DOCUMENT RESUME

ED 333 615 EC 300 366

AUTHOR Waaland, Pamela K.; Cockrell, Janice L.
TITLE Pediatric Traumatic Brain Injury. Special Topic Report #3.
INSTITUTION Children's Hospital, Richmond, VA. Rehabilitation Research and Training Center on Severe Traumatic Brain Injury.
SPONS AGENCY National Inst. on Disability and Rehabilitation Research (ED/OSERS), Washington, DC.
PUB DATE 90
CONTRACT H133B80029
NOTE 5p.
AVAILABLE FROM Rehabilitation Research & Training Center on Severe Traumatic Brain Injury, Box 434, MCV Station, Richmond, VA 23298-0434 ($3.50).
PUB TYPE Information Analyses (070)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Age Differences; At Risk Persons; Behavior Problems; *Child Health; Cognitive Development; Coping; Emotional Adjustment; Family Problems; *Head Injuries; *Incidence; Injuries; *Intervention; *Neurological Impairments; Neuropsychology; Outcomes of Treatment; Sex Differences
IDENTIFIERS *Pediatric Traumatic Brain Injury

ABSTRACT

This brief report summarizes what is known about pediatric traumatic brain injury, including the following: risk factors (e.g., males especially those ages 5 to 25, youth with preexisting problems including previous head injury victims, and children receiving inadequate supervision); life after injury; physical and neurological consequences (e.g., coma, neurologic and sensorimotor impairments, and milder symptoms including headaches and sleep disturbance); cognitive consequences (lowered intelligence quotient especially in performance scores, greatest recovery in the first 6 months, and impaired ability to concentrate and retain information); behavior and socioemotional consequences (increased incidence of persistent psychiatric or behavioral problems increasing for several years after injury); severity of injury and outcome; age and outcome (differential seizure rates between children under and over age 2, greater long-term cognitive impairment for young children, different affective effects for young children and adolescents, and increased somatic complaints); family consequences (family members often respond in predictable stages post-injury, caregiver needs change over time, and all caregivers value complete clear information). Desirable future directions identified include learning more about risk factors, increasing the effectiveness of early intervention and referral efforts, and providing schools with adequate financial and professional support. Includes 49 references. (DB)

Special Topic Report 1990 #3

Pediatric Traumatic Brain Injury

Pamela K. Waaland, Ph.D.
Co-Director, Children's Project
Rehabilitation Research and Training Center on Severe Traumatic Brain Injury
Neuropsychologist, Children's Neurological Services
Clinical Neuropsychologist, Children's Hospital
Richmond, Virginia

National Institute on Disability and Rehabilitation Research, United States Department of Education

Traumatic brain injury is the primary cause of death and disability to youth in the United States today (Rivara & Mueller, 1986; Frankowski, Annegers, & Whitman, 1985). Approximately 41% of pediatric deaths and 35% of accidents are caused by brain trauma, which far exceeds all other causes of mortality and morbidity in childhood. Based on our best estimate, 220/100,000 youth under age 15 will sustain a head injury annually (Kalsbeek et al, 1980; Annegers, 1983).

How are Youth Injured?

The cause of injury shifts with age and the youth's major form of transportation, ranging from walking in infancy to driving in adolescence (Klauber et al., 1981; Annegers, 1983). Falls and abuse are primary causes in preschool years. Children 5-14 are more often injured in sports-related, pedestrian and bicycle accidents. Children over 14, like adults, are most frequently injured in moving vehicle accidents.

Who is at Greatest Risk?

Epidemological studies consistently reveal gender and age to be important risk factors:

- From age 3 onward, boys are 2-4 times more likely to sustain brain injury and 4-6 times more likely to die from brain injury (Annegers et al., 1980; Moyes, 1980; Kraus et al., 1986).
- Youth from ages 15 to 25 are at highest risk from brain injury; Preschoolers constitute the second high risk group (Annegers, 1983; Klonoff, 1971).
- Males show increasing incidence rates from age 5-25, while rates for females gradually decline until they are of driver's age (Annegers, 1983).

Other demographic trends suggest that children who can least afford developmental insult are most likely to be the victims of traumatic head injury.

- Youth with preexisting problems such as hyperactivity, impulsivity, and aggression are four times more likely to incur a mild but not severe—head injury (Brown et al., 1981).
- Head injury victims are two times more likely to have a second injury (Annegers, 1983).
- A recent prospective study of 16,000 preschoolers indicates children with repeat injuries are more often hyperactive, aggressive, and destructive; their mothers are more often young, employed urban residents who are heavy smokers (Butler & Golding, 1986). Other prospective studies, however, have not found high-risk children to differ in their behavior (Larson & Pless, 1988).
- Families of head injury victims have more limited resources implied by a higher incidence of low income housing, marital instability, and crowded living conditions by some reports (Klonoff, 1971; Rune, 1971).
- By other reports, their families also have more limited social status, advantages, and support (Rutter el al., 1980; Brown et al., 1981; Waaland & Cockrell, 1990).
- Children under 14 are more often engaged in prohibited, unsupervised activities at the time of their injury, implicating poor parental supervision as contributory (Brown et al., 1981).

Life After Injury

How well a youth will fare following traumatic brain injury depends on a combination of factors. Among the most important of these factors are his or her preinjury emotional and social adjustment, intellect, and school abilities; age and severity of injury; and the quality of the postinjury family, school, and community environment (Waaland, 1990; Waaland & Cockrell, 1990). Unfortunately, standard psychological or academic tests typically underestimate true cognitive deficit and may create unrealistic family and community expectations. These youth may perform well in structured situations, but be unable to initiate activity, maintain motivation, or organize their day-to-day life. With these caveats and individual differences in mind, the following information outlines typical expectations following moderate to severe traumatic brain injury.

What are the Physical and Neurologic Consequences?

- Traumatic brain injuries typically causes damage at the site of impact, the site opposite the impact (or contrecoup) and diffusely due to rotation in the skull which causes "shearing" of nerve fibers (Lezak, 1983).

- Further damage can be caused by bleeding or clotting within the skull, raised intracranial pressure, oxygen (hypoxia) or blood (infarction) deprivation, infection, or brain swelling (edema) (Pang, 1985). These secondary problems often can be prevented by aggressive, state-of-the art medical treatment available through specialized trauma units.
- Coma is caused by the involvement of the reticular activating system. Absence of coma does not mean structural brain damage has not occurred.
- Because of rough bones at the skull base and the typical site of injury, the temporal and frontal lobes of the cortex are most vulnerable to injury. Damage to these cortical areas account for disturbance in behavior, affect, emotions, attention, and memory typifying traumatic brain injury.
- Severe head injury may be accompanied by extensive neurologic and sensorimotor impairments ranging from seizures, sleep disorders and visual/hearing deficits to motor paresis or spasticity.
- Even in milder injuries, frequently reported symptoms include headaches, dizziness, fatigue, irritability, and sleep disturbance (Boll, 1982; Cartlidge & Shaw, 1981).

What are the Cognitive Consequences?

- Not surprisingly, children with more severe brain injury (i.e., longer than one week in coma) typically display IQ scores 20 points below average and make slower academic progress when compared with agemates (Levin & Eisenberg, 1979).
- On standardized intelligence tests (e.g., the Wechsler Scales), verbal scores typically are significantly higher than performance scores following injury (Chadwick et al., 1981). Slowed processing time and fine motor impairments contribute to lowered nonverbal skills.
- As with adults, preinjury acquired knowledge and school learning are least affected by brain injury (Chadwick et al., 1981).
- Cognitive recovery can occur for several years following injury, but gains typically are most rapid during the first six months to one year post-injury (Rutter et al., 1983).
- Head injury victims are most impaired in their ability to sustain concentration, learn or retain information, process visuospatial relations, think conceptually or sequentially, and produce efficient verbal or motor output (Ewing-Cobbs & Fletcher, 1987).

What are the Behavior and Socioemotional Consequences?

The risk of psychiatric and behavior disorders is substantially increased following childhood injury (Rutter et al., 1983). Relative to intellectual and physical impairments, emotional and behavioral changes follow a different course of recovery. These changes also create the greater stress for family members and impediment to community adjustment (Livingston & Brooks, 1988; Lezak, 1986, 1978).

- Approximately 25-50% of children with head injury evidence persistent psychiatric or behavioral problems (Brink et al., 1970; Klonoff & Paris, 1974; Flach & Malros, 1972).
- Cognitive and psychiatric outcome do not appear to be strongly related to one another, particularly with increased time postinjury (Fletcher et al., in press).
- In contrast to cognitive outcome, the incidence and severity of psychiatric and behavior disorders steadily increase during the first several years after injury (Brown et al., 1981).
- Many investigators have not found a typical behavior pattern with the exception of inappropriate, uninhibited behavior following severe injury (Brown et al, 1981); and even the existence of this pattern has been questioned (Fletcher et al., in press). However, frequently reported problems include inattention, hyperactivity, impulsivity, and irritability (Waaland & Cockrell, 1990; Klonoff & Paris, 1974).
- Some investigators noted that children with even mild preinjury behavior problems or adverse family conditions develop notably higher rates of psychiatric disturbance (Brown et al., 1981); however, other researchers have not replicated these findings (Fletcher at al., in press).

How does Severity of Injury Affect Outcome?

Severity of injury typically is defined based on the presence of unresponsiveness, coma, or posttraumatic amnesia (inaccurate recall for recent events) since these measures correlate with functional outcome. The exact relationship between length of coma or posttraumatic amnesia and cognitive impairment, however, is controversial. Risk estimates have ranged from one hour, to one day, to several weeks (Levin & Eisenberg, 1979; Rutter, Chadwick, & Shaeffer, 1983). Obviously, the best measure of injury severity is the degree to which a person's preinjury abilities are chronically impaired following trauma.

How does Age Affect Injury and Outcome?

The young brain responds differently to injury than the mature brain. Differences in the mechanics of injury in childhood remain unclear (Ewing-Cobbs & Miner, 1989). However, the common belief that infants, toddler, or preschoolers are more "resilient" to traumatic brain injury clearly is unsubstantiated.

- The immature skull is thinner and more easily damaged by trauma; the immature brain has more limited protective covering, fewer dendritic connections, and incomplete myelination. Although undoubtedly increasing childhood risk, the precise effect of these differences is unclear (Shapiro, 1987; Bruce et al., 1979).
- Children appear to be more prone to increased intracranial pressure, diffuse swelling, and secondary brain injuries (Ewing-Cobbs & Miner, 1989).
- There is a low incidence of initial seizures, but a high incidence of late seizure onset in children under two, with the reverse pattern noted in children two or over (Black, Shepard, & Walker, 1975).
- The younger the child, the greater the long-term cognitive impairment due to his or her immature neuroanatomy and learning history (Ewing-Cobbs & Fletcher, 1987; Ewing-Cobbs, Fletcher, & Levin, 1986).
- Children under 6 years appear particularly susceptible to motor and expressive language impairments (Ewing-Cobbs et al., 1989). In contrast, motor speed and perceptual-motor skills are most vulnerable to long-term impairment among youth from 6 through 18 (Chadwick et al., 1981). Although patterns are still unclear, infants and toddlers may be at greater risk for speech and language disorders (Ewing-Cobbs et al., 1989).

- The severity of cognitive and learning problems decreases during the first several years postinjury. However, previously unrecognized deficits may emerge as the victim grows older and is expected to think conceptually and function independently (Black et al., 1971).
- Younger children tend to display heightened activity, distractibility, and aggression whereas adolescents evidence increased affective disturbance, impulsivity, and decreased initiative (Brink et al., 1970).
- Somatic complaints, including headaches, eating problems, and sleep disturbance, tend to occur among all age groups (Klonoff and Paris, 1974; Black et al., 1971).

What are the Family Consequences?

The lives of all family members can be shattered by childhood disability. Following the youth's injury, family members must without preparation adjust to a "new" person who may display extensive impairment, personality changes, and dependency. The roles and responsibilities of individual family members as well as the family's financial status, availability of leisure time, and priorities often shift dramatically.

- Family members often respond in predictable ways at different stages postinjury (Lezak, 1978, 1986; Polinko et al., 1985). Shock gives way to relief and often unrealistic optimism as the youth recovers from coma. As the child reenters the community, family members may vacillate between anxiety, guilt, and depression to withdrawal or anger directed at family members or even supportive professionals.
- Children in particular may experience significant resentment, anger, embarrassment, guilt, or depression as a consequence of changes in their sibling and life style (Sullivan, 1976).
- The coping skills of individual family members will be affected by the family's available resources, prior ways of coping with stress, and severity of problems presented by the injury victim (Waaland, 1989).
- Caregivers from higher socioeconomic groups rate the intactness of their children's abilities and progress postinjury as more important; they also rank the need to be an informed and active participant in their children's therapy program as very important relative to caregivers from lower socioeconomic groups (Waaland & Cockrell, 1990).
- Caregivers with more limited education, income, and job status also are more frequently single parents with limited extended family and community support to assist them with childcare needs.
- Caregivers rate concerns about their child's limitations, management issues, or their own personal needs low at the time of the injury and report that their most significant needs are met (Waaland & Cockrell, 1990).
- In contrast, at one to four years postinjury, caregivers view management issues, understanding from significant others, and community services (e.g., counselling and respite care) as among their most important and least satisfied needs.
- Irrespective of the time lapsed since injury, caregivers rate the need for honest, clear explanations, and complete information about their child's status as extremely important. Caregivers also prioritize concerns about the quality of care and availability of professional guidance.
- As time progresses postinjury, professionals should address family need for structured behavior management programs, community services, and school programs for the child; family therapy also may help to reduce primary caregivers' increasing feelings of isolation from spouse and other family members..

Concluding Remarks and Future Directions

In conclusion, the rapid onset and traumatic aftereffects associated with pediatric head injury place a tremendous burden on young patients and their family members. To effectively reintegrate youth into their communities, professionals must understand the unique nature of their disability and how to access needed services ranging from family support, rehabilitation, effective educational intervention, to community resources. From a systems perspective, we can implement programs or laws which prevent pediatric brain injury and reduce its long-term consequences through many channels.

First, we can learn more about who is at risk and why they are at risk. This information can be used to develop preventative programs and affect public policy. For example, knowledge of higher mortality rates for unrestrained child passengers has led to enactment of mandatory child restraint laws and subsequent lowered fatality rates. Safety programs and legislators are beginning to acknowledge the importance of helmets for bicyclers, education program for new drivers, and rigid penalties for drunken drivers. Future intervention programs should be targeted to reach poor, socially disadvantaged families as well as parents of preschool and elementary-school aged children at greatest risk for pedestrian, home, and playground accidents.

Second, we can increase the effectiveness of early intervention and referral efforts. Professional education can help to assure early, aggressive medical treatment and appropriate medical, psychological, and educational follow-up services. Standardized training and treatment protocol for community hospital and emergency room personnel represents a primary target area.

Third, the public school system, which assumes responsibility for "rehabilitating" students with brain trauma, requires the financial and professional support necessary to do so adequately. Because of the pivotal role of the school system, an entire RRTC Special Topic Report will be devoted to effective academic reentry following traumatic brain injury and the training needs of educational personnel. Under the present educational system, there is no special education category to address the unique needs of youth with traumatic brain injury. However, national legislation is pending which may create a separate special educational category of "Traumatic Brain Injury". Public support for this legislation ultimately will effect inadequacies in the educational programs of both youth with traumatic brain injury and the teachers who serve them (Savage, 1985).

Finally, we can learn more about the specific family, educational, and community needs of traumatically brain injured youth. This knowledge gap spans their needs as a group, relating to how preinjury adjustment, family functioning, and community support affects their recovery after injury.

References

Annegers, J F. (1983). The epidemiology of head trauma in children. In K. Shapiro (Ed), *Pediatric Head Trama*. New York: Futura Press.

Annegers, J.F., Grabow, J.D., Kurland, L.T., & Laws, E.R. (1980). The incidence, causes, and secular trends of brain injury in Olmsted Count, Minnesota, 1935-1974. *Neurology, 30*, 912-919.

Black, P., Blumer, D., Wellner, A.M., & Walker, A.E. (1981). The head injured child: Time course of recovery, with implications for rehabilitation. In *Proceedings of an International Symposium on Head Injuries*. Baltimore: Williams & Wilkins.

Black, P., Shepard, R.H., & Walker, A.L. (1975). Outcome of head trauma: Age and posttraumatic seizures. In R. Porter & D. FitzSimmons (Eds.), *Outcome of severe damage to the central nervous system*. Ciba Foundation Symposium 34. Amsterdam: Elsevier, Excerpta Medica.

Boll, T.J. (1982). Behavioral sequelae of head injury. In P. Cooper (Ed.), *Head injury* (pp. 363-377). Baltimore: Williams & Wilkins.

Brink, J.D., Garret, A.L., Hale, W.R., Woo-Sam, J., & Nickel, V.C. (1970). Recovery of motor and intellectual function in children sustaining severe head injuries. *Developmental Medicine and Child Neurology*, 12, 565-571.

Brown, G., Chadwick, O., Shaffer, D., Rutter, M., & Traub, M. (1981). A prospective study of children with head injuries: III. Psychiatric sequelae. *Psychological Medicine*, 11, 63-78.

Bruce, D.A., Raphaely, R.C., Goldberg, A.E., Zimmerman, R.A., Bilaniuk, L.T., Schult, L., & Kuhl, D.E. (1979). Pathophysiology: Treatment and outcome following severe head injury in children. *Child's Brain*, 5, 174-191.

Butler, N.R., & Golding, J. (Eds.). (1986). *From birth to five: A study of the health and behavior of Britien's 5-year-olds*. New York: Pergamon Press.

Cartlidge, N.E.F., & Shaw, D.A. (1981). *Head injury*. London: W.B. Saunders.

Chadwick, O., Rutter, M., Brown, G., Shaffer, D., & Traub, M. A prospective study of children with head injuries: II. Cognitive sequelae. *Psychological Medicine*, 1981a, 11, 49-61.

Chadwick, O., Rutter, M. Shaffer, D., & Shrout, P. A prospective study of children with head injuries: IV. Specific cognitive deficits. *Journal of Clinical Neuropsychology*, 1981b, 3, 101-120.

Ewing-Cobbs L, & Fletcer, J.M. (1987). Neurpsychological assessment of head injury in children. *Journal of Learning Disabilities* 20, 526-535.

Ewing-Cobbs, L., Fletcher, J.M., and Levin, H.S. Neuropsyhologic functions following closed-head injury in infants and preschoolers. Paper presented at the international Neuropsychology Meeting, Denver, 1986.

Ewing-Cobbs, L., and Miner, M.E. (1989). Traumatic brain injury in infants and children: Research Issues. Pediatric Research Group, National Head Injury Foundation.

Ewing-Cobbs, L., Miner, M.E., Fletcher, J.M., & Levin, H.S. (1989). Intellectual, motor, and language sequelae following closed head injury in infants and preschoolers. *Journal of Pediatric Psychology*, 14, pp. 531-548.

Field, J.H. (1976). *Epidemiology of head injury in England and Wales*. London: Her Majesty's Stationery Office.

Flach, J., & Malmros, R. (1972). A long-term follow-up study of children with severe head injury. *Scandinavia Journal of Rehabilitative Medicine*, 4, 9-15.

Frankowski, R.F., Annegers, J.F., & Whitman, S. (1985). Epidemiological and descriptive studies: Part I. In D. Becker & J.T. Povlishock (Eds.), *Central nervous system trauma. Status report* (pp. 33-45). Bethesda, MD: National Institutes of Health. National Institute of Neurological and Communicative Disorders and Stroke.

Kalsbeek, W.D., McLaurin, R.L., Harris, B.S., & Miller, J.D. (1980). The national head injury and spinal cord injury survey: Major findings. *Journal of Neurosurgery*, 53, S19-S31.

Klauber M.R., Barrett-Connor E., Marshall L.F., and Bowers S.A. (1981). The epidemiology of head injury: a prospective study of an entire community—San Diego County 1978. *American Journal of Epidemiology*, 113, 500-509.

Klonoff, H. (1971). Head injuries in children: predisposing factors, accident conditions, and sequelae. *American Journal of Public Health*, 61, 2405-2417.

Klonoff, H., & Paris, R. (1974). Immediate, short-term, and residual effects of acute head injuries in children: neuropsychological and neurological correlates. In R.M. Reitan and C.A. Davison (Eds.), *Clinical neuropsychology: Current status and applications*. New York: Halstead Press.

Krauss, J.F., Fife, D., Cox, P. Ramstein, K., & Conroy, C. (1986). Incidence, severity, and external causes of pediatric brain injury. *American Journal of Public Health*, 140, 687-693.

Larson, C., & Pless, B. (1988). Risk factors for injury in a 3-year-old birth cohort. *AJDC, 142*, 1052-1057.

Lezak, M.D. (1978). Living with the characterologically altered brain injured patient. *Journal of Clinical Psychiatry*, 39, 592-598.

Lezak, M.D. (1986). Psychological implications of traumatic brain damage for the patient's family. *Rehabilitation Psychology*, 31, 241-250.

Lezak, M.D. (1983). *Neuropsychological assessment*. New York: Oxford University Press.

Levin, H.S., & Eisenberg, H.M. (1979). Neuropsychological outcome of closed head injury in children and adolescents. *Child's Brain*, 5, 281-292.

Livingston, M.G., and Brooks, D. N. (1988). The burden on families of the brain injured: A review. *The Journal of Head Trauma Rehabilitation*, 3, 6-15.

Moyes, C.D. (1980). Epidimiology of serious head injuries in childhood. *Child Care, Health, and Development*, 6, 1-9.

Pang, D. (1985). Pathopysiologic correlattions of neurobehavioral syndromes following closed head injury. In M. Ylvisaker (Ed.), *Head injury rehabilitation: Children and adolescents* (pp. 3-71). San Diego: College-Hill Press.

Polinko, P.R., Barin, J.J., Leger, D., and Bachman, K.M. (1985). Working with the family. In M. Ylvisaker (Ed.), *Head Injury Rehabilitation*. San Diego: College Hill.

Rivara, F.P., & Mueller, B.A. (1986). The epidemiology and prevention of pediatric head injury. *Journal of Head Trauma Rehabilitation*, 1, 7-15.

Rosen, C.D., & Gerring, J.P. (1986). Head Trauma: Educational Reintegration. *Educational Reintegration*. San Diego: College Hill.

Rune, V. (1971). Acute head injuries in children. *Acta Paediatrica Scandinavica*, Suppl. 209.

Rutter, M., Chadwick, O., & Shaffer, D. (1983). Head injury. In Michael Rutter (Ed.) *Developmental Neuropsychiatry*. New York: Guilford Press.

Rutter, M., Chadwick, O., Shaffer, D., & Brown, G. (1980). A prospective study of childrenwith head injuries: I. Design and methods. *Psychological Medicine*, 1980, 10, 633-645.

Savage, R. (1985). *A survey of traumatically brain injured children within school-based special education programs*. Rutland, VT Head Injury/Stroke Independence Project, pp. 1-6.

Shapiro, K. (1987). Special considerations for the pediatric age group. In P.R. Cooper (Eds.). *Head injury* (second ed., pp. 367-389). Baltimore: Williams & Wilkins.

Sullivan, R.C. Siblings of autistic children. *Journal of Autism and Developmental Disorders*, 1979, 9, 287-298.

Waaland, P.K. (1990). Family response to childhood brain injury. In J. Kreutzer and P Wehman (Eds.). *Community Integration following traumatic brain injury*. Baltimore: Paul H. Brookes Publishing Co.

Waaland P., & Cockrell, J. Advances in pediatric TBI research. Paper presented at the Postgraduate Course on Rehabilitation of the Brain-Injured Adult and Child. Williamsburg, June 1990.

Waaland, P.K., & Kreutzer, J.S. Family response to childhood traumatic brain injury. Journal of Head Trauma Rehabilitation, 1988, 3, 51-63.

Recommended Readings

Begall, V. (1987). *Head injury in children and adolescents: A resource and review for school and allied professionals*. Brandon, VT. Clinical Psychology Publishing Co.

Deaton, A.V. (1987). *Pediatric head trauma. A guide for families*. New Kent, Va: HealthCare International, Inc.

Kreutzer, J., and Wehman, P., Eds. (1990). *Community Integration following traumatic brain injury*. Baltimore: Paul H. Brookes Publishing Co.

Lehr, E. (1990). *Psychological management of traumatic brain injuries in children and adolescents*. Maryland: Aspen Press.

Ylvisaker, M. (1985). *Head injury rehabilitation: Children and adolescents*. San Diego College-Hill Press.

ERRATUM

Co-Author:

Janice L. Cockrell, M.D.
Co-Director, Children's Project
Rehabilitation Research and Training Center on Severe Traumatic Brain Injury
Director, Physical Medicine and Rehabilitation
Children's Hospital, Richmond, VA
Associate Professor, Physical Medicine and Rehabilitation and Pediatrics
Medical College of Virginia

The RRTC on Severe Traumatic Brain Injury is funded by the National Institute on Disability and Rehabilitation Research, United States Department of Education, Award # H133B80029.