ORIGINAL ARTICLE

Non-Accidental Fatal Head Injury in Small Children - A Clinico-Pathological Correlation

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Summary

Non-accidental head injury leading to massive intracranial trauma has been identified as a leading cause of death in small children. In a typical case, a child usually below the age of one year is violently shaken, leading to rupture of the connecting veins between the dura mater and the brain substance with variable degrees of bleeding into the subdural space resulting in increased intracranial pressure. The accompanying venous thrombosis affecting the vessels of the brain substance leads to cerebral hypoxia and cellular death. In this study conducted throughout the year 1999, all children below the age of 3 years who were admitted to Hospital Kuala Lumpur and had died due to non-accidental injuries were included. Postmortems, including histopathological studies, were conducted to determine the most likely mechanisms of the injuries. Ten cases were identified for the whole year. In 2 cases, both below one year of age, the features presented showed evidence of violent shaking of the infants. In 6 other cases whose average age was 13 (range 4-24) months, there were evidences of direct trauma and violent shaking. In the last two cases, aged 24 and 33 months respectively, there was only evidence of direct trauma on the heads without being shaken.

This study shows that death due to intracranial trauma caused by shaking with or without direct impact is the most frequent cause of mortality in abused children. Death due to direct impact between the head and another object is a less frequent occurrence.

Key Words: Intracerebral trauma, Subdural haemorrhage, Shaken Baby Syndrome

Introduction

Death as a result of child abuse has been well documented in many studies since Kempe et al[1] published the article: The battered Child Syndrome" in the American Medical Journal in 1962. It is estimated that more than 1000 children in the USA die each year due to child maltreatment in the USA. At the local level, the 1996 Annual Report of the Suspected Child Abuse and Neglect (SCAN) Team of Hospital Kuala Lumpur [2] showed that from 1985 to 1996, out of a total of 63 deaths caused by child abuse, 41 deaths were due to intracranial haemorrhage. It was estimated that 95% of serious intracranial injury in the first year of life resulted from physical abuse (Hobbs et al [3]). The mechanism leading to the injury was first proposed by Gultkelch [4] and later by Caffey [5] describing a "Whiplash Shaking Syndrome" produced by repeated severe shaking leading to subdural and subarachnoid haematoma and intraocular haemorrhage. The action of violent shaking would cause a) opposing movements of the brain and skull leading to rupture of the connecting veins between the dura and the brain

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substance resulting in haemorrhage in the subdural and/or subarachnoid spaces, b) cerebral venous thrombosis leading to cerebral oedema, contusion and/or haemorrhage. In addition to the to-and-fro movements of the brain in the skull, there are also c) rotatory movements of the brain and its various layers due to their varying densities, resulting in tearing of the axons which are mostly found in the inner white matter from the bodies of the neurons located in the outer grey matter, leading to neuronal injuries and deaths (Duhaime[6,7]). The classical picture occurs without any skull fracture, bruising of the scalp, oedema or evidence of direct head trauma (Brown et al[8]). The mechanism of the injury was thought to be violent shaking without forceful impact of the head against a hard surface or a blunt object. However, Aoki et al [9] arrived at a conclusion from the results of their study of 6 cases that the real picture was often complicated by the fact that impact of the head against a surface often occurs resulting in the presence of both types of injuries. His findings were similarly confirmed by Duhaime at el[10] in a bigger series of 100 cases. Children younger than 2 years of age appear to be exposed to the greatest risk of intracranial trauma (Ophoven[11]). Unlike the older children, they may sustain significant head trauma without evidence of head injury to the scalp. Furthermore, the thin pliable skull of the young infant transmits force more diffusedly than the more rigid skull of the older child. The subdural space of the young infant is narrower and is thus less tolerant of a space-occupying lesion. Finally, the unmyelinated infant brain with its higher water content is more susceptible to rapid life-threatening, diffused brain swelling than is the brain of the older child (Kirschner[12]).

When there is evidence of blunt trauma, it is often difficult to determine whether the intracranial injury resulted from blunt trauma alone or from the trauma plus shaking. History of shaking is obtained in only a minority of cases. Sometimes, the history may be vague or vary with time or mechanism of injury.

The pathological findings in small children who had died due to non-accidental head injury are remarkably consistent. Intracranial haemorrhages (subdural and subarachnoid haemorrhages) combined with external injury (scars, bruises, contusions and lacerations) is a common feature often seen on postmortem. Histopathological changes observed in the brain (diffused axonl injury and cerebral oedema) and in the eyes (retinal haemorrhage, subhyaloid haemorrhage or dislocation of lens) helps the forensic pathologist to construct the manner of death in suspected non-accidental head injury.

Cases of small children who have died because of intracranial injury probably due to abuse are regularly documented in Malaysia[2,13]. However, the pathological features have not been adequately documented to enable the mechanisms of injury to be arrived at.

Thus the specific objectives of this study were:

1. To study the clinical features of fatal suspected non-accidental head injury cases,
2. To identify histopathological features in each case,
3. To draw conclusions obtained from both the clinical and histopathological findings regarding the manner of death of these children who had died after sustaining apparent non-accidental head injury and the probable cause of brain damage that occurred in those who survived.

Materials and Methods

A descriptive study was conducted where autopsy records of all children below the age of 3 years either confirmed or suspected to have died of head injury from January 1 to December 31, 1999 were reviewed. All cases of intracranial trauma due to Motor Vehicular Accidents (MVA), intracranial haemorrhages due to congenital causes and bleeding and/or intracerebral oedema associated with tumours or brain disease were excluded.

Relevant history to help in pointing out the cause of the injuries was elicited in each case. A thorough physical examination of the whole body and especially the head and neck to look for signs of trauma incurred at the same time or previous to the current injuries was conducted. Funduscopy was similarly conducted over both eyes to detect the presence of intraocular or retinal haemorrhage. CT scans were done to confirm or exclude the presence of collections of fluid in the skull, cerebral oedema and skull fractures not detected on physical examination.

Upon death, a full postmortem, conducted by the third author, was then done in each case. A thorough external examination was initially done to look specifically for bruises and old and recent scars over the scalp, face, neck and other parts of the body. The layers of the scalp were then opened to look for any bruising that suggest injury over the area. On opening up of the skull and the various layers of membranes

covering the brain substance, any collection of blood or fluid and the site of collection, whether extradural, subdural, or subarachnoid was noted. When cutting into the brain substance, any evidence of haemorrhage and the consistency of the brain substance suggesting the presence or absence of cerebral oedema were noted. Finally, slices of tissue over areas of haemorrhage and trauma were taken for histopathological examination. This last procedure with reporting of the findings was made by the fourth author.

The findings obtained from the history, physical examination and postmortem conducted on each of these children were then collated and the final cause of the injuries arrived at. The mechanisms of the brain injuries from these findings that led to death were then classified according to, a) Subdural or subarachnoid haemorrhage and neuronal injuries due to violent shaking of the child, b) Trauma due to direct impact between a hard object or surface and the head and brain, and c) Direct impact between an object and the head combined with features of shaking.

Shaking to the exclusion of other head trauma were assumed when there was complete absence of scalp and skull injuries and the presence of two or more of the criteria mentioned below. These criteria are:

1. History of shaking if present or obtained,
2. Finger marks and/or rib fractures on trunk and upper limbs,
3. Subdural and/ or subarachnoid haemorrhages,
4. Presence of retinal haemorrhages

Results

A total of 10 cases of children below the age of 3 years who died due to suspected head injuries were admitted to Hospital Kuala Lumpur from January 1 to December 31, 1999. Table I shows the characteristic features presented in each of these children.

In Case 1, the parents gave two conflicting histories on separate occasions of the 11-month-old child falling from a cot and also from a walker. In case 2, the father who was the last person to try comforting the irritable 5-month-old child was most unconcerned about his very sick child when admitted to the Paediatric Intensive Care Unit (PICU). In both children, other than bilateral retinal haemorrhages detected on examination when the children were still alive, there was no evidence of external scalp injury, skull fracture or injuries on the extremities. On postmortem, there was no haematoma detected externally or in the subgaleal region. There were also no fractures. However, when the skulls were opened up, Case 1 showed bilateral subdural haemorrhage (SDH) and Case 2 subdural and subarachnoid haemorrhages (SDH and SAH) (Plate No 1). Histological examination of the brain tissue in Case 1 (Plate No 2) showed a typical "retraction bulb" which was caused by bulbous swelling of an axon separated from the body of the neurone. Plate 3 shows in the same patient a slowly disintegrating nucleus in the body of a neurone dismembered from its axon. The features shown in both plates suggest the presence of shearing forces between the outer grey matter of the brain consisting mainly of the bodies of neurons and the inner white matter consisting of the axons of these neuron thus showing the effects of violent shaking of the child.

When Cases 3 to 8 were looked at, there were retinal haemorrhages in each of them except for Case No. 6, as the child was brought in dead. At postmortem, there were subgaleal haematomas found in all 6 cases. Skull fractures were also found in Cases 3,4,5,7 and 8 but not in Case 6. The presence of subgaleal haematomas and skull fractures either individually or together suggest that direct impact must have occurred between the skull and a hard object. When the skull was opened, there were subdural haemorrhages in all cases except for Case 5. In this latter case however, even though there were no subdural haemorrhages, histopathological examination showed the presence of diffuse axonal injury and axonal bulbs indicating rupture of bodies of neurons from their axons. These findings together showed that shaking must have occurred. In addition, cerebral oedema and/or surface contusion were also found in all 6 cases directly opposed to the fractures and the subgaleal haematomas. Thus the features present in these 6 cases showed that the injuries inflicted must have been caused by both shaking and direct impact between the head and a hard object or surface. The average age of these children was 13 months (ranging from 4 months to 24 months).

In the last 2 cases, involving children aged 33 and 24 months respectively, there was definite external evidence of physical abuse as shown by multiple bruises, scars and bite marks. Case 9 showed subgaleal haematoma and occipital bone fracture and cerebral haematoma. Similarly, there were subgaleal haematoma and occipital bone fracture and cerebral oedema beneath the fracture in Case 10. Plate 4 shows presence

of surface contusion but no laceration as evidenced by an intact meningeal layer but no subdural or subarachnoid haemorrhage. Thus these features show that there was evidence of direct trauma inflicted on the head by a hard object or surface but not by shaking.

Table I

Case No.	Age (months)	History	Clinical findings	Pathological findings (postmortemexam.)	Conclusion
1	11	Alleged to have fallen from both walker and hammock (inconsistent)	Vomiting, irregular breathing Retinal haemorrhage.(bil.)	Bil. SDH, petechial haemorrhage over cerebrum, no cerebral contusion, diffused axonal injury	Shaken Baby Syndrome
2	5	Father unconcerned about child's condition was last person to try comforting him	Vomiting, apnoea, bil. retinal haemorrhage	Bil. SDH and SAH, no intracerebral haemorrhage No skull fracture and subgaleal haem.	Shaken Baby Syndrome
3	8	Allegedly fell from hammock	Irregular breathing, in coma, L retinal haemorrhage.	# occipital bone, SDH, intracerebral haemorrhage, surface contusion blunt trauma &	Combined shaking
4	10	Child-minder admitted shaking child in cloth cradle and child fell to floor	Persistent vomiting, irregular breathing, bil. Retinal haemorrhage.	Subgaleal haemorrhage, # occipital bone, SDH, cerebral surface contusion	Combined blunt trauma & shaking
5	5	Allegedly fell out of bed	Retinal haemorrhage.	Subgaleal haemorrhage, parietal bone #, cerebral oedema, diffused neuronal injury	Combined blunt trauma & shaking
6	4	Allegedly fell from cradle	Nil (child brought in dead)	Subgleal haemorrhage, surface contusion SDH and SAH	Combined blunt trauma & shaking
7	27	Allegedly fell from standing position	Headache, bil. Retinal haemorrhage.	Skull #, subgaleal haemorrhage, cerebral oedema, SDH and SAH	Combined blunt trauma & shaking
8	24	Nil. Brought in straight to ICU	Multiple scars and bruises over body, Retinal haemorrhage.	Skull #, subgaleal haemorrhage. SDH, SAH, surface contusion	Combined blunt trauma & shaking
9	33	Childminder abusing and hitting child	Bruises over face and abdomen, bite marks (thigh)	Subgaleal haemorrhage, cerebral oedema, No SDH	Blunt trauma
10	24	Inconsistent history from physical injuries	Multiple scars and bruises all over body	Subgaleal haemorrhage, occipital bone #, cerebral oedema, no SDH	Blunt trauma

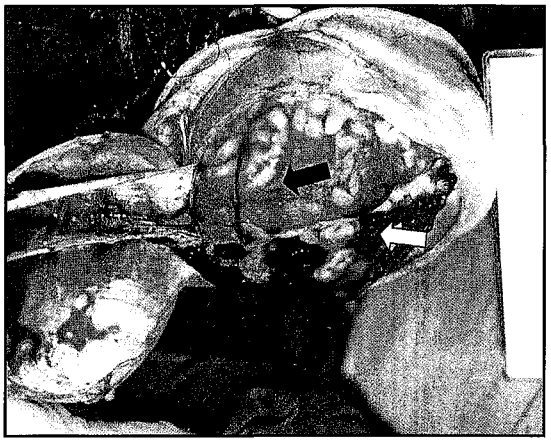

Plate 1 : Subdural haemorrhages (⇧) and subarachnoid haemorrhages (↑) seen after the opening of the skull. This picture was taken from the case 1 who was diagnosed as "Shaken Baby Sydrome"

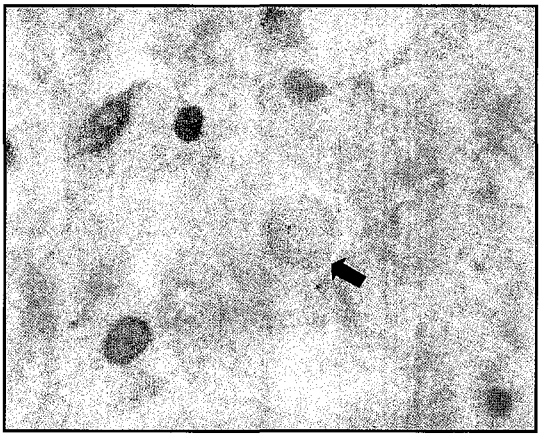

Plate 2 : Typical features of "retraction bilb" of axon (↑) i Diffuse Axonal Injury. This pictures was taken from case 1

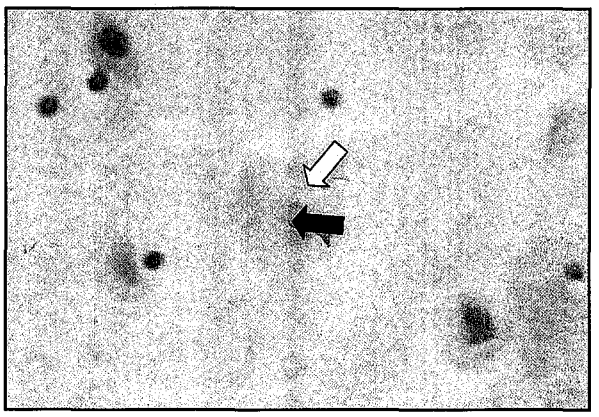

Plate 3 : Degeneration of axon with typical features of faded nucles (⇑) and loss of cytoplasm (⇧) from the axon. Case 1

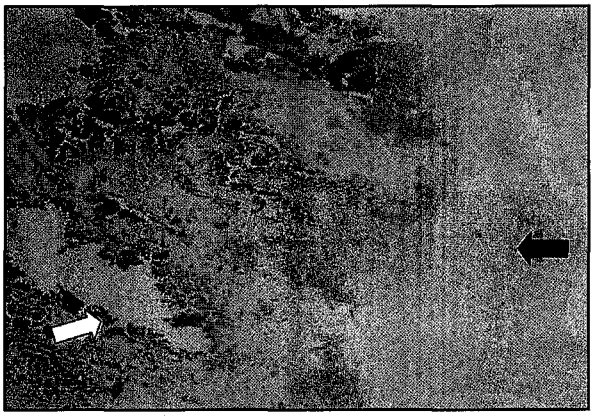

Plate 4 : Surface contusion (⇧). It was taken from case 9 who was suspected with direct impact. The meningeal layer is still intact (⇑) which means there is no laceration of the brain, only the contusion

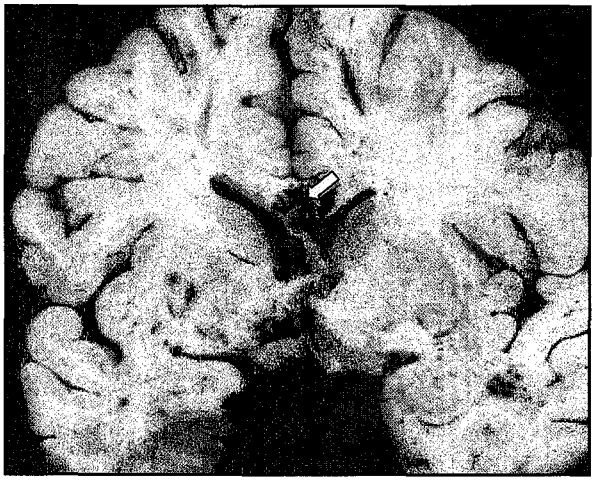

Plate 5 : Petechial haemorrhages (⇧) scattered in white matter and most predominant in corpus collusum. This finding accurred most in "shaked Baby Syndrome" and direct impact with features of being shaken

Discussion

This study conducted over a one-year period at a major hospital shows that fatal head injuries occur relatively frequently amongst small children. Most of these children were very young and this finding compares closely to the USDHHS report for the year 1997 in which the mean age of the victim was 5-6 months.

Most of these injuries were rarely accidental. Billmire and Myers[14] found that 95% of serious intracranial injuries and 64% of head injuries in infants were due to child abuse. However, the mechanism of the injuries has been debated. One mechanism was described by Caffey[5] as the "Shaken Baby Syndrome" in which subdural and/or subarachnoid haemorrhage with retinal haemorrhage occur due to sudden, sharp shaking of the young child. However, Duhamie et al[10] came to the conclusion that the majority of children with intracranial injuries had sustained their injuries not only through being shaken but, in addition, had their heads impacting on hard surfaces when the act of shaking was made.

This study has sought to find out which of these two mechanisms had been inflicted on the children who had died due to intracranial injuries. The findings from this study confirm the conclusion made by Duhamie at el that the majority of the deaths (6 out of 10 cases) were caused by a combination of shaking and impact between the head and a hard surface. These children were also relatively older with a mean age of 13 months. However, injuries leading to death by shaking alone was also found in 2 cases occurring amongst the younger children, thus showing that the mechanism as proposed by Caffey was still valid even though for only a minority of cases.

In all the 8 children, there was no evidence of abuse in any other part of the body except for the last child, a 24-month-old, who had superficial scars and bruises over his body. This suggests the importance of shaking as a direct cause of the intracranial haemorrhage.

Injuries caused by direct impact between the head and a hard surface or a hard object causing death has also been identified here occurring in two older children. Thus, the more likely mechanism of injury in both these children must have been being hit on the head with a hard blunt object. And this is confirmed further as there were signs of physical abuse in other parts of the body.

References

1. Kempe CH, Silverman FN, Steele BF, Droegemueller W, Silver HK. The battered child Syndrome. JAMA, 1962; 81: 17-24.
2. Annual Report 1996 Suspected Child abuse and Neglect (SCAN) Team Hospital Kuala Lumpur.
3. Hobbs C. ABC of Child Abuse 2nd Edition. London BMJ Publishing.
4. Gultkelch AN. Infantile subdural haematoma and its relationship to whiplash injuries. British Medical Journal, 1971; 2: 430-31.
5. Caffey J. The whiplash shaken infant syndrome: manual shaking by the extremities with whiplash-induced intracranial and intraocular bleeding, linked with residual permanent brain damage and mental retardation. Pediatrics, 1974; 54: 395-403.
6. Duhaime AC, Generalli TA, Thibault LE, Bruce DA, Marguulies SS, Wiser R. The Shaken Baby Syndrome. Journal of Neurosurgery, 1987; 66: 409-15.
7. Duhaime AC, Schut L, Sutton LN. Head injury in very young children: Mechanisms of injury and ophthalmic findings. Child's Nervous System, 1990; 6: 297-98.
8. Brown JK, Minns RA. Non-accidental head injury with particular reference to whiplash shaking injury and medico-legal aspects. Developmental Medicine and Child Neurology, 1993; 35: 849-69.
9. Aoki N, Masuzaw H. Subdural haematoma in abused children, report of six cases from Japan. Neurosurgery, 1986; 18; 475-77.
10. Duhaime AC, Alario AJ, Lewander WJ, Schut L, Sutton NL, Seidl TS, Nudelman S, Budenz D, Hertle R, Slovas W, Laporchio S. Head injury in very young children: mechanisms, injury types and ophthalmological findings in 100 hospitalised patients younger than 2 years of age. Pediatrics, 1992; 90: 179-85.
11. Kirschner RH. The pathology of child abuse. In The Battered Child, Fifth Ed. 1997. Chapter 11, 248-295.
12. Cheah IGS, Kasim MS, Shafie HM, Khoo TH. Intracranial haemorrhage and child abuse. Annals of Tropical Paediatrics, 1997; 14: 325-28.
13. Billmire ME, Myers PA. Serious head injury in infants; accidental or abuse? Pediatrics, 1985; 2: 340-2.