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Guidelines for the Management of Severe Traumatic Brain Injury. Part 1. Organization of Neutrauma-care System and Diagnosis

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Abstract: Traumatic brain injury is one of the main causes of mortality and severe disability in people of young and middle age. Comatose patients with traumatic brain injury are most difficult to manage. Adequate diagnosis of primary brain injuries, timely prevention and treatment of secondary injuries can reduce mortality and severe disabilities. These guidelines are based on the previous authors' experience of participating in the development of international and Russian recommendations for diagnosing and treating mild traumatic brain injury, penetrating gunshot wounds to the head and brain, severe traumatic brain injury, and severe complications of brain injuries, including the vegetative state. Furthermore, we used the materials of the recently published international and national recommendations on diagnosis, intensive care, and surgical management of severe traumatic brain injury. The proposed recommendations focus on the organization of medical aid and diagnosis of severe traumatic brain injuries in adults and first of all are intended for neurosurgeons, neurologists, neuroradiologists, anesthetists, and resuscitators who are involved in treatment of this group of patients on a daily basis.

Keywords: *severe traumatic brain injury, surgical management of traumatic brain injury, intensive care of traumatic brain injury.*

Over 700,000 people in Russia acquire traumatic brain injury (TBI) annually; this condition is among the main causes of mortality and disability among people of young and middle age. Patients with consciousness suppression up to the comatose state (score 8 and less according to the Glasgow Coma Scale (GCS)) are the group most difficult to manage, which indicates that they have severe TBI. These recommendations were designed for this very group of patients as they require an interdisciplinary approach involving neurosurgeons, neurologists, anesthesiologists, resuscitators, intensive care experts, neurorehabilitationists, and radiologists. Adequate diagnosis of primary brain injuries, timely prevention and treatment of secondary pathophysiological responses and injury mechanisms can reduce mortality and severe disabilities of TBI [1—6].

These guidelines are based on the previous authors' experience of participating in the development of international and Russian recommendations for diagnosing and treating mild traumatic brain injury [7—12], penetrating gunshot wounds to the head and brain [13], severe TBI [14], and severe complications of brain injuries, including the vegetative state [15, 16], as well as clinical guidelines [17—23]. Furthermore, we used the materials of the recently published international and national guidelines for the diagnosis, intensive care, and surgical management of severe TBI [24—32].

The proposed guidelines focus on the diagnosis and management of severe TBI in adults and first of all are intended for neurosurgeons, neurologists, neuroradiologists, anesthetists, and resuscitators who are involved in treating this group of patients on a daily basis. This document does not claim to systematically report all the aspects of diagnosis and treatment of the patients with severe TBI and bears a recommendative nature. The guidelines only represent the authors' opinion on the most important and disputable topics. In clinical practice, there can be situations that stretch beyond these guidelines; hence, the final decision on the strategy for managing every single patient should be made by the physician who is in charge for the treatment.

Methodology

In order to compile the evidential base, we searched for publications in Russian, English, and German languages in the National Library of Medicine database (www.nlm.nih.gov). The search depth was 20 years. The quality and strength of the evidence was assessed by the consensus panel of experts in accordance with the ranking table **(see Table).**

No studies with the evidence level higher than level 2 were retrieved because of the ethical limitations that do not allow one to perform control group studies in situations that might require surgical management. Hence, the theses involving the options were formulated in most sections. For these reasons, readers need to clearly understand that the volume and level of the recommendations presented result from summarizing the available literature and are interpreted in compliance with the rules of evidence-based medicine [33—35].

1.1. Organization of neurotrauma care

1.1.1. Primary care for patients with severe TBI

Basic life support needs to be provided: breathing (recovery of airway patency, management of hypoventilation disorders (hypoxemia and hypercapnia)) and circulation support (management of hypovolemia, arterial hypotension, and anemia) (standard).

1.1.2. Hospitalization of the patients with TBI

Recommendations

The patients diagnosed with severe traumatic brain injury require hospitalization to the neurosurgery or neuro-resuscitation unit of the emergency care unit. If there is no neurosurgery or neuro-resuscitation unit in

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the region, the patients are hospitalized to the trauma or intensive care unit (recommendations).

The in-patient care department that the patients with TBI are admitted to needs to be equipped with a computed tomography (CT) scanner available 24 hours a day (standard). The neurosurgeons should be trained in rendering medical aid to patients with TBI (recommendations).

2.1. Examination of patients with severe TBI upon admission

Recommendations

Upon admission to the neurosurgery or neuro-resuscitation unit, patients undergo thorough clinico-neurological examination that includes assessing the level of wakefulness according to the Glasgow Coma Scale (based on speech production, response to pain, and eye opening), which correlates with the degrees of suppression of consciousness used in Russia: score 15 according to the GCS corresponds to clear consciousness; score 13—14, moderate obtundation; score 9—10, semicoma; score 6—8, moderate coma; score 4—5, deep coma; and score 3, terminal (atonic) coma. Local, oculomotor, pupillary, and bulbar disorders are also assessed. The severity of patient's condition is assessed according to examination by a neurosurgeon, anesthetist-resuscitator (in needed, traumatologist and surgeon) and the data of instrumented and laboratory examination (electrocardiography, X-ray, blood tests). Clinico-neurological and instrumented examination are carried out over time.

2.1.1. Neuroimaging in patients with severe TBI

The mechanism of a traumatic injury, its area, and degree of damage to the brain and head need to be elucidated in patients with TBI. Various neuroimaging methods play a crucial role in revealing the damage, its classification, assessing the area affected, and sorting the patients for emergency surgical interventions or conservative treatment. The modern methods of computed and magnetic resonance imaging allow one to deeper understand the pathophysiological mechanisms of injury and identify the primary and secondary brain damage [36—43]. The international and national neuroradiology associations have recently developed and published recommendations and monographs focused on the use of the entire range of modern neuroimaging methods for patients with TBI, including X-ray CT imaging, magnetic resonance imaging, angiography, single-photon emission computed tomography, ultrasonic methods, etc. [22, 23, 29—32, 44, 45, 47]. In these recommendations, let us focus on the neuroimaging methods that are most typically used for patients with severe TBI.

2.1.1.2. X-ray diagnosis methods

X-ray imaging remains a useful technique in diagnosing injuries to bone structures, penetrating wounds, and intracranial X-ray-detectable foreign bodies. However, its role has become significantly lower as computed tomography started to be more common.

Today, X-ray computed tomography (CT) is the leading method in diagnosing TBI as it allows one to promptly detect and localize acute intracerebral hemorrhages, mass effect and edema, foci of cerebral contusion and crush injury, to determine the size and configuration of the ventricular system of the brain or skull fracture, and detect foreign bodies. Other advantages include its availability and compatibility with life support devices. Furthermore, CT shows low sensitivity in diagnosis of microhemorrhagic and non-hemorrhagic lesions typical of diffuse axonal injury, lesions localized in the structures adjacent to the skull base and cranial vault bones, acute ischemic and hypoxic disorders, and intracerebral hemorrhages in the subacute and chronic phases [22, 29, 43, 45, 46, 48—56].

Recommendations

Computed tomography is the method of choice for primary examination of patients in the acute phase of TBI of different severity (standard).

When performing CT, one needs to determine the presence, location, and volume of hemorrhages and hematomas; presence and the area of cerebral edema; presence, location, structure and the area of medullary contusion; position of the midline structures of the brain and the degree to which they shift; the condition of the CSF-containing system of the brain and cerebral cisterns; condition of the cerebral sulci and gyri; condition of the bone structures of the skull base and cranial vault (presence and type of fractures); condition and contents of the paranasal sinuses, and condition of soft tissues of the skull.

Ranking table for assessing the strength and quality of evidence presented in publications

Level of evidence	Type of recommendations	Description of publications
Level 1	Standards	Well-designed randomized controlled clinical trials, including reviews of such trials
Level 2	Recommendations	Well-designed clinical trials with the control group (non-randomized cohort studies, case-control studies, etc.)
Level 3	Options	Case series studies, comparative studies with the external control group (historical control), case reports, expert opinions

Repeated CT examination is recommended in patients with aggravated neurological status or increased intracranial pressure, especially during the first 72 h after injury in order to diagnose delayed intracranial hematomas, ischemic disorders, and brain swelling.

In patients with craniofacial injuries and suspected liquorrhea, 3D reformatted CT images should be recorded in the axial, coronal, and sagittal views. X-ray or CT scanning should be performed for patients with suspected injury to the cervical spine or other polytrauma.

Pronounced hemodynamic instability (uncontrolled arterial hypotension, systolic blood pressure below 90 mm Hg under continuous infusion of vasopressors) is the relative contraindication for CT of the brain.

2.1.1.3. Magnetic resonance imaging of the brain

Magnetic resonance imaging (MRI) is not so widely used in patients with the acute phase of TBI yet due to a number of limitations and contraindications (metal implants, the need for using nonmagnetic devices for monitoring and mechanical ventilation, duration of the examination procedure, etc.). However, MRI has a higher sensitivity compared to that of CT in diagnosis of the injuries to the brain structures adjacent to the cranial vault and skull base bones, diffuse and local microhemorrhagic and non-hemorrhagic lesions of the corpus callosum, basal ganglia, thalami, and the brain stem, which are typical of diffuse axonal injury. MRI is also a more sensitive method for detecting acute hypoxic and ischemic brain lesions, subacute and chronic hemorrhages, as well as differentiating various types of brain swelling [35, 39, 40, 41, 54, 57—60].

Based on a series of studies carried out using different MRI sequences [38—40, 42, 60], a new classification of localization and severity of damage to the hemispheric and brain stem structures was proposed that included 8 levels:

1 — no signs of parenchymal lesions;

2 — foci of lesions of cortical and subcortical localization, white matter;

3 — corpus callosum lesion±2;

4 — uni- or bilateral damage to subcortical formations and/or thalamus±(2—3);

5 — unilateral damage to the brain stem at any level±(2—4);

6 — bilateral damage to the brain stem at the midbrain level ±(2—4);

7 — bilateral damage to the brain stem at the pontine level±(2—6);

8 — bilateral damage to the medulla oblongata±(2—7).

Every next level can include signs of the previous ones. The new classification of brain damage based on the MRI data has demonstrated that there is a highly reliable correlation with the severity of patients' condition and outcomes of the injury; hence, it can be used to predict the outcomes of TBI [39—41, 45, 55, 56, 59—62].

Recommendations

MRI is indicated for patients with TBI when there is a mismatch between their clinical condition and the CT data. When choosing the MRI regimes and sequences, one needs to take into account the injury mechanisms, presence of focal or diffuse lesions, and localization of intracerebral hemorrhages and hematomas (**options**).

In addition to the routine MRI sequences, it is reasonable to use FLAIR, diffusion-weighted imaging and diffusion-tensor imaging to diagnose nonhemorrhagic brain lesions. The modern regimes of high spatial resolution gradient-echo sequences, such as SWI or SWAN, are used to diagnose microhemorrhage and hemorrhage in the late period after injury (**options**).

To diagnose diffuse axonal injury, it is reasonable to use dynamic diffusion-tensor imaging with qualitative assessment of fractional anisotropy parameters in the brain stem along the corticospinal tracts, in subcortical structures, and in the corpus callosum with 3D construction of the conduction pathway (**options**).

The conditions for performing MRI are as follows: no metal implants; no contraindications for transportation due to instability of arterial and intracranial blood pressure, seizures or psychomotor syndrome; capabilities for providing monitoring and continuing adequate intensive care (including mechanical ventilation) during transportation and examination (**options**).

2.1.1.4. Angiography

Angiographic examination is indicated in patients with suspected damage to intra- and extracranial vessels, which is typically observed upon skull base fractures, penetrating wounds, and concomitant cervical spine injury

The use of CT or MRI angiography has significantly reduced the demand for routine angiography.

2.1.1.5. Ultrasonic testing

Transcranial Doppler ultrasonography is used to assess the linear blood flow velocity in major cerebral vessels and their resistance, which may show vasospasm or vasoparesis during the acute phase of TBI. Ultrasound scanning is also used intraoperatively to localize intracranial hematomas, cerebral ventricles, foreign bodies, etc.

2.1.1.6. Perfusion CT and MRI

Perfusion CT and MRI are used for mapping parameters of the volumetric cerebral blood flow, blood volume and cerebral blood flow velocity in different vascular basins and selectively in the cortical, subcortical and brain stem structures in order to refine the role of hemodynamic factors in pathogenesis and prognosis of the course of traumatic brain injury and optimize the treatment strategy [37, 63, 64]. These methods are employed in patients with severe TBI in combination with monitoring of intracranial and cerebral perfusion

pressure under certain indications (see Monitoring of intracranial pressure and cerebral perfusion pressure).

2.1.1.7. MR spectroscopy, functional MRI, single-photon emission computed tomography, and positron emission tomography *is currently not used on a routine basis in patients with severe TBI.*

2.1.1.8. Neurophysiological examination methods (EEG; auditory, somato-sensoric, and visual evoked potentials) are used in patients with the acute phase of severe TBI under certain indications.

Authors declare no conflict of interest.

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Commentary

The steadily high incidence of severe TBI, significant mortality and disability levels, and the large number of currently performed studies make it necessary to create and constantly edit the recommendations for rendering medical aid to patients with severe TBI. These recommendations are devoted to all aspects of severe TBI: organizing medical care and diagnosis, intensive care and neuromonitoring, and surgical management. Being the leading experts in this field, the authors have analyzed the most modern literature and findings of the studies carried out both in Russia and abroad. Furthermore, they used the materials of the recently published national and international guidelines for diagnosis, intensive care, and surgical management of severe TBI.

The guidelines are written laconically using a good language style. A number of recommendations and standards have been refined compared to the previous editions. Unfortunately, for some points the data in the available literature are insufficient for formulating standards or recommendations, so the use of certain actions or procedures is optional in this case. Apparently, the status of some options will be changed to recommendations as new data are obtained in new studies.

The guidelines for severe TBI will be extremely useful for neurosurgeons, anesthetists, resuscitators, neurologists, and radiologists who deal with practical rendering this kind of medical aid to this group of patients that is difficult to manage, as well as for all the stages of training neurosurgeons and the related physician specialties.

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