Child's Nerv Syst (2002) 18:311–317
DOI 10.1007/s00381-002-0616-x

ORIGINAL PAPER

Aparna Hoskote
Peter Richards
Philip Anslow
Tony McShane

Subdural haematoma and non-accidental head injury in children

Received: 2 October 2001
Revised: 20 April 2002
Published online: 26 June 2002

A. Hoskote · T. McShane (✉)
Department of Paediatric Neurology,
John Radcliffe Hospital, Headley Way,
Headington, Oxford OX3 9DU, UK
e-mail: Tony.McShane@orh.anglox.nhs.uk
Tel.: +44-1865-220951
Fax: +44-1865-851066

P. Richards · P. Anslow
Department of Paediatric,
Neurosurgery and Neuroradiology,
The Radcliffe Infirmary, Woodstock Road,
Oxford OX2 6HE, UK

Abstract *Patients and methods:* In this retrospective study, 36 children referred to paediatric neurology and neurosurgery during April 1995-June 1998 with a diagnosis of subdural haematoma (SDH) were studied. Nine were accidental secondary to witnessed trauma and 4 were iatrogenic. Non-accidental head injury (NAHI) was suspected in the remaining 23 children. *Results:* After a full clinical, radiological and social assessment, NAHI was diagnosed in 14, lateral sinus thrombosis in 1, 2 were accepted as accidental and 6 remained unexplained. In the NAHI group (*n*=14), 12 were between 4 and 16 weeks of age, 12 (85%) had retinal haemorrhages and skeletal surveys showed evidence of additional injury in 8. Computerised tomography (CT) brain scans showed bilateral SDH in 11, and 6 had interhemispheric bleeding along with loss of grey-white differentiation. Eleven had magnetic resonance imaging (MRI), which yielded additional information in 7. Seven required intensive care, and 2 died. Twelve had surgical aspiration. In the group with no satisfactory explanation for SDH (*n*=6); 5 had neonatal problems, all except 1 were older than 5 months of age and not as ill with bilateral, old SDH. All but 1 had skeletal surveys, which were normal, and eye examination showed no retinal haemorrhages. A social services enquiry was non-contributory. *Conclusions:* SDH is frequently traumatic whether accidental or non-accidental. SDH due to NAHI tends to present before 4 months of age with an inconsistent history; the patients are more seriously ill and have other findings, such as fractures and retinal haemorrhages. A small subgroup of patients was identified who had isolated, old SDH and in whom full investigation remained inconclusive. A consistent, comprehensive approach needs to be maintained in all cases with the essential backup of detailed neuro-imaging including MRI.

Keywords Child abuse · Head trauma · Intracranial haemorrhage · Traumatic brain injury · Neuro-imaging · Shaking injury

Introduction

Subdural haematoma (SDH) is an important indicator of serious head injury, including non-accidental head injury (NAHI) of the whiplash shaking type [3, 4, 7, 12, 21]. The presence of subdural haemorrhage mandates a full investigation for NAHI in the absence of a history of significant accidental trauma [6, 7, 12, 14]. Differentiating subdural haemorrhage caused by intention versus that caused by accident can be extremely challenging [3, 13, 17, 20, 22]. There are few papers in the literature studying the full spectrum of the causes of SDH in children up to 16 years of age. This retrospective study of children referred to paediatric neurology and neurosurgery with a

diagnosis of SDH was carried out with the aim of studying the initial presentation, management and ultimate outcome and seeing how many were to be considered caused by NAHI.

Patients and methods

All children under the age of 16 years admitted with a diagnosis of SDH were retrospectively identified from the central coding department, neurosurgery database, radiology department and social services database (April 1995 to June 1998). Patient demographics, presenting history, risk factors for non-accidental injury, neuro-imaging, management and outcome, including the social outcome, were recorded. The CT and MRI scans were reviewed by P.A. and compared with the reported result. Any new information obtained from the MRI scans was noted.

Results

All together 36 patients with SDH, either isolated or as a part of the wider spectrum of intracerebral haemorrhage, were identified. The majority were tertiary referrals (*n*=29), with only 7 being from within Oxfordshire.

Two groups were identified on initial presentation (Table 1):

1. Group A (*n*=13) – witnessed accidents or obvious identifiable cause – not NAHI
2. Group B (*n*=23) – possible NAHI as no obvious identifiable cause for SDH

In Group A (*n*=13), 9 SDHs were due to witnessed trauma. Six children had been involved in road traffic accidents. One 13-year-old girl was a victim of an assault with a hammer in a public place. One 9-year-old had been injured on the head by concrete pipes whilst playing in the garden. One 14-year-old teenager had an acute, unilateral SDH in association with an arachnoid cyst probably triggered by a "head banging" (shaking) dance. Two SDHs were subsequent to insertion of ventriculo-peritoneal shunts and another 2 were related to severe birth trauma in the immediate neonatal period – both being instrumental deliveries and presenting within 72 h of birth. One was following a ventouse extraction; the patient presented at 13 h of age with fits and posterior fossa bleeding. The other SDH occurred after a traumatic forceps delivery with a lateral convexity SDH.

Group B (*n*=23) consisted of children in whom there was no obvious identifiable cause for the SDH and therefore NAHI was suspected. A full clinical, radiological and social assessment was carried out, and NAHI seemed very likely in 14 children (Table 2). In 1 child, lateral sinus thrombosis on CT was misinterpreted by the local radiologist as being a posterior subdural bleed and in 2 an accidental cause was accepted (Table 3). Six cases of SDH remained unexplained (Table 4).

The 8-month-old infant with lateral sinus thrombosis presented with fits and reduced level of consciousness.

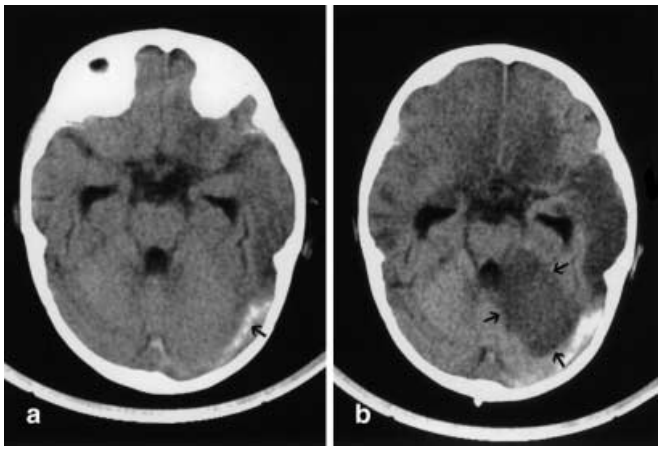

Fig. 1 **a** CT scan misinterpreted as posterior fossa subdural haematoma (SDH), but in fact showing thrombus in the lateral sinus (*arrow*). **b** CT scan a day later shows the presence of thrombus, with extensive infarction of the cerebellum (*arrows*)

Table 1 Distribution of subdural haematoma (SDH) in two groups on initial presentation: Group A – witnessed accidents or obvious identifiable cause – not non-accidental head injury (*NAHI*), and Group B – possible NAHI as no obvious identifiable cause for SDH (*VP* ventriculo-peritoneal)

Group A (*n*=13)		Group B (*n*=23)	
Road traffic accidents	6	NAHI	14
Assault	1	Lateral sinus thrombosis	1
Head injury	1	Accidental	2
Head banging dance	1	Unexplained	6
Iatrogenic			
Post VP shunt insertion	2		
Post birth trauma	2		

The diagnosis of SDH was based on a misinterpreted first scan (Fig. 1a), and he had a full work-up for NAHI, including a skeletal survey and social services investigation. A repeat CT scan (Fig. 1b) a day later showed the presence of thrombus in the lateral sinus with extensive infarction of the brain. The radiological diagnosis was later revised. Blood cultures were positive for *Streptococcus pneumoniae*. This child died and a post mortem was not obtained.

Two cases were accepted as accidental after negative skeletal survey, ophthalmology and social investigations – an 11-month-old infant who fell off a high bed and a 5-week-old who fell out of his father's arms. The clinical presentation was judged by the supervising consultant to be consistent with the history given.

The NAHI group

In the NAHI group (*n*=14), an inconsistent history was present in all of the patients (Table 2. Four had been ini-

Table 2 SDH due to NAHI (*n*=14). Characteristics of the 14 children with SDH due to NAHI including the age, presence of inconsistent history, presence of retinal haemorrhages, skeletal survey, CT and MRI results, surgical drainage of SDH and RF score (*f* fracture, *CO* cerebral oedema, *IH* interhemispheric bleed, *RF* risk factor; *RH* retinal haemorrhages)

	Age (weeks)	Inconsistent history	Bruising	RH	Skeletal survey	CT – SDH	MRI – SDH	SDH drained	Number of RF present
1	16	Yes	No	Yes	Normal	Bilateral old + new	Subtentorial blood	Yes	3
2	16	Yes	No	Yes	Yes, multiple f (skull, humerus, rib, radius, tibia)	Bilateral, new	Not done	Yes	4
3	12	Yes	No	No	Yes, skull f	Bilateral, old + new IH, CO	Not done	Yes	3
4	28	Yes	Yes	Yes	Yes, tibia, fibula f	Bilateral, old + new	Bilateral, old + new high signal in optic chiasm	Yes	4
5	12	Yes	No	Yes	Yes, skull f	Bilateral, old + new	Old + new subtentorial blood signal changes	Yes	4
6	4	Yes	Yes	Yes	Yes humerus, tibia f	Bilateral, new, subtentorial blood, IH, CO	Not done	Yes	5
7	16	Yes H/o of SIDS	No	No	Yes, skull f	Bilateral, old + new	Old + new signal changes	Yes	3
8	13	Yes	No	Yes	Yes, multiple f (skull, rib, femur)	Bilateral, old + new	Old + new signal changes	Yes	4
9	5	Yes	No	Yes	Normal	Bilateral, old + new	Old + new IH right frontal contusion	Yes	3
10	28	Yes	Yes	Yes	Normal	Unilateral, new, CO	Unilateral, subtentorial blood	Yes	3
11	9	Yes H/o shaking injury in sibling	No	Yes	Normal	Unilateral, new, IH, CO	Subtentorial blood, IH, laminar necrosis of cortex, shear haemorrhage	No	3
12	10	Yes, sibling died at 10 months of age	No	Yes	Normal	Bilateral, new	Bilateral, new	Yes	3
13	4	Yes	No	Yes	Normal	Unilateral, new, IH, CO	Yes, signal changes	Yes	3
14	16	Yes	Yes	Yes	Multiple f (rib, long bones)	Bilateral, old + new IH, CO	Bilateral, old + new IH	No	5

Table 3 SDH – other causes (accidental 2 and lateral sinus thrombosis 1). Characteristics of the 3 children with SDH due to other causes, including the age, presence of inconsistent history, presence of retinal haemorrhages, skeletal survey, CT results, Child Protection Team (CPT) investigation outcome, surgical drainage of SDH and RF score

	Age (weeks)	Inconsistent history	Bruising	RH	Skeletal survey	CT – SDH	CPT outcome	SDH drained	Number of RF present
1	5	Yes	No	No	Normal	Bilateral, old	Accidental	Yes, SDP shunt	2
2	44	No	No	No	Normal	Unilateral, new	Accidental	Yes	0
3	32	No	No	No	Normal	Posterior SDH second scan – lateral sinus thrombosis – *Streptococcus pneumoniae* positive	Not NAI	No	0

Table 4 Unexplained SDH (*n*=6). Characteristics of the 6 children with unexplained SDH including the age, birth details, presence of retinal haemorrhages, skeletal survey, CT and MRI results, surgical drainage of SDH and RF score (*LSCS* lower segment caesarean section, *NOL* non-progression of labour, *IVH* intra-ventricular haemorrhage)

Number	Age (weeks)	Birth details	Bruising	RH	Skeletal survey	CT	MRI	SDH drained	Number of RF present
1	32	Forceps preterm (31 weeks)	No	No	Normal	Bilateral, old	Yes	Yes	0
2	28	LSCS – NOL	No	No	Normal	Bilateral, old	Yes	Yes	0
3	7	LSCS preterm 33 weeks), IVH	No	No	Not done	Bilateral, old	Not done	Yes	1
4	20	Breech home delivery	No	No	Normal	Not done	Bilateral, old	Yes	0
5	44	LSCS	No	No	Normal	Bilateral, old	Not done	Yes	0
6	52	LSCS cephalohaematoma	No	No	Normal	Bilateral, old	Delayed myelination	No	0

tially treated as meningitis patients, resulting in a delayed diagnosis. All were less than 7 months of age, the majority (*n*=12) being between 4 and 16 weeks of age. Only 4 had documented bruising, and 5 had an enlarged head circumference above the 90th percentile. Formal eye examination by a senior ophthalmologist revealed retinal haemorrhages in 12. Special clotting studies in liaison with the regional haemophilia centre were carried out in 12, and all were negative. All had skeletal surveys revealing fractures in 8. Five had skull fractures. Long bone fractures were seen in 5, 3 of whom had additional rib fractures.

On CT scans, bilateral SDH was present in 11 and unilateral in 3, whilst 6 had inter-hemispheric bleeding along with loss of grey/white differentiation. In 8, there was a new bleed in addition to an old SDH. MRI scanning was done in 11. In 7, the MRI scans yielded additional information by contributing to the possible age of the SDH on the basis of signal changes. Signal changes in the optic tract were noted in 1 patient, with possible implications for vision.

Seven were admitted to the Intensive Care Unit, and all required ventilation. Of these, 6 had seizures, which were difficult to control; and 4 required intracranial pressure monitoring. Aspiration of the SDH was performed in 12.

Further enquiry revealed a sibling death (SIDS) in 1 case of SDH and unexplained neurological illness in older siblings in a further 2, which were in retrospect probably non-accidental in origin. A retrospective review of the post-mortem pathology of the child with reported SIDS showed optic nerve sheath haemorrhages. Of the 2 children with unexplained neurological illness, 1 was being treated for unexplained hydrocephalus after an encephalopathic illness, and retrospective examination of the first scan showed parafalcine blood (Fig. 2) with the subsequent development of ex vacuo hydrocephalus. The other had an episode of unexplained floppiness and apnoea, again due to possible shaking injury, and had been taken into care.

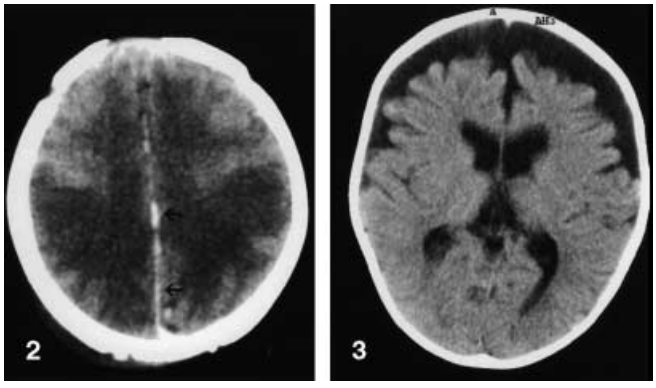

Fig. 2 Previous scan of the sibling of one of the patients in this series who had unexplained hydrocephalus. CT on day 1 shows extensive loss of grey-white differentiation and parafalcine blood. Note a cutaneous soft tissue swelling posteriorly (*arrows*). In retrospect it is most probably NAHI

Fig. 3 Bilateral chronic SDHs – a close differential to benign enlargement of the subarachnoid spaces

Two in the NAHI group died and the remaining 12 were put on the 'at risk' register, 5 were placed with extended family, 4 were placed with a foster family and 3 were returned to their family after rehabilitation. In 7, there has been limited information available on the neurodevelopmental outcome, although 1 has been left with profound neurological disability.

Unexplained – the group with no satisfactory explanation for SDH

Neonatal problems were noted in 5 out of the 6 (Table 4): 2 preterm (31/40, 33/40), 1 prolonged labour (26 h, right occipito-posterior position), 1 precipitous breech delivery at home and 1 large cephalohaematoma. Their ages ranged from 1.5–13 months, with 5 being

Table 5 Probability of NAHI with the presence of associated risk factors. Positive predictive value of the SDH being NAHI if any one, two and three or more of the following risk factors – age less than 12 weeks, inconsistent history, retinal haemorrhages, positive skeletal survey and unexplained bruising were found

	NAHI	Not NAHI	Total	Positive predictive value (%)
Three or more RF	14	0	14	100
Two or more RF	14	1	15	93
One or more RF	14	2	17	82

more than 5 months of age. All had head circumference above the 97th percentile with bilateral, old SDH seen on scans (CT in 5, MRI in 4). The CT scan in 1 case (Fig. 3) was highly suggestive of benign enlargement of the subarachnoid spaces, but blood-stained fluid was aspirated on tapping and an MRI scan at a later date showed subdural effusions. All but 1, who had been born prematurely with intraventricular bleeding, had skeletal surveys, which were normal. Eye examination did not reveal any retinal haemorrhages. Social services enquiries were non-contributory with no subsequent concerns. None were put on the 'at risk' register. Aspiration of SDH was carried out in 5.

Scoring system with risk factors for the possibility of NAHI

When SDH was present with certain risk factors (RF) the probability of NAHI increased (Table 5). These risk factors were: age less than 12 weeks, inconsistent history, retinal haemorrhages, positive skeletal survey and unexplained bruising. All 23 patients in whom there was no obvious, identifiable cause for SDH were scored from 1 to 5 depending on the number of RF present. The NAHI group scored 3 or more, the unexplained group scored 0 except for 1 patient, and in the 'other causes' group 1 patient scored 2.

Discussion

Head trauma from child abuse is a major cause of morbidity and mortality [2, 7, 8, 11, 17]. Subdural haematoma is rare following accidental injury, whereas it is one of the most common manifestations of head trauma in abused children [3, 17, 21]. Unlike subarachnoid haemorrhage, spontaneous SDH has rarely been reported in the presence of clotting disorders [15, 19].

In our series of SDH in children up to 16 years of age, NAHI was considered the most likely cause of SDH in 14 of the 36 (39%). Jayawant et al. [12] found a much higher incidence in their study – 27 of 33 (82%), which reflects their study population of children less than 2 years of age in whom it is known that there is a high risk of NAHI [3]. In contrast, Sunderland [20] found a high incidence of SDH following cerebral tumours that was almost equal in number to those due to NAHI: 22 out of 108 (20%). Although we provide a regional neuro-oncology service, we have not seen any SDH in association with cerebral tumours.

Traumatic SDH, though rare, is recognised in the neonatal period. It is believed that SDH may occur after apparently atraumatic deliveries, including caesarean sections, and that birth events may be relevant up to 3–4 weeks of age [14]. It is uncertain up to what age an event at birth could account for a subsequent subdural bleed. It is not known whether or at what rate SDH occurs in asymptomatic neonates after traumatic or normal deliveries. Two infants in our study presented with birth-related SDH; 1 presented with uncontrolled seizures with a large posterior fossa bleed and needed to have emergency evacuation of the bleed, and the other infant had a small lateral convexity SDH associated with a depressed skull fracture. The baby was clinically well, and the finding of a subdural haemorrhage was a surprise. Posterior fossa SDHs are rare, and though surgery is lifesaving there is a variable neurodevelopmental outcome [16]. Spontaneous or post-traumatic haemorrhage related to an arachnoid cyst is rare but has been reported in teenagers [18]. We have not come across any reports of similar SDHs caused by a head banging/shaking dance.

In the absence of any documented trauma, the possibility of NAHI needs to be seriously considered in any child with subdural haemorrhage, particularly in the presence of other unexplained injuries. However, there may be little or no evidence of external cranial trauma [4, 13]. In the NAHI group, only 4 had evidence of bruising and 5 had associated skull fractures supporting the shake plus impact model of injury [8]. A family history of an unexplained neurological event, which was positive in 3 of our patients, is an invaluable clue. Retrospective post-mortem identification of optic nerve sheath haemorrhages suggested a severe shaking injury [10], and this was helpful information in the investigation. All of the patients with NAHI had retinal haemorrhages except for 2. Retinal haemorrhages in the presence of an unexplained SDH are highly indicative of NAHI, especially a shaking injury [5, 8, 9, 10, 11, 17]. Though they can occur in accidental head injury, their presence is a major distinguishing factor of NAHI [5, 7, 8, 9, 12, 14, 21, 22]. We found that scoring of the five risk factors strengthened confirmation of NAHI. The positive predictive value for the probability of SDH being due to NAHI increased from 82% to 93% and to 100% if one, two and three or more risk factors, respectively, were present. The diagnosis of NAHI was considered definite when supported by confirmatory court proceedings.

In our series, 11 in the NAHI group and 4 in the unexplained group had MRI scans. In the former group this

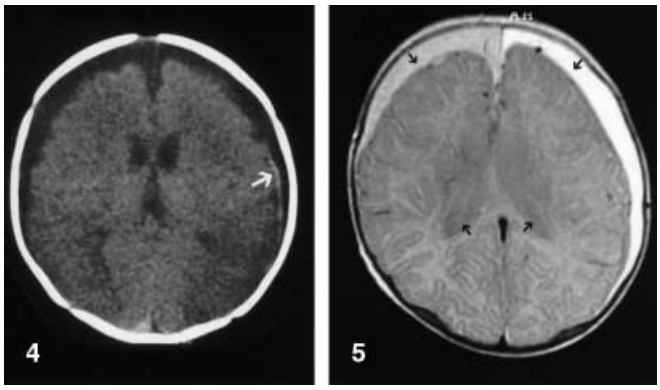

Fig. 4 Patient with bilateral chronic SDH. Note the difference in density between ventricular cerebrospinal fluid (CSF) and subdural fluid. Note also the more acute SDH on the left (*arrow*)

Fig. 5 The proton density (PD) sequence is especially useful in discriminating chronic subdural collections from benign enlargement of the extra-axial fluid spaces. Note the high signal subdural collection (different signal on 2 sides – *top left and right arrows*). The CSF signal is different from both subdural collections and isodense to the normal brain (*middle left* and *right arrows*)

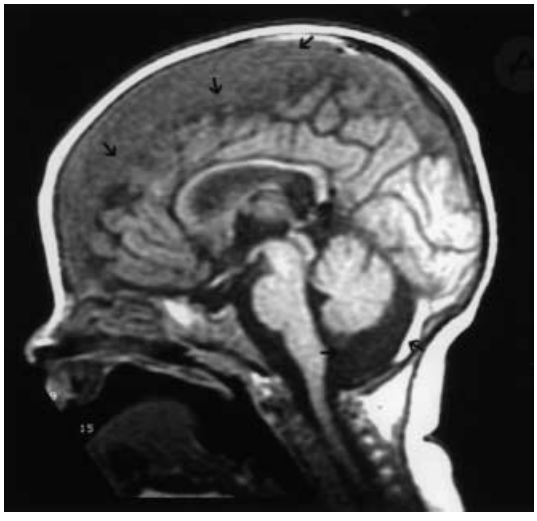

Fig. 6 MRI scan showing subacute subdural haemorrhage layering under the tentorium (*bottom arrow on the right*), acute on chronic parafalcine subdural (*top arrows*) and subarachnoid fluid in an enlarged cisterna magna (*bottom arrow* on the *left*)

added information for predicting the age of the SDH by virtue of different signal changes (Fig. 4) and in the latter group it confirmed the chronic subdural bleeds with the added information of delayed myelination in 1 patient. Proton density (PD) images help delineate the age of the SDH by clearly showing the different densities of blood (Fig. 5). Interhemispheric bleeding is accepted as an early and specific finding in intracranial bleeds caused by shaking [23]. In addition, subtentorial blood was seen in 5 of the MRI scans (Fig. 6). This finding is relatively common in NAI, rare in accidental trauma and may be another, more specific, feature that is useful for diagnosing NAHI. CT is the imaging modality of choice in the initial investigation of the encephalopathic infant. It is easily performed and widely available and has a high sensitivity for detecting intracranial bleeds. MRI is an essential second investigation; best performed 5–10 days after the insult, when it can reliably differentiate between acute and chronic subdural collections. It can also give information regarding parenchymal damage and shearing injuries [1, 23]. In our centre, scans are obtained in three planes using a minimum of three sequences.

1. Sagittal T1-weighted sequences – sensitively detect fresh subtentorial SDH and subacute blood elsewhere in the cranium
2. Axial T2-weighted sequences – best for parenchymal damage and parafalcine haematoma
3. Coronal PD for detecting convexity subdural bleeds

The coronal plane is best adapted to the diagnosis of subdural collections. The PD sequence is designed to place the signal of CSF at the same signal as grey matter. Proteinaceous CSF (from an old SDH) is almost always highlighted against a grey background (Fig. 5). Gradient echo scans are similarly very sensitive to blood breakdown products and also help to differentiate SDH from benign enlargement of the subarachnoid spaces. The latter is a close differential to SDH and may be seen frequently in the 1st year of life as a normal feature of head growth.

This study highlights the possibility that subdural bleeds may be missed, mistaken or misinterpreted, as illustrated in examples in this series (Figs. 2, 3, 1, respectively). Small SDHs may be missed, and some may be mistaken for prominent extra-axial cerebrospinal fluid spaces and vice versa. MRI is particularly useful in these situations, especially prior to any surgical intervention. Examination of aspirate for cells and protein can help in the differentiation of SDH from prominent extra-axial cerebrospinal fluid spaces.

Some subdural haematomas may remain unexplained even after detailed investigations. In our series, 6 (16%) remained unexplained in spite of detailed investigations. All had significant neonatal events. Jayawant et al. [12] found 5 (15%) patients in whom there was no evidence of NAHI and therefore the SDH remained unexplained, but no neonatal history is available for comparison. In his series, Sunderland found 7 that could not be explained (6%), and 20 were chronic due to unspecified causes [20].

The authors feel that there is a need for consistency of approach in the management of subdural haematomas, especially in those where there is no obvious accidental cause. All children with SDH should have a comprehensive medical examination, special coagulation studies in

addition to routine clotting screen, skeletal survey and specific neuro-imaging with CT and MRI. Identification of risk factors as described in this series is further helpful for estimating the probability of possible NAHI. The authors unanimously feel that MRI is an essential part of the investigation and that PD images can be used to advantage for further clarification, especially in acute or chronic haematomas.

There is no doubt that interpretation of subdural haematomas is challenging for medical experts. Not all SDHs are due to abuse, and it is equally important to absolve as to incriminate. Though it is mandatory to rule out NAHI in all children with SDH, it is important to bear in mind that subdural collections can occur in association with other causes, as seen in this series, and that some may remain unexplained.

Conclusions

1. SDH is frequently traumatic and either accidental or non-accidental
2. In the group that were unexplained on initial presentation (n=23), 14 were due to NAHI. The useful predictors for NAHI were age less than 16 weeks, inconsistent history, presence of retinal haemorrhages, positive skeletal survey and unexplained bruising
3. Some may be missed, mistaken or misinterpreted, and some may remain unexplained. We identified a small subgroup of patients with isolated, old SDH in whom full investigation remained inconclusive
4. A comprehensive history, medical examination, special clotting studies, thorough imaging and an appropriate social investigation are crucial and mandatory in all children with subdural bleeds
5. MRI is emerging as an essential part of the investigation into unexplained subdural bleeds

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