

# Assessment and Treatment of Children with Traumatic Brain Injury

*Karen McCord, PT*

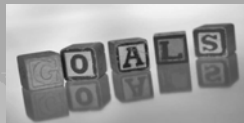
## Assessment and Treatment of Children with Traumatic Brain Injury

Karen McCord, PT  
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March 17, 2012



### Goals:

- Identify common causes and types of pediatric brain injury
- Determine how the pediatric brain differs from adult brain, and therefore how the assessment and treatment of pediatric traumatic brain injuries (TBIs) differ from those of adults
- Explore medical and treatment issues for pediatrics, with consideration of age groups
- Be aware of general outcome measures/outcomes
- Identify when to refer to pediatric rehab
- Recognize community issues/prevention



### Definitions:

- Acquired brain injury  
Includes traumatic, infectious, ischemic, anoxic, genetic, metabolic, oncologic, and vasculitic injuries
- Traumatic brain injury is the most common type of acquired pediatric brain injury with 450,000 children seen in E.D.s for evaluation annually
- Concussion = mild TBI  
Acceleration/deceleration force imparted to the head that results in temporary alteration in mental status



# Assessment and Treatment of Children with Traumatic Brain Injury

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## Demographics:

- Trauma is the #1 cause of death in children over 1 yrs old
- Traumatic Brain Injury: 1.5 million kids/year
- Mild traumatic brain injury: 80%
- Moderate and severe TBI: 20%
- Severe childhood traumatic brain injury: 15,000 per year
- 50% with severe TBIs have other associated injuries



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## Demographics:

- Infants/children 0-4 yrs, and adolescents 15-19 yrs are the highest risk groups for TBI
- The most common mechanisms of injury vary with age groups in pediatrics
- 60% of those injured are male
- Pre-injury diagnosis of ADHD in 20% of children with TBI and incidence of ADHD is 6% in the general population
- Higher incidence in minority population~ no difference in severity



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## Causes of Injury in Pediatrics:



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## Causes of Injury in Pediatrics:

- MVA responsible for 66% of injuries in adolescents and 20% in young children
- Falls responsible for 39% of injuries under 14yrs old and leading cause of injury under 4yrs old



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## Causes of Injury in Pediatrics-Infants:

### •Non-accidental trauma (NAT)

- 17% TBI in infants, 5% in 1-4 yr olds
- Median age for inflicted TBI is 2-4 months
- Intensive care hospitalization rates have been estimated at approximately 30 per 100,000 children annually
- May be occult, may be a delay in presentation to the E.D.



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## Causes of Injury in Pediatrics-Infants:

- In infants (less than one year of age), inflicted or non-accidental trauma (NAT) must always be considered
- NAT should be suspected if the head injury is unwitnessed or when no clear, appropriate mechanism explains the head injury
- Patients younger than 2 years of age suspected of being abused should undergo a complete skeletal survey
- An ophthalmology consultation should be obtained

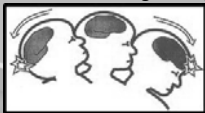


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## Causes of Injury in Pediatrics-Infants:

### Shaken Baby Syndrome (SBS)

- SBS is a leading cause of child abuse deaths in the United States
- At least one of every four babies who are violently shaken dies from this form of child maltreatment
- Babies (newborn to 4 months) are at greatest risk of injury from shaking
- Inconsolable crying is a primary trigger reported for shaking a baby



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## Causes of Injury in Pediatrics-Toddlers:



- By toddler age, children have developed the motor capabilities to encounter more hazards but lack the cognitive ability for avoidance

- Inflicted TBI requiring hospitalization is much less common in this age group (four per 100,000 annually)

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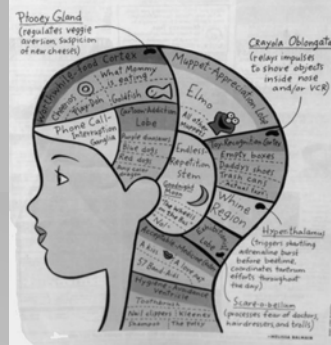
## Causes of Injury in Pediatrics- Toddlers:



- Among motor vehicle related injuries in toddlers, pedestrian versus vehicle crashes are more common than motor vehicle occupant injuries
- Falls are a common cause of injury in this age group, with the first point of contact in falls likely to be the head.



## Inside a toddler's brain



## Causes of Injury in Pediatrics- School Aged:

- Falls requiring hospitalization decrease with age
- There is a rise in injuries associated with bicycle, skateboard, and scooter crashes



## Causes of Injury in Pediatrics- Teens:

- Vehicular accidents and sports are leading causes
- Incidence of assaults increasing in adolescents and young adults.



# Assessment and Treatment of Children with Traumatic Brain Injury

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## How are Kids Different?

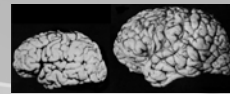
- The immature brain has some inherent advantages (injury response and recovery) compared to the adult brain
- Vulnerabilities based upon underlying developmental processes at the time of injury
- Prognosis can be worse at younger ages (<2-3 years)
- Cognitive impairments of children may not be immediately obvious after the injury, but become apparent as child gets older and faces increased expectations for new learning and more complex, socially appropriate behavior



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## How are Kids Different?

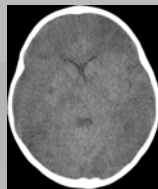
- A child's brain is still developing
- Children's skulls are not as strong
- Children have relatively larger heads with weaker necks
- Less myelin and higher brain fluid content
- Forces go to deeper parts of the brain
- Decreased middle cerebral artery flow rate compared to adults
- More impaired cerebral auto regulation
- Increased propensity for apoptosis



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## How are Kids Different?

- Increased excitotoxic neurotransmitters
- Increased inflammation
- Increased blood-brain barrier permeability
- Diffuse cerebral swelling
- Increased risk for seizures
- Responses to medications



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## What is typical??

### Infants:

#### Physical:

- Rough, random, uncoordinated, reflexive movement, progressing to more coordinated/ purposeful movements and eventually independent mobility

#### Cognitive:

- Physically explores environment to learn about it
- Repeats movements to master them, which also stimulates brain cell development

#### Social:

- Baby settles when parent comforts

#### Emotional:

- Learns fundamental trust in self, caretakers, environment



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## Toddlers:

### Physical:

- More complex motor skills; walking, climbing

### Cognitive:

- Multiple word phrases
- Uses more complex toys and understands sequence of putting toys, puzzles together

### Social:

- Seeks comfort from parent, safe-base exploration
- Imitation, parallel and symbolic, play

### Emotional:

- Mastery of body and rudimentary mastery of environment (can get other's to take care of him)
- Emotionally attached to toys or objects for security



## School Aged:

### Physical:

- More complex gross and fine motor skills
- Athletic development
- Steady growth: 3 -4 inches per year
- Motor & perceptual motor skills better integrated
- 10-12 yrs: puberty begins for some children

### Cognitive:

- Progression from ego-centric, illogical, magical thinking to more concrete thinking
- Explosion of vocabulary
- Poor understanding of time, value, sequence of events
- Vivid imaginations
- Receptive language better than expressive till age 4

### Social:

- Wants to please adults
- Development of conscience



## School Aged:

### Emotional:

- Self-esteem based on what others tell him or her
- Increasing ability to control emotions, less emotional outbursts
- Curious
- Self-directed in many activities
- Self esteem based on ability to perform and produce
- Alternative strategies for dealing with frustration and expressing emotions

## Adolescents:

### Physical:

- Growth spurts: Girls: 11-14 yrs  
Boys: 13-17 yrs

### Puberty:

- Girls: 11-14 yrs  
Boys: 12-15 yrs

- Youth acclimate to changes in body

### Cognitive:

- Insight, perspective taking: understand and consider others' perspectives, and perspectives of social systems
- Systematic problem solving: can attack a problem, consider multiple solutions, plan a course of action
- Cognitive development is uneven, and impacted by emotionality



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## Adolescents:

### Social:

- Psychologically distance self from parents; identify with peer group

### Emotional:

- Psycho-social task is identity formation
- Self conscious about physical appearance and early or late development
- Forms identity by organizing perceptions of ones attitudes, behaviors, values into coherent "whole"

## Wild cards:

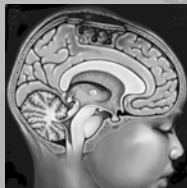
- Pre-existing medical/social issues
- Behavior
- Circumstances of Injury
- Socioeconomic Environment
- Support System
- Parenting/ability of parent to be present



## Mechanisms of Injury in TBI:

- **Primary injury**- direct mechanical force

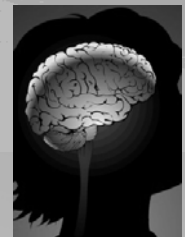
- Diffuse axonal injury
- Focal contusion
- Multiple petechial hemorrhages
- Cranial nerve injury
- Hemorrhages
  - epidural
  - subdural
  - intracerebral



## Mechanisms of Injury in TBI:

### Secondary injury

- Cerebral edema
- Hypotension
- Vasospasm
- Failure of auto regulation
- Increased ICP
- Hypoxia
- Excitotoxicity
- Production of free radicals



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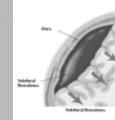
## Common types of traumatic brain injuries in children:



### Epidural hematomas:

- Rapid hemorrhages caused by tears of meningeal arteries/veins
- Are often convex, as blood accumulates between the skull and dura mater
- Often associated with temporal bone fractures
- May have a lucid period for up to several hours after the initial injury, followed by rapid deterioration in mental status
- If clinically unrecognized, may be fatal as can lead to increased intracranial pressure and herniation
- Require close observation and immediate neurosurgical consultation and evaluation for possible surgical evacuation

## Common types of traumatic brain injuries in children:



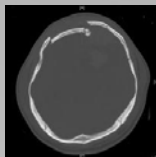
### Subdural hematomas:

- More common in children experiencing head trauma and frequently are associated with skull fractures
- Due to tears of the parasagittal bridging veins, are classically concave, as the blood accumulates in the subdural space along the surface of the brain
- If child with a subdural hematoma does not regain consciousness after the head injury, immediate surgical intervention is often required as a result of underlying damage/pressure on the other structures of the brain

## Common types of traumatic brain injuries in children:

### Blunt head trauma:

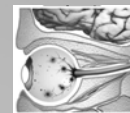
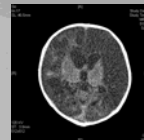
- Often have cerebral contusions that occur primarily in cortical tissue, usually under the site of impact
- Cerebral contusions may be small, causing relatively minor symptoms, or large and accompanied by cerebral edema and increased ICP



## Common types of traumatic brain injuries in children:

### Shaken baby

- Acute and chronic subdural hemorrhages
- Retinal hemorrhages
- Multiple fractures of ribs/long bones
- Fractures and bruises in various stages of healing

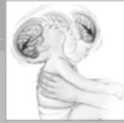




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## Common types of traumatic brain injuries in children:



### Rapid acceleration or deceleration injuries:

- Often seen in motor vehicle accidents, falls, and abusive trauma (severe shaking)
- May develop diffuse axonal injury (DAI)
- Patients experiencing DAI frequently develop increased intracranial pressure (ICP)
- DAI also may occur after relatively minor head trauma to a person who recently had a first concussion (second impact syndrome)

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## Concussion

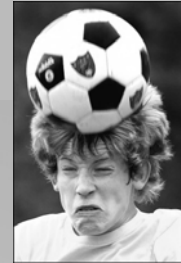
- Transient loss of consciousness and occurs as the result of head trauma
- Neurologic examination often normal initially; diagnosis is usually a retrospective one

### Initial Symptoms:

- Vomiting
- Headache
- Crying and inability to be consoled
- Restlessness or irritability

### Persistent Symptoms:

- Excessive crying
- Persistent headache
- Poor attention
- Changes in sleep patterns



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## Concussion

- Infants and young children
- Have a higher incidence of posttraumatic seizures
- Often experience delayed somnolence and vomiting

- Older children
- Post-traumatic amnesia more common
- Waxing and waning of mental status in the absence of any morphologic changes



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## Common Neurobehavioral Sequelae

- Altered arousal
- Impaired cognition-memory and processing speed
- Agitation
- Impaired impulse control
- Executive dysfunction becomes apparent as delirium improves



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## Treatment of the child in a minimally responsive state

- Establish day-night cycle
- Sensory stimulation
- Maintain familiar routine/surroundings
- Medications
  - Amantadine
  - Neurostimulants
  - Sleep aids
  - Limit/wean all sedating medications



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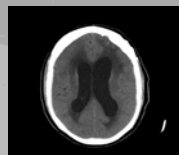
## Seizures:



- **Immediate** <24 hr from time of injury
- **Early** 1-7 days from time of injury
- **Late** >7 days from time of injury
- Early seizure 20%-39%, late 7%-12%
- <2 yr olds have 3x greater risk compared to 2-12 yr old

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## Hydrocephalus



- Suspect if patient starts to plateau
- Symptoms in infant and young children include:
  - Prominent scalp veins
  - Separation of sutures
  - Vomiting, sleepiness, irritability
  - Headache, nausea, vision changes
  - Downward deviation of eyes
  - Tense bulging fontanelles

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## Agitation



- Normal part of recovery process
- Causes
  - Environmental
    - ~Number of distractions in room
    - ~Presence of tubes or restraints
  - Pain and discomfort
  - Infection
  - Electrolyte/metabolic abnormalities
  - Medications

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## Neurostorming/Paroxysmal Autonomic Instability with Dystonia (PAID):

- Hyperthermia
- Hypertension
- Diaphoresis
- Rigidity
- Tachypnea
- Decerebrate posturing
- Tachycardia
- Pupil changes
- Cycles 1x per day



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## GI and GU complications:

- Dysphagia in 5.3% of children TBI
  - Mild 1%, moderate 15%, severe 68% pediatric TBIs
  - Usually resolves within 12 weeks of injury
- Bowel/bladder incontinence



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## Visual impairment

- Optic atrophy – seen within 1 month after injury correlated with site of impact
- Homonymous hemianopsia associated with hemorrhage and hemiparesis
- Central visual dysfunction – involves not just occipital, but also temporal and parietal lobes
- Cranial nerve palsy
- Symptoms of diplopia
- Treatment – alternative patching
- Usually resolves in 6 months



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## Heterotopic ossification

- 14-23% of pediatric TBI survivors
- More common at age >11 or 2 or more extremity fractures
- Presence of spasticity and fractures increase risk
- Usually hips, elbows, shoulder and knees



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## Case Presentation:

KP



- 16 yr old peds v. auto
- Severe TBI with multiple bilateral parenchymal hemorrhages
- Right tibial plateau fracture

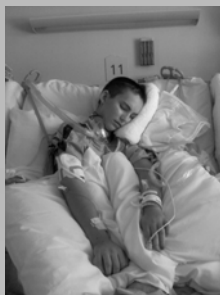
## Acute Hospital Course (2 months)

### History:

- Coma
- VP shunt
- Tracheostomy
- G-tube placement
- PAID treated by beta-blockers
- Late seizure due to bilateral posterior cerebral artery infarcts with EEG c/w slowing
- Ventilator associated pneumonia
- Severe heterotopic ossification
- Left upper extremity/right lower extremity involvement

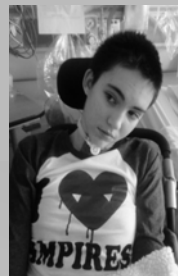


## Acute Hospital Course -> Pediatric Rehab



- Post injury depression
- Sleep cycle disruption
- Poor initiation
- Dysphagia
- Agitation

## Admission Level of Function:



- Eating: Total Assist
- Grooming: Total Assist
- Dressing: Total Assist
- Toileting: Total Assist
- Swallowing: Total Assist
- Transfers: Total Assist
- Locomotion: Total Assist
- Comprehension: Inconsistent
- Reading: Max assist
- Problem solving: Total Assist
- Memory: Total Assist

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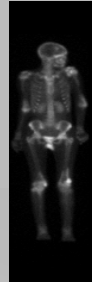
## Discharge Level of Function:

(post 6 weeks of Acute Rehab)



- Eating: Moderate assist
- Grooming: Maximum assist
- Dressing: Maximum assist
- Toileting: Moderate assist
- Swallowing: Minimum assist
- Transfers: Maximum assist
- Locomotion: Maximum assist
- Comprehension: Moderate assist
- Reading: Supervision
- Problem solving: Mod/Max assist
- Memory: Moderate assist

## Radiotracer findings: Active heterotopic ossification



- Avid areas of increased radiotracer uptake in the soft tissues surrounding
  - Bilateral elbow and knee joints
  - Left glenohumeral joint
  - Left femoral acetabular joint

## Heterotopic ossification

- Progressive loss of joint mobility  
increase osteoclastic activity
- Treatment –
- Bisphosphonate therapy
- Radiation
- Surgery



## Outcome Measures



- Rancho Los Amigos Scale
- Rappaport Coma/Near-Coma Scale
  - Applied to children and adults with low level of consciousness
  - Looks at specific responses to certain stimuli
- WeeFIM between 6mo-7yr
- Pediatric Glasgow Coma Scale



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## Measures of Improvement:

### Admit:

- Rancho Los Amigos Scale: 3
- Glasgow Coma Scale: 7 (GCS 5 immediately after accident)
- FIM/FAM: 64

### Discharge (6 weeks):

- Rancho Los Amigos Scale: 6
- Glasgow Coma Scale: 14
- FIM/FAM: 110



## Outcomes

- Duration of coma appears to be the most sensitive indicator of neurocognitive outcome

Children whose coma lasts < 2 wks have > neurocognitive outcomes and < developmental and behavioral sequelae than children whose coma lasts > 2 wks

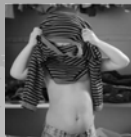


- Recovery goes from proximal -> distal, and simple -> complex
- Gait – 1 year after injury
  - 46% walked independently without assistive devices
  - 27% walked independent with assistive devices



## Outcomes

- **Fine motor**  
Effected long term  
Pattern of recovery is worse compared to gait
- **Balance**  
Vestibular, integration of sensory/motor programming
- **Tremor**  
Seen proximally and increases with effort and intentional movement



## Outcomes

### Cognitive impairment

- Attention and arousal
  - Amantadine has been shown to increase Rancho level in inpatients
- Memory impairment
  - Related to overall severity of injury
  - Verbal memory more impaired than visual memory
  - Need compensatory strategies and avoid purely verbal teaching



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## Outcomes

### Cognitive Impairment

- Behavior
  - Impulsivity, personality changes, depression, anxiety, aggression, insomnia
  - Persistent in 10-50% of children with TBI
  - Can worsen over time
  - Worse when TBI sustained when younger



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## Outcomes

### Cognitive Impairment

- Communication
  - Word finding and verbal learning deficit common
  - Reduced rate of speech
  - Usually more impaired than shown in standard intelligence testing



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## Community issues

- **Individuals with Disabilities Education Act (IDEA) – enacted in 1990**  
States that children with disabilities have a right to receive appropriate public education in the least restrictive environment
- **School services**  
75% need special services especially in first 5 years  
Goal is to return to school early  
IEP – individual education plan (IEP)
- **Appropriate outpatient follow-up and referrals**



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## Timely referrals:

- Many children with TBIs are not seen in rehabilitation programs
- The National Pediatric Trauma Registry Report found that out of 18,000 pediatric head traumas recorded in the registry (from over 50 trauma centers) only 2% of these admissions were discharged to rehabilitation services despite the recognition of noted cognitive, behavioral, and/or motor deficits in 3 or more areas.



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## Timely referrals:

- The survival of children who sustain major or life-threatening trauma depends upon good pre-hospital care, appropriate triage, resuscitation by an experienced trauma team in an emergency center, and effective emergent surgery
- Given the great numbers of childhood injuries occurring yearly in the United States, integrated echelons of care are needed that include regional pediatric trauma centers with pediatric commitment and emergency departments that are appropriate for children.



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## Timely referrals:

It has been demonstrated that pediatric trauma mortality is significantly improved in a pediatric trauma center or in an adult center with pediatric trauma certification, compared with level I or II adult trauma centers.



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## Case Presentation: SF: 17 month old, typically developing



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### History:

- S/p fall while being lifted out of bathtub
- Immediately cried then became lethargic with associated emesis
- Left epidural hematoma with herniation syndrome
- Craniectomy and evacuation of epidural hematoma, removal of bone flap



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- Respiratory distress~intubated
- TPN -> NJ tube for feeding
- Dependent mobility
- Right hemiparesis

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## Rapid recovery (2 weeks):



- Extubated to room air
- Full p.o. feeds
- Close SBA mobility
- Mild right hemiparesis
- Language skills nearing baseline

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- Bone flap replaced
- Helmet on
- Home in 3.5 weeks!

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## Why Pediatric Rehab?



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## Why Pediatric Rehab?



## Different tools for different ages/sizes



## Family Centered Care

- Families need information to build a knowledge base about their child's brain injury
- Training on strategies for managing their child's cognitive, behavioral and physical challenges
- Advocacy skills for negotiating services at school over the course of their child's development and education
- Supply resources for parent's and family's emotional trauma to help them develop coping skills, find support for grieving, and reduce caregiver stress



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## Prevention

- Adequate supervision and safety instruction
- Bicycle/scooter/skateboard safety, use of proper fitting helmet and protective gear
- Car seat/child restraint adherence



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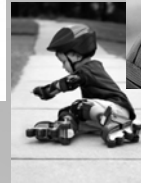
## Prevention



- Use gates on stairways and doors to prevent injuries in infants and young children
- Install window guards on all windows above the first floor
- Secure heavy furniture and televisions/electronics to the wall
- Do not use wheeled baby walkers or baby bouncers that affix to door jams/frames



## Helmets and safety equipment



## Child Passenger Safety law in California

Effective January 1, 2012, all children *under the age of 8 must be properly buckled into a car seat or booster seat in the back seat.*



## Why?

- Car crashes kill more children age 4-8 years old than any other cause
- Seat belts are designed for adults and do not properly fit children under 4'9" tall, regardless of the child's weight
- A seat belt that doesn't fit properly won't protect a child in a crash
- Booster seats reduce risk injury for children 4-8 years old by 45% compared to seat belts alone



# Assessment and Treatment of Children with Traumatic Brain Injury

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