This is a revised version of the article published in the October 2015 issue (BCMJ 2015;57:331-335). The author corrected an error that appeared on pages 331, 332, and 334. The sentence that read "… the leading cause of traumatic death in children under 2 years of age …" should have read "… a leading cause. …"

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Abusive head trauma: Evolution of a diagnosis

Contributions from a variety of medical disciplines have led to an unprecedented growth in our understanding of inflicted head trauma in children.

ABSTRACT: Over the past 60 years, the diagnosis of abuse in children has been challenged within both the medical and the legal communities. Nowhere has this been more apparent than in the literature addressing abusive head trauma in infants and children. The diagnostic terminology used currently, while more encompassing than terminology used in the past, has contributed to confusion about the strength of scientific evidence for inflicted injuries. Fortunately, a variety of medical disciplines, including pediatrics, emergency medicine, radiology, ophthalmology, pathology, biomechanics, neurosurgery, and neurology, have contributed to an unprecedented growth in our understanding of inflicted head trauma in children. We can now confirm that abusive head trauma does occur, that it is a leading cause of traumatic death in children under 2 years of age, that it has a characteristic clinical presentation and injury pattern, and that it can involve a variety of different injury mechanisms. Awareness of these mechanisms and rigorous efforts to ensure comprehensive clinical assessments will best inform the diagnostic process. Being able to identify abusive head trauma and finding answers to the challenging questions that remain, including how to mitigate damage when a young patient presents with head trauma, will lead ultimately to improvements in both outcomes and prevention.

Few medical diagnoses have come under such intense scrutiny as abusive head trauma (AHT) in infants and children. The controversy over this medical diagnosis exists primarily within the courts and popular media, creating confusion about inflicted head injuries in infants and young children. While many argue against using the term "shaken baby syndrome" on semantic grounds, others do not believe injuries can occur with violent shaking and think there has been a misunderstanding or misrepresentation of the extensive scientific research base that supports this diagnosis.

Although it is unlikely any medical professional practising currently would deny the existence of inflicted trauma in either children or adults, it is disconcerting to note that some continue to suggest that a diagnosis of abusive head trauma cannot be made. This rather confusing and surprising perspective suggests that we should almost completely ignore the wealth of published evidence

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supporting physical abuse as an underlying mechanism for some forms of head trauma in children.

In 2004, the *BCMJ* published an overview of AHT in children to provide guidance to health care providers on management.[1] With few exceptions, the recommendations and the literature cited in that article are as relevant today as they were 10 years ago. AHT has been recognized and researched for decades, and while the specific terminology has evolved, it is important to note that we are still talking about the infliction of violent force that results in a consistent spectrum of injuries and complications in young children. As well, physicians still have a pivotal role to play in both educating parents and recognizing and managing inflicted trauma in children.

Historical perspective

Over the last century a variety of medical disciplines, including pediatrics, emergency medicine, radiology, ophthalmology, pathology, biomechanics, neurosurgery, and neurology, have contributed to an unprecedented growth in our understanding of inflicted head trauma in children. We can now confirm that abusive head trauma does occur, that it is a leading cause of traumatic death in children under 2 years of age, that it has a characteristic clinical presentation and injury pattern, and that it can involve a variety of different injury mechanisms.

The earliest medical literature on abusive head trauma in children was based largely on observational data, including carefully detailed clinical case reports and comprehensively reported case series. As scientific research and technology have evolved, so has the medical literature and, along with it, our ability to understand, diagnose, and treat many conditions with underlying causes that once eluded us.

In the late 19th century, Auguste Ambroise Tardieu, a French forensic physician, first suggested the causal link between intracranial injury and physical abuse with his detailed report on 32 cases of child abuse.[2,3] In the early 20th century, surgeons began to recognize trauma as the most common cause of subdural hemorrhage (SDH) in general. Subsequent published case series of SDH in infants also noted the common presence of other traumatic injuries, including long bone fractures, rib fractures, and retinal hemorrhages. While many authors suggested an underlying diagnosis of child abuse, it was a landmark paper by Kempe and colleagues in 1962, "The Battered-Child Syndrome," that offered the first comprehensive description of the spectrum of clinical presentations, the underlying traumatic etiology, and the appropriate investigative and management considerations.[4]

The medical literature of the early 1970s went further, proposing that shaking or repeated whiplash-like forces were the root cause of much of the inflicted head trauma in children.[5,6] This seemed particularly pertinent to a subset of infants presenting with distinct injuries and no external signs of physical trauma. John Caffey, a radiologist, coined the term "whiplash shaken infant syndrome" to describe the condition of infants presenting with SDH, metaphyseal traction fractures, and retinal hemorrhages but no external evidence of trauma.[7] Caffey's suggestion that abuse was the underlying cause of injury in these cases was novel, given that many children present with clear clinical evidence of direct trauma to the head in the form of bruises, cephalohematoma, and skull fractures.

Technological advances since the 1970s have led to substantial improvements in our ability to recognize and understand this constellation of traumatic injuries. In an oft-cited paper published in 1987, researchers found evidence of impact to the head in 63% of the young children with abusive head trauma included in their case series.[8] Further, of the children who died, all had evidence of blunt impact to the head. This study also used doll models to quantify the forces generated by both shaking and impact, and compared the results to data collected from previous reports of single impulse whiplash forces in nonhuman primates. Based on these results, the authors suggested that shaking alone could not generate the forces necessary to cause such injuries and that a more appropriate term for this constellation of findings might be "shaken impact syndrome."[8]

Over the ensuing years, various groups have argued for a less mechanistic label for making a diagnosis of child abuse, recognizing that many of the infants studied had been subjected to a range of violent forces and actions. Other terms such as "nonaccidental trauma," "inflicted head trauma," and "inflicted brain injury" have been suggested.

In 2007 the Canadian Paediatric Society published their Multidisciplinary Guidelines on the Identification, Investigation and Management of Suspected Abusive Head Trauma, with the intent to build on their earlier 2001 Joint Statement on Shaken Baby Syndrome.[9,10] In 2009, the American Academy of Pediatrics recommended adopting abusive head trauma as the diagnostic term for the constellation of cranial and spinal injuries caused by inflicted head trauma in infants and children.[11] The authors recognized that while violent shaking can cause significant injury, focusing too narrowly on one kind of force might

limit the diagnostic possibilities to be considered.

Evidence for abuse as a factor in head trauma

The process of forming a medical diagnosis is a probabilistic exercise based on both clinical experience and knowledge of the relevant medical literature. Relatively recent developments in medical informatics have given researchers the ability to synthesize large volumes of medical data for comprehensive systematic reviews that can help inform our diagnostic decisions.

In children younger than 2 years, inflicted head injury is one of the leading causes of both mortality and significant morbidity.[12,13] Numerous comparative research studies and systematic reviews have highlighted the distinct patterns of injuries and clinical presentations that distinguish accidental from nonaccidental trauma in children.[13-20] Clinical features that have a significantly higher association with AHT include the presence of apnea, seizures, SDH (particularly if found diffusely over the cerebral convexities or interhemispheric falx), retinal hemorrhages, retinoschisis, and both rib and long bone fractures. In addition, when these factors appear concurrently, the probability of a correct diagnosis of AHT increases.[21]

Two recent systematic reviews of ocular findings in pediatric head trauma have documented the significance of retinal hemorrhage to the diagnosis of inflicted trauma. Bhardwaj and colleagues reported an overall sensitivity of 74% and specificity of 94% for any degree of intraocular hemorrhage.[16] An even more recent review confirmed that the probability of abuse is 91% when a child with head trauma is found to have retinal hemorrhages.[17] When present in an extensive, multilayered pattern, retinal hemorrhages have been shown in multiple studies to have a highly significant association with AHT.[16,17,22]

Current research also highlights significant differences in the long-term outcomes of accidental head trauma and abusive head trauma, particularly the spectrum of serious and often permanent neurological sequelae associated with inflicted intracranial injury.[13,23]

So can violent shaking really result in head injury? As physicians involved in the management of injuries to children, our first intuitive response would be "absolutely," yet this question has been debated in the popular media and continues to face challenges in the legal arena.[24] We now have decades of medical and scientific literature that supports the contention that violent shaking can cause serious injury.[25] While most of the scientific evidence remains indirect, both clinical and nonclinical research have shed light on this concern.

Experimental animal studies

Although the injury thresholds for SDH and brain injury in living human infants are not yet known, animal models can be used to study injury patterns and mechanisms. While such models on their own cannot be used to predict injuries in human infants and children, animal research can be informative. Experimental animal studies have taught us that:

- SDH and brain injury can be induced in adult primates by even a single severe acceleration impulse without direct impact.[26]
- The developing brain of a young piglet sustains greater injury at a lower threshold than the brain of an adult pig subjected to the same forces.[27]
- Repetitive impulse loads to the developing piglet brain result in greater injury than single impulse loads.[28]
- Violent shaking of young lambs can result in death.[29]

Perpetrator confessions

Numerous studies have detailed the confessions of perpetrators responsible for inflicted head trauma in children caused by shaking, shaking with impact, or impact-alone mechanisms.[30-34] While it is possible that some of these confessions are incomplete or misleading, it is striking that shaking is a significant and consistent component of the histories reported in the hundreds of cases published to date. A variety of perpetrators who confess to shaking children later found to have serious traumatic brain injuries have been identified in multiple countries. One well-documented case describes the death of an adult prisoner of war who sustained SDH, retinal hemorrhages, and bruises to the arms and torso after a violent shaking by his interrogators.[35]

Associated neck injury

Neck and spinal injuries are relatively uncommon in young children following accidental injury; however, recent evidence suggests that neck injuries in children following abusive head trauma are much more common than previously thought.[20,36] In a comparative study of children sustaining either AHT or accidental trauma, the significantly greater frequency of posterior ligamentous cervical injury with AHT supports the argument that infants with AHT are subjected to more significant neck forces than infants with accidental injuries.[36] The more substantial neck injuries in the children with AHT are very likely a result of the severe flexion caused by violent shaking.

Retinal hemorrhages

Numerous studies have documented the highly significant correlation of

extensive, multilayered retinal hemorrhages with abusive head trauma, yet the exact mechanism of injury eludes us. Recent research creating finite element modeling of the infant eye confirms that rhythmic shaking significantly increases the stress on the retina.[37] Further, the areas of greatest stress are found at the posterior pole and the peripheral retina, precisely where retinal hemorrhages are typically documented in cases of abusive head trauma.

Prevention research findings

Despite the limitations of prevention and education research, it is noteworthy, and perhaps most encouraging, that efforts to educate parents and caregivers about the dangers inherent in shaking young infants have been shown to significantly reduce the incidence of AHT.[38] While indirect, this evidence suggests that shaking is one of the contributing mechanisms to traumatic neurological injury in young babies.

Medicolegal issues

Despite the widely recognized validity of AHT as a medical diagnosis by numerous medical and health organizations, challenges to the diagnosis continue in many individual legal proceedings.[24] Unfortunately, irresponsible medical experts have provided testimony for both the defence and the prosecution, undermining the credibility of the medical profession as impartial educators in the judicial process. Unprofessional conduct can take a variety of forms, including:

- Offering evidence without having the required subject expertise.
- Presenting unique theories of causation.
- Suggesting unique interpretations of medical findings.
- Alleging nonexistent medical findings.
- Making false statements.
- Deliberately omitting important facts relevant to the opinion being offered.[39]

Fortunately, some medical organizations have begun to take disciplinary action against physicians presenting biased or misleading opinions in court.

Conclusions

Thanks to more than a century of meticulous and painstaking work by doctors and scientists from a variety of medical disciplines, there has been unprecedented growth in our understanding of inflicted head trauma in children. We can now confirm that abusive head trauma is a leading cause of traumatic death in children under 2 years of age, that it has a characteristic clinical presentation and injury pattern, and that it can involve a variety of injury mechanisms. Despite what we now know, we cannot become complacent. There are still many issues that we do not completely understand:

- The biomechanical properties of the developing brain and spinal cord.
- The response of the orbit and its contents to various traumatic forces.
- The evolution and dating of injury when the history provided is unclear.
- The complex physiological response of the brain to both injury and to our resuscitative efforts to mitigate permanent damage.

It is time to focus our efforts on seeking answers to these challenging questions. Whether our medical diagnosis remains abusive head trauma or evolves yet again to some alternate terminology, we cannot ignore the extensive body of research that has been published to date. It continues to be a very sad and unfortunate reality that infants and children are injured at the hands of trusted caregivers. As medical practitioners, we have a duty to our young patients to include the possibility of abusive head trauma with other diagnostic considerations in specific clinical situations. We have come a long way since the time of Tardieu, when the physical abuse of children was either not recognized or not acknowledged by the medical profession. Whether we arrive at a medical diagnosis of accidental trauma, abusive head trauma, or trauma of undetermined cause, we must aspire to the highest ethical and professional standards and call things what they are. Only then will we achieve our primary goal of supporting the future health and safety of our young patients.

Competing interests

None declared.

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