Frequency and natural history of subdural haemorrhages in babies and relation to obstetric factors

E H Whitby, P D Griffiths, S Rutter, M F Smith, A Sprigg, P Ohadike, N P Davies, A S Rigby, M N Paley

Summary

Background Subdural haematomas are thought to be uncommon in babies born at term. This view is mainly based on findings in symptomatic neonates and babies in whom subdural haemorrhages are detected fortuitously. We aimed to establish the frequency of subdural haemorrhages in asymptomatic term neonates; to study the natural history of such subdural haematomas; and to ascertain which obstetric factors, if any, are associated with presence of subdural haematoma.

Methods We did a prospective study in babies who were born in the Jessop wing of the Central Sheffield University Hospitals between March, 2001, and November, 2002. We scanned neonates with a 0·2 T magnetic resonance machine.

Findings 111 babies underwent MRI in this study. 49 were born by normal vertex delivery without instrumentation, 25 by caesarean section, four with forceps, 13 ventouse, 18 failed ventouse leading to forceps, one failed ventouse leading to caesarean section, and one failed forceps leading to caesarean section. Nine babies had subdural haemorrhages: three were normal vaginal deliveries (risk 6·1%), five were delivered by forceps after an attempted ventouse delivery (27·8%), and one had a traumatic ventouse delivery (7·7%). All babies with subdural haemorrhage were assessed clinically but no intervention was needed. All were rescanned at 4 weeks and haematomas had completely resolved.

Interpretation Presence of unilateral and bilateral subdural haemorrhage is not necessarily indicative of excessive birth trauma.

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Section of Academic Radiology, University of Sheffield, Sheffield, UK (E H Whitby FFRRCSI, Prof P D Griffiths FRCR, Prof M N Paley PhD)**; Department of Radiology, Sheffield Children's Hospital, Sheffield** (A Sprigg FRCR)**; Department of Cardiology, University of Hull, Kingston-upon-Hull, UK** (A S Rigby MSc)**; and Department of Obstetrics and Gynaecology** (S Rutter MRCOG, N P Davies MRCOG) **and Regional Neonatal Intensive Care Unit** (M F Smith FRCPCH, P Ohadike MRCPCH)**, Jessop wing, Central Sheffield Teaching Hospitals, Sheffield**

Correspondence to: Dr Elspeth Whitby, Academic Radiology, MRI Department, Floor C, Royal Hallamshire Hospital, Glossop Road, Sheffield S10 2JF, UK
(e-mail: e.whitby@sheffield.ac.uk)

Introduction

Subdural haemorrhages in infants are sometimes associated with non-accidental head injury. Occasionally, this sign is the only manifestation of child abuse. In such cases, it is usual defence in a court of law to claim that haematomas were a result of an injury sustained at delivery but not recognised at the time. To our knowledge, no studies have been done to establish the frequency of clinically silent subdural haemorrhages in liveborn term infants as a result of delivery, and natural history of these haematomas is unknown. We aimed to establish if asymptomatic subdural haemorrhages arise after delivery, to assess their frequency, and to ascertain their resolution.

Participants and methods

Participants

Between March, 2001, and November, 2002, we undertook an MRI study of subdural haematomas in normal-term asymptomatic babies born in the Jessop wing of the Central Sheffield University Hospitals. A paediatrician (PO) approached all mothers of term newborn babies on postnatal wards and provided them with verbal information and a written information sheet about the study and left them to think about participation. The same paediatrician revisited them later that day and, if they were willing to take part, obtained their written consent. Preterm babies and neonates with symptoms of encephalopathy were excluded from the study. We also imaged babies with symptomatic subdural haemorrhages, and these results have been used for clinical comparison. The local ethics committee approved the study.

All scans were done within 48 h of delivery. Ophthalmoscopy was not done. All babies in whom we detected subdural haematomas were followed up with MRI until they had completely resolved: parents were immediately informed. A consultant paediatrician (MS) saw the parents and baby before discharge. All babies were rescanned at 4 weeks of age and were reviewed in clinic at the same visit (MS). They were also seen in the clinic at 6 months and 2 years of age (MS).

Procedures

We scanned all babies with a specialist magnetic resonance system (InnerVision MRI, London, UK), a permanent magnet system, operating at 0·2 T (7·2 MHz), using 15 mT/m gradients, installed in a modular screened enclosure (1·5×1 m) within a small room (4×2·5 m) on the neonatal intensive care unit. The system was passively shimmed to achieve a 16 cm uniform field (5 ppm full-width half maximum). We used magnetic resonance compatible pulse oximetry (MR 3500, MR Resources, Florida, USA) to assess blood oxygen saturation and pulse rate through an infrared probe. All monitoring equipment leads were fed

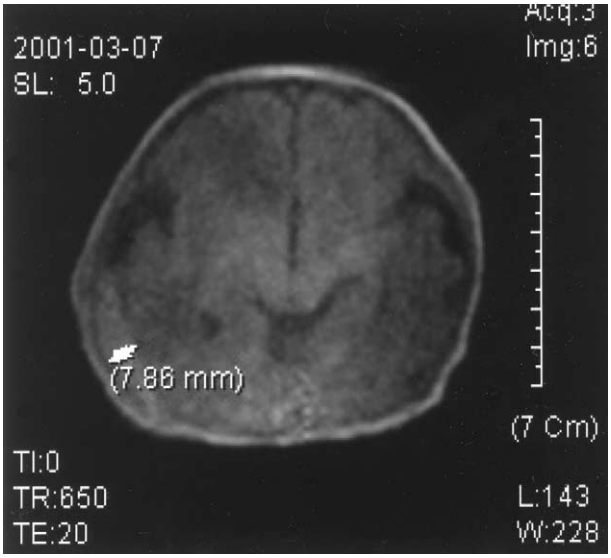

Figure 1: **Measurement of maximum depth of subdural haemorrhage in axial plane**

through waveguides into the enclosure. We obtained T1-weighted images in axial and coronal sections and T2-weighted images in coronal planes. In-plane resolution of images was 1 mm, and we obtained 5-mm thick slices. We imaged babies without use of sedation or anaesthesia.

A skilled neonatal radiologist (EW) masked to obstetric details and method of delivery interpreted scans and measured subdural haemorrhage maximum depth in the axial plane (figure 1). An independent obstetrician (SR) obtained obstetric details retrospectively from patients' notes. These details included parity, whether onset of labour was spontaneous or induced, use of oxytocin, duration of first and second stages of labour, mode of delivery, and indications for operative delivery. The following details were noted: position and station of the fetal head, degree of caput and moulding (at delivery, noted by attending staff as either present or absent), presence or absence of meconium, presence of cord round the neck, Apgar scores at 1 min and 5 min, and whether paediatric resuscitation was needed. The obstetrician was masked to results of the MRI scan.

Statistical analysis

We analysed data by Student's *t* tests for continuous variables and categorical data by calculating odds ratios with 95% CIs. We also presented risks (%). We set a nominal level of 5% significance. When more than 50% of data were missing, we did not do formal statistical analysis—eg, for cord pH. Normal vaginal delivery was used as the baseline for statistical analysis.

Role of the funding source

The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

111 babies were scanned, which represents about 40% of parents approached about the study (n=278 in total). Nine babies had subdural haemorrhages, which were clinically silent at the time of diagnosis and remained so throughout the study. All haematomas had resolved by

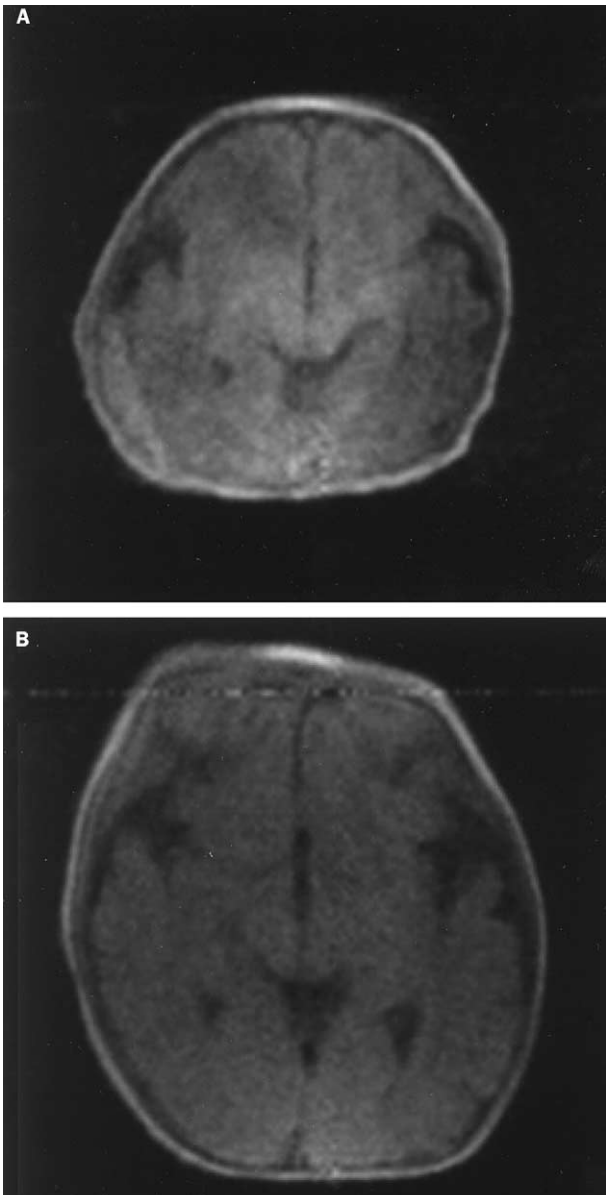

Figure 2: **Baby with (A) acute subdural haemorrhage and (B) complete resolution at 4 weeks**
This neonate was delivered by forceps after an attempted ventouse delivery.

	Number of cases	Number of haema-tomas	Risk (%)	Odds ratio (95% CI)	p
Normal vertex delivery	49	3	6·1	1·0	..
Emergency caesarean section	9	0	0	..	..
Elective caesarean section	16	0	0	..	..
Ventouse only	13	1	7·7	1·28 (0·12–13·4)	0·8377
Forceps only	4	0	0	..	..
Failed ventouse to forceps	18	5	27·8	5·9 (1·24–28)	0·0154
Failed ventouse or forceps to emergency caesarean section	2	0	0	..	..

Odds ratios are relative to normal vertex delivery.

Table 1: **Risk of subdural haemorrhage related to mode of delivery**

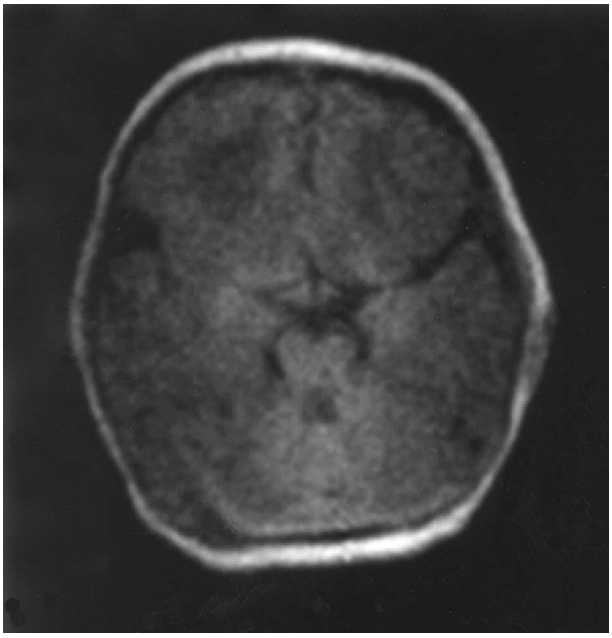

Figure 3: **Acute subdural haemorrhage after a normal vaginal delivery**

4 weeks. On formal clinical neurological testing, these babies were normal.

49 were born by normal vertex delivery without instrumentation, 25 by caesarean section, four with forceps, 13 ventouse, 18 failed ventouse leading to forceps, one failed ventouse leading to caesarean section, and one failed forceps leading to caesarean section. Babies with and without subdural haemorrhages did not differ by various obstetric factors apart from method of delivery and Apgar score at 1 min. Those delivered by forceps after attempted ventouse delivery were more likely to have a subdural haemorrhage than by any other method of delivery (figure 2, table 1). One baby was delivered after many attempts with a silicone and metal ventouse cup. In three babies, subdural haemorrhages happened after normal delivery without instrumentation (figure 3). None of the 25 babies born by caesarean section (16 elective and nine emergency) in this study had subdural haematoma on MRI. Babies with haemorrhages had lower Apgar scores at 1 min than did those without, but no difference was noted for Apgar score at 5 min (table 2).

Mode of delivery was independent of duration of second stage of labour, presence or absence of caput and moulding, Apgar scores, and fetal position. Table 3 shows birthweight, mode of delivery, and size and location of subdural haemorrhages. Maximum depth of infratentorial bleeds in the axial plane was 2–7 mm (mean 4·1 mm [SD 1·73]) and of supratentorial bleeds 1–10 mm (mean 5·3 mm [SD 4·51]). One neonate had an infarction in the right parietal lobe (figure 4).

During the same period, three other babies had clinical signs and symptoms that prompted investigation, and subdural haemorrhages were detected. These haematomas were bilateral in two and unilateral in one, supratentorial in two, and infratentorial in three. Maximum depth in the axial plane was 3 mm and 5 mm in the infratentorial compartment and 7 mm and 8 mm in the supratentorial compartment (table 4).

In both groups of neonates (asymptomatic and symptomatic), the supratentorial component was in a posterior location over the occipital or parietal lobes. No subdural haemorrhages were located over the frontal lobes. Of the nine infants with asymptomatic subdural haemorrhages, one had isolated supratentorial haematomas, six had isolated infratentorial haematomas, and two had subdural haemorrhages in both compartments.

Discussion

We have shown that clinically silent subdural haemorrhages do arise in the newborn at term. Most, but not all, are associated with an instrumental delivery. All haemorrhages were small and resolved completely by

	Subdural absent	Subdural present	Mean difference (95% CI)	Odds ratio (95% CI)
Continuous variable				
First stage of labour (h)	6·3	7·5	–1·2 (–4·4 to 2·0)	..
Second stage of labour (h)	1·4	1·3	0·1 (–0·9 to 1·2)	..
Apgar at 1 min	8·5	6·0	2·5 (1·5 to 3·5)	..
Apgar at 5 min	9·1	8·0	1·1 (0·5 to 1·7)	..
Birthweight (g)	3374	3724	–350 (–713 to 3·1)	..
Categorical variable				
Meconium staining				
No	95	9	..	1·0
Yes	7	0	..	0·7 (0·04 to 13·2)
Caput degree				
0	72	7	..	1·0
1	17	1	..	0·6 (0·07 to 5·3)
2	13	1	..	0·8 (0·09 to 7·0)
Moulding				
0	94	7	..	1·0
1+	8	2	..	3·4 (0·6 to 18·9)
Cord around neck				
No	94	7	..	1·0
Yes	8	2	..	3·4 (0·6 to 18·9)
Oxytocin				
No	75	8	..	1·0
Yes	27	1	..	0·4 (0·04 to 2·9)
Parity				
0	39	4	..	1·0
1	26	4	..	1·5 (0·3 to 6·5)
2+	16	0	..	0·3 (0·02 to 5·8)
Not known	21	1	..	0·5 (0·05 to 4·4)

Table 2: **Association of subdural haemorrhage with other variables**

	Weight (g)	Delivery achieved and reason	Subdural haematoma		Parity	Duration of second stage	Apgar score at 1 min and 5 min
			Maximum depth (mm)	Area of brain affected			
Case							
1	3700	Normal vertex delivery	4	Bilateral cerebellar	1	20 min	8, 10
2	3728	Normal vertex delivery	5	Bilateral cerebellar	1	31 min	2, 3
3	4000	Normal vertex delivery	3	Bilateral cerebellar	0	1 h 5 min	9, 10
4	3862	Traumatic ventouse; prolonged second stage	6	Left cerebellar	1	2 h 45 min	9, 9
5	2840	Neville Barnes forceps, failed ventouse	10	Parietal lobe, right-sided	0	2 h 40 min	9, 9
6	3478	Neville Barnes forceps, failed ventouse	5	Right occipital, left occipital and parietal	0	55 min	6, 9
			7	Bilateral cerebellar; parietal infarct			
7	4220	Neville Barnes forceps, failed ventouse	1	Left parietal	0	2 h 58 min	4, 6
			3	Bilateral cerebellar			
8	3569	Neville Barnes forceps, failed ventouse	2	Bilateral cerebellar	1	1 h 43 min	6, 8
9	4125	Neville Barnes forceps, failed ventouse	3	Bilateral cerebellar	1	1 h 45 min	2, 4

Table 3: **Neonates with asymptomatic subdural haemorrhages**

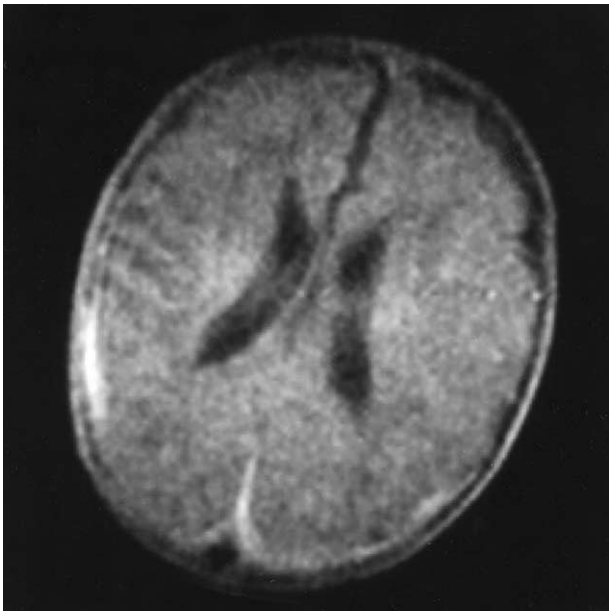

Figure 4: **Acute subdural haemorrhage and parietal lobe infarction**
This neonate was delivered by forceps after an attempted ventouse delivery.

4 weeks of age; their clinical significance, if any, remains to be established. Presence of a subdural haemorrhage seems to be independent of obstetric factors apart from method of delivery. Previously, subdural haemorrhages have been thought to be caused by a difficult delivery[1,2] or abnormal labour.[3] Possible mechanisms include tears in the falx and tentorium or bridging cortical veins secondary to stretching.[4]

A relation might exist between presence of a clinically silent subdural haemorrhage and some methods of delivery—ie, failed ventouse followed by forceps delivery or a difficult ventouse delivery—that is independent of the length of second stage of labour. The type of cup used for ventouse delivery did not seem to be associated with risk of a subdural haematoma. We did not detect a subdural haemorrhage in any babies delivered by forceps, only when a previous attempt at a ventouse delivery had been made. The relevance of this finding is uncertain, but forceps blades and the ventouse cup apply force to the fetal head in different anatomical regions: the combination of forces could be very damaging, or the degree of obstruction to delivery might be great. Also, the attempted ventouse extraction may have caused a bleed before application of forceps.

Some reports have suggested occurrence of antenatal subdural haemorrhages, but there is usually history of trauma,[5] although not in all cases.[6] A few cases have been reported of small subdural haemorrhages in symptomatic neonates after an atraumatic spontaneous normal vertex vaginal delivery.[7] In all these cases, the baby had abnormal clinical findings within the first few days of life. Chamnanvanakij and colleagues[7] postulated that the cause of the clinical symptoms was not attributable to the blood, but probably to coexistent cerebral injury not visible on imaging with CT. We only noted one case with coexistent cerebral injury visible on MRI in all babies imaged, including those with clinical symptoms—this area was of focal infarction, not diffuse hypoxic ischaemic injury.[8–10] This finding contrasts with the pattern seen in non-accidental head injury.

The locations of subdural haematomas in asymptomatic babies differed from those typically reported in non-accidental head injury.[11] In our group, haemorrhages were usually infratentorial (overlying cerebellar hemispheres), whereas in infants with non-accidental head injury, subdural haemorrhages are

	Weight (g)	Delivery achieved	Maximum transverse diameter of bleed (mm)	Area of brain affected	Parity	Second stage	Apgar score at 1 and 5 min
Case							
1	3154	Ventouse	5	Bilateral cerebellar hemispheres	0	52 min	3, 7
			7	Bilateral occipital, temporal and parietal			
2	2095	First twin, forceps	8	Unilateral, right side, occipital, temporal, parietal	0	1 h 15 min	8, 9
3	4880	Emergency caesarean section for uterine rupture	3	Bilateral cerebellar	1	2 h 50 min	9, 10

Table 4: **Symptomatic neonates**

more typically supratentorial—bilateral or inter-hemispheric.[4] Haematomas related to non-accidental head injury can be reported at this infratentorial site; however, they are difficult to see on CT and can be overlooked.

This study is important from the aspect of non-accidental head injury: in a court of law, the defence may claim that an isolated subdural haemorrhage presenting in later infancy is due to a birth injury. Babies with subdural haemorrhage in this study were followed up until age 2 years. A subsequent MRI scan at age 4 weeks showed complete resolution of the haematoma in all babies. Therefore, these lesions seem to be benign, clinically asymptomatic, and of no long-term importance.

The medicolegal implications for the finding of asymptomatic isolated subdural haemorrhages in infants older than 4 weeks of age, in whom there is suspicion of non-accidental head injury, are important. In most cases, associated findings will lend support to a diagnosis of non-accidental injury—eg, metaphyseal fractures, bruising, retinal changes, and cerebral parenchymal changes.[12] In infants in whom an apparently isolated subdural haemorrhage is reported, the diagnosis of non-accidental head injury is generally questioned. Even in infants with an isolated subdural haemorrhage and no other findings, child protection issues need to be looked at, because the child could be at risk of further injury.

MRI was chosen for this study because this technique is more sensitive for some pathological findings than ultrasound.[13] It is particularly useful for peripheral and posterior fossa subdural haematomas, and we suspected that most haemorrhages would arise in these areas, on the basis of previous work with this scanner.[13] The 1·5 T magnetic resonance machines in our institution are physically remote from the neonatal unit, which made it impractical to scan babies on these machines. A 0·2 T magnetic resonance scanner is situated on the neonatal intensive care unit, so transport to the scanner and paediatric support was readily available. Unlike standard 1·5 T scanners, the 0·2 T scanner is very quiet. Parents can sit adjacent to the scanner throughout the imaging time. Because it is a dedicated machine on the neonatal unit, time pressures are less than those of larger radiology departmental magnetic resonance machines, and we were able to image around babies' care needs.

Acute subdural collections are difficult to detect by MRI and some acute subdural haemorrhages could have been missed in this study. Imaging was done within 48 h because most patients are discharged within this length of time. Appearances on MRI of neonatal haemorrhage can differ from that in adults because they may change intensity faster than adult blood. Difference in signal intensity is possible because of differing haemoglobin concentrations, proportion of fetal versus adult haemoglobin, and magnetic resonance field strength.[14]

We had about a 40% uptake of parents approached to join the study. The remaining 60% either refused to join (the majority) or were discharged home before the scan could be done. Many normal deliveries are discharged within 6 h of birth, which affected our ability to recruit from this group. In about 2% of cases, the baby was too unsettled to obtain images of diagnostic quality and parents did not want to repeat the scan at another time—these were excluded from the study.

The population group is biased, because methods of delivery reported in this study do not reflect the general population of the hospital. At our institution, the operative delivery rate was 33·7% (7·3% emergency caesarean section, 10·1% elective caesarean section, 5·5% forceps, 10·8% ventouse). This bias was unavoidable because we were relying on parental consent and bias reflects choice of the parents. A parent who perceives that they have had a difficult delivery is more likely to join the study than those who have had an easy delivery. Babies delivered normally were recruited from those being admitted to the postnatal ward rather than going home at 6 h direct from the labour ward, which gives a potential bias in the normal delivery group. Another bias is the high proportion of babies delivered by forceps after failed ventouse, which may create bias towards a higher incidence of subdural haemorrhage in our cohort. We recognise the bias in this study, including the few babies with subdural haemorrhage on MRI. A larger cohort should improve validity of our observations.

Contributors

E H Whitby had the initial idea for and designed the study, obtained ethics approval, and interpreted images and analysed data. P D Griffiths had the initial idea for the study, helped interpret images, and wrote the report. S Rutter had a role in study design, coordinated the obstetric component, and obtained and helped to interpret data. A Sprigg was involved in study design, ethics submission, and manuscript preparation. M F Smith had a role in study design, followed up patients in the clinical setting, and prepared the manuscript. P Ohadike was involved in recruitment, data collection, and manuscript preparation. A Rigby had a role in statistical analysis of data. N P Davies was involved in study design, collection of data, coordination of the obstetric component, and manuscript preparation. M N Paley had a role in study design and image analysis and acquisition, provided physics support for the imaging process, and was involved in manuscript preparation. All authors have seen and approved the final version of the manuscript, including all alterations.

Conflict of interest statement

MNP is a managing director of InnerVision, the company that manufactures the magnetic resonance scanner. The remaining authors have no conflict of interest.

Acknowledgments

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References

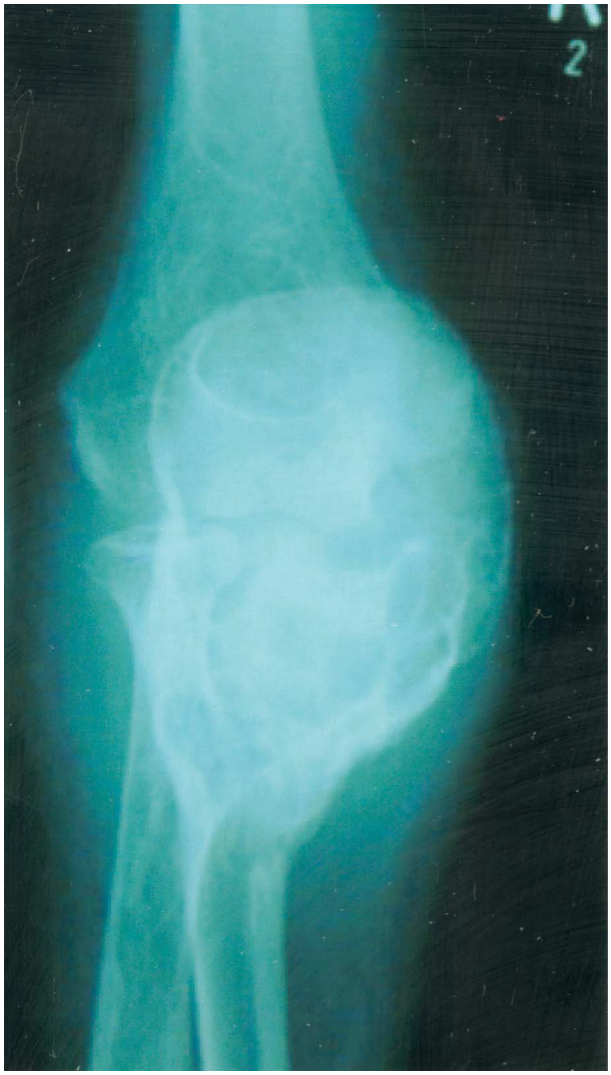
1 Doward W, Sgouros S. Acute subdural haematomas following ventouse-assisted delivery. *Pediatr Neurosurg* 2001; **35:** 335.
2 Pollina J, Dias MS, Li V, Kachurek D, Arbesman M. Cranial birth injuries in term newborn infants. *Pediatr Neurosurg* 2001; **35:** 113–19.
3 Towner D, Castro MA, Eby-Wilkens E, Gilbert WM. Effect of mode of delivery in nulliparous women on neonatal intracranial injury. *N Engl J Med* 1999; **341:** 1709–14.
4 Duhaime AC, Christian CW, Rorke LB, Zimmerman RA. Nonaccidental head injury in infants: the "shaken-baby syndrome". *N Engl J Med* 1998; **338:** 1822–29.
5 Stephens RP, Richardson AC, Lewin JS. Bilateral subdural hematomas in a newborn infant. *Pediatrics* 1997; **99:** 619–21.
6 Breningstall GN, Patterson RJ. Intrauterine subdural hematoma. *Pediatr Radiol* 2000; **30:** 630–31.
7 Chamnanvanakij S, Rollins N, Perlman JM. Subdural hematoma in term infants. *Pediatr Neurol* 2002; **26:** 301–04.
8 Geddes JF, Hackshaw AK, Vowles GH, Nickols CD, Whitwell HL. Neuropathology of inflicted head injury in children: I—patterns of brain damage. *Brain* 2001; **124:** 1290–98.
9 Geddes JF, Vowles GH, Hackshaw AK, Nickols CD, Scott IS, Whitwell HL. Neuropathology of inflicted head injury in children: II—microscopic brain injury in infants. *Brain* 2001; **124:** 1299–306.
10 Geddes JF, Tasker RC, Hackshaw AK, et al. Dural haemorrhage in non-traumatic infant deaths: does it explain the bleeding in 'shaken baby syndrome'? *Neuropathol Appl Neurobiol* 2003; **29:** 14–22.

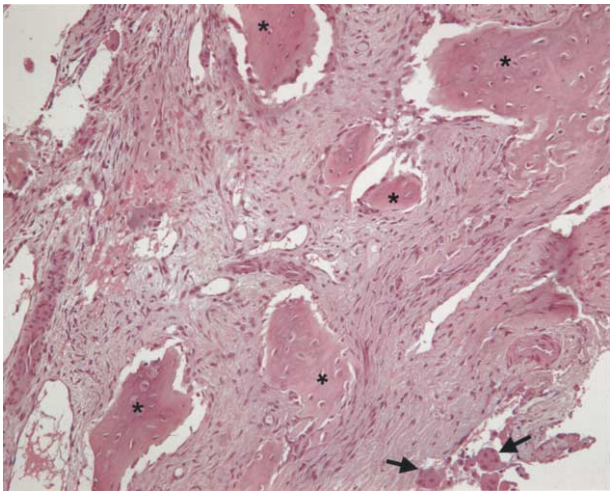
11 Barkovich AJ. Brain and spine injury in infancy and childhood. In: Barkovich AJ, ed. Pediatric neuroimaging, 3rd edn. Philadelphia: Lippincott, Williams, and Wilkins, 2000: 239.
12 Kemp AM. Investigating subdural haemorrhage in infants. *Arch Dis Child* 2002; **86:** 98–102.
13 Whitby EH, Paley MN, Smith MF, Sprigg A, Woodhouse N, Griffiths PD. Low field strength magnetic resonance imaging of the neonatal brain. *Arch Dis Child Fetal Neonatal Ed* 2003; **88:** F203–08.
14 Brooks RA, Di Chiro G, Patronas N. MR imaging of cerebral hematomas at different field strengths: theory and applications. *J Comput Assist Tomogr* 1989; **13:** 194–206.

Clinical picture

Bone tumour and haemodialysis

Christian Stefan Haas, Kerstin Amann, Johann Braun





A 59-year-old woman on haemodialysis for more than 8 years with end-stage renal disease complained of pain in her right elbow. She had a swollen joint with hot, red skin and restricted movement. A radiograph of the elbow (figure, left) showed a polycystic, demineralised tumour of the olecranon. MRI showed periarticular oedema and a joint effusion. We took a biopsy sample of the tumour and found a granulation tissue with fibroblasts, histiocytic cells, and a few plasma cells and lymphocytes, (figure, right). Numerous osteoclastic giant cells (arrows) and osteoid-rich bone fragments (asterisks) were present. As the patient had secondary hyperparathyroidism, we diagnosed an aneurysmal bone cyst, a so-called brown tumour. Parathyroidectomy improved calcium-phosphate metabolism and stopped both the enlargement of the tumour and the pain.

Departments of Internal Medicine/Nephrology (C S Haas MD) **and Pathology** (K Amann MD)**, University Erlangen-Nuernberg, D-91054 and KfH Dialysis Centre** (J Braun MD)**, Erlangen, Germany**