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When Traumatic Brain Injuries in Children become Chronic Health Conditions

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The CDC Report to Congress on the Management of Traumatic Brain Injury (TBI) described the management of TBI in children as an important public health issue.¹ A brain injury of any severity can occur at one or multiple times during childhood. As a result of TBI during childhood, changes in health, cognition, family environment, and behavior, can affect learning, self-regulation, and social participation, which are critical skills to optimize functioning in adulthood.² TBI affects children differently than adults because it can impact brain development during key periods that may alter developmental trajectories over time.² Although most children recover well physically, they can experience changes in behavior and cognition that may not be recognized immediately.² During childhood, a history of TBI is often associated with several health conditions, including epilepsy, headache/migraine, autonomic disturbances, intellectual disability, vision problems, speech and language problems and behavior and mental health problems.³

TBI in adults has been described as a “disease process” and “chronic health condition” because there is evidence, primarily from individuals with moderate to severe TBI, that health conditions persist or emerge over time.⁴ The effects of TBI can evolve beyond the initial injury period requiring ongoing screening, prevention, and management of multiple sequelae.⁴ The World Health Organization (WHO) defines a chronic disease as having one or more of the following characteristics: 1) have a long duration, 2) caused by non-reversible pathologic alterations, 3) requires specialized training of the patient for rehabilitation and /or 4) may require a long period of observation, supervision or care.⁵

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Contributors' Statement Page

Drs. Kurowski, Haarbauer-Krupa, and Giza conceptualized manuscript topic, drafted the initial manuscript, and reviewed and revised the manuscript.

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Research is emerging about the late effects of TBI in children, although there is a paucity of investigations evaluating adults who sustained a TBI during childhood.¹ Post-TBI health problems and behavioral changes can emerge over time and are associated with significant financial and social challenges for adults having sustained a TBI during childhood.^{6–8} Further, as adults with TBI age, they have a higher all-cause mortality and are more likely to develop medical and neurologic complications earlier, including cardiovascular and neurodegenerative conditions.⁹ There is stronger evidence for complications when individuals of all ages experience moderate to severe TBI, and conflicting results for resultant long-term complications for those who experience a single mild TBI (mTBI).⁹ Comparison of adults who experienced a childhood TBI with unaffected siblings demonstrated that a childhood TBI resulted in lower educational attainment, more psychiatric conditions and disability and this risk was observed even for individuals who experienced a mTBI.^{8,10} TBI during childhood may require ongoing monitoring and management over one's lifespan; thus, there is growing recognition that once TBI is experienced, care should be approached like a chronic health condition as is done for adults that necessitates ongoing, pro-active prevention, rehabilitation and habilitation interventions to promote long-term health and wellness.⁴

To date, most studies have examined long-term outcomes for children who experienced moderate to severe TBI. While many children with mTBI recover fully, a significant subgroup develop persistent post-concussive symptoms that require longer-term monitoring and care.^{1,8,11,12} Given the estimated millions of children who experience mTBI overall, even this subgroup represents a major public health issue in terms of additional sequelae, lost productivity and potential interference with normal developmental trajectories.¹ Existing validated prediction rules can help to identify those at risk for persistent problems and so allow earlier recognition, monitoring and initiation of treatment.^{12,13} Recent reports on sports-related concussions and mTBI in children indicate persistent or emerging effects 1–3 years post injury with cognition, behavior and mental health.^{1,2} Furthermore, children who experience a childhood TBI are at increased risk for repeat injuries throughout development.^{1,14,15} Experiencing multiple injuries over the course of child development can catalyze long-term effects of the injury.^{15–17} While most children recover well after mTBIs, injuries occurring during a critical developmental window, such as before age 5 years or during adolescence^{8,16,18}, can result in long-standing changes in neuroplasticity and loss of developmental potential.^{1,2} Research indicates that there can be significant healthcare and school service needs years after all severities of TBI in children, with unmet needs primarily in the areas of mental health, speech therapy, pain management, educational services, and global healthcare service access.¹

A challenge in the field is how to determine when children have fully recovered from their injury from a clinical, functional, and neuro-physiologic perspective versus when they are at risk for ongoing issues. Therefore, it is critical that we find better ways to define recovery, both clinical and neuro-physiologic; identify those at risk for long-term issues; develop monitoring and screening procedures; and identify ways to intervene to optimize brain health and function long-term. A further challenge for the field is how to distinguish between TBI-related effects versus other developmental or behavioral issues. These distinctions become potentially challenging as the events surrounding a TBI and

recovery (e.g., traumatic event, missed time from school) could trigger post-traumatic responses, depression, anxiety, and social isolation, which can manifest changes similar to the direct neurocognitive effects of a TBI. TBI is a complex process and likely needs to be analyzed from multiple perspectives, including individual, injury-related, experiential, and social and environmental, to fully understand recovery.¹⁹

TBIs are a leading cause of morbidity and mortality in children. Behavioral, cognitive, medical, and pain-related sequelae across the lifespan after TBI can occur for all levels of injury severity even though most children with mTBI can recover from the initial symptoms. Evidence suggests that a moderate to severe TBI or multiple (e.g., repetitive) TBIs sustained during childhood are associated with long-term issues, including potential development of aging-related and neurodegenerative disease, that have a profound effect on children's ability to become productive adults. However, complete understanding of the characteristics of those who develop long-term issues and how many children experience long-term effects after the injury into adulthood demands further investigation. What is currently known about persistent effects of TBI in children aligns with the WHO definition of a chronic disease.⁵ Documentation of unmet needs for services both in the healthcare setting and school further supports the significant and ongoing burden of TBI well beyond the initial injury.^{1,2,8,9} Although long-term studies of children are limited, emerging research demonstrates that TBI effects can persist throughout childhood and span into adulthood.

There is a critical need to understand chronic post-TBI biological, psychological, social and ecological mechanisms, better characterize long-term issues, and develop management and treatment approaches that help individuals who experience a TBI of any severity over their lifespan rather than only the acute period. Characterizing TBI as a chronic health condition facilitates insurance coverage to fund services and supports needed long after the injury occurs. It is also important to engage in prevention efforts for childhood TBI to avoid the initial injuries but also multiple injuries that have been reported to happen across a child's lifespan. In addition, there are issues related to healthcare disparities, including insurance coverage, racial and ethnic disparities, income and parents' level of education that can contribute to the unmet needs observed in the literature that require further research to improve outcomes for all children who experience TBI. Because we know of so many unmet needs in the population of children who experience TBI, care after the injury should take a chronic health condition approach with ongoing, pro-active monitoring, rehabilitation and school interventions to promote long-term health and wellness.^{1,9} It is important for children to have a medical home. Pediatricians who see children for regular visits can consider monitoring children over time, educating parents about the effects of TBI, attending to the child's behavior, facilitating access to health and education services during critical developmental transitional periods, and ensuring that the child has a medical home for ongoing care in adulthood. It is important for adult providers to have the knowledge and expertise to provide continued monitoring for later appearing health problems such as mental health symptoms, risky substance use and substance use disorders, neurocognitive, endocrine, pain and seizure-related issues along with screening for typical healthcare issues in adults as they age. Viewing childhood TBI outcomes from the lens of a chronic health condition is imperative to move the field toward a research and clinical agenda that will

positively transform outcomes, across the lifespan, for these children, their families, and society.

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Abbreviations:

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| CDC | Centers for Disease Control and Prevention |
| TBI | traumatic brain injury |
| WHO | World Health Organization |

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