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Two Infant Boys Misdiagnosed as "Shaken Baby" and Their Twin Sisters: A Cautionary Tale

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Benign external hydrocephalus (BEH) is a subtype of hydrocephalus with rapid increase of the head circumference (HC) in infancy; enlarged subarachnoid spaces, especially overlying the frontal lobes; and normal or enlarged ventricles.[1-8] For an extensive review, see Zahl, et al.[6] Additionally, our recent population-based study provides additional information on the epidemiology.[9]

Many terms have been used for this or similar conditions, namely, *subdural hygroma*,[10] *subdural effusion*,[11] *benign subdural collections*,[12] *extraventricular obstructive hydrocephalus*,[13] *idiopathic/benign hydrocephalus*,[1,3] *primitive megalencephaly*,[14] *benign enlargement of the subarachnoid spaces*,[15,16] and *macrocephaly*.[17,18] The condition is referred to as BEH in the following discussion.

Many of these names indicate a benign condition; BEH may, however, be associated with cognitive problems[3,19] or have considerably more severe consequences, including a predisposition for subdural hematomas (SDHs).[14,16,20-33] This predisposition for SDH does not appear to be well-understood by many of the physicians who deal with child abuse. Moreover, the scientific evidence supporting a causal connection between nonaccidental trauma and SDH in infants is at best scant.

This article describes two pairs of dizygotic twins with nearly identical histories. Both twin pairs were born preterm just three weeks apart; each pair consisted of a boy and a girl, and most importantly, the boys, but not the girls, developed symptoms of increased intracranial pressure (ICP). All the children were diagnosed with wide subdural-blood-containing fluid collections, mainly over the frontal lobes, and medical expert witnesses told the court that all four children had been subjected to violent shaking. As a consequence one parent was sentenced to 1.5 years in jail and all four children were taken from their biological parents and raised in foster homes for more than three years until appeal courts decided in favor of the parents.

These children are by no means unique, but they may serve to illustrate some important points concerning BEH and "shaken baby syndrome" or abusive head trauma, including some striking epidemiologic similarities. In addition to documenting these four children, this contribution reviews the literature on the shaken baby syndrome or abusive head trauma with an emphasis on the possibility that some infants with BEH might be mistaken for shaken baby syndrome.

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Patient Descriptions

The first twins

These twins were delivered vaginally four weeks preterm after an otherwise uncomplicated pregnancy and delivery. The girl (head birth) was born first and her brother later in breech presentation; their birth weights were 2500 and 2600 g, respectively. Their psychomotor development was unremarkable during the first months, except for the boy's tendency to regurgitate or vomit when he was fed, until he became acutely ill at age three months and three weeks.

Boy 1

According to his father, who was alone with the twins and was feeding his son water from a bottle, the boy suddenly vomited

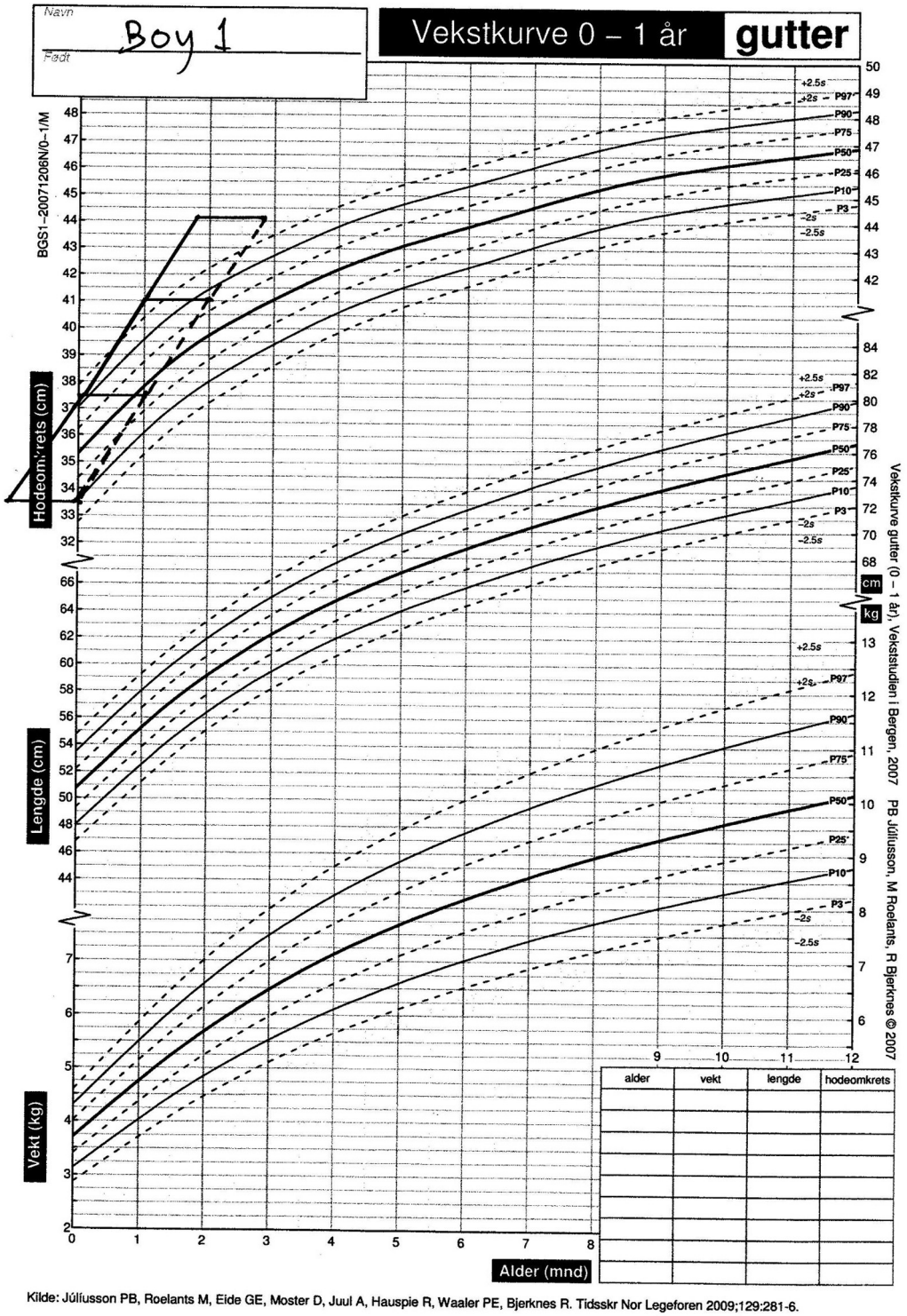

FIGURE 1. Boy 1: head circumference (HC) chart. Stippled line, HC curve not corrected for four weeks prematurity; fully drawn line, HC corrected for prematurity.

vigorously, became stiff, and stretched out his arms and legs in spasms, after which he stopped breathing and turned blue. An on-call doctor arrived 15 minutes later, finding the baby to be pulseless, cyanotic, and with rudimentary, gasping respiratory movements. Heart and lung resuscitation was initiated with chest compression and mask ventilation. After a short while, normal electrocardiographic complexes appeared, but he was still pulseless. He was intubated, ventilated, and brought to the hospital's pediatric department two hours after the acute incident; he then had a pale, greyish skin color; was hypothermic (33.6°C); and had a tense fontanel. There was no sign of direct impact to the head. On admission his HC had increased nearly 3 cm since the last measurement two weeks earlier and now measured 44 cm (Fig 1). Arterial pH was 7.24 and his base excess was −12. He was gradually warmed to 36.5°C. Computed tomography (CT) the next day showed fluid collections in widely enlarged subdural spaces, especially in the frontal region, with higher density than cerebrospinal fluid (CSF), but only a few, minor acute blood clots (Fig 2). The initial radiological description listed external hydrocephalus as a diagnosis; this was later abandoned, and the CT was finally described as showing a "large subdural hematoma," SDH.

Child abuse was suspected. A total skeleton x-ray evaluation revealed no fractures; he had no bruises or subcutaneous hematomas. Ophthalmoscopy showed bilateral, extensive retinal hemorrhages (RH).

He was sedated and ventilated in the intensive care unit while gradually being warmed, and the following morning he started breathing spontaneously, began opening his eyes, and exhibited spontaneous movements. Because of this apparent clinical improvement, extubation was planned, but later postponed due to airway edema; laryngoscopy revealed severe edema of the epiglottis. Regurgitation and larynx spasm was suspected as the underlying cause of the acute episode the day before.

The next morning (the second day after the acute incident), his condition deteriorated. He no longer had spontaneous movements and did not respond to pinching.

Magnetic resonance imaging (MRI) the following day confirmed the CT findings (Fig 3). Because of his poor condition, still unconscious with no response to pain stimuli, a decompressive neurosurgical procedure was performed with bilateral opening of the dura. At the first dural incision, fluid under "markedly increased pressure" escaped; the fluid was described by the neurosurgeon as clear and straw-colored, without visible blood components.

Based on the radiological description of "a large subdural hematoma" and bilateral retinal hemorrhages (RH), the case was reported to the child protection team and the police, followed by a charge of child abuse against his father. The medical experts in the lower court (forensic medicine, ophthalmology, and pediatrics) testified in favor of child abuse, disregarding the perioperative finding of only clear fluid without visible blood. The father was sentenced to 1.5 years in jail but appealed the verdict. Both twins were taken from the parents and raised in foster homes for the next three years.

The boy had sustained severe brain injury; the follow-up MRI was described as follows: "*The restricted diffusion as seen here is a finding that in nearly all cases can be taken as a sign of severe lack of oxygen and an early permanent brain damage*" (the author's translation from Norwegian). The boy is permanently vegetative.

Girl 1

His twin sister was hospitalized and examined to find out if she also had been subjected to abuse. There was no external sign of inflicted injury, and CT and MRI scans revealed large extracerebral spaces, described as subdural fluid collections "compatible with bilateral hematomas" (Fig 4). A skeleton radiological evaluation revealed no fractures, and ophthalmoscopy was normal. The prosecutor did not include her in the legal process, but the medical experts were of the opinion that she too had been subjected to shaking. Her long-term outcome was good.

The appeal court

In the appeal court, the author was appointed expert witness in addition to those from the primary court, who still favored the abuse explanation. The father was found *not* guilty, as the court accepted BEH and associated complications as a more likely cause of the condition than physical abuse.

The second pair of twins

These twins, a boy and a girl, were delivered vaginally nearly five weeks preterm, just three weeks before the birth of the first

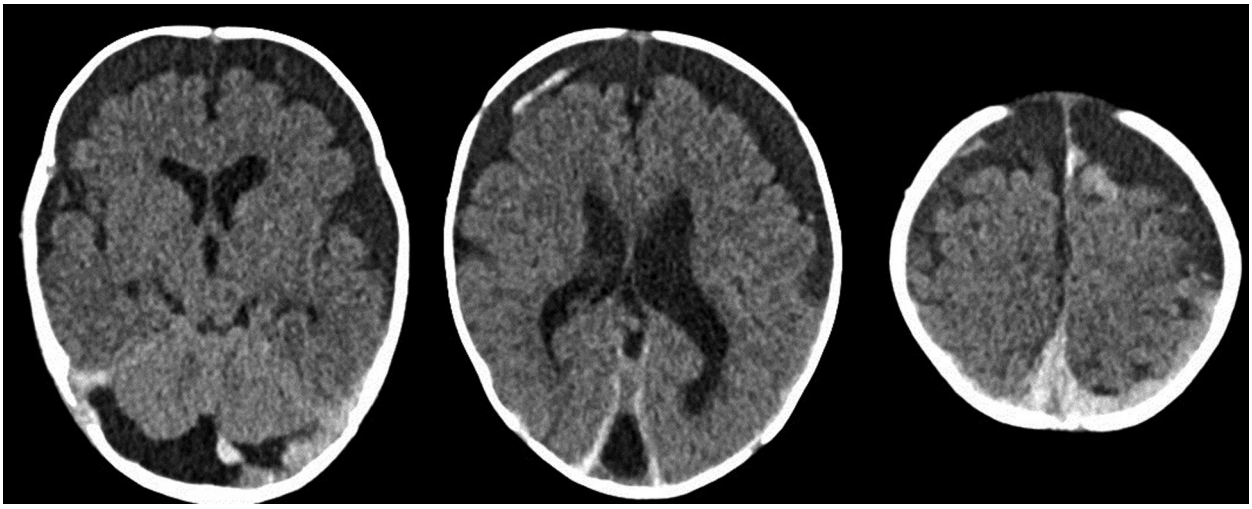

FIGURE 2. Boy 1, aged three months and three weeks. Initial computed tomographic scan the day after the alleged shaking, showing typical features for benign external hydrocephalus: moderately enlarged ventricular system, enlarged extracerebral fluid spaces, and a widened frontal interhemispheric fissure. In addition, the boy had a mega cisterna magna in the posterior fossa with a small acute blood clot, a streak of coagulated extracerebral blood in the right frontal region, and increased density in the subdural fluid collections, mostly on the left side.

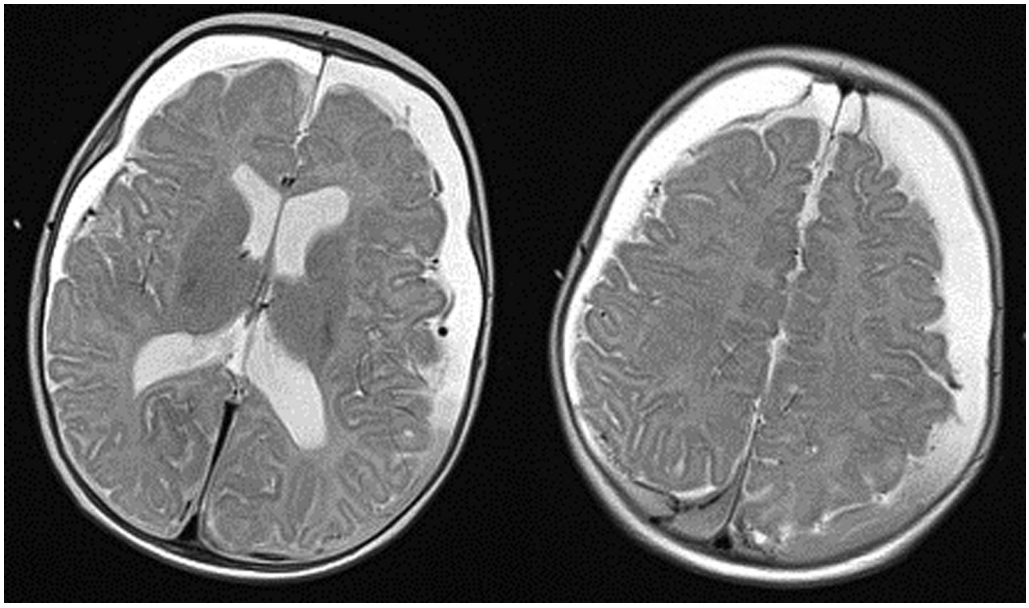

FIGURE 3. Boy 1. Initial T2 magnetic resonance imaging two days after the alleged shaking, showing in principle the same benign external hydrocephalus features as the CT the day before (Fig. 1). Note that the brain appears "suspended" in frontal bridging veins and that there is a signal intensity difference between the subdural fluid (white over the frontal cortex, darker further posteriorly) and the thin brim of cerebrospinal fluid (CSF) close to the brain and the intraventricular CSF. Note that the extracerebral fluid collections do not compress the brain surface or the lateral ventricles or cause a midline shift, despite the fact that the collections are much wider on the left side.

pair of twins, both in a breech position; birth weights were 2095 and 2120 g. The boy had postnatal respiratory problems and was therefore hospitalized for 10 days. After that, both children had normal psychomotor development until age three months.

Boy 2

He had a brief seizure (minutes) with symmetrical convulsions in the extremities and reduced consciousness at age three months. The next morning he had similar, longer-lasting seizures in series. His father managed to record these seizures on his mobile phone, and a neuropediatrician diagnosed the seizures as epilepsy. He remained unconscious and was acutely hospitalized.

On admission, his general condition was described as "reduced" and he was irritable and crying. His forehead was bulging; he had a slight sunset gaze and tense fontanel. The HC measured 40.5 cm upon admission, but increased more than 1 cm during the first week, thus crossing two to three percentiles, reaching the ninety-seventh percentile corrected for prematurity (Fig 5).

He had no bruises or other external indications of injury. On the third day, MRI and CT scans were performed. The CT scan showed "*a subdural haematoma/fluid collection with a definitely*

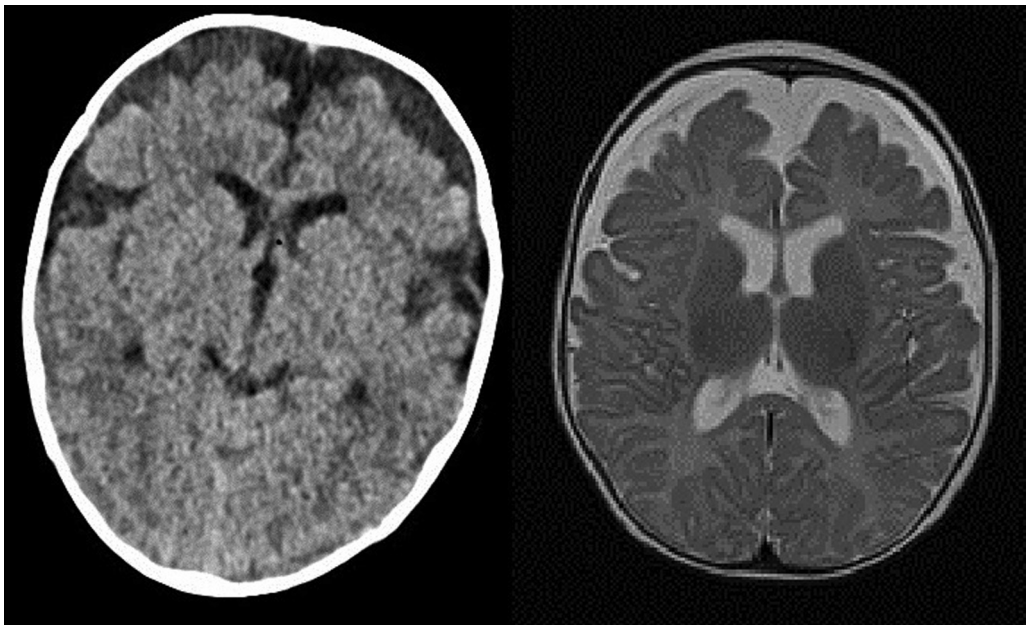

FIGURE 4. Girl 1, aged four months. Computed tomographic (left) and magnetic resonance imaging (MRI) (right) scans showing radiological features consistent with benign external hydrocephalus. The MRI scan reveals a thin bilateral subdural fluid compartment (white) and a thicker layer of cerebrospinal fluid compared with her twin brother.

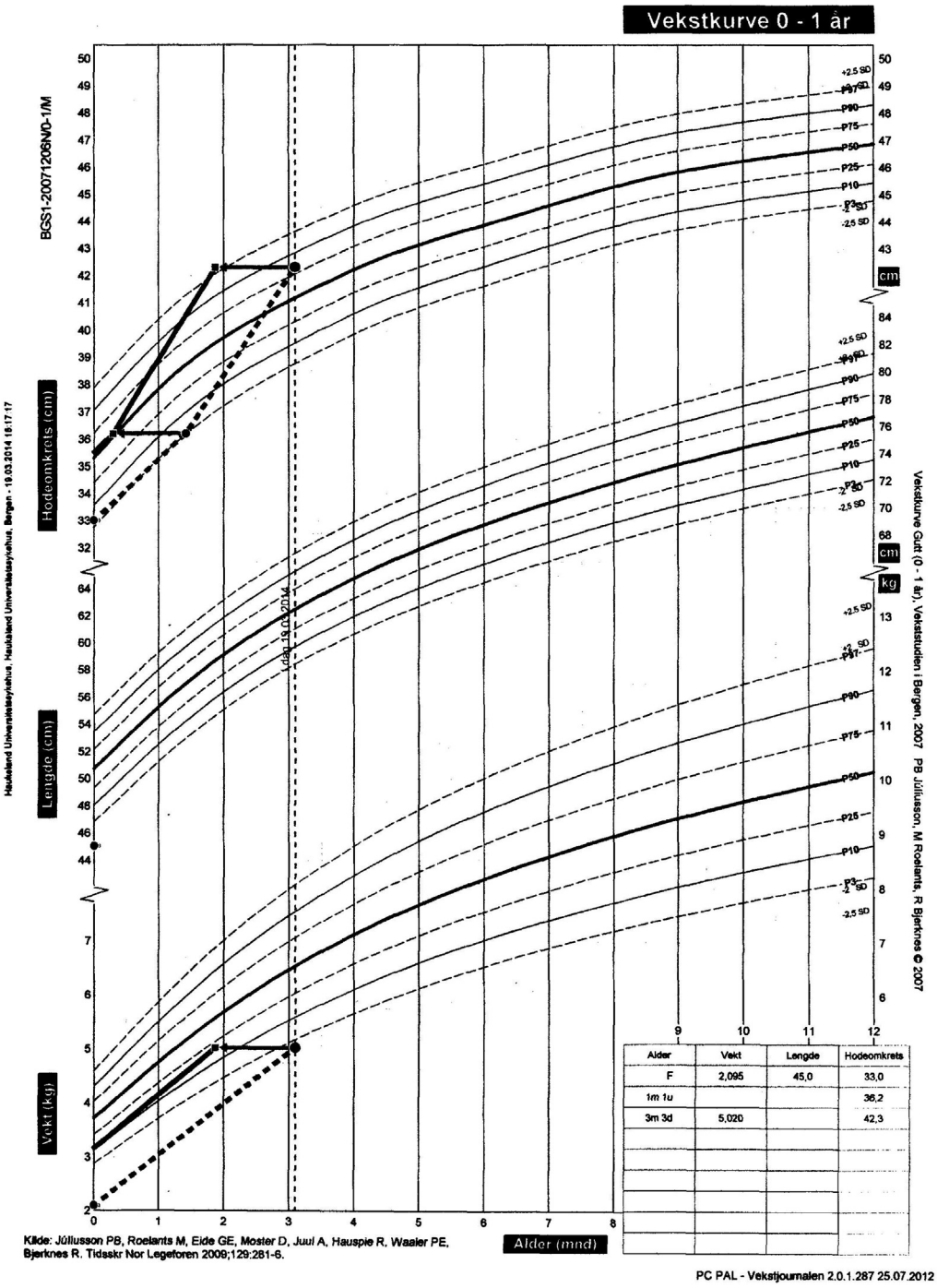

FIGURE 5. Boy 2: head circumference (HC) chart. Stippled line, HC curve not corrected for 4.5 weeks prematurity; fully drawn line, HC corrected for prematurity.

higher density than CSF, but lower density than cerebral cortex (hypodense/isodense) with hyperdense stripes in the frontal subdural space, probably representing fresh blood in the subdural space" (the author's translation). The MRI scan was interpreted as showing the same, with the age of the hematomas estimated as two to three days to a few weeks (Fig 6). Twelve plain skeleton X-rays revealed no fractures.

Fundoscopy disclosed multiple RH in several layers of retina in one eye but only two minor peripheral bleedings in the other, the conclusion being "*findings compatible with retinal haemorrhages as seen in the shaken-baby syndrome, although it is atypical that the extent of bleedings is so different in the two eyes*" (the author's translation).

Girl 2

On suspicion his sister was hospitalized and subjected to extensive physical and neuroimaging examinations. These were all normal, except for the MRI that was described as "*bilateral subdural haematomas … without a plausible explanation, therefore one must suspect non–accidental injury*" (the author's translation, Fig 7).

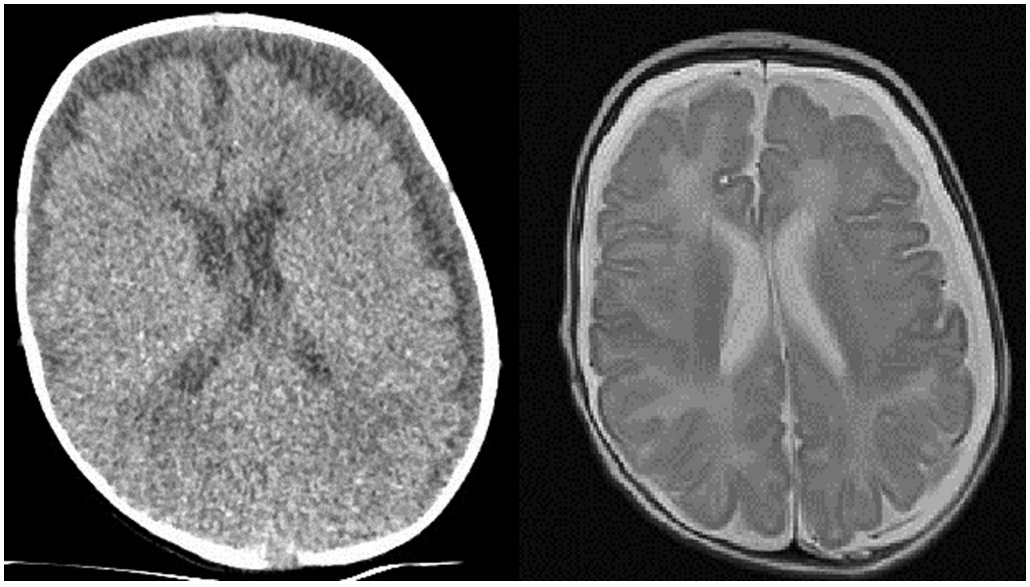

FIGURE 6. Boy 2, aged three months. Computed tomographic (CT) (left) and magnetic resonance imaging (MRI) (right) scans three days after admission, showing a subdural fluid collection with a higher density than the cerebrospinal fluid on CT and a brighter signal on MRI. Please note the relatively wide extracerebral space and the fact that the fluid collection neither compresses the cortex or the ventricles nor shows any other signs of being expansive.

Child protection authorities and police were notified, and both infants were routinely placed in a foster home, where they remained for the next three years.

The appeal court

The police found it difficult to prove physical abuse and rested the case. The child protection authorities, however, insisted on keeping the children separated from their parents. A lower court had decided in favor of the parents, but the child protection authorities appealed that decision and delayed the transfer of the children back to their parents for another 16 months. The appeal trial was almost identical to the one described above, with almost the same set of expert witnesses, including the present author. The court decided in favor of the biological parents, and after more than three years, the children were reunited with their parents.

Discussion

This report describes two pairs of three-month-old premature dizygotic twins who were separated from their biological parents for three years under the assumption that they had been subjected to vigorous shaking. This assumption was based solely on neuroimaging findings of extracerebral or subdural fluid collections

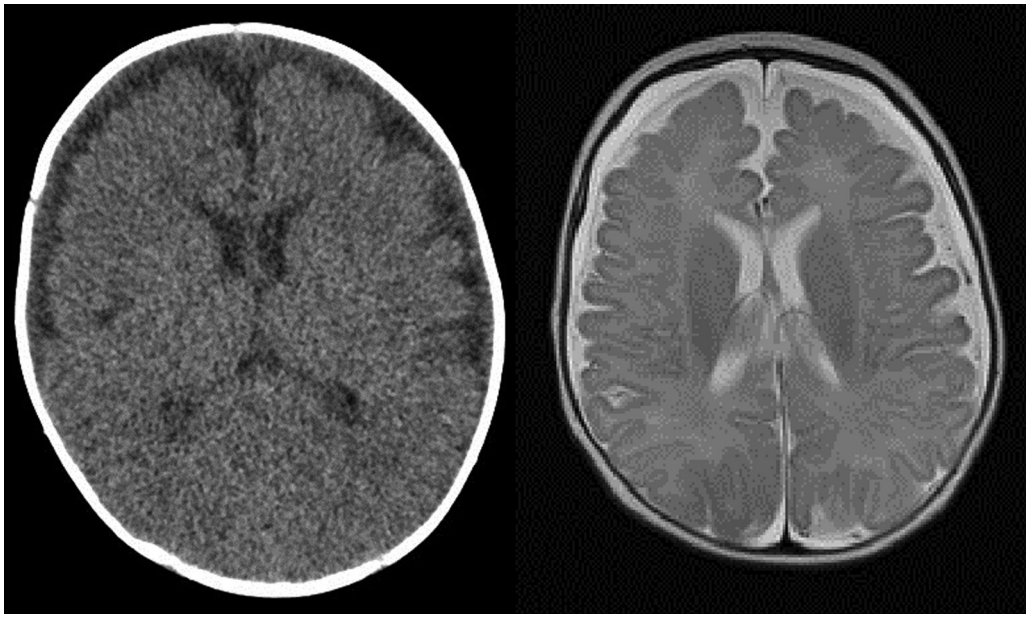

FIGURE 7. Girl 2, aged three months. Computed tomographic (CT) (left) and magnetic resonance imaging (MRI) (right) scans showing findings similar to those in her twin brother: a subdural fluid collection with a higher density than cerebrospinal fluid on CT and with a brighter signal on MRI. The subarachnoid space underneath the white subdural fluid is relatively wide, and the subdural fluid collection does not compress the cortex or the ventricles.

described as containing chronic hematomas and small amounts of fresh blood. In addition, the boys, but not the girls, had dramatic symptom debuts and were found to have RH described as compatible with nonaccidental head injury caused by shaking. None of the twins had any sign of impact to the head or any extracranial finding indicating violence. Duhaime et al. stated in 1987 that impact is required to cause the findings of the triad.[34]

In the author's opinion, all four infants exhibited extracerebral fluid collections compatible with external hydrocephalus, as defined by several authors.[1,5,15,35-37] Most likely, their BEH condition had been complicated by spontaneous bleeding or oozing of blood products into the subdural space; BEH is known to predispose for spontaneous subdural bleedings in infants,[16,21-24,26,27,29,31,32,37-39] and this predisposition can be a pitfall in the diagnosis of abusive head trauma.[16,26,29]

Shaken baby syndrome and lack of medical evidence

These infants were diagnosed as having been shaken with the most serious consequences for their families. It therefore seems appropriate to analyze the quality of medical evidence behind the widely accepted notion that a triad consisting of SDH(s), RH, and encephalopathy[40] can be used to prove a criminal act—shaking. As in other countries, in Norway guilt has to be proven beyond reasonable doubt. The solidity of the triad as proof of a criminal act must therefore not be doubted.

It is difficult to find scientific evidence above level 3 for a causal relationship between the triad and violent shaking, as also concluded after an extensive earlier review.[41] A more recent review, based on thousands of articles, concluded as follows: "*There is limited scientific evidence that the triad and therefore its components can be associated with traumatic shaking (low quality evidence). There is insufficient scientific evidence on which to assess the diagnostic accuracy of the triad in identifying traumatic shaking (very low quality evidence)*".[42,43] No study based on *observed* shaking could be identified. Only two studies in the literature were found to be based on *confessed* shaking[44,45]; these confessions came during police custody or judicial investigations, weeks to months after the diagnosis. Confessions obtained under such circumstances are known to be encumbered with uncertainties.[46] These conclusions underline the importance of considering alternative etiologies for the triad and its findings.

BEH: a possible cause of the triad?

Subdural hematomas will inevitably raise suspicion of child abuse; SDH may, however, also appear spontaneously in infants, often precipitated by one of two congenital conditions, namely, arachnoid cysts[47,48] or BEH.[14,16,20-31,38] Several mechanisms may explain why external hydrocephalus predisposes for SDH. To me as a neurosurgeon, the most likely is leakage of small amounts of blood from where the bridging veins enter the dura. It is a common intraoperative observation that even minor manipulations of normal bridging veins during a craniotomy may cause such leakage. In external hydrocephalus, these veins may ooze blood spontaneously just because they are stretched.

Subdural hematomas also occur in newborns, especially in preterm deliveries and twins[23,49]; our twins were born four to five weeks preterm. Subdural hematomas occur more frequently after vaginal delivery than after a planned Caesarean section[50] and even more frequently after emergency Caesarean sections and forceps or vacuum-assisted deliveries.[51] These subdural blood collections may gradually develop into larger hematomas over time. There are factors in old hematomas that may induce neovascularization in the parietal hematoma membrane, and these pathologic vessels bleed easily.[52-55] Other factors disturb normal coagulation in subdural blood collections.[56,57]

Male preponderance and age in abusive head traumas, external hydrocephalus, and subdural hematomas

Male preponderance: Our group has recently found a male preponderance of 86% in a population-based epidemiologic study of BEH.[19] Others have documnted a similarly high male preponderance,[12,13,23,32,58-67] even as early as in 1944 by Ingraham and Matson.[68]

Adamsbaum et al. and Vinchon et al. also reported male preponderance in their abuse cases, 76%[44] and 64%,[45] respectively. Pooled together, these two studies show a male preponderance of 73%. A male preponderance has also been demonstrated in most published series on shaken baby syndrome or abusive head trauma. The large number (157) of infants in the two studies above renders it unlikely that this male dominance is coincidental. Moreover, in a national register study comprising 306 infants with SDHs, we have recently demonstrated that even in this cohort, there was a clear overrepresentation of males.[49]

Age: Both abusive head trauma and external hydrocephalus appear to occur very early in life, in most cases during the first six months.[44,45]

As external hydrocephalus predisposes for SDHs and as there are so many striking epidemiologic similarities, *one may question whether some infants who have been characterized as victims of shaking simply suffered from benign external hydrocephalus.*

Radiology

In the four infants presented here, the subdural collections, described as SDHs of different ages, neither reached nor flattened the underlying cortical surface; in fact a thin layer of subarachnoid CSF can be seen on the MRIs between the assumed hematoma and the normal cortical gyri. Moreover, the ventricles were not compressed as one would expect if a hematoma compressed the brain from the outside. On the contrary, the lateral ventricles were moderately increased in size, as described in numerous publications on external hydrocephalus.[2,3,5,12-14,36,39,58-61,69-71] In addition, the frontal interhemispheric fissures were widened as observed already in 1978 by Robertson et al.[5] and later described in detail by Maytal et al. as a typical feature in external hydrocephalus.[36]

To the present author, the twins' MRI and CT scans carry no resemblance to an acutely acquired traumatic hematoma. In this context, it is of interest that the Adamsbaum et al.[44] report included a CT scan (see their Fig 1) of an allegedly shaken infant; the scan appears to show the exact features of external hydrocephalus, as defined by Maytal et al.[36]: slightly widened lateral ventricles, a large extracerebral space, and widening of the frontal interhemispheric fissure. Girard et al. provided a detailed discussion of external hydrocephalus as a differential diagnosis to abusive head trauma.[72]

The only plausible explanation of the combination of an increased or rapidly growing HC, increased extracerebral fluid, and enlarged ventricles is that there is an increased ICP equally distributed within the intracranial compartments, in both the extracerebral space and the ventricles. A traumatic acute or chronic SDH would normally compress the brain, including the ventricles, and if unilateral, would cause asymmetry of the ventricles and a midline shift. These characteristic features were absent in our twins and surprisingly, also in other children published as victims of shaking.[44,73-76]

Retinal hemorrhages

Bilateral, extensive bleeding in several retinal layers has been regarded as a key feature of abusive head trauma.[77-84] However, RH

may not be pathognomonic for abusive head traumas; they can also be seen in infants not related to abuse, e.g., in a large number of healthy newborns,[85-87] in infants with "macrocephaly,"[88] after "high-risk" deliveries,[89] following acute life-threatening events,[90] and after cardiopulmonary resuscitation.[91-93] RHs have also been documented in premature infants; contrary to the rapid resolution of the bleeding one usually sees in most newborns, the bleeding in preterms tend to be long lasting.[94]

As for the rest of the triad, there is no high-quality evidence that proves a causal relationship between retinal bleedings and violent shaking. The problem lies again in the lack of objective proofs of shaking.

What are then the mechanisms behind the intraocular bleeding in infants? The most likely explanation seems to be the transmission of an increased ICP through the optic nerve sheath to the intraocular compartment, causing the Terson syndrome.[95] In a patient cohort comprising older children (three years or older), it was demonstrated that high ICP could cause retinal hemorrhage.[96] The optic nerve sheath is much shorter in infants than in older children; consequently, one would expect an increased ICP to be conveyed more easily to the eye and cause retinal bleeding in infants.

Epilepsy

Both boys described here had epileptic seizures as their first overt symptom. Epileptic seizures occur frequently in children with external hydrocephalus.[14,16,21,23,29,58,65,97-100] There are at least two good reasons for why external hydrocephalus should provoke seizures: the increased ICP and blood elements in the subdural fluid collections, most probably in combination.

Conclusions

My concern in this report is that many infants appear to be diagnosed as shaken babies without any clear signs of an inflicted trauma (impact). The scientifically weak documentation of a causal relationship between the triad and the criminal act of violent shaking without impact cannot be used as judicial evidence for child abuse, *beyond reasonable doubt*.

When suspecting the shaken baby syndrome or abusive head trauma, external hydrocephalus should always be ruled out as a possible alternative diagnosis, as this condition may have medical findings compatible with those claimed to prove violent shaking. Unfortunately, many physicians who deal with child abuse seem unfamiliar with the manifestations of benign external hydrocephalus in children.

Acknowledgments

The parents of both twin pairs approved the publication of this report.

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