A traumatic brain injury (TBI) is caused by a bump, blow, jolt, or penetrating wound to the head that disrupts the normal functioning of the brain (1). In 2009, CDC estimated that at least 2.4 million emergency department visits, hospitalizations, or deaths were related to a TBI, either alone or in combination with other injuries (2). Approximately 75% of TBIs are mild, often called concussions (3). Children, adolescents, and older adults are most likely to sustain a TBI (4). Nearly one third (30.5%) of all injury deaths included a diagnosis of TBI (5). In addition, an estimated 5.3 million U.S. residents are living with TBI-related disabilities, including long-term cognitive and psychologic impairments (6). A severe TBI not only affects a person's life and family, but also has a large societal and economic toll. The economic costs of TBIs in 2010 were estimated at $76.5 billion, including $11.5 billion in direct medical costs and $64.8 billion in indirect costs (e.g., lost wages, lost productivity, and nonmedical expenditures) (7,8).

These data underestimate the national burden because they include neither TBIs managed in nonhospital settings nor >31,000 military personnel diagnosed with TBI and treated in the U.S. Department of Defense or Veterans Administration medical systems in 2010 (9).

The leading causes of TBI in the general population are falls (35.2%), motor vehicle crashes (17.3%), blunt impact (e.g., being struck by or against a moving or stationary object) (16.5%), and assaults (10%) (4). Different age groups are affected to varying degrees (Table). Falls account for a large proportion of TBIs among children aged 0–14 years and among adults aged ≥65 years (4). Motor vehicle crashes and assaults are the predominant causes of TBIs in teens and young adults aged 15–34 years (4). Military personnel, both in and out of combat, and rescue workers and victims exposed to blasts also are at risk for TBI (10).

TBIs can be categorized as mild (often called concussions), moderate, or severe based on the Glasgow Coma Scale (11). This and other categorization systems, although crucial for clinical management, generally do not reflect the underlying pathologic processes of the injury or nonfatal outcomes. The lack of a system for severity classification is one of the major gaps in the clinical assessment and treatment of TBIs (12,13).

Much of the brain injury occurs after the primary injury, not at the moment of initial impact. A complex biologic cascade begins immediately after the trauma and can continue for hours to weeks after the initial injury. It is this secondary injury that can significantly increase the overall morbidity and mortality that follows a TBI. Although research is ongoing, no drugs have yet been proven to reduce secondary injury and improve functional outcome of TBIs (14). The long-term or lifelong physical, cognitive, behavioral, and emotional consequences of a severe TBI can affect all aspects of a person’s life, including the ability to return to work or school and sustain relationships with family, friends, and community (2).

**Public Health Role in Addressing Severe TBIs --- Challenges and Opportunities**

Public health efforts coordinated across organizations and communities could help to reduce the incidence of TBIs and mitigate their short- and long-term consequences. Those efforts can include primary prevention, early management, and comprehensive approaches to rehabilitation and reintegration.

**Primary Prevention**

Public health plays a key role in primary prevention of TBI by conducting surveillance, identifying and disseminating evidence-based strategies, and promoting implementation of effective policies. Several systems collect and report national and state-based TBI data used for surveillance, including multiple cause of death mortality data and vital statistics submitted to the National Vital Statistics System from all 50 states and the District of Columbia, basic TBI surveillance from the 20 states funded through the Core Violence and Injury Prevention Program, reports and data from the National Trauma Data Bank, and national estimates of injury-related emergency department visits from the National Electronic Injury Surveillance System.* These data collection tools are critical for monitoring TBI incidence and informing decision making on prevention initiatives, research needs, and education priorities. However, current data sources do not provide the level of detail needed to fully understand the epidemiology and long-term outcomes of TBI. A more

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* Additional information available at http://www.cdc.gov/nchs/deaths.htm; http://www.cdc.gov/nchs/nvss.htm; http://www.cdc.gov/injury/stateprograms; http://www.facs.org/trauma/ntdb/index.html; and http://www.cpsc.gov/library/neiss.html.
Comprehensive national injury surveillance system that enables population-based longitudinal or follow-up studies would better guide prevention efforts and aid in the evaluation of the effectiveness of interventions (2).

Public policies can advance prevention of TBIs and other injuries through education, enforcement of safety laws and regulations, engineering, and economic incentives. This is demonstrated by recent progress in reducing deaths and serious injuries from motor vehicle crashes. Since 1980, the rate of TBI-associated deaths caused by motor vehicle crashes decreased approximately 40%, in part because of a multitude of public policies and law enforcement. Those initiatives have included state laws and sustained, high-visibility enforcement that increased nationwide seatbelt use to 85% (15), universal motorcycle helmet laws in states that sustained helmet usage of 90% or higher (16), and enforcement of state laws lowering the legal limit for blood alcohol concentration to 0.08 g/dL and raising the minimum drinking age from 18 to 21 years (17). Despite these policy successes, ongoing challenges to injury and TBI prevention remain. In 2011, for example, alcohol-impaired driving still accounted for 31% of the total motor vehicle traffic fatalities in the United States (18).

Because the causes of TBIs vary among population groups, multiple educational and awareness efforts are needed to improve the primary prevention of severe TBI. For example, in the last decade, the number of children and adolescents who sought care in emergency departments for sports- and recreation-related TBIs, including concussions, increased 60% (19). In response, CDC, in collaboration with the National Collegiate Athletic Association, National Football League, and many associations governing sport activities, created concussion educational resources for coaches, athletes, and medical professionals.³ To prevent fall-related TBIs among older adults, CDC partnered with stakeholder organizations to develop educational materials that describe evidence-based interventions to help public health practitioners, clinicians, community-based organizations, and older adults to prevent, recognize, and respond to the signs and symptoms of TBI.⁴ A leading cause of child maltreatment deaths in the United States, is “shaken baby syndrome” (abusive head trauma). The steps to implement evidence-based intervention strategies and integrate specific education messages into existing programs for new parents, caregivers, professionals, and the general public are outlined in the CDC publication, Preventing Shaken Baby Syndrome: Guide for Health Departments and Community-Based Organizations.⁵

## TABLE: Estimated average annual numbers and rates* of emergency department visits, hospitalizations, and deaths related to traumatic brain injury, by age group and external cause — United States, 2002–2006

| Age group (yrs) | Motor vehicle crash | Falls | Assault | Blunt impact | Other/Unknown |
|-----------------|---------------------|-------|---------|-------------|--------------|
|                 | No. | Rate | No. | Rate | No. | Rate | No. | Rate | No. | Rate | No. | Rate |
| 0–4             | 15,429 | 77.1 | 167,950 | 838.7 | 1,619 | 8.1 | 54,811 | 273.7 | 27,974 | 139.7 |
| 5–9             | 10,180 | 51.7 | 44,114 | 223.9 | 1,091 | 5.5 | 36,139 | 183.4 | 22,740 | 115.4 |
| 10–14           | 9,076 | 43.3 | 44,750 | 213.4 | 11,991 | 57.2 | 35,826 | 170.8 | 27,568 | 131.5 |
| 15–19           | 52,408 | 252.4 | 34,911 | 168.1 | 24,528 | 118.1 | 37,595 | 181.0 | 36,646 | 176.5 |
| 20–24           | 54,224 | 261.3 | 21,191 | 102.1 | 36,337 | 175.1 | 19,464 | 93.8 | 30,594 | 147.4 |
| 25–34           | 54,161 | 135.8 | 35,368 | 88.7 | 41,197 | 103.3 | 31,399 | 78.7 | 48,467 | 121.5 |
| 35–44           | 29,888 | 67.8 | 39,662 | 89.9 | 25,285 | 57.3 | 22,744 | 51.6 | 45,162 | 102.4 |
| 45–54           | 29,031 | 69.8 | 39,871 | 95.8 | 17,058 | 41.0 | 17,743 | 42.6 | 32,205 | 77.4 |
| 55–64           | 18,951 | 65.2 | 22,940 | 78.9 | 8,031 | 27.6 | 10,579 | 36.4 | 24,740 | 85.1 |
| 65–74           | 8,653 | 46.7 | 37,466 | 202.2 | 1,567 | 8.5 | 7,627 | 41.2 | 16,294 | 87.9 |
| ≥75             | 10,193 | 57.1 | 106,872 | 599.2 | 909 | 5.1 | 5,957 | 33.4 | 42,306 | 237.2 |

* Per 100,000 population.

³ Available at http://www.cdc.gov/concussion.

⁴ Available at http://www.cdc.gov/homeandrecreationalsafety/falls/index.html.

⁵ Available at http://www.cdc.gov/concussion/headsup/sbs.html.

## Early Management

An effective public health response to TBI requires concerted programs to minimize adverse outcomes among injured persons, including efforts to improve acute care and early management, and strategies to ensure patient access to appropriate care and services. The CDC publication, Guidelines for Field Triage of Injured Patients, Recommendations of the National Expert Panel on Field Triage, 2011, was developed to help prehospital-care providers recognize injured patients who are most likely to benefit from specialized trauma center resources (20). The risk for death for a severely injured adult patient is 25% lower when the patient receives care at a Level I trauma center than at a nontrauma center (21). Unfortunately, nearly 45 million U.S. residents live more than an hour away from Level I or II trauma centers (i.e., hospitals that have the resources to treat patients with life-threatening injuries).

The Brain Trauma Foundation (BTF) guidelines for prehospital and in-hospital management of severe TBIs provide...
Comprehensive Approaches to Rehabilitation and Reintegration

Because of the variability in how disabilities associated with TBI might permanently alter a person's vocational aspirations and social and family relationships, each patient needs an individualized approach to rehabilitation and community reintegration. This ensures that each person reaches their maximum functional potential, learns to adapt to their disability, and maximizes the possibility that they will be able to return to their employment or former role in households and communities.

Current evidence shows that a comprehensive program of rehabilitation is the most effective way of helping patients regain function and minimize negative consequences of TBIs (24). Public health plays a critical role in supporting the rehabilitation and reintegration of patients into their communities and in identifying mechanisms for reimbursement that allow access to comprehensive care. Public health and the clinical community also need to collaborate to build the evidence base for effective strategies of comprehensive rehabilitation programs, disseminate best practices, and link rehabilitation care to public health interventions that support life-long health.

Conclusions

TBI is an important public health problem that requires more attention, societal engagement, and research. The major aspects of public health interventions for TBI include primary prevention, early management, and comprehensive approaches to rehabilitation and community reintegration. TBIs can be prevented through available interventions, but those interventions must be implemented in coordination with commitment of multiple sectors of society, including efforts at federal, state, local and community levels. More research also is needed to understand the basic mechanisms and pathophysiology of TBI, and to identify treatments and therapies that can mitigate its long-term consequences.

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References

1. Marr AL, Coronado VG, eds. Central nervous system injury surveillance data submission standards—2002. Atlanta, GA: US Department of Health and Human Services, CDC; 2004. Available at http://www.dhs.state.tx.us/injury/registry/coronadoandmarrcnsdefinitions.doc.
2. Coronado VG, McGuire LC, Sarmiento K, et al. Trends in traumatic brain injury in the U.S. and the public health response: 1995–2009. J Safety Res 2012;43:229–307.
3. CDC. Report to Congress on mild traumatic brain injury in the United States: steps to prevent a serious public health problem. Atlanta, GA: US Department of Health and Human Services, CDC; 2003. Available at http://www.cdc.gov/ncipc/pub-res/mb/mbreport.pdf.
4. Fuld M, Xu L, Wald MM, Coronado VG. Traumatic brain injury in the United States: emergency department visits, hospitalizations and deaths 2002–2006. Atlanta, GA: US Department of Health and Human Services, CDC; 2010. Available at http://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf.
5. CDC. Injury and traumatic brain injury (TBI)-related death rates, by age group—United States, 2006. MMWR 2010;59:303.
6. Selasie AW, Zaloshnja E, Langlois JA, Miller T, Jones P, Steiner C. Incidence of long-term disability following traumatic brain injury hospitalization, United States, 2003. J Head Trauma Rehabil 2008;23:123–31.
7. Finkelstein ES, Corso PS, Miller TR. The incidence and economic burden of injuries in the United States. New York, NY: Oxford University Press; 2006.
8. Coronado VG, McGuire LC, Faul ME, Sugerman DE, Pearson WS. Traumatic brain injury epidemiology and public health issues. In: Zasler ND, Katz DI, Zafonte RD, eds. Brain injury medicine: principles and practice. 2nd ed. New York, NY: Demos Medical Publishing; 2012:84–100.
9. Champion HR, Holcomb JB, Young LA. Injuries from explosions. J Trauma 2009;66:1468–76.
10. Täber KH, Warden DL, Hurley RA. Blast-related traumatic brain injury: what is known? J Neuropsychiatry Clin Neurosci 2006;18:141–5.
11. Rimel R, Giordani B, Barth JT, Jane JA. Moderate head injury: completing the clinical spectrum of brain trauma. Neurosurgery 1982;11:344–51.
12. Stein SC. Classification of head injury. In: Narayan RK, Wilberger Jr JE, Povlishock JT, eds. Neurotrauma. New York, NY: McGraw-Hill; 1996:31–41.
13. Williams DH, Levin HS, Eisenberg HM. Mild head injury classification. Neurosurgery 1990;27:422–8.
14. Levin HS, Gary HE, Eisenberg HM, et al. Neurobehavioral outcome 1 year after severe head injury. Experience of the Traumatic Coma Data Bank. J Neurosurg 1990;73:699–709.
15. CDC. Ten great public health achievements—United States, 2001–2010. MMWR 2011;60:619–23.
16. National Highway Traffic Safety Administration. Evaluation of the reinstatement of the motorcycle helmet law in Louisiana. Washington, DC: US Department of Transportation, National Highway Traffic Safety Administration; 2008. Available at http://www-nrd.nhtsa.dot.gov/pubs/811700.pdf.
17. Community Preventive Services Task Force. Reducing alcohol-impaired driving: maintaining current minimum legal drinking age (MLDA) laws. In: Guide to Community Preventive Services. Atlanta, GA: Community Preventive Services Task Force; 2000. Available at http://www.thecommunityguide.org/mvoi/aid/mlda-laws.html.
18. National Highway Traffic Safety Administration. Traffic safety facts—2011 data: alcohol-impaired driving. Washington, DC: US Department of Transportation, National Highway Safety Administration; 2012. Available at http://www-ndt.nhtsa.dot.gov/pubs/811700.pdf.
19. CDC. Nonfatal traumatic brain injuries related to sports and recreational activities among persons aged ≤19 years—United States, 2001–2009. MMWR 2011;60:1337–42.
20. CDC. Guidelines for field triage of injured patients: recommendations of the National Expert Panel on Field Triage. MMWR 2012;61(No. RR-1).
21. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. N Engl J Med 2006; 354:366–78.
22. Faul M, Wald MM, Rutland-Brown W, Sullivent EE, Sattin RW. Using a cost-benefit analysis to estimate outcomes of a clinical treatment guideline: testing the Brain Trauma Foundation guidelines for the treatment of severe traumatic brain injury. J Trauma 2007;63:1271–8.
23. Hesdorffer DC, Ghajar J. Marked improvement in adherence to traumatic brain injury guidelines in United States trauma centers. J Trauma 2007;63:841–8.
24. Sander AM, Constantinidou F. The interdisciplinary team. J Head Trauma Rehabil 2008;23:271–2.