

REVIEW

Forensic aspects related to pediatric pathology – Medicolegal aspects of pediatric head injuries

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Abstract. The pathological examination and assessment of inflicted head injuries in infants and young children are often complicated by the subtle nature of the injuries, the non-specificity of lesions, and the lack of experimental data that can be used to clarify possible forces and mechanisms of damage. Opinions often have to be given on a number of issues, with a paucity of information in the literature and lack of specific individual experience. The following paper reviews some of the problems that are currently found in the medicolegal evaluation of infants and young children with inflicted craniocerebral trauma and issues that consequently arise in court. (Keio J Med 55 (4) : 149–152, December 2006)

Key words: inflicted injury, death, infancy, medicolegal issues

Introduction

Lethal inflicted injuries in young children are most often due to craniocerebral trauma. Injuries to the abdominal organs are the next most common serious problem. One of the difficulties in the assessment of significant head trauma in infants is the non-specificity of the clinical presentation, with infants often arriving to hospital in an encephalopathic state with minimal signs of external injuries.^{1,2} Infants may be fitting with neurological deficits, or be apneic and lethargic with poor feeding. Raised intracranial pressure with hydrocephalus may be associated with progressive loss of consciousness.

A common difficulty is the lack of a reliable history of events leading up to the infant's collapse, with deliberate falsification of details in an attempt to protect the perpetrator(s). This has been a significant problem with studies in the past that have accepted the history as given by carers, without providing critical analyses of the likelihood of the described events being responsible for the resultant injuries, or independent corroboration of the carers' stories.³ Significant and life-threatening injuries are often unexplained, attributed to low level falls, or blamed on a sibling.

Medicolegal issues

The Literature

The literature cited on inflicted childhood head injury contains papers with unclear data. This is a particular problem with earlier studies, where cases were either taken from data bases without any indication that the presenting histories had been accurately obtained and independently verified, or where the carers' histories were accepted without question. This has led to considerable debate, particularly concerning the likelihood of lethal craniocerebral trauma resulting from simple low level falls. In an attempt to provide a correlation of carers' histories and clinical outcome Chadwick *et al* analysed a series of 317 cases of children who were brought to emergency centers with carers' histories of falls.³ Seven deaths occurred in alleged falls from 4 feet or less, with only one death in falls from 10 to 45 feet. Given the logical inconsistency of a fall of less than 4 feet being eight times more lethal than a fall from a much greater height, an alternative explanation must be sought. It seems clear that the mechanism of death was not accurate and that other forces were involved in the children who died after the alleged low level falls, with perpetrators giving false

information in an attempt to disguise their involvement in the deaths. Infants and young children survive simple falls well and deaths have occurred in witnessed falls only when the height was greater than three stories.⁴

Experience and Research

Questions are often raised in court concerning the amount of force that may be required to cause either a particular injury in, or the death of, an infant. These questions are sometimes unanswerable, as each case often has quite idiosyncratic features that may make generalising from experience or the literature difficult. Individual medical experience may be limited and it is difficult to envisage how prospective studies can be conducted on infants to assess responses to trauma. Unfortunately the lack of data on injury forces in infants has led to assertions that significant and potentially life-threatening injuries may derive from minimal trauma. The suggestions that normal 'wear and tear' and handling of infants and toddlers may cause serious damage can, however, be questioned by the examination of playgrounds and child care centers. Toddlers and young children often sustain impacts with considerable force in falls and collisions in playgrounds and yet deaths under these circumstances are exceedingly rare. This suggests that usual wear and tear in normal young children is not lethal.

Experiments using models of infant heads and brains also require careful interpretation as animals and dolls are not babies. Animals have quite different anatomical configurations to human infants and extrapolating from the forces required to cause (or not cause) certain injuries in a rat or sheep model to a human infant may not be possible. Mechanical models also suffer from problems, as it is difficult if not impossible to replicate the complex nature of the human infant brain, with anatomical features including different tissue densities, nerve fibre tracts and meningeal coverings, chemical responses to neurotransmitters and autonomic changes resulting in variable blood flow and changing tissue permeability. Mechanical models may also oversimplify the trajectory that an infant head has followed, as shaking does not necessarily follow a simple anterior and posterior path, with oblique, lateral and circular movements all being possible. These trajectories may also be combined and involve different forces in different directions.^{2,5-9}

Anatomical Features

Particular anatomical features of infancy that are not present in older children predispose to cerebral injuries. Infant heads are relatively large compared to their body mass and are poorly supported by immature neck muscles. This means that infant heads may move quite violently if shaking or impact occurs. The bones of the

developing skull are thin, fragile and unfused, with a smooth base of skull that does not provide the tethering effect on the brain that occurs with the better-developed prominent ridges that separate cranial fossae in older age groups. Immature myelination of the brain renders it softer than in older children, and a greater relative volume of cerebrospinal fluid also provides more room for movement. The summation of these features renders the infant brain more vulnerable to shearing injuries when an infant is exposed to acceleration or deceleration forces.^{2,10,11}

External examination

Internal injuries may occur in infants without much in the way of external findings; e.g. infants may be thrown or shaken and sustain lethal head injuries without having bruises or abrasions. Intracranial hemorrhage, axonal injury and cerebral swelling may occur from shaking, with bruising of the chest being prevented by the interposition of clothing. Throwing or hitting an infant against a surface with a soft covering but a firm to hard base, such as the padded arm of a sofa, may produce unilateral cerebral hemorrhage and bruising without necessarily causing externally obvious injuries. A problem that may arise in the medical assessment of such infants is the assumption that the absence of external injuries implies that the forces involved in the lethal episode were not great. This, however, cannot be presumed. Another difficulty arises when inflicted injury is not suspected because of a lack of external injuries. This may result in significant delays in the investigation, assessment and management of the infant and his or her family.¹

Cervical injury

Recently it has been proposed that features of shaking may result from less severe force that has injured the upper cervical spinal cord damaging respiratory control and causing death from hypoxic ischemic encephalopathy.^{12,13} Certainly injury to the cervical cord may have devastating effects and so it is vital to examine the cord in all cases of unexpected infant death. It must be emphasized, however, that retinal hemorrhages, cerebral edema and subdural hemorrhages in an infant may occur in the absence of any injury to the upper cervical cord, and that hypoxic ischemic encephalopathy is not a recognised cause of subdural hemorrhage.¹⁴

Terminology

A typical case of inflicted head injury involves an infant either being found dead at home with no relevant history, or being taken for medical assessment in an unconscious state. Clinical examination may reveal finger-

tip bruises of the arms and back, with extensive retinal hemorrhages on fundoscopy. Radiological investigations may then show cerebral edema with bilateral thin subdural hemorrhages. At autopsy these findings will be confirmed and neuropathological studies may show symmetrical staining for β -amyloid precursor protein (β -APP). While some would find these features typical of shaking, others would disagree, and it has been argued that shaking alone cannot be responsible for death, and that impact must also occur.^{15,16} Certainly impact of an infant head on a firm surface with a soft covering may cause significant cerebral injury in the absence of external bruising. Lack of bruising or skull fracture, symmetry of findings and documented confessions of shaking by perpetrators do add support to shaking being responsible for infant deaths.¹⁷ However, it may be extremely difficult in individual cases to try to determine the sequence and nature of the lethal injuries from the findings at postmortem. “Blunt craniocerebral trauma” may be the preferred term as this clearly indicates that there has been significant injury to the head, while allowing for the complexity of possible contributing injuries. Thus, while shaking may be favoured, impact may not have been excluded in certain cases. Similarly, asymmetric findings with unilateral scalp bruising and comminuted skull fractures indicate that an impact injury has occurred, but does not exclude the possibility that shaking may have also been a factor if there are bilateral thin subdural and retinal hemorrhages present. Impact includes situations where an infant has been held and slammed into a hard object, or where an infant has been stationary and has been hit with an object or a fist. The significant issue is that inflicted injury must be suspected when a previously well infant is found lifeless with evidence of head trauma and without a reasonable explanation.

Problem cases

Sally Clark was an English lawyer who was convicted of the murder of her two sons in 1999. The conviction was overturned by a Court of Appeal in 2003. Part of the prosecution case was that her second son showed evidence of shaking, however what was initially considered to be retinal hemorrhage was later found to be normal retinal vessel congestion, and cerebral lacerations were ultimately found to be due to post-mortem artefact. The dangers of too readily using the diagnosis of shaken infant syndrome are exemplified by this case.^{18,19}

In addition to misinterpretation of findings, a further problem that has beset pediatric forensic pathology has been the variation in quality of autopsies that have been performed. Individual pathologists have often exhibited quite idiosyncratic styles in their autopsy practice in the very young. For example, cases have occurred where no histological assessment of the brain and cord has been

performed, and sometimes the cranial cavity has not even been opened. Specialised ancillary testing such as radiological and microbiological screening may not have been done.²⁰ Because of the complex nature of many issues that are raised by infant deaths it is often not possible to go back and clarify mechanisms if appropriate dissections, examinations and tests have not been undertaken. Audits have confirmed these problems and comments may be found in the literature that ‘investigations into the pathology and circumstances of sudden infant death are often scanty and inexperienced’.^{21,22} An appropriate way to avoid omissions and errors at the time of autopsies is for pathologists and investigators to follow recognised national and/or international protocols that provide clear guidelines for the type of examinations that are required and the range of tests that are recommended.^{23,24}

Another issue which is not restricted to pediatric forensic pathology is the use of ‘unique theories of causation’ in the analysis of injuries and in postulating possible mechanisms. An example would be the proposal that intracranial hemorrhages typical of those found in shaking could be caused by immunization, something that has not been supported by research. Problems with expert evidence have been reviewed by Chadwick and Krous who have listed a series of issues that may arise in addition to the use of unique theories. These include unique or very unusual interpretations of the medical findings, misquoting of the literature, proposing nonexistent medical findings, making false statements and deliberately omitting important facts.²⁵

Conclusions

Evaluating inflicted craniocerebral trauma in the very young is often difficult and involves considerable debate. Difficulties may arise at all stages of the process due to incomplete investigations, badly recorded or inadequately assessed autopsy findings, and conflicting opinions on injuries and lesions. Infants have unique anatomical features that may predispose them to certain forms of injuries, and the interpretation of such injuries is made even more difficult by the lack of controlled studies involving head injury in infants, and the problems associated with the validity, or not, of non-human models. Recognition by pathologists of the complexities involved in such cases and the avoidance of speculative theories and hypotheses in evolution will, however, assist in the evaluation of these matters.

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References

1. Byard RW, Cohle SD: Homicide and suicide. Ch 3 In: *Sudden Death in Infancy, Childhood and Adolescence*. Byard RW. Cambridge University Press, Cambridge, 2nd edition 2004; 77–166
2. Case ME, Graham MA, Corey Handy T, Jentzen JM, Monteleone JA: Position paper on fatal abusive head injuries in infants and young children. *Am J Forensic Med Pathol* 2001; 22: 112–122
3. Chadwick DL, Chin S, Salerno C, Landsverk J, Kitchen L: Deaths from falls in children: how far is fatal? *J Trauma* 1991; 31: 1353–1355
4. Barlow B, Niemirska M, Gandhi RP, Leblanc W: Ten years of experience with falls from a height in children. *J Pediatr Surg* 1983; 18: 509–511
5. Finnie J: Animal models of traumatic brain injury: a review. *Aust Vet J* 2001; 79: 628–633
6. Duhaime AC, Gennarelli TA, Thibault LE, Bruce DA, Margulies SS, Wiser R: The shaken baby syndrome. A clinical, pathological and biomechanical study. *J Neurosurg* 1987; 66: 409–415
7. Smith SL, Andrus PK, Gleason DD, Hall ED: Infant rat model of the shaken baby syndrome: preliminary characterization and evidence for the role of free radicals in cortical hemorrhaging and progressive neuronal degeneration. *J Neurotrauma* 1998; 15: 693–705
8. Gennarelli TA. Mechanisms of brain injury. *J Emerg Med* 1993; 11 Suppl. 1: 5–11
9. Cory CZ, Jones MD, James DS, Leadbeater S, Nokes LD: The potential and limitations of utilizing head impact injury models to assess the likelihood of significant head injury in infants after a fall. *Forensic Sci Int* 2001; 123: 89–106
10. Duhaime AC, Christian CW, Rorke LB, Zimmerman RA: Nonaccidental head injury in infants - the “shaken-baby syndrome”. *N Engl J Med* 1998; 338: 1822–1829
11. Shannon P, Smith CR, Deck J, Ang LC, Ho M, Becker L: Axonal injury and the neuropathology of shaken baby syndrome. *Acta Neuropathol* 1998; 95: 625–631
12. Geddes JF, Whitwell HL, Graham DI: Traumatic axonal injury: practical issues for diagnosis in medicolegal cases. *Neuropathol Appl Neurobiol* 2000; 26: 105–116
13. Geddes JF, Tasker RC, Hackshaw AK, Nickols CD, Adams GGW, Whitwell HL, Scheimberg I: Dural haemorrhage in non-traumatic infant deaths: does it explain the bleeding in ‘shaken baby syndrome’? *Neuropathol Appl Neurobiol* 2003; 29: 14–22
14. Byard RW, Rutty G, Blumbergs P, Spermhake J, Banner J, Krous HF: Lack of evidence for a causal relationship between hypoxic ischemic encephalopathy and subdural hemorrhage in fetal life, infancy and early childhood. *Pediatr Develop Pathol (Under Consideration)*.
15. Krous HF, Byard RW: Controversies in pediatric forensic pathology. *Forensic Sci Med Pathol* 2005; 1: 9–18
16. Leestma JE: Case analysis of brain-injured admittedly shaken infants: 54 cases 1969-2001. *Am J Forensic Med Pathol* 2005; 26: 199–212
17. Krous HF, Byard RW: Shaken infant syndrome: selected controversies. *Pediatr Develop Pathol* 1999; 2: 497–498
18. Byard RW: Persistent problems in cases of unexpected infant death - the Sally Clark case. *Med J Aust* 2004; 181: 52–54
19. Bacon CJ: The case of Sally Clark. *J Roy Soc Med* 2003; 96: 105
20. Byard RW: Inaccurate classification of infant deaths in Australia: a persistent and pervasive problem. *Med J Aust* 2001; 175: 5–7
21. Bacon CJ: Cot death after CESDI. *Arch Dis Child* 1997; 76: 171–173
22. Unexplained deaths in infancy. Editorial. *Lancet* 1999; 353: 161
23. Krous HF, Byard RW: International standardized autopsy protocol for sudden unexpected infant death. Appendix I. In: Byard RW, Krous HF, editors. *Sudden Infant Death Syndrome: Problems, Progress and Possibilities*. London: Arnold 2001; 319–33
24. Centers for Disease Control and Prevention (CDC) Guidelines for death scene investigation of sudden unexplained infant deaths: recommendations of the Interagency Panel on Sudden Infant Death Syndrome. *Morbidity Mortality Weekly Report* 1996; June 21
25. Chadwick DL, Krous HF: Irresponsible testimony by medical experts in cases involving the physical abuse and neglect of children. *Child Maltreat* 1997; 2: 313–321