CASE REPORT

Shaking infant trauma induced by misuse of a baby chair

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A 2 month old infant presented with bilateral subdural haemorrhages and bilateral subhyaloid haemorrhage. The parent admitted to forceful bouncing of the child in a baby rocker. Experiments showed that violent rocking in the chair could produce extreme alternating acceleration/deceleration forces in excess of those induced by shaking alone. Such handling could not be interpreted as accidental mismanagement and the abusive nature of the process was graphically shown in video recordings of the experiment. Prosecution resulted in a conviction for cruelty, and a suspended sentence.

A 2 month old boy was admitted with a short history of recurrent vomiting. He was observed for a few hours and appeared to improve with oral rehydration therapy. He was readmitted two days later because of persistent crying and irritability, and following three brief focal seizures.

On examination he was noted to be irritable, obtunded, and hypotonic with a soft fontanelle. He was pale with cool peripheries and there were petechiae on the back of the calves. The differential diagnosis was of sepsis, meningoencephalitis, or intracranial haemorrhage.

He received a bolus of colloid, antibiotics, acyclovir, and phenytoin. Investigations revealed anaemia (Hb 80 g/l) but an otherwise normal blood count and serum biochemistry. A computed tomography scan confirmed the presence of fresh bilateral subdural haemorrhages in the frontotemperoparietal region; xanthochromic cerebrospinal fluid with 360 red blood cells and 0 white blood cells was obtained at lumbar puncture.

Re-examination of the child with a Woods light revealed some old bruising on the anterior chest and behind the calves. He was still slightly irritable with poor visual fixation and brisk symmetrical reflexes. Bilateral subhyaloid haemorrhages were seen by an ophthalmologist but visual evoked responses were normal, as was a skeletal survey, and there were no additional findings on magnetic resonance imaging brain scan.

The boy's general condition improved slowly over the next few days and there were no further seizures. Antibiotics were discontinued when all cultures were negative.

A diagnosis of shaking/impact trauma was made and both parents were interviewed by the police. It emerged that there was a history of domestic violence, and on the night prior to the child's original admission he had been in the care of his father. The father was

tired through working nights and had had difficulty settling the baby. He admitted becoming frustrated, taking amphetamines, rocking the baby in his arms, and bouncing the infant "too hard" in a baby chair, using his foot as a pedal against the back of the chair.

Despite medical scepticism and rejection of the father's explanation, he persisted in his account, finally stating that he had been "high on Speed" and that the bouncing in the chair had been very forceful.

The paediatrician (CSL) advised the police that the mechanism was potentially testable and the prosecution was delayed. An approach was made to the Department of Mechanical Engineering at Northumbria University and an experiment designed to test the father's account.

METHODOLOGY

The methodology was to recreate the conditions described by the father using an infant size crash test dummy and the actual chair used to rock the child. The forcefulness of the rocking was measured using an accelerometer mounted in the head of the dummy. The accelerations resulting from various levels of rocking were then compared to those arising from violent shaking of the same dummy followed by impacting it onto a soft surface. All of the tests were videotaped.

The dummy was a standard type normally used for car crash tests. It weighed 9 kg and was fully jointed. A piezoelectric accelerometer was fitted to a mounting plate located near the middle of the head and was aligned to measure backward and forward linear acceleration.

The output of the accelerometer was fed to a standard charge amplifier signal conditioning unit and then to a digital oscilloscope with printing facility. The complete instrumentation system was calibrated against a reference vibration source before commencing the tests.

Acceleration versus time curves were recorded for the following scenarios:

(1) Dummy in the baby rocker
- Gentle rocking (fig 1A)
- Violent rocking (fig 1B)
- Violent rocking to the extremes allowed by the chair (fig 1C).

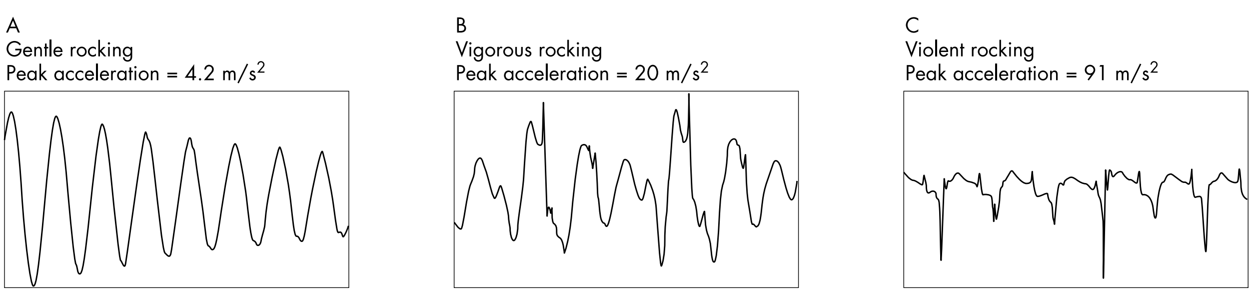

Figure 1 Accelerations produced by rocking the chair.

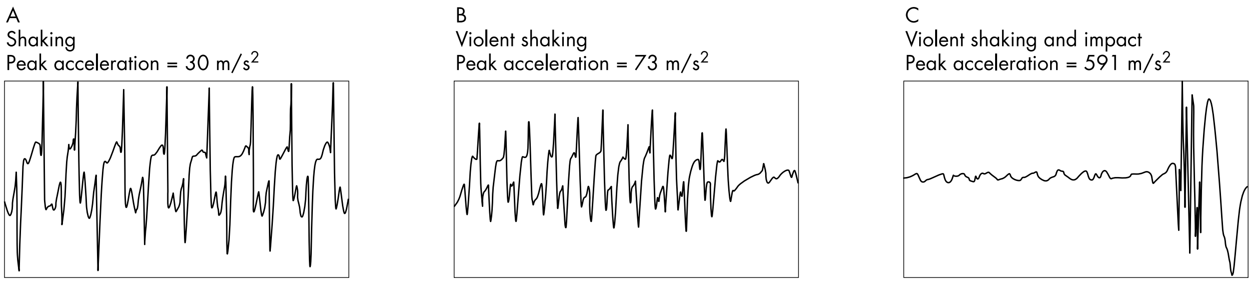

Figure 2 Accelerations produced by shaking in arms.

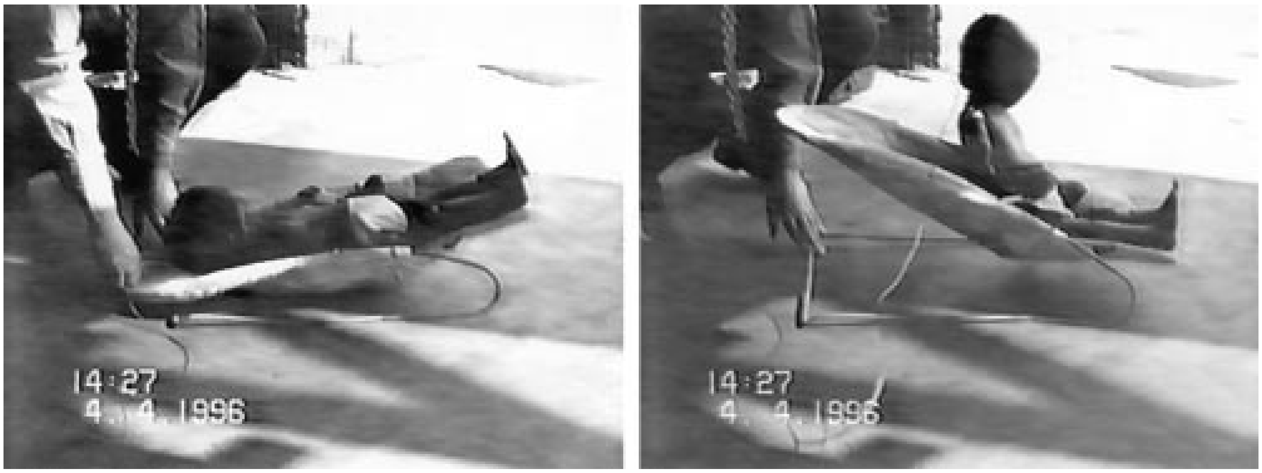

Figure 3 Video stills showing extremes of head movement with violent rocking in the chair.

(2) Dummy out of the rocker

- Shaking (fig 2A)
- Violent shaking (fig 2B)
- Violent shaking followed by impact onto a soft surface (fig 2C).

RESULTS

Sample acceleration versus time curves are shown in figs 1 and 2 for each of the test scenarios. Peak acceleration values are indicated on the graphs.

Peak accelerations measured for the dummy in the baby rocker varied from 4.2 to 91 m/s^2 depending on the degree of vigour used. Gentle rocking produced peak accelerations of the order of 4.2 m/s^2. Vigorous rocking increased these values to 20 m/s^2 and caused the head and limbs of the dummy to repeatedly lift away from and fall onto the fabric covering of the chair. When the rocking was increased to the extremes allowed by the chair the peak accelerations rose to 91 m/s^2, the head and limbs of the dummy flailed about violently, and at the lowest point of the motion the head struck the floor through the chair's fabric covering (fig 3).

When the dummy was lifted out of the chair and shaken the peak accelerations varied from 30 to 73 m/s^2 depending on the degree of vigour used.

When the shaking was followed by impact onto a soft surface the peak accelerations varied greatly depending on the severity of the throwing action. The lowest recorded value was 53 m/s^2 when the dummy was dropped down onto the soft surface from a low height. The highest values, which were in excess of 1000 m/s^2, were recorded when the dummy was lifted high in the air and thrown down violently.

The following general observations were made from the tests.

(1) Violent rocking of the dummy in the chair gave rise to head accelerations of a similar order to values recorded for shaking in the arms.

(2) Extremely violent rocking in the chair gave rise to higher accelerations than were measured for violent shaking, and was associated with impact.

(3) Throwing the dummy down onto a soft surface gave rise to accelerations far in excess of those recorded for either rocking in the chair or shaking in the arms.

DISCUSSION

Non-accidental head trauma and subdural haematoma are widely acknowledged to be the major cause of morbidity and mortality in the abused infant. Prevalence is highest in infants under 6 months of age and relatively uncommon after the age of 2 years.[1]

Starling *et al*, in 1995, found fathers and boyfriends to be the commonest perpetrators,[2] a study supported by our own Newcastle study.[3]

While the classical shaking trauma syndrome involves subdural haemorrhages, retinal haemorrhages, and rib and metaphyseal fractures, individual cases vary in presentation.

Mechanisms suggested for retinal haemorrhage include acceleration/deceleration forces within the orbit and raised intrathoracic pressure from chest squeezing. This is perhaps supported by the findings of retinal haemorrhages in perpetrator admitted episodes of shaking.[4]

Kleinman suggests that rib fractures are caused by anterio-posterior compression, and stress at the costo-vertebral junctions. His laboratory experiments with rabbits support this hypothesis.[5]

Accidental head injuries in young infants most often involve low velocity domestic incidents, falls from worktops and cots, or tripping over in the newly mobile toddler. These incidents are almost all benign in outcome as major rotational forces and sudden decelerations are not involved in these situations.[6]

Caffey's original and later paper reported bilateral subdural haematomas as a component of confessed shaking. Whiplash trauma, traction, and shearing forces applied to subdural veins is now strongly believed to be the mechanisms implicated in subdural bleeding in infants. In the absence of a clear history of significant accidental deceleration trauma, shaking injury should be considered by far the most likley explanation in children with subdural haematoma.[7]

While numerous studies have raised controversy about alternative diagnosis and mechanisms (notably Duhaime *et al* in 1987[8]), it is par for the course that studies of child abuse are beset by the problems of false history, delayed presentations, variable selection, and unreliable confessions. A parent may be more inclined to admit to something which appears societally less malign.

However, reported cases of acute subdural bleeds and retinal haemorrhage within custody and interrogation conditions with adult prisoners provide strong evidence for the whiplash mechanism.[9]

In this presented case, there were signs of eye trauma but no retinal haemorrhage, or rib or metaphyseal fractures. Petechial bruising along the calves suggested minor repetitive contusions to these areas.

The videotaped experiment showed jerking of all four limbs with the swinging of the chair, and the calves sustained impact against the hard frame of the chair. In addition large scale displacement movement of the head and the upper torso was noted.

The experiment shows that forceful repetitive whiplash injury to the head was possible and that "shaking" trauma could have been induced without picking up the child.

Videotaped recordings of the experiment produced clear evidence that considerable reckless violence was required to generate shearing forces. However, it was also clear that repetitive impact against the springy chair material and the floor could also be implicated in the event. It is recognised that rotational forces are also involved in the diffuse axonal injury seen in some shaking trauma events. We accept that this experiment only tested linear acceleration coupled with frequent impact deceleration events.

We are not convinced that manufacturing instructions need be amended in the light of this case. It seems clear that the chair served as a means of abusive violence and the experimental videos graphically confirmed the unacceptability of the manoeuvres used.

This case illustrates that violence producing shaking/impact brain injury, may be inflicted on an infant without direct handling. Perpetrators will always minimise their actions and victim impact. With vigorous testing of this self confessed history it was possible to show the level of violence required to produce the clinical picture. Criminal prosecution resulted in a conviction for cruelty.

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