Recommendations of the Colombian Consensus Committee for the Management of Traumatic Brain Injury in Prehospital, Emergency Department, Surgery, and Intensive Care (Beyond One Option for Treatment of Traumatic Brain Injury: A Stratified Protocol [BOOTStRaP])

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Abstract

**Background** Traumatic brain injury (TBI) is a global public health problem. In Colombia, it is estimated that 70% of deaths from violence and 90% of deaths from road traffic accidents are TBI related. In the year 2014, the Ministry of Health of Colombia funded the development of a clinical practice guideline (CPG) for the diagnosis and treatment of adult patients with severe TBI. A critical barrier to the widespread implementation was identified—that is, the lack of a specific protocol that spans various levels of resources and complexity across the four treatment phases. The objective of this article is to present the process and recommendations for the management of patients with TBI in various resource environments, across the treatment phases of prehospital care, emergency department (ED), surgery, and intensive care unit.

**Methods** Using the Delphi methodology, a consensus of 20 experts in emergency medicine, neurosurgery, prehospital care, and intensive care nationwide developed recommendations based on 13 questions for the management of patients with TBI in Colombia.

**Discussion** It is estimated that 80% of the global population live in developing economies where access to resources required for optimum treatment is limited. There is limitation for applications of CPGs recommendations in areas where there is low availability or absence of resources for integral care. Development of mixed methods consensus, including evidence review and expertise points of good clinical practices can fill gaps in application of CPGs. BOOTStraP (Beyond One Option for Treatment of Traumatic Brain Injury: A Stratified Protocol) is intended to be a practical handbook for care providers to use to treat TBI patients with whatever resources are available.

**Keywords**
- traumatic brain injuries
- intensive care
- emergency care
- prehospital care
- critical care
- intensive care
- Colombia
- guideline

Introduction

Traumatic brain injury (TBI) is a global public health problem.¹ The World Health Organization (WHO) estimates that by the year 2020, TBI will be one of the leading causes of death and disability globally.² Approximately 1,250,000 people die each year as a result of road traffic accidents (RTAs).³,⁴ TBIs affect more than 10,000,000 people annually and are the leading cause of death among persons between 15 and 29 years of age.³,⁴

Epidemiological studies show regional variations, with higher mortality in patients from rural areas and low- and middle-income countries (LMICs), in comparison with urban areas of high-income countries (HICs).³,⁴ This higher mortality and disability associated with TBI in the areas of lower income groups are associated with the lack of prevention, less control of risk factors, and lower capacity for acute care and rehabilitation.⁵ The WHO Global Report of Road Safety for the year 2015 states that 90% of deaths from RTAs occurs in LMICs.⁶ However, while LMICs account for 82% of the world’s population, only 54% of the world’s registered vehicles are in LMICs, indicating a disproportionate number of road traffic deaths.⁶ Colombia is a country that still maintains a high incidence of trauma from social violence and traffic accidents.⁷ Of these traumas, the estimates associated with TBI range from 49 to 70%.⁷ There is little accurate information in Colombia about the deaths attributed to TBI. However, estimates from autopsy reports of the National Institute of Legal Medicine and Forensic Sciences indicate that 70% of deaths from violence and 90% of deaths from RTAs are TBI related.⁷

In the year 2014, the Ministry of Health of Colombia, through the convocation 563-2012 of the Administrative Department of Science, Technology and Information (COLCIENCIAS), funded the development of a clinical practice guideline (CPG) for the diagnosis and treatment of adult patients (older than 15 years) with severe TBI.¹ This guideline was developed under the direction of the Meditech Foundation, utilizing expert clinical representatives from multiple disciplines involved in the comprehensive care of TBI patients. The document, including recommendations based on scientific evidence, is intended to decrease the heterogeneity in the management of these patients across the four treatment phases of prehospital care, emergency department (ED) management, surgery, and intensive care.
unit (ICU) (please refer http://gpc.minsalud.gov.co/gpc_sites/Repositorio/Conv_563/GPC_trauma_craneo/CPG_TBI_professionals.pdf). Two years after its publication as a technical paper of the Ministry of Health, there were various meetings to advance implementation. During this process, an essential barrier to the widespread implementation was identified—that is, the lack of a specific protocol that spans various levels of resources and complexity across the four treatment phases.

Based on the current required regulations for enabling health services in Colombia, where complexity levels are described as shown in Table 1, a consensus process involving clinical experts was conducted to develop a series of management protocols to articulate treatment options for TBI specific to different levels of resources and complexity across the prehospital, emergency care, neurological surgery, and intensive care phases. The expert panel included representatives from the Colombian Association of Universities with programs in Prehospital Care, the Colombian Association of Specialists in Emergency Medicine, the Colombian Association of Neurosurgery, Chapter of Neurotrauma, and the Colombian Association of Critical Care Medicine and Intensive Care through the Chapter of Neurointensive Care. The objective of this article is to present the process and recommendations for the management of patients with TBI in various resource environments, across the treatment phases of prehospital care, ED, neurosurgery (NSG), and ICU.

### Table 1 Definitions of levels of complexity of prehospital, emergency care, surgery, and intensive care

<table>
<thead>
<tr>
<th>Level of resource definitions</th>
<th>Ambulances</th>
<th>Emergency room</th>
<th>Neurological surgery</th>
<th>ICU with CT, center of medium–high complexity</th>
<th>ICU with CT, in a center of medium–high complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic emergency transport</strong></td>
<td>Basic health facility (without CT) Low complexity</td>
<td>Advanced health facility with CT Medium–high complexity</td>
<td>Operation room with CT access but without neurosurgery</td>
<td>Facility with CT, center of medium complexity</td>
<td>Unit with CT, in a center of medium–high complexity</td>
</tr>
<tr>
<td><strong>Advanced emergency transport</strong></td>
<td>Facility with: General physician, advanced life support training</td>
<td>Facility with: General physician, advanced life support training</td>
<td>Facility with: General surgeon, Anaesthesiologist</td>
<td>Facility with: Anesthesiologist, Operative room available</td>
<td>Unit with: Respiratory therapy, Electronic monitoring of vital signs</td>
</tr>
<tr>
<td><strong>Vehicle with first responder (with or without training)</strong></td>
<td>Mechanical ventilator with battery for at least 4 h</td>
<td>Electronic monitoring of vital signs</td>
<td>Surgical instrumentation</td>
<td>Surgical instrumentation</td>
<td>Surgical instrumentation</td>
</tr>
<tr>
<td><strong>Vehicle with or without electronic monitoring of vital signs</strong></td>
<td>AED</td>
<td>Drug infusion pumps</td>
<td>Surgical nurses</td>
<td>Surgical nurses</td>
<td>Surgical nurses</td>
</tr>
<tr>
<td><strong>Vehicle without advanced airway management equipment</strong></td>
<td>Airway suction system</td>
<td>Airway suction system</td>
<td>Clinical laboratory</td>
<td>Clinical laboratory</td>
<td>Clinical laboratory</td>
</tr>
<tr>
<td><strong>Vehicle with or without IV fluids capability</strong></td>
<td>Advanced airway management kit</td>
<td>Advanced airway management kit</td>
<td>Pharmacy</td>
<td>Pharmacy</td>
<td>Pharmacy</td>
</tr>
<tr>
<td><strong>Facility with: Basic radiology without CT</strong></td>
<td>Basic radiology without CT</td>
<td>Basic radiology without CT</td>
<td>Basic surgical equipment</td>
<td>Basic surgical equipment</td>
<td>Basic surgical equipment</td>
</tr>
<tr>
<td><strong>Available in crystals, supports</strong></td>
<td>Availability of crystalloids fluids</td>
<td>Availability of crystalloids fluids</td>
<td>Facility without neurosurgery availability</td>
<td>Facility without neurosurgery availability</td>
<td>Facility without neurosurgery availability</td>
</tr>
<tr>
<td><strong>Pharmacological support</strong></td>
<td>Pharmacological support</td>
<td>Pharmacological support</td>
<td>Facility with ICU capabilities</td>
<td>Facility with ICU capabilities</td>
<td>Facility with ICU capabilities</td>
</tr>
</tbody>
</table>

Abbreviations: AED, automated external defibrillator; CC, critical care; CT, computed tomography; ICU, intensive care unit.

Materials and Methods

In March 2017, a national consensus conference for the development of the protocol for comprehensive care of adults with TBI was held in Bogota, Colombia. Twenty experts in prehospital care, emergency medicine, neurosurgery, and intensive care attended, accompanied by five methodologists. Six participants attended through videoconferencing and 19 in person. The process took 3 days; 2 meeting days with 1 final consensus day during which participants discussed possible answers to the following questions.

Prehospital Care
What is the best protocol (step by step) for treating an adult patient:

1. Mild TBI in a basic ambulance or basic emergency transport (BET)?
2. Moderate–severe TBI in a BET?
3. Mild TBI in a medical ambulance or advanced emergency transport (AET)?
4. Moderate–severe TBI in an AET?

Emergency Care
What is the best protocol (step by step) for managing an adult patient with:

5. Mild TBI in a low complexity ED without computed tomography (CT)?
6. Mild TBI in a medium–high complexity ED with CT?
7. Moderate–severe TBI in a low complexity ED without CT?
8. Moderate–severe TBI in a medium–high complexity ED with CT?

Neurological Surgery
9. What is the best protocol to determine if a patient with TBI requires immediate neurological surgery?

What is the best protocol to manage a patient who requires immediate surgery in a medical center that: Does it not have neurosurgery?
10. Does it not have neurosurgery?
11. Have neurosurgery but no ICU?

Intensive Care
12. What is the best protocol to manage a patient with moderate–severe TBI in an intermediate care unit (no ICU) within a center of medium complexity?
13. What is the best protocol to manage a patient with moderate–severe TBI in an ICU within a center of medium–high complexity?

We conducted a systematic search for publications that described methods for conducting consensus processes when evidence alone was insufficient to establish protocols. One publication described the use of the Delphi method combined with the nominal group method to achieve consensus in developing guidelines for the management of severe sepsis and septic shock. In this document, investigators provided specific information about the iterative process they used to funnel disparate opinions into a manageable set of questions, and about how they quantified the convergence of opinions. The process developed for this project is a modification of the one used for the sepsis guidelines. We used the principles and practices of the Delphi method and Nominal Group Method to conduct this project.

Participants were organized into subgroups of prehospital care, emergency medicine, neurosurgery, and intensive care, according to their expertise and background with a moderator for each subgroup. A month in advance of the meeting, each subgroup was provided with preparation material, which included the scientific evidence on specific interventions for each area, as well as CPGs—those based on evidence and those based on expert consensus. The questions were allocated to each subgroup, and in the first session (day 1), through a series of voting rounds, an agreement was reached among the subgroups. A 70% agreement rate was required to specify each recommendation. Next, a representative of each subgroup presented its recommendations to the entire group, which discussed the recommendations considering the scientific evidence and expert opinion. The entire group then voted on each recommendation and continued this iterative process of discussion and voting until a 90% agreement rate was obtained to endorse a recommendation. Facilitators of the methodological team support the discussion and voting sessions all the time.

In the final session, management algorithms were presented, which integrated the recommendations, adjusted, and stratified according to the availability of resources in centers of varying complexity. The product was named as BOOTStraP—Beyond One Option for Treatment of Traumatic Brain Injury: A Stratified Protocol [online only].

Results

How to Interpret and Use the Proposed Algorithms
We have created categories for each treatment phase, according to real scenarios presented by experts from different regions of the country, and identified in different surveys during the development of the Colombian TBI guidelines.

- **Prehospital**: Basic ambulance or BET; medical ambulance or AET.
- **Emergency care**: Low complexity (without CT), medium–high complexity with CT.
- **Neurological surgery**: Does not have neurosurgery available; has neurosurgery but no ICU availability.
- **Intensive care**: Has an intermediate care unit but no ICU availability and no neurosurgery availability; has ICU and neurosurgery availability.

Therefore, the algorithms for treatment shown later are not organized according to strict categorizations. They are
stratified. In this way, a medical provider in any of the four treatment phases can select the best practice treatment option, depending on the available resources as shown in ►Fig. 1. The treatment options in the algorithms below are presented in red, yellow, or green background. A red background indicates the proposed intervention can be performed in the lowest level of resources; a yellow background indicates the intervention can be performed at a medium level of resources, and green background indicates the interventions are regularly performed in the most advanced level of resources. All the options (proposed interventions) can be selected from the algorithms and organized in different levels of care according to the availability of the mentioned resources.

**Questions 1 and 2**

**What is the best protocol for treating an adult patient with mild, moderate, or severe TBI in a BET?**

**Recommendation**

- It is recommended that the management of adult patients who present with mild TBI (without criteria for prehospital care or transfer in an AET) can be performed in a BET. However, if the planned transfer is longer than 30 minutes, and AET should be requested if available.
- It is recommended that no patient with moderate or severe TBI be transported in a BET, but if this situation occurs in any region, algorithm in ►Fig. 2 should be followed.

![Fig. 1 Three-dimensional stratified scheme according to the level of resources and complexity.](image)

![Fig. 2 Management algorithm of the patient with traumatic brain injury (TBI) in basic emergency transport (BET).](image)
To determine the requirement for prehospital care and transfer, parameters such as the mechanism of injury, type of injury, clinical status, age, comorbidities, history, and Glasgow coma scale (GCS) should be evaluated.

Questions 3 and 4
What is the best protocol for treating an adult patient with mild, moderate, or severe TBI in an AET?

Recommendation
- It is recommended not to remain at the scene for more than 30 minutes, regardless of the patient’s clinical status because the time at the scene can diminish the possibility of a good neurological result. The GCS to classify the severity of the injury in the patient should be performed after the initial resuscitation.
- It is recommended to follow the algorithm shown in Fig. 3, including interventions shown in Tables 2 and 3.

Question 5
What is the best protocol for managing an adult patient with mild TBI in a low complexity ED (without CT)?

Recommendation
- Every mild TBI patient who enters the ED should be treated for any life-threatening event according to the advanced trauma life support (ATLS) primary evaluation, including those with penetrating injuries to the head. Patients

Fig. 3 Management algorithm of the patient with traumatic brain injury (TBI) in advanced emergency transport (AET).

Table 2 Medication sequence for endotracheal intubation

<table>
<thead>
<tr>
<th>Medication</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductors</td>
<td>Ketamine Amp × 500 mg Dose: 1.5–2 mg/kg For a patient of 70 kg: 105–140 mg</td>
<td>Midazolam Amp × 5 mg/amp × 15 mg Dose: 0.1–0.3 mg/kg For a patient of 70 kg: 7–21 mg</td>
<td>Etomidate Amp × 20 mg Dose: 0.3 mg/kg For a patient of 70 kg = 21 mg</td>
</tr>
<tr>
<td>Muscular blockers</td>
<td>Succinylcholine Amp × 250 mg Dose: 1–2 mg/kg For a patient of 70 kg: 70–140 mg</td>
<td>Rocuronium Amp × 50 mg Dose: 0.7–1 mg/kg For a patient of 70 kg = 50–70 mg</td>
<td>Vecuronium Amp × 50 mg Dose: 0.1 mg/kg For a patient of 70 kg = 7 mg</td>
</tr>
<tr>
<td>Analgesics</td>
<td>Fentanyl Amp × 500 μg Dose: 2–4 μg/kg For a patient of 70 kg = 140–280 μg</td>
<td>Ketamine Amp × 500 mg Dose: 1.5–2 mg/kg For a patient of 70 kg = 105–140 mg</td>
<td></td>
</tr>
</tbody>
</table>

Note: Select any option for each one of the categories according to the availability of medications.
presenting with a penetrating injury to the head and/or any abnormal finding in the primary clinical evaluation should be referred to a center of high complexity for neuroimaging (see CT reading suggestions at Appendix A in Supplementary Material S2 [online only]), evaluation by the neurosurgery service, and integrated management according to the criteria in ►Tables 4 and 5 and ►Fig. 4. • If the patient does not have abnormal findings in the primary clinical evaluation, or does not have a penetrating brain injury, or does not meet the referral criteria in ►Table 4, the patient should be observed in the ED. After 4 to 6 hours of observation, if the patient does not develop referral criteria (►Table 4), consider discharge with recommendations and warning signs.

It is recommended to follow the algorithm shown in ►Fig. 5.

Questions 6

What is the best protocol for managing an adult patient with mild TBI in a medium or high complexity ED (with CT scan)?

Table 3 Suggestions for HTS preparation

<table>
<thead>
<tr>
<th>Hypertonic fluids</th>
<th>HTS 3% Peripheral vein</th>
<th>HTS 7.5% Peripheral vein</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NS (0.9%) 400 mL + sodium chloride ampoules 100 mL (ampoules of 20 mEq in 10 mL)</td>
<td>NS (0.9%) 100 mL + sodium chloride ampoules 150 mL (ampoules of 20 mEq in 10 mL)</td>
</tr>
<tr>
<td>Dose: 3–4 mL/kg</td>
<td>For a patient of 70 kg = 210–280 mL per dose Only for use if SBP &lt; 100 mm Hg or clinical signs of brain herniation</td>
<td>Dose: 2 mL/kg For a patient of 70 kg = 140 mL per dose Only for use if SBP &lt; 100 mm Hg or clinical signs of brain herniation</td>
</tr>
</tbody>
</table>

Abbreviations: HTS, hypertonic saline; NS, normal saline; SBP, systolic blood pressure.

Table 4 Criteria for transfer of patients with TBI to a high-level facility for neuroimaging or neurosurgical consultation

It is recommended that patients with moderate to severe TBI (GCS 3–12) should be transferred immediately to high level of care hospitals with access to neuroimaging and neurosurgery

It is recommended that patients with mild TBI (GCS 13–15) who present one or more of the following criteria be referred for evaluation at an institution that has access to neuroimaging and neurosurgery:

- GCS under 15 up to 2 h after injury
- Severe headache
- More than two episodes of vomiting
- Skull fracture, including depressed fractures or clinical signs of fracture of the skull base (raccoon eyes, retroauricular ecchymosis, otorrhea, or rhinorrhea)
- Age older than or equal to 60 y
- Blurred vision or diplopia
- Posttraumatic seizure
- Focal neurological deficit
- Previous craniotomy
- Fall of more than 1.5 m
- Retrograde amnesia more than 30 min and/or anterograde amnesia
- Suspected intoxication with alcohol and/or psychoactive substances

It is recommended that patients with mild TBI and who are in active treatment with anticoagulants, have active coagulopathies, or are pregnant should be transferred to centers with neurosurgery and neuroimaging services

Abbreviations: GCS, Glasgow coma scale; TBI, traumatic brain injury.
with recommendations and warning signs is appropriate. If the CT is abnormal, request an assessment by the neurosurgery service to determine medical or surgical management.

It is recommended to follow the algorithm shown in – Fig. 6.

**Question 7**

What is the best protocol for managing an adult patient with moderate to severe TBI in a low complexity ED (without CT)?

**Recommendation**

- It is recommended that adult patients with moderate to severe TBI who enter the ED of low complexity centers receive a comprehensive evaluation as described by the ATLS, through primary and secondary evaluation, and prepare the patient for immediate referral under the best conditions to the nearest center with availability of neurosurgery and neuroimaging as shown in – Fig. 5.
Question 8

What is the best protocol for managing an adult patient with moderate to severe TBI in a medium or high complexity ED (with CT scan)?

Recommendation

- It is recommended to manage an adult patient with moderate to severe TBI in an ED of medium or high complexity, when available.
It is recommended to follow the algorithm shown in ►Fig. 6.

**Question 9**

What is the best protocol to determine if a patient with TBI requires immediate surgery?

**Recommendation**

- To determine those patients admitted to the ED with TBI that require immediate surgical intervention, the patient must have one or more clinical criteria and one or more imaging criteria (►Table 6). It is recommended that a neurological examination be performed after adequate resuscitation in the emergency room to determine the clinical criteria.

**Table 6** Surgical indications for immediate transfer to a higher level facility with neurosurgery capabilities

<table>
<thead>
<tr>
<th>Clinical criteria</th>
<th>Imaging criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupillary asymmetry with 1 mm of difference</td>
<td>Midline shift &gt; 5 mm</td>
</tr>
<tr>
<td>GCS motor response of 4 or less</td>
<td>Total cisterns compression (Grade III)</td>
</tr>
<tr>
<td>Epileptiform</td>
<td>Epidural hematoma ≥ 30 mL in volume</td>
</tr>
<tr>
<td>Intracerebral hematoma ≥ 50 mL in volume</td>
<td>Subdural hematoma &gt; 10 mm in width</td>
</tr>
<tr>
<td>Posterior fossa hematoma with hydrocephalus</td>
<td></td>
</tr>
</tbody>
</table>

**Table 7** Criteria for medium-high complexity center for patients with moderate to severe TBI

<table>
<thead>
<tr>
<th>Medium complexity</th>
<th>High complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitalization</td>
<td>Hospitalization</td>
</tr>
<tr>
<td>Radiology and diagnostic imaging, CT scan</td>
<td>Surgery</td>
</tr>
<tr>
<td>Clinical laboratory, arterial gases</td>
<td>Intensive care</td>
</tr>
<tr>
<td>Pharmaceutical service</td>
<td>Intensive neonatal care (if pediatric center)</td>
</tr>
<tr>
<td>Sterilization process</td>
<td>Physiotherapy or respiratory therapy</td>
</tr>
<tr>
<td>Blood transfusion</td>
<td>Pharmaceutical service</td>
</tr>
<tr>
<td>Pathology</td>
<td>Radiology and diagnostic imaging</td>
</tr>
<tr>
<td>Respiratory therapy</td>
<td>Clinical laboratory</td>
</tr>
<tr>
<td>Nutrition</td>
<td>Blood transfusion</td>
</tr>
<tr>
<td>Transportation assistance</td>
<td>Hospital support services</td>
</tr>
<tr>
<td>Sterilization process</td>
<td>Transportation assistance</td>
</tr>
<tr>
<td>Pathology</td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviation:** GCS, Glasgow coma scale.

**Note:** One clinical criterion + one imaging criterion = surgical indication.

**One isolated clinical criterion = medical management.**

**One isolated imaging criterion = medical management.**

- It is suggested that personnel with appropriate training provide strict neurological follow-up to a patient who presents clinical criteria without imaging criteria, or imaging criteria without clinical criteria. Surgery may be indicated in the patient with neurological impairment, defined as a decrease in the GCS of more than 2 points.

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**Fig. 7** Management algorithm of patient with traumatic brain injury (TBI) who requires immediate surgery.
• Finally, it is suggested that patients who, after adequate resuscitation, have bilateral mydriasis and a score of 3 on the GCS, should be assessed by the neurosurgeon to determine whether to perform a quick surgical procedure or not.

**Question 10**
What is the best protocol to manage a patient who requires immediate surgery in a health care facility that does not have neurosurgery?

**Recommendation**
• Many hospitals in low-resource settings do not have a neurosurgery service; those located in remote rural areas. It is recommended that close communication occurs between the lower level facility and the referral site to ensure appropriate management during the transportation of patients who will undergo surgery to avoid secondary complications (►Table 7).

It is recommended to follow the algorithm shown in ►Fig. 7.

**Question 11**
What is the best protocol to manage a patient who requires immediate surgery in a medical center that has neurosurgery but no ICU?

**Table 10** Management objectives in medium complexity center

<table>
<thead>
<tr>
<th>Target RASS</th>
<th>RASS description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+4</td>
<td>Combative, violent, danger to staff</td>
</tr>
<tr>
<td>+3</td>
<td>Pulls or removes tube(s) or catheters; aggressive</td>
</tr>
<tr>
<td>+2</td>
<td>Frequent non purposeful movement, fights ventilator</td>
</tr>
<tr>
<td>+1</td>
<td>Anxious, apprehensive, but not aggressive</td>
</tr>
<tr>
<td>0</td>
<td>Alert and calm</td>
</tr>
<tr>
<td>-1</td>
<td>Awakens to voice (eye opening/contact) &gt; 10 s</td>
</tr>
<tr>
<td>-2</td>
<td>Light sedation, briefly awakens to voice (eye opening/contact) &lt; 10 s</td>
</tr>
<tr>
<td>-3</td>
<td>Moderate sedation, movement, or eye opening. No eye contact</td>
</tr>
<tr>
<td>-4</td>
<td>Deep sedation, no response to voice, but movement or eye opening to physical stimulation</td>
</tr>
<tr>
<td>-5</td>
<td>Unarousable, no response to voice, or physical stimulation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target RASS</th>
<th>RASS description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+4</td>
<td>Combative, violent, danger to staff</td>
</tr>
<tr>
<td>+3</td>
<td>Pulls or removes tube(s) or catheters; aggressive</td>
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<td>-3</td>
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<td>-4</td>
<td>Deep sedation, no response to voice, but movement or eye opening to physical stimulation</td>
</tr>
<tr>
<td>-5</td>
<td>Unarousable, no response to voice, or physical stimulation</td>
</tr>
</tbody>
</table>

**Table 9** Criteria for admission to the ICU

<table>
<thead>
<tr>
<th>Condition</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCS ≤ 12 with or spinal cord injury</td>
<td></td>
</tr>
<tr>
<td>ICU support for any other system</td>
<td></td>
</tr>
<tr>
<td>Planned trauma surgery urgent (24 h)</td>
<td></td>
</tr>
<tr>
<td>Comorbidities: (antiocoagulated patients, liver failure, chronic kidney disease in dialysis, heart failure, epilepsy, or who are being treated with ASA/clopidogrel)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ICU, intensive care unit; GCS, Glasgow coma scale.

**Recommendation**
• It is recommended to perform surgery for a patient with TBI that meets the criteria for immediate surgery (►Table 6) in the context of a hospital that has a neurosurgery service and anesthesiologist but does not have an ICU. During the immediate postoperative period, a referral to a medical center with an ICU should be requested. If such a center is available, the patient should be transported immediately. If not, the patient should be maintained with mechanical ventilation and sedation (►Table 10). See the algorithm shown in ►Fig. 7.

**Question 12**
What is the best protocol to manage a patient with moderate to severe TBI in service of intermediate care (no ICU) in a health care center of medium complexity?

**Table 10** Management objectives in medium complexity center

<table>
<thead>
<tr>
<th>Target RASS</th>
<th>RASS description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+4</td>
<td>Combative, violent, danger to staff</td>
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<td>Pulls or removes tube(s) or catheters; aggressive</td>
</tr>
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**Abbreviations**: CT, computed tomography; INR, international normalized ratio.
Recommendation

- It is recommended that the management of adult patients with moderate to severe TBI takes place in a medium complexity care center that has intermediate care if it does not meet ICU criteria (see Table 9). The criteria to determine a center of medium complexity are shown in Table 10.
- All patients who are hospitalized in intermediate care in medium complexity centers should be monitored for evaluation and management with an emphasis on the prevention of secondary injury and the progress of the primary lesion. For this purpose, target maintenance of parameters is shown in Tables 10 and 11.

It is recommended to follow the algorithm shown in Fig. 8.

**Question 13**

What is the best protocol to manage a patient with moderate to severe TBI in an ICU within a center of medium-high complexity?

**Recommendation**

- It is recommended that the management of adult patients with moderate to severe TBI in a medium–high complexity health care center be performed in the ICU if it meets the established criteria shown in Table 7 (see Supplementary Material S1, Algorithm 10 [online only]).
- Specialized medical personnel should carry out the management of such a patient with the availability of face-to-face neurosurgeon consultation.

**Table 11** Minimum monitoring—patient with moderate TBI

<table>
<thead>
<tr>
<th>Cardiogram, pulse oximeter, MAP</th>
<th>Arterial blood gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow GCS, pupil reactivity, and motor deficit every hour</td>
<td>Follow vital signs every hour</td>
</tr>
<tr>
<td>Monitoring the temperature by the axillary route and every hour</td>
<td>Glycemia monitoring every 8 h</td>
</tr>
<tr>
<td>Monitoring daily sodium except if it has osmotic therapy or dysnatremias. In this case, it needs to be monitoring more often</td>
<td>Monitoring of K, Mg, CI daily or at the doctor’s discretion</td>
</tr>
<tr>
<td>Monitoring of PT, PTT, fibrinogen, platelets should be repeated if they are altered according to medical criteria</td>
<td>Monitoring hemoglobin levels every day</td>
</tr>
</tbody>
</table>

Abbreviations: GCS, Glasgow coma scale; MAP, mean arterial pressure; PT, prothrombin time; PTT, partial thromboplastin time; TBI, traumatic brain injury.

**Fig. 8** Management algorithm of patient with moderate to severe traumatic brain injury (TBI) in service of intermediate care.
### Table 12  Patient monitoring in the ICU

<table>
<thead>
<tr>
<th>Cardioscope</th>
<th>Pulse oximeter</th>
<th>Capnography</th>
<th>Invasive blood pressure</th>
<th>Jugular bulb catheter</th>
<th>Urinary catheter</th>
</tr>
</thead>
</table>

- Watch the sedation state according to the RASS scale
- Monitor the clinical status of the patient with an emphasis on pupillary reactivity, and motor deficit
- It is recommended to use continuous EEG if available, especially in patients with unexplained altered consciousness, or patients with GCS of 8 or less with cortical injury, depressed fracture, or penetrating injury
- Following vital signs every hour
- Monitoring the temperature: It is recommended to measure the central temperature if available, otherwise perform the axillary temperature measurement
- Glucose monitoring every 4 h
- Monitoring daily sodium except if the patient has osmotic therapy or if the patient does not have dysnatremia
- Monitoring of K, Mg, Cl daily or at doctor’s discretion
- Monitoring of coagulation is suggested: thromboelastogram measurement, TP, PTT, fibrinogen, and platelets, which should be repeated if they are altered or medical criteria
- Monitoring Hb levels every day
- Monitoring of ICP in patients with GCS less than 8 and abnormal CT
- Doppler monitoring is recommended for all patients in the sites where this resource is available, measuring the pulsatility index and vascular reactivity with reserve
- \( \text{PTiO}_2 \) monitoring: Measurement is recommended for all patients in the places where this resource is available
- Maintain oxygenation with saturation more than 90%, \( \text{PaO}_2 \) more than 60 mm Hg
- Keep \( \text{PaCO}_2 \) in normal parameters for age and height above sea level
- SBP ≥ 100 mm Hg in patients between 50 and 60 y of age, or 110 mmHg or more for patients aged 15 to 49 or older than 70 y
- CPP between 60 and 70 and varies according to metabolic needs
- Keep heart rate at normal levels (60–90)
- Urinary output between 0.5 and 3 mL/kg/h
- Monitor the onset of seizures, and if it has EEG indications
- Preserve the clinical neurological condition of the patient and before a change of GCS more than 2 points perform evaluation by images
- Keep glucose levels between 110 and 170 mg/dL to avoid hypoglycemia
- Maintain temperature between 36 and 37.5°C. It is suggested not to perform prophylactic or therapeutic hypothermia and if there is spontaneous hypothermia, do not do active rewarming, and maintain regulated normothermia
- Keep sodium levels between 135 and 155 mmol/L
- Keep normal levels of other electrolytes
- Maintain hemoglobin above 9 g/dL
- Initiate enteral nutrition early. Evaluate tolerance and without contraindications
- Initiate mechanical prophylaxis in the first 24 h. And then, pharmacological thrombus prophylaxis after 24 h if there are no hemorrhagic lesions and after 72 h if the hemorrhagic lesions are stable in the CT scan
- Keep ICP at levels lower than 18–20 mm/Hg in the first 24 h and 22 mm/Hg after 24 h
- Brain tissue oxygen tissue (\( \text{PtO}_2 \)) must be more than 25 mm/ Hg and less than 55 mm Hg
- Maintain venous jugular oxygen saturation (\( \text{SjO}_2 \)) more than 55%
- Evaluation and rehabilitation, according to the patient’s condition in the first 48 h

Abbreviations: CT, computed tomography; GCS, Glasgow coma scale; ICP, intracranial pressure; INR, international normalized ratio; RASS, Richmond agitation–sedation scale; TBI, traumatic brain injury.
• When the patient arrives in the ICU, they should evaluate: complete medical record with emphasis on physical, neurological, and paraclinical exams performed so far; verify oxygenation status, hemodynamic status, and presence of other injured organs, especially cervical spine injury; and additionally to perform identification, prevention, and management of secondary injury (►Table 12) (see ►Supplementary Material S1, Algorithm 10 [online only]).
• The management of the patient in the ICU should emphasize the prevention of secondary injury and the prevention of the progress of the primary injury, for which the patient should be monitored, with a target to maintain the parameters according to the proposed criteria (►Tables 9–11) (see Supplementary Material S1–S3, Appendix B [online only]).

Discussion
Current evidence-based guidelines for the treatment of TBI were generated from studies conducted in developed countries. It is estimated that 80% of the global population live in developing economies in which access to resources required for optimum treatment is limited. There are few guidelines focused on the management of TBI in low and middle income countries with organized international methodology. Most of these guidelines, developed in high and low–middle income countries do not fill the gaps of different scenarios in real-life situations due to the methodology itself, attached to the evidence-based methodological science. In real circumstances, not all the resources are always available on time, especially in LMICs. The present effort is focused on filling these gaps with a mixed methods approach combining evidence-based recommendations and expert opinion where there is no evidence-based medicine to develop helpful recommendations for real-life situations in different context with resources level variation. The BOOTStraP is two dimensional. The first dimension is the treatment phase (prehospital care, ED, surgery, and ICU). The second dimension is the level of resources. Resource availability in LMICs is ever-changing. Even a high-resource center can find itself without enough medications, or with a sudden loss of personnel. Furthermore, one system may have enough resources in one treatment phase (e.g., ED) but insufficient resources in another (e.g., emergency transport). While the two-dimensional categorization in ►Fig. 1 is over-simplified, it illustrates the territory, and we attempted to cover with the stratified treatment options of BOOTStraP (Supplementary Material S1, available online only).

The strength of this project includes the participation of experts from different specialties since they contribute to connecting the guidelines between the different dimensions. On the contrary, the color teaching material makes it easier for interested people to apply the recommendations according to the context in which they are.

Limitations of this project are the noninclusion of patients younger than 15 years, therapies or tools undergoing experimentation, and the direct nonadvocacy of primary prevention and the rehabilitation process since they were outside the scope of this consensus.

Future steps for this project will include (1) to disseminate BOOTStraP globally, performing an external validation of the exercise by an international group of experts, with the support of international collaborators such as the World Federation of Neurosurgical Societies, the WHO, and the Global Health Research Group on Neurotrauma from the United Kingdom and (2) to conduct a study to measure its influence on outcomes for patients with TBI in low-resource environments.

BOOTStraP is intended to be a practical handbook for care providers to use to treat patients with TBI whatever resources are available. BOOTStraP is an attempt to provide treatment options to 80% of the world’s population, in regions of LMICs economies, where disparities in health care resources and workforce exist daily, challenging the application of guidelines and protocols developed for HICs.

Conclusion
Current evidence-based recommendations of the guidelines for the treatment of TBI are generated with significant flaws in aspects where evidence does not exist or is limited. Knowledge transferability of these recommendations to practice generates critical disconnection from real scenarios were training, or resources are limited. Development of expert consensus-based recommendations, even for areas were training or resources are weak or absent, is possible using validated methodologies. Stratification of recommendations for interventions according to the availability of the resources on different stages of integral care is a proposed method for filling gaps in actual evidence, to organize a better strategy for interventions in different real-life scenarios. We develop 10 algorithms of management for building TBI protocols based on expert consensus to articulate treatment options in prehospital care, EDs, neurological surgery, and intensive care, independent of the level of availability of resources for care.

Note
No human subjects were involved in this work.

Authors’ Contributions
Andrés M. Rubiano, MD, PhD(c): Principal investigator, senior author.
David S. Vera, MD, José N. Carreño, MD, Oscar Gutiérrez, MD, Jorge Mejía, MD, MSc, Juan D. Ciro, MD, Ninel D. Barrios, MD, Alvaro R. Soto, MD, Paola A. Tejada, MD, MSC, PhD, Maria C. Zerpa, MD, Alejandro Gómez, TAPH, MD, Norberto Navarrete, MD, MSc, Oscar Echeverry, TAPH, Mauricio Umaña, MD, Claudia M. Restrepo, MD, María P. Bravo, MD, Mauricio Umaña, MD, Claudia M. Restrepo, MD, José L. Castillo, MD, Oscar A. Sanabria, MD, Maria P. Bravo, MD, Claudia M. Gómez, MD, Daniel A. Godoy, MD, German D. Orjuela, TAPH, Augusto A. Arias, MD, Raúl A. Echeverri, MD, Jorge Páraños, MD: Coinvestigators, coauthors.
Jorge H. Montenegro, MD, Nancy Ann Carney, PhD, and Angelica Clavijo MD: Coinvestigators, coauthors also.
References


Dewan MC, Rattani A, Fiegen G, et al; We would like to thank the following individuals for their dedication and contribution to identifying the global neurosurgical deficit. Collaborators are listed in alphabetical order; Executive Summary of the Global Neurosurgery Initiative at the Program in Global Surgery and Social Change. Global neurosurgery: the current capacity and deficit in the provision of essential neurosurgical care. J Neurosurg 2018;123:295–299
