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OPTIMIZATION OF INTENSIVE CARE IN CHILDREN WITH TRAUMATIC BRAIN INJURY

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Abstract: Traumatic brain injury (TBI) remains one of the leading causes of morbidity, mortality, and disability among children worldwide. Severe forms of TBI often require intensive care to prevent secondary brain damage and intracranial hypertension (ICH). This review summarizes data from the past 10 years (2016–2026) on optimizing intensive care in children with TBI, with an emphasis on dehydration therapy, the use of hyperosmolar agents (mannitol, hypertonic NaCl solution), and contemporary guidelines. Special attention is given to the epidemiological situation and research efforts in the Republic of Uzbekistan, where TBI in children remains a significant public health issue. The effectiveness of mannitol and hypertonic solution is compared, highlighting the potential advantage of the latter in terms of survival and functional recovery. The need for a personalized approach is emphasized due to the high heterogeneity of studies and regional specifics. Keywords: severe traumatic brain injury in children, intracranial hypertension, intensive care, mannitol, hypertonic sodium solution, dehydration therapy, clinical guidelines.

Introduction

Traumatic brain injury in children remains one of the most significant medical and social problems in modern healthcare, both globally and in the Republic of Uzbekistan [1, 6]. According to data from the World Health Organization and numerous national registries, TBI annually claims the lives of tens of thousands of children and leads to severe disability in hundreds of thousands of survivors [4, 9, 13]. In the structure of pediatric trauma, severe TBI accounts for 40 to 55% of all cases of severe mechanical injury, with isolated injuries to the skull and brain occupying a leading position among the causes of lethality and persistent loss of functional capacity in childhood and adolescence [1, 3]. Global epidemiological data over the past 10 years indicate a consistently high incidence of TBI in children: from 47 to 280 cases per 100,000 pediatric population per year, depending on the region and the level of socioeconomic development of the country [5, 8, 20]. In developing countries and countries with middle-income levels, to which the Republic of Uzbekistan belongs, the primary mechanisms of injury remain road traffic accidents (especially pedestrian

strikes), falls from height (including from roofs, trees, construction sites), domestic and sports-related trauma, as well as a significant proportion of non-accidental (criminal) trauma in young children [2, 13, 19]. Of particular concern is the extremely high frequency of secondary brain damage, which in most cases determines the outcome of the disease. According to pathoanatomical studies from recent years, only 10–18% of fatal outcomes in severe TBI are due to primary, life-incompatible brain damage, whereas in 82–90% of cases, death occurs as a result of secondary factors: intracranial hypertension, brain edema, ischemia, hypoxia, hypotension, hyperthermia, seizures, and systemic inflammatory response [2,7]. Intracranial hypertension is recorded in 75–85% of children with severe TBI, and refractory ICH, which responds poorly to pharmacological correction, develops in 25–40% of such patients and is associated with a mortality rate of 60–90% [4, 7, 22]. In the Republic of Uzbekistan, the issue of pediatric TBI is particularly acute due to several factors: · High intensity of road traffic and a significant number of road traffic accidents involving child pedestrians and passengers; · Predominance of domestic trauma in young children in rural areas and small towns; · Insufficient equipping of some peripheral medical institutions with modern means of neuromonitoring and neurosurgical care; · Limited access to timely specialized care in the first "golden hours" after injury in remote regions; · Pronounced socioeconomic gradient in outcomes: children from low-income families and those living in rural areas have significantly worse prognoses. According to unofficial clinical data from leading centers in the Republic of Uzbekistan, mortality in severe TBI among children in recent years ranges from 15–35%, depending on the severity of the injury, timeliness of transportation, and quality of intensive care. Moreover, up to 65–90% of surviving children have neurological deficits of varying severity, cognitive, behavioral, and emotional disorders, leading to a significant reduction in quality of life, social maladaptation, and a high economic burden on the family and the state in the long term [3, 8, 16, 20]. International guidelines for the treatment of severe TBI in children and national clinical guidelines of several countries detail strategies for controlling intracranial pressure; however, significant gaps remain regarding optimal regimens of dehydration therapy specifically in children, especially in the context of developing healthcare systems [8, 14, 18, 23]. In particular, the following remain insufficiently studied: · Comparative effectiveness and safety of various concentrations of hypertonic sodium solution; · Feasibility and optimal schemes for combined use of mannitol and other diuretics; · Impact of early aggressive dehydration therapy on long-term neurological outcomes in children; · Adaptation of international protocols to conditions in countries with limited resources. In the Republic of Uzbekistan, the situation is complicated by the fact that until recently, there were no large national studies dedicated specifically to optimizing intensive care for severe TBI in children. Only in recent years, based at Samarkand State Medical University and the Republican

Scientific Center for Emergency Medical Care, systematic research has begun, aimed at developing adapted stepwise algorithms for treating intracranial hypertension, taking into account local epidemiological, organizational, and resource specifics. Thus, the relevance of optimizing intensive care in children with severe traumatic brain injury in modern conditions remains extremely high from medical, social, and economic perspectives. This problem is particularly acute in the Republic of Uzbekistan, where the combination of high injury frequency, pronounced regional disparities in specialized care provision, and insufficient study of optimal treatment strategies requires the prompt conduct of high-quality clinical research and the implementation of modern protocols for intensive care adapted to local conditions.

Epidemiology and Burden of TBI in Children

According to global estimates, TBI is recorded annually at rates of 47 to 280 cases per 100,000 children, with falls and road traffic accidents (RTAs) predominating [2, 7, 16]. In developing countries and regions of Central Asia, pedestrian trauma in RTAs constitutes a significant proportion of cases [17]. In Uzbekistan, precise nationwide statistical data on pediatric TBI are limited due to registration peculiarities; however, regional studies and clinical practice indicate high frequency. TBI accounts for a substantial portion of pediatric trauma, especially in the Samarkand region, where SamSMU and its clinics actively treat such patients. Severe TBI in children in the republic is often associated with RTAs, domestic trauma, and falls from height [20]. In recent years, there has been an increase in hospitalizations to specialized centers, including the multidisciplinary clinic of SamSMU and the Republican Center for Emergency Medical Care (RCEMC). Mortality in severe TBI in the region ranges from 12–30% (depending on the timeliness of care and availability of specialized departments), and among survivors, a significant portion (up to 60–90%) has physical, cognitive, and emotional impairments [1,3]. In Uzbekistan, infrastructure is actively developing: at Samarkand State Medical University, a Specialized Scientific and Practical Center for Neurosurgery and Neurorehabilitation has been established, where research on pediatric neurotraumatology is conducted, including optimization of intensive care for severe TBI.

Pathogenesis of Secondary Brain Damage

Primary damage in TBI is mechanical in nature, while secondary damage develops as a result of a cascade of pathological processes: excitotoxicity, inflammation, brain edema, and intracranial hypertension [2,7]. In children, the immature nervous system is particularly vulnerable to metabolic disturbances. ICH plays a leading role in 30–50% of cases of deterioration [1]. With ICP >20 mm Hg, mortality reaches 47% compared to 17% with normal ICP [4]. Contemporary studies emphasize disruption of cerebral blood flow autoregulation, the role of hypoxia, and

the connection between pulmonary function and coagulational and electrolyte disturbances, which correlate with the severity of ICH [5,6,8,9].

Contemporary Clinical Guidelines

Since 2019, the third edition of the Brain Trauma Foundation guidelines for severe TBI in children has been in effect, recommending ICP thresholds of 20 mm Hg and minimum cerebral perfusion pressure of 40 mm Hg. Hypertonic sodium solution is considered a first-line agent, with mannitol as an alternative [8, 23]. In Uzbekistan, clinical practice relies on international guidelines with adaptation to local conditions, including the use of stepwise algorithms in SamSMU centers.

Strategies for Intensive Care

Monitoring and Stabilization Priority is given to ensuring airway patency, adequate oxygenation, and stable hemodynamics. Modern approaches include multimodal monitoring (ICP, PbO_2, CPP) [20]. Dehydration and Hyperosmolar Therapy Mannitol and hypertonic NaCl solution remain the primary agents. Contemporary data (2025) show comparable effectiveness of 3% hypertonic solution and 20% mannitol in terms of impact on mortality and functional outcomes. However, a 2025 meta-analysis revealed an advantage of 5% hypertonic solution in reducing overall mortality (OR 0.34; 95% CI 0.14–0.72) [5, 16, 19]. Combined use (alternating agents) reduces coma duration and lowers mortality compared to mannitol monotherapy.

Conclusion

Optimization of intensive care for severe TBI in children requires a comprehensive approach: early multimodal monitoring, stepwise algorithm for ICH control, rational use of hyperosmolar agents, and comprehensive neurorehabilitation. In the Republic of Uzbekistan, the issue of TBI in children is actively studied at leading centers such as Samarkand State Medical University. Contemporary data (2016–2026) indicate comparable effectiveness of mannitol and hypertonic solution, with a tendency toward the latter's advantage in certain patient groups. Combined regimens of dehydration therapy represent a promising direction for improving outcomes in children with severe traumatic brain injury in Uzbekistan and worldwide.

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