KRONKOSKY CHARITABLE FOUNDATION

RESEARCH BRIEF

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BRAIN INJURY

"Brain injury has become a national epidemic. It is estimated that more than 50,000 Americans die annually from brain injuries and that over 300,000 have injuries severe enough to require hospitalization. Of this group, approximately 80,000 people a year are left with cognitive or behavioral deficits of such a degree as to result in lifelong disabilities" (Brain Injury Association of Texas [BIAT], 2012c). In Texas someone sustains a traumatic brain injury every four minutes and more than 381,000 Texans live with a disability due to a traumatic brain injury (BIAT, 2012c).

The **definition of brain injury** can be slightly confusing. Brain injuries are generally categorized by the mechanism of injury as either traumatic or acquired brain injuries:

- Traumatic Brain Injury—an alteration in brain function, or other evidence of brain pathology, caused by an external force
- Acquired Brain Injury—an injury to the brain which is not hereditary, congenital, degenerative, or induced by birth trauma

Based on these definitions, any brain injury that occurs after birth can be considered an Acquired Brain Injury (ABI), including traumatic injuries. In actual practice however, the term ABI usually refers to injuries that are caused by processes other than trauma such as stroke, tumor, encephalitis, near drowning, seizures, anoxia (lack of oxygen), etc.; Traumatic Brain Injury (TBI) refers to injuries caused by accidents, falls, blows to the head, etc. (Brain Injury Association of America [BIAA], 2012a).

Mechanisms of Injury

The top three causes of brain injury are car accidents, firearms, and falls. There are two basic types of head injuries:

- Closed head injury – injury to brain is caused by movement of brain within the skull
- Penetrating head injury – injury to brain is caused by a foreign object entering the skull (CDC, 2011a)

Ways in which the brain may be damaged include:

- *Deceleration injuries* – the brain moves at a slightly different rate than the skull because it is softer than the skull. When the skull stops moving suddenly, the brain hits the inside of skull causing direct brain injury due to contusion, swelling, and diffuse axonal shearing: "when the brain is slammed back and forth inside the skull it is alternately compressed and stretched because of the gelatinous consistency. The long, fragile axons of the neurons (single nerve cells in the brain and spinal cord) are also compressed and stretched. If the impact is strong enough, axons can be stretched until they are torn. This is called axonal shearing. When this happens, the neuron dies. After a severe brain injury, there is massive axonal shearing and neuron death" (TraumaticBrainInjury.com, 2004, p4).
- *Lack of Oxygen* – irreversible brain injury can occur if the blood flow is depleted of oxygen (anoxia – no oxygen; hypoxia – reduced oxygen). Often a result of heart attack, respiratory failure, drop in blood pressure, or near drowning, this type of brain injury can result in severe cognitive and memory deficits.
- *Chemical/toxic* – harmful chemicals such as insecticides, carbon monoxide poisoning, lead poisoning, etc. damage the neurons.
- *Tumors* – damage to brain can be caused by cancer growing on or over the brain; tumors can invade the spaces of the brain causing direct damage or pressure effects around enlarged tumors.
- *Infections* – viruses and bacteria can breach the blood-brain barrier causing diseases of the brain

(encephalitis) and of the surrounding membranes (meningitis).

- *Stroke* – cell death occurs in the area deprived of blood (oxygen) by blocked vessels. "If there is bleeding in or over the brain (hemorrhage or hematoma) because of a tear in an artery or vein, loss of blood flow and injury to the brain tissue by the blood will also result in brain damage" (TraumaticBrainInjury.com, 2004, p4).

The **incidence of TBI** is tracked by the Centers for Disease Control and Prevention (CDC) through the Safe States Alliance, in which 36 states provide data on fatal and non-fatal injuries (Texas does not participate). TBI national indicators for 2006 included:

- TBI fatalities – 17.9 per 100,000 persons
  - Males – 28.0 per 100,000
  - Females – 8.8 per 100,000
- TBI hospitalizations – 94.6 per 100,000
  - Males – 127.5 per 100,000
  - Females – 62.2 per 100,000

(CDC, 2010b)

There is no central reporting mechanism for ABI-related statistics, however, relevant statistics of ABI causative conditions include:

- Approximately 795,000 individuals have a stroke each year
  - 87% ischemic (blood clot cuts off flow of blood to brain tissue resulting in tissue damage due to lack of oxygen)
  - 10% intracerebral hemorrhage (blood vessel bursts and bleeds into the brain)
  - 3% subarachnoid hemorrhage (blood vessel bursts and bleeds into the space between the brain and the skull)

(Roger, et al., 2012)

- 3,443 non-boating and 496 boating-related fatal drownings occurred in 2007
  - For every child who dies from drowning, another four receive emergency care for nonfatal submersion injuries
  - More than 55% of drowning victims treated in emergency departments require hospitalization (compared to 3-5% for all unintentional injuries)

(CDC, 2011b)

- Incidence rates of brain tumors 2004-2008
  - U.S. – 6.7 per 100,000
  - Texas – 6.5 per 100,000
  - Bexar County – 6.1 per 100,000
  - Comal County – 8.0 per 100,000
  - Bandera & Kendall counties had 3 or fewer

(National Cancer Institute, 2012)

- Additional TBI statistics include:
- Falls are the leading cause of TBI (35.2%) and account for half of all TBIs among children aged 0 to 14 years and 61% of all TBIs among adults aged 65 and older
- Motor vehicle and traffic-related incidents (17.3%) result in the largest percentage of TBI-related deaths (31.8%)
- 18% of all TBI-related emergency room visits involve children aged 0 to 4 years
- 22% of all TBI-related hospitalizations involve adults aged 75 years and older

(CDC, 2010a)

Diagnosis

The severity of a brain injury is initially assessed by measuring eye opening, verbal, and motor responses on the Glasgow Coma Scale (GCS). This 15 point scale is used to estimate and categorize brain injuries. Using the following chart, the patient is assessed for each response and the sum of the three is the GCS score.

Glasgow Coma Scale		
Eye Opening (E)	**Verbal Response (V)**	**Motor Response (M)**
4=Spontaneous 3=To voice 2=To pain 1=None	5=Normal conversation 4=Disoriented conversation 3=Words, but not coherent 2=No words.....only sounds 1=None	6=Normal 5=Localizes to pain 4=Withdraws to pain 3=Decorticate posture 2=Decerebrate 1=None
		Total = E+V+M

Scores range from 3 (deep coma or death) to 15 (fully awake person). The latest guidelines for field triage recommend that anyone with a GCS score of ≤13 be transported to the nearest trauma center (CDC, 2012).

Levels of Brain Injury

Mild brain injury (GCS score of 13-15) is generally referred to as concussion. Concussion is caused by a blow or jolt to the head that disrupts the function of the brain and "results in a constellation of physical, cognitive, emotional and/or sleep-related symptoms and may or may not involve a loss of consciousness" (CDC, n.d., p2).

It is estimated that 75%-90% of all TBI-related deaths, hospitalizations, and emergency department

visits each year are due to concussions. Signs and symptoms include:

- Physical – headache, nausea, vomiting, dizziness, visual problems, sensitivity to light and/or noise, numbness/tingling
- Cognitive – feeling mentally foggy, difficulty concentrating and/or remembering, confused about recent events, feeling slowed down
- Emotional – irritability, sadness, more emotional, nervousness, mood swings
- Sleep – drowsiness, sleeping more or less than usual, having trouble falling asleep

(CDC, n.d.)

Moderate brain injury (GCS score of 8-12) results in a "loss of consciousness that can last minutes or a few hours and is followed by a few days or weeks of confusion. Physical, cognitive, and/or behavioral impairments may last for months or be permanent" (BIAT, 2012a). Individuals with this level of injury can make a good recovery with treatment, learning to compensate for deficits.

Severe brain injury (GCS score below 8) always results in prolonged unconsciousness or coma which may last days, weeks or months. There are three states of low neurological activity:

- Coma – individual is unresponsive and unaware, typically lasts no longer than three to four weeks; eyes usually closed
- Vegetative state – individual is unaware of internal and external environment but typically displays "vegetative functions" such as normal digestive and sleep/wake cycles; eyes usually open
- Minimally conscious state – individual shows minimal but definite behavioral evidence of being aware of self and/or environment such as making yes/no gestures or responding to simple commands

(Zasler, 2007)

Survivors of this level of injury may have limited function of extremities, abnormal speech or language, loss of cognitive ability, or emotional problems. Long-term rehabilitation is often necessary to maximize function and independence (TraumaticBrainInjury.com, 2004).

Assessment

No two brain injuries are alike and much is still unknown about how the brain functions and responds to injuries. Even a mild TBI can have significant effects months after the injury occurs.

Some methods of determining extent and effects of brain injuries include:

- *Neuropsychological tests* – provide quantifiable data about reasoning and problem-solving ability, ability to understand and express language, working memory and attention, long and short term memory, processing speed, visual-spatial organization, visual-motor coordination, and planning, synthesizing, and organizing abilities which can be compared to norms to determine extent of deficits (Malik, 2011)
- *Computed Tomography (CT)* – cross-sectional imaging of brain structure to show extent of physical injury is particularly useful in determining skull fractures and intracranial hemorrhage (Maruta, J, et al., 2010)
- *Magnetic Resonance Imaging (MRI)*
  - Conventional MRI (structural) is better than CT in detecting diffuse axonal injury (DAI) and secondary lesions (abnormal structural changes)
  - Functional MRI (fMRI) can detect brain activation elicited by stimuli by imaging blood flow through the brain while the patient performs simple tasks (answers questions, moves limbs, thinks, etc.)
  - Resting State fMRI (rs-fMRI) can detect whole-brain neural connectivity without active participation of the patient (no stimulus response needed)
  - (Maruta,J., 2010; Thomason, M., et al., 2010; Hermoye, L., 2007)
- *Electroencephalography (EEG)* detects abnormal brain activity caused by structural damage
- *Single-photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET)* measure brain cell metabolism, not tissue density, and can detect changes in brain activity (Swiercinsky, D., n.d.)

Newer imaging techniques aimed at visualizing specific neuronal pathways to pinpoint damaged areas include magnetic resonance diffusion tensor imaging (DTI) and high-definition fiber tracking (HDFT). These imaging techniques can show microstructural changes and quantify the degree of axonal fiber damage to predict functional deficits (Marut, J., et al, 2010; Shin, S., et al., 2012).

Treatment

It is estimated that traumatic brain injuries accounted for $76.5 billion in direct and indirect medical costs associated with TBIs in 2010 and that 43% of

individuals hospitalized for a TBI, including non-fatal severe TBI, have a related disability one year after the injury (CDC, 2011a).

Generally, *mild TBIs* do not require specific treatment other than close monitoring at home for worsening symptoms. Rest and gradual return to normal routines is usually advised (Mayo Clinic, 2010). Even so, "there may be no correlation between the initial Glasgow Coma Scale score and the initial level of brain injury and a person's short or long term recovery or functional abilities" (BIAA, 2012a). One study revealed that, even after the symptoms of concussion abated, rs-fMRI of athletes with mild TBI showed altered patterns of brain activity 10 days post-injury (Slobounov, S., et al., 2011).

Moderate to severe brain injuries require immediate attention to minimize secondary damage to the brain due to inflammation, bleeding or reduced oxygen supply. Treatment options include:

- *Medications*
  - Diuretics to reduce fluid in tissues and help reduce pressure inside the brain
  - Anti-seizure drugs given in first week post-injury to avoid additional brain damage caused by seizures (after first week, used only if seizures occur)
  - Coma-inducing drugs – "doctors sometimes use drugs to put people into temporary comas because a comatose brain needs less oxygen to function… especially helpful if blood vessels, compressed by increased pressure in the brain, are unable to deliver the usual amount of nutrients and oxygen to brain cells" (Mayo Clinic, 2010)
- *Surgery* may be used to address problems such as:
  - Removing hematomas – bleeding within or outside of the brain puts pressure on and damages brain tissues
  - Repairing skull fractures
  - Opening a window in the skull to relieve pressure by draining accumulated cerebral spinal fluid or making room for swollen tissues (Mayo Clinic, 2010)

Rehabilitation

Most individuals who sustained a moderate to severe brain injury require rehabilitation to improve their ability to function at home and in the community:

- *Acute Rehabilitation* begins as soon as possible in an inpatient setting and consists of regaining as many activities of daily living as possible including dressing, eating, toileting, walking, and speaking.
- *Postacute Rehabilitation*, most often conducted in a residential rehabilitation facility, is more intensive and focuses on relearning processes to regain the most independent level of functioning possible. Depending on individual needs, this may include:
  - Physical therapy to increase mobility, strength, endurance, balance, and coordination
  - Occupational therapy including feeding, swallowing, grooming, bathing, dressing, thinking skills, homemaking, money management, durable medical equipment training, etc.
  - Speech/language therapy including the use of assistive technology
  - Neuropsychological therapy to focus on thinking skills, behavior, and emotional processing
- *Subacute Rehabilitation*, often provided in a skilled nursing facility or nursing home, is for patients who have made progress in acute therapy but cannot tolerate intensive therapy.

(BIAA, 2012b)

Once an individual with brain injury has made as much progress as possible in acute rehabilitation, additional services may or may not be required. Options include:

- Outpatient therapy to maintain and/or enhance recovery
- Home Health services to continue rehabilitation at home
- Community Re-entry programs which focus on preparing the person to return to independent living and potentially to work – may include vocational evaluation and training
- Independent Living program provide housing and several different levels of assistance and therapies to allow individuals to live as independently as possible

(BIAA, 2012b)

One recent study compared the rehabilitation outcomes of two sets of patients (one group with TBI and one group with ABI (anoxic.) It found that the patients who had a brain injury due to lack of oxygen had a slower recovery rate than patients who had a brain injury due to trauma. It was also discovered that in the ABI group, physical recovery was slower than cognitive recovery (Cullen, Crescini, & Bayley, 2009).

Resources

"The Office of Acquired Brain Injury was established by the Texas Legislature and serves as the state's lead department in providing guidance, referrals and service coordination for survivors of brain injuries and their families, including returning combat veterans" (Texas Health and Human Services Commission, n.d.). Government supported programs are limited in the numbers of spaces available. There are stringent qualification requirements and long waiting lists.

Several agencies exist to assist individuals who have sustained a brain injury including:

Texas Department of Assistive and Rehabilitative Services (DARS), which is state and federally funded, provides services to individuals with brain injuries through its Department of Rehabilitation Services (DRS) including:

- *Comprehensive Rehabilitation Services Program* which helps brain injured Texans receive intensive therapies to increase independence
  - Lists only two inpatient comprehensive medical rehabilitation programs in the San Antonio area
  - Lists two residential post acute brain injury rehabilitation providers
  - Lists five non-residential post acute brain injury rehabilitation providers
  - Served 488 individuals in 2011 (over 120 less than the previous four years due to budget reduced to $12.7 million)
- *DRS Rehabilitation Technology Resource Center* keeps track of new equipment and engineering services designed to help people with disabilities be more independent
- *Independent Living Services and Centers* provide assistance through peer counseling, information and referral, to promote self-sufficiency and quality of life, even if work potential is limited
- *Vocational Rehabilitation program* helps people with disabilities prepare for, find and keep employment

(DARS, n.d.)

Texas Department of Aging and Disability Services (DADS) provides help with a number of programs for persons with disabilities including home and community-based programs, adult day care, assisted living facilities, residential care for people with intellectual and developmental disabilities, and more (DADS, 2012).

The Brain Injury Association of Texas (BIAT), an affiliate of the national Brain Injury Association of America, is a 501(c)(3) organization whose mission is "to improve the quality of life for survivors of brain injury and their families" (BIAT, 2012b). BIAT provides a comprehensive website which provides information on treatment and recovery resources including links to rehabilitation resources, provider lists, general information and a resource library, networking and support group opportunities, caregiver assistance, and more.

The Alamo Head Injury Association also provides valuable information including resources, networking, and education about the recovery process (Alamo Head Injury Association, n.d.).

Many factors affect a person's recovery from a head injury – the severity of the injury, the location of the injury and portion of the brain affected, the age and general health of the individual, the number of previous injuries, and the type of immediate response, to name a few. The workings of the brain are still much of a mystery and research continues to develop strategies and therapies to treat brain injury and improve long-term recovery.

REFERENCES

Alamo Head Injury Association. (n.d.) *About AHIA*. Retrieved March 12, 2012, from http://alamoheadinjury.org/whoweare.html

Brain Injury Association of America. (2012a). *About Brain Injury*. Retrieved from http://biausa.fyrian.com/about-brain-injury.htm

Brain Injury Association of America. (2012b). *Treatment*. Retrieved from http://www.biausa.org/brain-injury-treatment.htm

Brain Injury Association of Texas. (2012a). *About Brain Injury*. Retrieved from http://www.biatx.org/about-brain-injury.htm#EpilepsySeizures

Brain Injury Association of Texas. (2012b). *About Us.* Retrieved from http://www.biatx.org/about.htm

Brain Injury Association of Texas. (2012c). *Brain Injury Statistics*. Retrieved from http://www.biatx.org/statistics.htm

Centers for Disease Control and Prevention (CDC). (n.d.). *Heads up: Facts for physicians about mild traumatic brain injury (MTBI).* Retrieved March 6, 2012, from http://www.cdc.gov/concussion/headsup/pdf/Facts_for_Physicians_booklet-a.pdf

Centers for Disease Control and Prevention. (2011a). *Severe traumatic brain injury*. Retrieved from http://www.cdc.gov/TraumaticBrainInjury/severe.html

Centers for Disease Control and Prevention. (2010b). *State injury indicators report: Fifth edition – 2006 Data.* Retrieved from http://www.cdc.gov/injury/pdfs/SII_Data_Report_5th_edition-a.pdf

Centers for Disease Control and Prevention. (2011a). *Severe traumatic brain injury*. Retrieved from http://www.cdc.gov/TraumaticBrainInjury/severe.html

Centers for Disease Control and Prevention. (2011b). *Unintentional drowning: Fact sheet*. Retrieved from http://www.cdc.gov/homeandrecreationalsafety/water-safety/waterinjuries-factsheet.html

Centers for Disease Control and Prevention (CDC). (2012). *Guidelines for field triage of injured patients: Recommendations of the National Expert Panel on Field Triage, 2011*. Retrieved from http://www.cdc.gov/mmwr/pdf/rr/rr6101.pdf

Cullen, NK, Crescini, C, & Bayley, MT (2009). The Rehabilitation Outcomes After Anoxic Brain Injury: A Case-Controlled Comparison with Traumatic Brain Injury. *PM&R, Vol. 1 (12), pp 1069-1076*. Retrieved from http://www.brainline.org/content/2010/03/research-update-comparing-traumatic-brain-injury-and-anoxic-brain-injury-in-rehabilitation.html

Hermoye, L., (2010). *Functional MRI (fMRI) of patients in a vegetative or minimally conscious state.* Retrieved from, http://www.imagilys.com/fmri-consciousness-vegetative-state/

Malik, A. (2011). *Neuropsychological evaluation.* Retrieved from http://emedicine.medscape.com/article/317596-overview#showall

Maruta, J., Lee, S., Jacobs, E., and Ghajar, J. (2010) A unified science of concussion. *Annals of the New York Academy of Sciences, 1208, 58-66*. Retrieved from http://www.braintrauma.org/pdf/maruta2010ann_nyas.pdf

Mayo Clinic. (2010). *Traumatic brain injury: Treatments and drugs.* Retrieved from, http://www.mayoclinic.com/health/traumatic-brain-injury/DS00552/DSECTION=treatments-and-drugs

National Cancer Institute. (2012). *State cancer profiles*. Retrieved from http://www.statecancerprofiles.cancer.gov/incidencerates/index.php?stateFIPS=48&cancer=076&race=00&sex=0&age=001&type=incd&sortVariableName=rate&sortOrder=default

Roger, V., Go, A., Lloyd-Jones, D., Benjamin, E., Berry, J., Borden, W.,…Bravata, D. (2012). Heart disease and stroke statistics – 2012 update: A Report from the American Heart Association. *Circulation. 2012;125:e12-e230*. Retrieved from http://circ.ahajournals.org/content/early/2011/12/15/CIR.0b013e31823ac046

Shin, S., Verstynen, T., Pathak, S., Jarbo, K., Hricik, A., Maserati, M.…Schneider, W. (2012). High-definition fiber tracking for assessment of neurological deficit in a case of traumatic brain injury: finding, visualizing, and interpreting small sites of damage; Case report. *Journal of Neurosurgery, published online March 2, 2012 DOI: 10.3171/2012.1.JNS111282.* Retrieved from http://thejns.org/doi/abs/10.3171/2012.1.JNS111282

Slobounov, S., Gay, M., Zhang, K., Johnson, B., Pennell, D.,Sebastianelli, W., Horovitz, S., Hallett, M. (2011). Alteration of brain functional network at rest and in response to YMCA physical stress test in concussed athletes: rsfMRI study. *NeuroImage, April 15, 2011, Vol. 55(4), pp. 1716-27.* Retrieved from http://www.ninds.nih.gov/news_and_events/news_articles/rsfMRI_athlete_concussion.htm

Swiercinsky, D. (n.d.). *When brain injury occurs*. Retrieved March 9, 2012 from, http://www.bapta.com/brain_injury.htm

Texas Department of Aging and Disability Services (DADS). (2012). *Access and Intake Services Community Options Booklet*. Retrieved from http://www.dads.state.tx.us/providers/community_options.pdf

Texas Department of Assistive and Rehabilitative Services [DARS]. (n.d.) *Comprehensive Rehabilitation Services.* Retrieved March 12, 2012, from http://www.dars.state.tx.us/drs/crs.shtml

Texas Health and Human Services Commission. (n.d.). *Office of Acquired Brain Injury*. Retrieved March 12, 2012, from http://www.hhsc.state.tx.us/hhsc_projects/abj/index.shtml

Thomason, M., Dennis, E., Joshi, A., Joshi, S., Dinov, I., Chang, C.…Gotlib, I. (2010). Restin-state fMRI can reliably map neural networks in children. *NeuroImage. Doi: 10.1016/j.neuroimage.2010.11.080*. Retrieved from, http://www.loni.ucla.edu/~thompson/PDF/MoriahRSfMRI-kids-ni10.pdf

TraumaticBrainInjury.com. (2004). Understanding traumatic brain injury. Retrieved from http://www.traumaticbraininjury.com/content/understandingtbi/effectsoftbi.html

Zasler, N. (2007). A Physician talks about severe brain injury: The Basics. Retrieved from http://www.biausa.org/brain-injury-diagnosis.htm