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Epidemiology of Traumatic Brain Injury in Children

Abel Murgio

Pediatrician and Head co-ordinator of the I.S.H.I.P. Group

Abstract: The problem of child injury has always been with us. Lately, interest in brain trauma has increased for a number of reasons. Advances in medical care and public health have had a major impact on mortality and morbidity from a wide variety of infectious and other diseases. Similar changes have not occurred in trauma, and consequently, its relative importance has increased. An increasingly scientific approach to injury causation has led to progressively more effective prevention programs in specific areas. Traumatic brain injury (TBI) is one of the leading causes of mortality in children, but morbidity among people who have sustained a TBI is only beginning to be appreciated. (Pan American Health Organization, 1994; Losh, 1994; Jaffe & Wesson, 1991) Information as to the nature, prevalence, prognosis and treatment of such disabilities is becoming available and clinical experience suggests that persistent impairments related to childhood TBI may be more common and problematic than was previously realized. This article describes the magnitude of the problem, the groups at greatest risk, factors that increase the risk of brain injury, and a reasonable basis for understanding and evaluating the effects of TBI on the developing brain. **Key words:** traumatic brain injury, children, epidemiology.

Epidemiología del daño cerebral traumático en la infancia

Resumen: El problema del trauma cerebral en la infancia ha estado siempre presente entre nosotros. Los avances tanto en el cuidado medico como en la salud pública han tenido un gran impacto en cuanto a la morbilidad y mortalidad de las infecciones y otras enfermedades, pero no han ocurrido cambios similares en el daño cerebral adquirido. Recientemente, el interés en el trauma se ha incrementado por varias razones y progresivamente se ha visto un avance en el tratamiento científico con el empleo de programas de prevención en áreas específicas. El Traumatismo Craneoencefálico es una de las principales causas de mortalidad en la infancia, pero la morbilidad en esta población sólo recientemente comienza a ser apreciada. En la actualidad se dispone de información sobre la naturaleza, prevalencia, pronóstico y tratamiento de este trastorno y la experiencia clínica sugiere que la persistencia del daño cerebral relacionado con un trauma en la infancia podría ser más común y problemática de lo que inicialmente se suponía.

Correspondence concerning this article should be addressed to Abel Murgio, Via Bruno Giorgi, 99, Cesena, FC, 47023, Italy. Electronic mail may be sent via internet to a.murgio@virgilio.it

Este artículo describe la magnitud del problema, los grupos de alto riesgo, los factores que incrementan los riesgos del daño cerebral, y las bases para comprender y evaluar los efectos del trauma en el cerebro en desarrollo.
Palabras clave: traumatismo craneoencefálico, infancia, epidemiología.

Definition

Traumatic brain injury (TBI) is defined as an acquired injury to the brain, caused by an external physical force, resulting in total or partial functional disability or psychosocial impairment, or both, that adversely affect a child's educational performance. (Code of Federal Regulations, 1993; Rivara, 1994) The term applies to open or closed head injuries resulting in impairments in one, or more areas, such as cognition; language; memory; attention; reasoning; abstract thinking; problem-solving; judgement; sensory; perceptual, and motor abilities; psychosocial behavior; physical functions; information processing; and speech. The term does not apply to brain injury that are congenital or degenerative, or brain injuries induced by birth trauma. The severity of brain injury can be graded using physiological measures such as the Glasgow Coma Scale (GCS) (Teasdale, & Jennett, 1974) and the Children's Orientation and Amnesia Test (COAT) (Ewing-Cobbs, Levin, Fletcher, Milner, & Eisenberg, 1990) or anatomic measures such as the Abbreviated Injury Scale (AIS). (Committee on Injury Scale, 1990)

The physiological scales are most useful clinically and correlate well with prognosis and functional outcome. The anatomic scales usually are calculated after the fact and correlate better with risk of death and serve various research needs.

Severity of brain injury generally has been classified on the basis of the GCS at the time of admission to the hospital or emergency room. Mild injuries are usually described as those that have a GCS score of 14 to 15, Moderate injuries have a GCS score of 9 to 13, and Severe injuries have GCS score of 8 or less.

Finally it is necessary to explain the general concept about what epidemiology means, that it is the science concerned with the study of the factors, which determine and influence the frequency and distribution of disease in a defined human population for the purpose of establishing a program for prevention and to control its development and spread.

Incidence

Traumatic brain injury (TBI) is the leading cause of death and disability among children and adolescents in the United States as in other industrialized nations of the world. (Kraus, & McArthur, 1996; Adekoya, Thurman, White et al., 2002). Unfortunately in Latin America up to the present moment we are unable to make a comparative analysis with other African or Asian countries (Zwi, 1993; National Institute of mental Health and Neurosciences, 1993; Li, & Baker, 1991; Butchart, Nell, Yach, et al., 1991; Bouraga, 1980; Australian Injury Prevention Bulletin, 1994) and in this way have an overall panorama of world incidence due to lack of comparative data, this also inhibits the establishment of strategies of prevention.

The incidence of all TBI in the United States is approximately 200 per 100,000 persons per year; severe brain injury occurs in 20 per 100,000. (Kraus, & Sorenson, 1994) Recently reports from Argentina (Murgio, Andrade, Sánchez-Muñoz, Boetto, & Leung, 1999) and United States (McCarthy, Serpi, Kufera, Demeter, & Paidas, 2002) revealed that the incidence in a population was approximately 400 to 600 per 100,000 persons per year. In most areas, transport-related events are the single largest cause, and these injuries are usually of closed head injury variety (during times of war, penetrating head injury assumes greater importance).

The prevalence of TBI (including patients not admitted to hospital care) is estimated at 800 per 100,000 (Kurtzke, 1982; Boswell, McErlean, & Verdile, 2002), a staggering figure which renders brain injury the most common major neurological disability. Brain injured children and adolescents may be burdened with many decades of significant impairment. As will be seen, the most difficult aspect of TBI survival is in the area of neurobehavioral functioning, since long after such functions as strength and coordination improve, cognitive and emotional problems can persist.

Patterns of Injury

The most frequent cause of childhood injury is blunt trauma. Motor vehicle causes, whether occupant, pedestrian or bicycle related are implicated most frequently across all age groups over the age of 1 year (Adekoya, Thurman, White, et al., 2002; Center for Disease Control, 1990).

Falls, another common mechanism of pediatric injury, also occur across all pediatric age groups, but occur frequently in children ages 5 through 9, (Murgio, Muñoz-Sánchez, Boetto, Leung, Andrade, & Patrick, 2001). Although a frequent cause of injury, falls carry a relatively low mortality rate (Losh, 1994). Approximately 170 per 100,00 children, on average, will be treated for a fall related injury (Adekoya, Thurman, White, et al., 2002; Center for Diseases Control, 1990). Other forms or blunt childhood trauma include recreational type accidents (non-motor vehicle related bicycle injuries, roller blading accidents and sports related injuries), burns, drownings and assault.

Penetrating trauma among children and adolescents still comprises only a small percentage (approximately 1.2%) of childhood injuries (Rouse, & Eichelberger, 1992), but the mechanism of pediatric injury is becoming more frequent, especially in the inner city 15 to 19 age group. The most common causes of penetrating pediatric trauma include gunshot wounds, stabs wounds and infrequently, wounds sustained from pellet rifles.

Brain injuries occur mostly during the summer months, mostly on weekends, and mostly during the late afternoon to early evening hours (Murgio, Andrade, Sánchez-Muñoz, Boetto, & Leung, 1999). There are additional patterns of TBI, which are of both interest and concern. Males have approximately twice the rate of brain injuries than females (Mahalick, Yalamanchi, Ruzicka, & Bowen, 1990). These differences appear very early in life during the preschool years and probably reflect a combination of differences in behavior between boys and girls, as well as differences in exposure to hazards resulting in injury. (Rivara, 1994; Mahalick, Yalamanchi, Ruzicka, & Bowen, 1990). In addition, approximately 7% of the patient population who sustain brain injury will go on to sustain a second TBI.

Generally, rates of brain injury are stable throughout childhood, but increase dramatically at the age of 15 years. (Adekoya, Thurman, White, et al., 2002; McCarthy, Serpi, Kufera, Demeter, & Paidas, 2002; Kraus, Rock, & Hemayari, 1990)

This probably reflects changes in developmentally appropriate activities, particularly the acquisition of a driver's licence and, an increase in motor vehicle driving. Some studies also have demonstrated high rates of brain injuries among preschool-aged children. (Rivara, Bergman, LoGerfo, & Weiss, 1982). These children have a high center of gravity and usually fall head-first, thus increasing the proportion of injuries that involve the head.

In addition, parents also may be more concerned about relatively minor trauma in children of this age and will seek care more readily than for older children with the same degree of injury. (Duhaime, Alario, Lewander, et al., 1992).

Variation with race and socioeconomic status

Brain injury and death rates vary considerably by race and socioeconomic status. Among children less than 15 years old in the United States, deaths rates from unintentional injury are highest for native American, followed by blacks, Hispanics, and then whites; Asians have the lowest rates. (Kraus, Rock, & Hemayari, 1990) For all races, injury death rates are inversely related to income level, and much, if not all, of the difference seen in death rate between racial groups may be the result of differences in income.

The reasons for the increased risk of poor children probably include both decreased supervision, lower level information about and use of prevention strategies (such as bicycle helmets), and exposure to more hazardous environments such as high-rise tenements (leading to falls from windows) and higher volume, faster moving traffic (resulting in pedestrian injuries).

Types of Traumatic Brain Injury

Children who are victims of child abuse may display all of these mechanisms of injury. Subdural hemorrhages in young children are much more common from child abuse than from unintentional trauma. Retinal hemorrhage rarely occurs in unintentional injury in children; its presence usually implies the child is the victim of the shaken-impact syndrome , - the so-called “shaken baby syndrome”. (Caffey, 1974)

For the remainder of the pediatric and adolescent population, brain injury is most often associated with motor vehicle crashes . (McCarthy, Serpi, Kufera, Demeter, & Paidas, 2002; Adekoya, Thurman, White, et al., 2002; Center for Disease Control, 1990). Occupant injuries account for 44% of all motor vehicle related childhood trauma, and usually presents in the form of a child who was the unrestrained passenger of a moving vehicle that decelerated abruptly upon impact. The forces associated with deceleration project the child within the confines of the automobile at very high velocities toward structures which absorb impact poorly. The majority of these deceleration type forces are then transferred back to the cranial vault, and brain tissue is damage. The extent and severity of injury depend on the forces generated during deceleration, angle of impact, and anatomical location of the injury.

Other forms of motor vehicle related pediatric brain injury occur to pedestrians and bicyclists. For the latter group, helmets worn consistently have been shown to reduce the number of closed head injuries by more than 80%. (Rivara, 1994). The mechanism of brain injury is the same, with impact and shearing forces to the vital tissues implicated most.

Pathophysiology

Most of the data concern severe traumatic brain injury in adults, and experiments with higher primates have expanded our understanding of the various lesions which can occur. Some information on mild TBI is also available. The neuropathology of severe TBI primarily involves one or more of three major processes: diffuse axonal injury (DAI), focal cerebral lesions, and hypoxic-ischemic injury (Alexander, 1987). DAI is the term referring to a widespread pattern of neuronal and white matter damage deep in the brain, which results from the shearing effects of rapid rotational (angular) acceleration and deceleration. (Adams, Graham, Murray, & Scott, 1982). An older term for this process is “diffuse degeneration of the cerebral white matter ”, (Stritch, 1956) and the concept of diffuse white matter injury is now widely accepted. These lesions, which are most prominent in the brainstem and cerebral white matter, account for the initial period of coma, and the duration appears to parallel the severity of DAI. The enlargement of cerebral ventricles that occurs in many people with TBI probably also reflects the impact of DAI.

Superimposed on this pattern are focal cortical contusions, which are often related to an overlying skull fracture, and tend to involve frontal and temporal lobes. Focal contusions can occur at the site of a direct blow (the “coup” lesions), or across the skull on the other site of the brain (the “contrecoup” lesion). Intracerebral hemorrhage may also be seen, related to deep parenchymal injury. Subdural and epidural hematomas may occur secondary to lacerations in venous or arterial vessels walls, respectively. These often require neurosurgical intervention, but ordinarily they cause no permanent sequelae unless an associated contusion of the underlying cortex is present or local pressure effects have damaged the brain. As a general rule, focal lesions are less common in children and adolescents than in adults, especially below the age of 3. (Courville, 1965)

The other major neuropathologic lesion in severe TBI is hypoxic-ischemic injury. This is a state of reduced oxygenation and blood flow in the brain due to lowered arterial blood pressure and, in many cases, increased intracranial pressure. (Graham, Adams, & Doyle, 1979).

The brain is exquisitely sensitive to oxygen deprivation, and damage to the hippocampus or cerebral cortex can be extensive. Infarction of the occipital lobe, supplied by the posterior cerebral artery, is common in cases with increased intracranial pressure. For reasons that are not yet clear, children and adolescents are more prone to the development of massive intracranial pressure elevation due to TBI than are adults. Engorgement of the brain's blood vessels (cerebrovascular congestion) causes brain swelling which can lead to severe disability or death. (Bruce, Raphaely, Goldberg, et al., 1979).

I agree with others (Kelly, Nichols, Filley, Lillehei, Rubenstein, Kleinschmindt-DeMasters, 1991) that in the pediatric age group is very susceptible to the rapid development of these forms of brain swelling, from autoregulatory dysfunction, specially after repeated concussions. This congestion then leads to elevation that may be difficult, if not impossible, to control.

It is very important to understand that there is no single "post TBI syndrome"; rather, a variety of syndromes may appear, depending on the interaction of many different lesions and the location and severity of each.

Differential effects of age in traumatic brain injury

The complex processes of development oblige the clinician to appreciate the many stages a child passes through on the path to maturity. This problem is nowhere more difficult than in clinical neurology, as the developing nervous system is exceedingly complex. Not only are children and adolescents different from adults, they also differ markedly from each other. Recent evidence has suggested that the child's recovery from brain insults of many sorts is less complete than once thought. Cerebral "plasticity" is a term used to explain the allegedly greater recovery of cerebral function following brain disease in the young. Because cognitive functions can return faster in children, it is reasoned, the young brain must be more "plastic" – that is, capable of committing undamaged areas of brain to the function that was lost. With respect to this concept it is very important to consider recent data which have suggested that the outcome in children of less than 6 , (Filley, Cranberg, Alexander, & Hart, 1987), 10 (Brink, Garrett, Hale, et al., 1970) and 12 (Levin, Amparo, Eisenberg, et al., 1987) years of age may be worse than in older children.

These data, may be summarized by distinguishing focal and diffuse central nervous system disease. Children may recover somewhat better after focal lesions, but show no special resilience against diffuse insults. Indeed, young children and infants may do worse after diffuse injuries. Since TBI in children typically involves diffuse injury and relatively little focal disease, people with head injury in childhood may not be expected to have an advantage because of cerebral plasticity.

Differential effects of Age upon neurobehavioral presentation

In this field we can explain that there are different effects of age upon acute neurobehavioral presentation in that symptoms which commonly appear as result of TBI in the adult are either absent or short-lived in the child.

One differential effect is on language function. Most adults who sustain injury to the left temporal lobe (which in a great portion of the population is known to observe language) will experience severe aphasia. Aphasia is a disturbance of language, wherein the patient may elicit: paraphasic response (e.g. literal versus semantic), decreases in fluency (dysnomia) of output, and difficulties involving comprehension, naming, repetition, reading (alexia), and writing (agraphia). One language type disorder that children may often present with is aprosodia. Aprosodia is the lack of emotional involvement associated with language output. These aphasic disorders tend to be long-lived and, frequently, permanent in adults. In contrast, children who sustain similar injury usually experience an aphasic disorder which resolves quickly, often within weeks. This is not to say that they will be free of language dysfunction, however, it may not be as acutely debilitating.

Another point to note is that children rarely experience unilateral hemineglect syndromes for protracted periods of time. Unilateral hemineglect is thought to be a disorder of directed attention and results in the patient's inability to attend to certain aspects of their visual, auditory, or kinesthetic input. For example, the patient with sensory neglect who may consistently forget about the right side of their visual field and bump into things as a result.

Agnostic disorders are rarely observed in children for any length of time, if at all! Visual agnosia is present when a patient (who is alert, oriented, and monophasic) is show an object such as a pencil or a fork and they are unable to recognized it. Prosognosia is usually thought of as the inability to recognized previously known faces, although the disorder goes beyond this simplified description.

Dyspraxias are commonly seen in pediatric patients with TBI, but is short-lived. Apraxia is the inability to carry out motor based behavior despite intact motor and sensory functioning and sample cooperation. Ideomotor dyspraxia is the inability to perform a motor activity upon command, but rather it is carried out in a spontaneous fashion. Ideational Dyspraxia is the inability to carry out a sequence of functionally related activities despite the fact that each individual aspect of the behavior can be performed independently.

With respect to TBI and its effects on personality functions, we should explain that young children, typically under the age of 10 years, will typically manifest symptoms characteristic of an Attention Deficit Disorder without the hyperactive component; whereas preadolescents and adolescents may experience depression, anxiety, irritability, explosivity, etc. It should be noted when there are preexisting problems that these are always greatly exacerbated.

We have described some of the more prevalent symptoms which differentially manifest themselves according to age, however, a more comprehensive discussion would far exceed the scope of this article.

Evaluation and Management

Several approaches may be used in the assessment of a child or adolescent who has a TBI. Data can be gathered from a thorough case history and careful examination from testing performed by a pediatrician.

The overriding goal of caring for the pediatric trauma victims is to optimize the medical management at every stage of health care delivery; in prehospital care, initial stabilization, interhospital transport (specialized transport teams) and definitive treatment. The most important point is to do no harm either by performing an unsafe transport or by inappropriately delaying therapy (Kanter, & Tompkins, 1989; Kearney, Terry, & Burney, 1991; Macnab, 1991; Mayer, 1985; Bueno-Campaña, Calvo-Rey, Rodríguez-Martinez & Zafra-Anta, 1994). Definitive evaluation and treatment of severe or complex injuries may be better accomplished at a referral center; however, the child with major injuries must be stabilized prior to transport. Both inordinate delays in referral and transport of unstable patients have been shown to have adverse effects on outcome (Pfenninger, & Santi, 2002; Andrews, Piper, & Dearden, 1990; Deane, Gaudry, & Woods, 1990; Ramenofsky, Luterman, & Quindlen, 1984).

Like that of the adult, the initial stabilization describe in the Advanced Trauma Life Support Course and management of the pediatric trauma victim require an organized, systematic approach in order to diagnose and intervene in the multiple, potentially life threatening injuries sustained by the trauma patient. (Mayer, 1985; Nakayama, Copes, & Sacco, 1991).

The child's airway must be secured from the initial insult definitive care is well under way. The child's airway that is intact at presentation my become compromised due to deterioration of condition or even from iatrogenic complications during treatment and transport. The child initially should be placed in a sniffing position. The sniffing position is that of the head slightly extended and the neck slightly flexed (American Heart Association, 1988).The cervical spine still must be restrained during this period of time. The airway must be suctioned free of debris, blood, and secretions. The younger infant, being an obligate nose breather, also must have the nasal passages cleared of obstruction. The airway must not be compromised by facial fractures. The child who sustains severe facial fractures may not be able to tolerate intubation. In these cases should be considered for the rare procedure of cricothyroidotomy with needle jet insuflation. This is a temporary measures only and should be replaced with more definitive airway control, such as tracheostomy (American Heart Association, 1988). The child who requires prolonged artificial ventilation for a progressively unestable airway or who is likely to require such during transport should undergo elective intubation and ventilation. Likewise, children who have sustained severe head injury require intubation and hyperventilation. The resultant hypocarbia ($PaCO_2$ = 25-28 mm Hg) decrease intracranial pressure.

Physicians must understand the physiologic principles surrounding resuscitation and what medications and types of resuscitative fluids are acceptable in their initial management. Fluids should be warmed whenever possible, because children become hypothermic very quickly after injury.

Case History

An adequately compiled case history, depending on the state of the patient, should include the mechanism and circumstances of the trauma: traffic, a fall, associated injuries. Time elapsed since the brain injury. Cronology – that is to say – the initial and later level of conciousness, lucidity, and progress of the disabilities. Related symptoms: pre-post trauma amnesia, temporospacial disorientation, motor and sensory alteration, dizziness, ataxia, vomiting, convulsions, irritability, drowsiness, headache, fever. Previous neurological illnesses, coagulation pathology, previous medication. The physical examination should include temperature, heart rate, respiratory frequency, arterial blood pressure, a general physical examination and a correct neurological examination.

Neurologic evaluation

Level of consciousness is the most common and reliable clinical parameter used for evaluating brain injury severity. The most widely used measure of level of consciousness is the Glasgow Coma Scale (GCS).

Best Eye Response : (4)
1.No eye opening.
2.Eye opening to pain.
3.Eye opening to verbal command.
4.Eyes open spontaneously.

Best verbal Response (5)
1. No verbal response
2. Incomprehensible sounds.
3. Inappropiate words.
4. Confused
5. Orientated

Best Motor response (6)
1.No motor response.
2.Extension to pain.
3.Flexion to pain.
4.Withdrawal from pain.
5.Localising pain.
6.Obeys Commands

A coma Score of 13 or higher correlates with a Mild Brain Injury (or Minor H.I.), 9 to 12 is a Moderate Injury and 8 or less a Severe Brain Injury.
Paediatric Glasgow Coma Scale: (under 3 years old)

Table 1. *Glasgow Coma Score (from 3 to 12 years old) It is composed of three parameters: best Eye Response, best Verbal Response, best Motor Response, as given below:*

Best Eye Response. (4)	Best Verbal Response (5)
1.No eye opening.	1. No vocal response.
2.Eye opening to pain.	2. Inconsolable, agitated.
3.Eye opening to verbal command.	3. Inconsistently consolable moaning.,
4.Eyes open spontaneously.	4.Cries but consolable inappropriate Interactions
	5. Smiles, oriented to sounds, follows objects, interacts.

Best Motor Response (6)
1.No motor response.
2.Extension to pain.
3.Flexion to pain.
4.Withdrawal from pain.
5.Localising pain.
6.Obeys commands.

Table 2: *Paediatric Glasgow Coma Scale: (under 3 years old)*

The GCS uses a simple integrated scoring of eye opening, verbal response, and motor function. Difficulties in comparability of the GCS stem from incomplete assessments and different timing. For example, intubation and sedation of the head-injured patient while being transported to the hospital will affect verbal, motor, and ocular responses profoundly. Neurologic assessment also will be affected by such factors as psychological stress, injuries to other parts of the body, alcohol and drugs, and a variety of pre-existing conditions. In general, however, the later that the GCS measurement is made, the better its prognostic value with respect to long-term mortality and total disability. The majority of hospital-admitted brain injuries are classified as mild, (GCS score of 13–15). Mild, however, is a highly imprecise description of brain trauma and is conceived differently by various researchers. (Kraus, & Sorenson, 1994). Of patients admitted to the hospital alive, the ratio of Mild (GCS 14-15) to moderate (GCS 9-13) to severe (GCS < 8) is 8:1:1. (Kraus, & McArthur, 1996; Jagger, Levine, & Jane, 1984).

The physical and neurologic examination should document signs of injury, such as facial deformity, and neurologic problems suchs as hemiparesis, ataxia, and dysarthria. On mental status examination, efforts should be focussed on survey of areas that may be affected by TBI: attention and concentration, memory, language, visuo-spatial skills, complex cognitive abilities (arithmetic, abstraction, insight), and mood and affect.

A typical component of a comprehensive neuropsychological test battery is the Wechsler Intelligence Scale for Children (WISC) or its revised form (WISC-R). This is a test for “intelligence quotient” (IQ) in school-age children and is similar to the Wechsler Adult Intelligence Scale (WAIS) and its revised version (WAIS-R). A test for preschool age children is also available: the Wechsler Preschool and primary Scale of Intelligence (WPPSI). It should be stressed that tests such as these are never a substitute for a careful mental status examination done by the physician; neuropsychology is helpful in evaluation of people with traumatic brain injury, but its results and conclusions should always be interpreted in light of the clinical picture as determined by a neurologist, psychiatrist or physiatrist.

Current laboratory technology has revolutionized the assessment of individuals with virtually any kind of nervous system disorder. The skull radiography and electroencephalogram (EEG) once the mainstays of brain injury evaluation, have taken a secondary role to powerful new techniques which have greatly improved the visualization and functional analysis of nervous system structures. It is very important to consider that when CT is not available, skull radiographs provide some screening information, because the relative risk of intracranial injury is greatly increased in the presence of a skull fracture. (Masters, McClean, Areasese, Brown, Campbell, Freed, et al., 1987).

There is general agreement that children with moderate and severe head injury should be examined with CT as soon as feasible. (Gean, Kates, & Lee, 1995).

However, there is less agreement on the management of the child arriving in the emergency department (ED) or office with a brief loss of consciousness, the athlete who has his “bell rung” at the high school soccer or football game, or the child in a car crash who is taken to a rural hospital without capabilities for CT and has a GCS of 15.

Previous retrospective studies have identified predictive clinical criteria for intracranial injury in children. Hennes, Lee, Smith, Sty, & losek, 1988, retrospectively studied 55 children and identified altered mental status, evidence of increased intracranial pressure, seizures, and focal deficits as predictors of intracranial injury. Rivara, Tnaguchi, Parish, Stimac, & Mueller, 1987, retrospectively studied 98 children, and described an abnormal Glasgow Coma Scale (GCS) score, altered consciousness, and focal neurologic abnormality as predictors of intracranial injury. Dietrich, Bowman, Ginn-Pease, Kosnik, & king, 1993; and Ramundo, McKnight, Kempf, & Satkowiak, 1995, prospectively studied children who underwent head CT for evaluation of head injury after presentation to the ED, reported loss of consciousness, amnesia, GCS score less than 15, and neurologic deficit as significant associations with intracranial injury. Ramundo, McKnight, Kempf, & Satkowiak, 1995, described suspicion of child abuse, focal motor deficit, and pupillary asymmetry as predictors of intracranial injury. The presence of neurologic deficits was the only predictor common to all studies, including our recent study. (Murgio, Muñoz-Sánchez, Boetto, Leung, Andrade, & Patrick, 2001) The significance of the signs such as vomiting, headache, drowsiness, and amnesia is still unclear. Although these clinical findings were not statistically associated with intracranial injury, I intend to explain respect the loss of consciousness in general was not a predictor of intracranial injury, but a loss of consciousness for more than 5 minutes was predictive in the univariate analysis, this may reflect a power limitation of a recent study publicated. (Quayle, Jaffe, Kuppermann, Kaufman, Lee, Park, et al., 1997). However, on review of the data, none of the 7 patients who were unconcious for more than 5 but less than 20 minutes had intracranial injury.

Moreover, all of the patients unconscious for 20 minutes or longer had altered mental status at presentation to the ED. Because of the relationship between these two variables, prolonged loss of consciousness was not identified as an independent predictor in the multivariate analysis. Prior studies (Dietrich, Bowman, Ginn-Pease, Kosnik, & King. 1993; Pietrzak, Jagoda, & Brown, 1991; Dacey, Alves, Rimel, Winn, & Jane, 1986) have suggested that loss of consciousness should still be considered in the evaluation of intracranial injury in children.

Recently a number of studies, conducted both in trauma centers and community hospitals, indicate that the probability of intracranial pathology among children with a loss of consciousness is about 5%; some of these children receive surgery for these lesions. (Schunk, Rodgerson, & Woodward, 1996).

Clinical predictors of positive CT findings unfortunately have low sensitivity and predictive value.

These studies have led to the routine screening of all children with head injury, with accompanying enormous cost. The need for a prospective study of all children with symptoms, particularly in office settings, is striking. Such a study could be conducted as a large cohort study or even as randomized controlled trial, in which some children undergo CT and others do not. Key information needs include the true incidence of this problem in the community, the likelihood of finding a positive CT finding, the likelihood of needing surgical intervention, and the difference in outcomes between children who have undergone scanning and those who have not. Without such data, any clinical guidelines on management of head injuries will be flawed. At the present moment several countries in the world under of I.S.H.I.P. group (International Study of Head Injury at Pediatric age) are working with these data, the principal purpose being to evaluate different clinical predictors and the value of CT scanning, over a period of two years and with a follow-up within 3 months after trauma. We recommended CT for head-injured children with altered mental capacity, focal neurologic deficits, signs of a basilar skull fracture, seizure, or a palpable depression of the skull.

Because, intracranial injuries can occur in the absence of these findings, head CT should be considered for neurologically normal children with histories of loss of consciousness, vomiting, headache, drowsiness, or amnesia. Careful observation of these children at home or in the hospital may be an alternative approach depending on the availability of head CT, hospital beds, or reliable care givers. Children without the signs and symptoms listed above may be carefully observed at home by reliable adults.

The significance of brain injury in neurologically normal children is unclear. Neurosurgical interventions are extremely rare in this subgroup. (Dietrich, Bowman, Ginn-Pease, Kosnik, & King, 1993; Davis, Mullen, Makela, Taylor, Cohen, & Rivara, 1994). The long-term impact of subtle, nonsurgical intracranial injury on the neuropsychologic development of children is controversial. There is general agreement in the literature that severe head injuries are associated with significant disabilities in both children and adults. The adult literature has described disabilities after minor head injury (Gronwall, & Wrightson, 1974), however, conflicting reports exist concerning disability after mild head injury in children. The report by Di Scala, Osberg, Gans, hin, & Grant, 1991, on children with a spectrum of injury severity revealed impairments of daily living functions, cognition, and behavior in children with minor head injury. Casey, Ludwig, & McCormick, 1986, surveyed the parents of children with minor head trauma and discovered transient functional and behavioral problems in a significant number of the children. More recent reports found no clinically significant neurobehavioral impairments in children with minor head injuries. (Asarnow, Satz, Light, Zaucha, Lewis, & McCleary, 1995; Bijur, & Haslum, 1995).

Prediction of Outcome

Many children who survive moderate and severe head traumas experience immediate and lasting neurobehavioral consequences. (Pfenninger, & Santi, 2002; Costeff, Groswasser, & Goldstein, 1990; Ewing-Cobbs, Levin, Fletcher, Miner, Eisenberg, 1990). Persistent impairment of intellect, language, visual motor skills and motor speed is commonly described. (Costeff, Groswasser & Goldstein, 1990; Levin, Gary, Eisenberg, & Ruff, 1990).

A number of different scales have been suggested for the evaluation and classification of permanent damage in patients following brain injuries. (Langfitt, 1978).

At present, the most widely used scale appears to be the Glasgow Outcome Scale (GOS) (Jennett, & Bond, 1975). The GOS has five outcome categories. These include death, persistent vegetative state, severe disability, moderate disability and good recovery. "Good recovery" is meant to indicate that the patient has regained his pre-injury abilities, even though there may be a minor neurological deficit.

1. **Good recovery:** a patient who can lead a full and independent life with or without minimal neurological deficit;
2. **Moderately disabled**: patients having neurological or intellectual impairment but are independent;
3. **Severely disabled**: conscious patients but totally dependent on others to get through the activities of the day;
4. **Vegetative survival**;
5. **Death**.

Table 3***:*** *Glasgow Outcome Score*

This classification has proven useful in adults. (Hall, Cope, & Rappaport, 1985). It may be adequate to speak of a good recovery in adults who have returned to their previous mental level.

However, with regard to children, this is a questionable and difficult definition. In children, additional aspects have to be considered: children's psychomotor abilities have not yet reached a stable level. Thus permanent development and maturation require far more than "regaining the pre-injury" level of performance. Nevertheless, the GOS has been used in a number of recent studies to describe the outcome in children (Pfenninger, & Santi 2002; Auld, Ashwal, Holshouser, Tomaski, Perkin, Ross, et al., 1995; Kalff, Kocks, Pospiech, & Grote, 1989; Marshall, Gautille, Klauber, & Eisenberg, 1991; Mohanty, Kolluri, Subbakrishna, & Satish, 1995; Pople, Muhlbauer, Sanford, & Kirk, 1995; Murgio, Andrade, Sánchez-Muñoz, Boetto, & leung, 1999) even though the cognitive abilities of these children were not examined in any of the studies. We used in a recent study (Murgio, Muñoz-Sánchez, Boetto, Leung, Andrade & Patrick, 2001) the Children's Outcome Scale (COS) to evaluate the results after traumatic brain injury within 2 weeks and 2 months (COS 1= excelent recovery, 2= moderate, but nondisabling deficit, 3= either a severe motor or cognitive deficit, 4= vegetative, 5= death).

COS 1 and 2 were considered good outcomes, and COS 3-5 were considered poor outcomes. We recommended use this scale in children aged from 1 to 36 months.

1 = Excelent recovery
2 = Moderate, but nondisabling deficit
3 = Either a severe motor or cognitive deficit
4 = Vegetative

Table 4: *Children's Outcome Scale: children age from 1 to 36 months.*

COS 1 and 2 were considered good outcomes, **COS** 3-5 were considered poor outcomes.

Comparison between studies are difficult because of wide variations in such crucial points as the definition of the severity of the injury, inclusion or exclusion of the most severely injured patients in study populations, selection criteria for controls or the lack of controls altogether, differential timing of testing after the injury, and the myriad of neuropsychological test and procedures used in assessment. (Jaffe, Fay, Polissar, Martin, Shurtleff, Rivara, et al., 1993; Shapiro, & Smith, 1993). Although cranial CT remains the initial diagnostic test in the evaluation of the pediatric brain injury patient, Magnetic resonance imaging (MRI) is better able to demonstrate parenchymal defects after brain injuries. (Gentry, 1994; Hadley, Teasdale, & Jenkins, 1988).

MRI is a more sensitive method to detect lesions in a subacute and chronic phase because contusions and signs of shear injuries are often difficult to identify on CT scan. (Gentry, 1994; Wilson, Wiedmann, & Hadley, 1988).

Conclusion

TBI in children and adolescents is a problem of enormous magnitude, and , because of improving survival rates, the number of people with TBI is due to increase. The problems these people face as they return to a challenging world are often insurmountable, sometimes because of their physical disabilities, but more often because of neurobehavioral problems. The ability to interact effectively with other people and to control inappropriate impulses may be most seriously impaired, exceeding even deficits in memory and intelligence as a cause of functional disability.

Much work remains to be done on the phenomenology of childhood TBI, including mild TBI, this paucity of information being also reflected in adults. Some evidence suggests that children may be more vulnerable to TBI sequelae than adolescents, but all cases demand our attention because of the lifetime residua many are likely to face. Treatment of these people is elementary at best, and improvements must await better understanding of the fundamental processes of injury.

Finally numerous primary TBI prevention strategies are possible. (Adekoya, Thurman, White, et al., 2002; Centers for Diseases Control, 1989; Haddon, 1980; World Health Organization, 1984). Some specifically related to persons at risk. Others involve environmental improvements or legislative changes. (Kraus, & Mc Arthur 1996).

The primary areas that appear to be most amenable to modification by these strategies are vehicles and transport, falls, firearms, and sports. The expected reduction in TBI deaths can be estimated from existing preventive measures data.

Abel Murgio is now the pediatrician and principal coordinator of the international group ISHIP which analyzes child head injury in different countries in the world.
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