web? UNIR [Internet]; 2025 [citado 31/07/2024]. Disponible en: https://www.unir.net/revista/ingenieria/que-es-css/.

11. Deyimar A. ¿Qué es Bootstrap? - Una guía para principiantes [Internet]. Tutoriales Hostinger; 2020 [citado 31/07/2024]. Disponible en: https://www.hostinger.es/tutoriales/que-es-bootstrap

12. ¿Qué es Bootstrap y cómo funciona este framework? [Internet]. Santanderopenacademy.com; 2023 [citado 31/07/2024]. Disponible en: https://www.santanderopenacademy.com/es/blog/que-es-bootstrap.html

13. Hernández Rastrollo R. Traumatismos craneoencefálicos. Pediatría integra[Internet]l. 2019 [citado 31/07/2024]; *XXIII(1).* Disponible en: https://www.pediatriaintegral.es/publicacion-2019-01/traumatismos-craneoencefalicos-2019/

14. Pérez Suárez E, Serrano A, Casado Flores J. Traumatismo craneoencefálico en edades pediátricas. Revista Española de Pediatría [Internet]; 2010 [citado 31/07/2024]. Pag.60. Disponible en: https://www.seinap.es/wp-content/uploads/Revista-de-Pediatria/2010/REP%2066-1.pdf#page=56

15. Madrigal Ramírez E, Hernández Calderón C. Generalidades de Trauma Cráneo Encefálico en Medicina Legal. Med Leg Costa Rica [Internet]. 2017 [citado 31/07/2024]; 34(1): 147–56. Disponible en: https://www.scielo.sa.cr/scielo.php?script=sci_arttext&pid=S1409-00152017000100147

16. PROTOCOLO BOOTStraP: Más allá de una opción para el tratamiento de la lesión cerebral traumática Lww.com; 2021 [citado 31/07/2024]. Disponible en: https://cdn-links.lww.com/permalink/neu/d/neu_2022_03_25_griswold_neu-d-22-00169_sdc1.pdf

17. Tasker, R. Elevated intracranial pressure (ICP) in children: Management [Internet]. Uptodate.com; 2025 [citado 31/07/2024]. Disponible en: https://www.uptodate.com/contents/elevated-intracranial-pressure-icp-in-children-management

18. Rucián AF, del Toro Riera M. Hipertensión intracraneal en Pediatría. Asociación Española de Pediatria [Internet]. 2022 [citado 31/07/2024]; 1: 135-144. Disponible en: https://www.aeped.es/sites/default/files/documentos/14.pdf

19. Williamson, C. Traumatic brain injury: Epidemiology, classification, and pathophysiology. UPTODATE[Internet]; 2025 [citado 31/07/2024]. Disponible en: https://www.uptodate.com/contents/traumatic-brain-injury-epidemiology-classification-and-pathophysiology

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(S2): e7017

20. Lan Zhigang MD, Seidu AR, PhD MD, Li Qiang MD, Wu Cong MD, Zhang Qiao MD; Chen L et al . Outcomes of patients undergoing craniotomy and decompressive craniectomy for severe traumatic brain injury with brain herniation. Medicine [Internet]. 2020 [citado 31/07/2024]; 99(43): e22742. Disponible en: https://journals.lww.com/md-journal/fulltext/2020/10230/outcomes_of_patients_undergoing_craniotomy_and.51.aspx

21. Theran León JS, Rolanlly Robles J, Jaimes Hernández LX , Ramírez Zambrano CL, Solano Díaz LC, Guerrero Moreno JS, et al.Vista de Revisión del manejo del trauma craneoencefálico en urgencias. Ciencialatina [Internet]. 2022 [citado 31/07/2024]; 6(3). Disponible en: https://ciencialatina.org/index.php/cienciala/article/view/2251/3285

22. Caballero MM. Tiempedia: Modelos Bootstrap para Estimación de Incertidumbre en Series de Tiempo. Linkedin [Internet]. 2023 [citado 31/07/2024]; 6(3). Disponible en: https://es.linkedin.com/pulse/tiempedia-modelos-bootstrap-para-estimaci%C3%B3n-de-en-mora-caballero-mruue

23. Porras JC. APLICACIÓN DEL BOOTSTRAP EN MÉTODOS INDIRECTOS DE ESTIMACIÓN EN MUESTREO ESTRATIFICADO. An Cient [Internet]. 2015 [citado 31/07/2024]; 76(2): 306. Disponible en: https://revistas.lamolina.edu.pe/index.php/acu/article/view/795