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ORIGINAL ARTICLE

Shaken baby syndrome in New Zealand, 2000–2002

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Aim: To describe the epidemiology of subdural haemorrhage (SDH) in New Zealand infants.

Methods: Prospective enrolment of all cases of infantile SDH from 2000 to 2002. Retrospective analysis of national discharge and death data for the same period.

Results: Seventy-seven cases of infantile SDH were identified prospectively, and a further 49 cases retrospectively. Of these 126 cases, 92 resulted from non-birth-related trauma. Forty-eight of these were attributed to abuse and 28 to accidental injury. Sixteen cases were undetermined. The 'minimum' annual incidence of inflicted infantile SDH in New Zealand is 14.7 per 100 000 (95% confidence interval(CI) 10.8–19.4), and the 'maximum' 19.6 per 100 000 (95% CI 15.1–25.0). Among Maori, the 'minimum' is 32.5 per 100 000 (95% CI 21.4–47.3), and the 'maximum' 38.5 per 100 000 (95% CI 26.3–54.4).

Conclusions: The epidemiology of infantile subdural haemorrhage in New Zealand is similar to that described elsewhere. Non-accidental head injury is a significant child health issue in New Zealand, and the incidence is particularly high among Maori.

Key words: child abuse; shaken baby syndrome; subdural hematoma; traumatic brain injury.

While subdural haemorrhage (SDH) can result from non-traumatic or accidental causes, many cases result from abuse.[1–3] The term 'shaken baby syndrome' (SBS) is often applied to such cases, although controversial, because it implies one particular mechanism of injury.[4–8] Many infants show signs of impact to the head, and for these shaken impact syndrome may be a better term.[9,10] Other terms such as non-accidental head injury (NAHI) or inflicted traumatic brain injury do not imply any specific mechanism. However, the older term remains widely known, and there is good evidence that violent shaking (with or without impact) is often involved.[11–15] We use the term SBS because it is widely recognised, not because we regard it as a precise description of the mechanisms of NAHI.

There is population-based data on the incidence of NAHI in the UK[16–18], North Carolina[19] and Canada,[20] but none from New Zealand (2001 population 3 820 749) (http://www.stats.govt.nz/census/2001-census-statistics/2001-national-summary/default.htm. Accessed 18 June 2006).

Key Points

1 In New Zealand, there is a high rate of non-accidental head injury among Maori infants.
2 In most cases of both abusive and accidental infantile head trauma, the injuries are restricted to the head alone.
3 A significant number of cases of serious head trauma in infancy may not receive an adequate assessment for child abuse.

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We aimed to describe the New Zealand incidence of infantile SDH, medical investigations, diagnoses, short-term neurological outcome and demographic characteristics, in order to guide further local research in prevention, diagnosis and treatment.

Materials and Methods

The New Zealand Paediatric Surveillance Unit (NZPSU) was established in 1997 'to operate a system for monitoring acute flaccid paralysis, as part of the global certification of eradication of poliomyelitis, required by the World Health Organisation' (WHO) (http://www.inopsu.com/index.html. Accessed 18 June 2006). Other conditions can be placed under surveillance for a specified period at the request of researchers (http://www.paediatrics.org.nz/PSNZold/nzpsu/nzpsu1.html#1. Accessed 18 June 2006).

Every New Zealand paediatrician receives a monthly card or email asking them to tick a box if they have seen any of the conditions under surveillance. Replies go to the NZPSU, which notifies the relevant investigator. The investigator then sends a questionnaire to the notifier.

Our study was approved by the Northern Regional Ethics Committee and the NZPSU Scientific Review Panel. From 1 January 2000 to 31 December 2002, SDH in infants under 2 years was on the list of conditions under surveillance. We included all neurosurgeons in 2002. The study protocol was clear that we wished to be informed of all cases of infantile SDH, regardless of cause.

The two-page questionnaire details definitions used and data requested (Fig. 1). At the time, there was little information on risk factors particular to NAHI, so we sought information identified as relevant for infant homicide.[21] Each infant was identified by a code entered by the notifier, and date of birth. Age at

NEW ZEALAND PAEDIATRIC SURVEILLANCE UNIT STUDY

Please keep a record of the child's unit number in your NZPSU folder. Please ring Dr Patrick Kelly (office: 09 3074907; locator: 09 358 0825 4770; email: patrickk@adhb.govt.nz) if you have any problems with the form. Thank you for your time.

REPORTING CLINICIAN

1. NZPSU Dr. Code ☐☐☐☐
2. Month / Year of Report...../.....

PATIENT

3. First 2 letters of first name ☐☐
4. First 2 letters of surname ☐☐
5. Date of Birth: day ☐☐ month ☐☐ year ☐☐
6. Sex M ☐ F ☐
7. Postcode ☐☐☐☐

ETHNICITY

The child's primary caregiver identifies the child as:

European ☐ Maori ☐ Pacific Islander ☐ Other ☐

If this patient is primarily cared for by another physician who you believe will report the case then there is no need to complete the remainder of this questionnaire at this stage. Please keep the patient's name and other details in your records. If no other report is received for this child we will contact you for further information

HISTORY OF INJURY

No history available ☐ No history of injury ☐
Fall ≤ 1 m ☐ Fall 1–3 m ☐ Fall > 3 m ☐
Other / comment.....

BRUISING

Head and/or neck No☐ Yes ☐
Elsewhere on body No☐ Yes ☐

SUBDURAL HAEMORRHAGE *(Tick more than one box if appropriate)*

Site Unilateral ☐ Bilateral ☐ Interhemispheric ☐
Age Chronic[1] ☐ Acute[2] ☐
Specify how this was determined to be a subdural haemorrhage rather than a non-haemorrhagic effusion or CSF collection

OTHER CENTRAL NERVOUS SYSTEM FINDINGS

Subarachnoid blood No ☐ Unknown ☐ Unilateral ☐ Bilateral ☐
Cerebral contusion No ☐ Unknown ☐ Unilateral ☐ Bilateral ☐
Cerebral oedema No ☐ Unknown ☐ Unilateral☐ Bilateral ☐
Intracerebral bleeding No ☐ Unknown ☐ Unilateral☐ Bilateral ☐
Retinal haemorrhage No ☐ Unknown ☐ Unilateral☐ Bilateral ☐
Axonal shearing injury[3] No ☐ Unknown ☐ Unilateral☐ Bilateral ☐
Cervical cord injury No ☐ Unknown ☐ Yes☐
Other (specify).....

BONY INJURY

Skull fracture (simple)[4] No ☐ Yes ☐
Skull fracture (complex)[5] No ☐ Yes ☐
Rib fracture (number) No ☐ Yes ☐ *Specify number*.....
Rib fracture (site) Post ☐ Ant/lat ☐ Post + Ant/lat ☐
Metaphyseal fracture No ☐ One ☐ Multiple ☐
Other fracture No ☐ One ☐ Multiple ☐
Different ages of fracture No ☐ Yes ☐ Unknown ☐
Other bony injury (specify) .....
OTHER INJURY *(specify)*
.....

INVESTIGATIONS

CT scan No ☐ Brain ☐ Other than head ☐
MRI No ☐ Brain ☐ Other than head ☐
Skeletal survey No ☐ Yes ☐
Bone scan No ☐ Yes ☐
FBC / PR(INR) / APTT No ☐ Yes ☐
Subdural tap No ☐ Yes ☐ Result:.....

MEDICAL DIAGNOSIS OF CAUSE OF FINDINGS

Not abuse ☐ (*Specify*).....Child abuse ☐ No definite conclusion ☐

FAMILY DEMOGRAPHICS

"Marital" status of mother Single ☐ Not single ☐ Unknown ☐
Antenatal care in this pregnancy:
None ☐ After 6 months' gestation ☐ Before and after 6 months' gestation ☐ Unknown ☐
Primary caregivers during period in which subdural probably arose:
Mother ☐ Father ☐ Mother & father ☐ Mother & partner ☐ Father & partner ☐Other family ☐
Non-relative ☐ Multiple ☐ Unknown ☐
Had this infant or their siblings ever been previously notified to CYP&FA for child abuse or neglect:
Unknown ☐ No ☐ Yes ☐ *If yes, did previous notification refer to this infant*.....
For the following demographic questions, if unknown, state unknown:
Maternal age:.....Mother's years of education.....
Paternal age:..... Father's years of education.....
Prior to this infant, number of live-born children of this mother :.....

REFERRAL TO STATUTORY AGENCIES

No referral ☐ Police ☐ CYP&FA ☐

PERPETRATOR (if diagnosis of non-accidental injury)

Mother ☐.....Father ☐..... Other family ☐.....Non-relative ☐.....Multiple ☐ Unknown ☐
Comment on how perpetrator was identified:.....

NEUROLOGICAL STATUS AT ONE WEEK FROM ADMISSION

Normal ☐ Not normal, feeding orally☐ Not normal, NG fed ☐ Dead ☐[6]

ANY OTHER COMMENTS:

[1] Chronic = no signs of acute haemorrhage on CT (collection is lower attenuation than grey matter)
[2] Acute = signs of acute haemorrhage on CT (higher attenuation than grey matter)
[3] Axonal shearing injury on MRI or postmortem
[4] None of Hobbs criteria for complex skull fracture - see footnote 5
[5] One or more of: multiple #; non-parietal #; more than one cranial bone involved; # width > 3mm; growing #; depressed #
[6] Please note below if a post-mortem was performed, and if so, the findings

Fig. 1 Paediatric Surveillance Unit Questionnaire.

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injury was calculated by date of first neuroradiology. We had no communication with the care giver and no investigations were requested.

Forensic pathologists were not surveyed. However, the design included a retrospective analysis of data provided to the New Zealand Health Information Service (NZHIS). This is the 'group within the New Zealand Ministry of Health responsible for the collection and dissemination of health-related data', and uses (among other sources) hospital discharge codes and death certificates (http://www.nzhis.govt.nz/. Accessed 18 June 2006). We intended, through data from death certificates, to include cases discovered at autopsy. We were aware that in cases of infantile SDH, death certificates may not be filed until a coroner's inquest or criminal investigation has occurred. We did not collect NZHIS data until July 2005, 2.5 years after prospective data collection ceased. At this time, we also audited our prospective method, by retrospective analysis of hospital discharges during the same period. We searched NZHIS data (death or discharge) for codes selected from the WHO International Classification of Diseases, Tenth Edition (ICD 10) (http://www.who.int/classifications/icd/en/. Accessed 18 June 2006). The codes were: P100 (SDH due to birth injury), P528 (other intracranial non-traumatic haemorrhages of fetus and newborn), I620 (SDH acute non-traumatic) and S065 (traumatic SDH). Although P528 was likely to identify infants who had conditions other than SDH, the net was spread widely to reduce the risk of under-ascertainment.

Identifying National Health Index numbers (NHI) were removed before NZHIS data were provided to us. We received a complete set of ICD codes for each patient, including E codes (information on mechanism of injury). It remained possible to match the two datasets, and thus avoid duplication. Where data were available from both sources for any case, we analysed the NZPSU dataset. Where we received more than one NZPSU notification per case, the most complete data were entered.

Data from the NZPSU were coded, entered on a spreadsheet and analysed using STATA version 8.2 (http://www.stata.com/products/overview.html. Accessed 18 June 2006). Data obtained from the NZHIS were much more limited. We merged the two datasets only for incidence, age, gender and ethnicity.

We recorded NZPSU cases as abuse when diagnosed as such by the notifier, and NZHIS cases as abuse if there was a child maltreatment code. In cases of traumatic SDH with no such code, the NZHIS dataset could not tell us whether assessment for child abuse had occurred. The absence of such a code does not mean abuse was not diagnosed.[1] We recorded NZHIS cases as accidental if the codes described a mechanism which we felt would be widely accepted as consistent.

This left a number of infants in both datasets with traumatic SDH, no diagnosis (or code) for abuse, yet no history (or code) of significant accidental trauma. In these cases, the accidental mechanisms recorded seemed below the threshold of force that one would normally expect to cause intracranial bleeding. While acknowledging that this threshold is difficult to define, if we accepted these cases at face value, we might underestimate the incidence of abusive SDH. To achieve consistency in identifying cases best regarded as indeterminate, we chose to apply Duhaime's algorithm.[10] Given the limitations of the data, we did not use the algorithm to change any diagnosis from accident to abuse.

Dr Duhaime classified infantile SDH as 'presumptive' for abuse, in three situations. First, if accompanied by unexplained or old fractures and/or inflicted soft tissue injury. Second, if the mechanism was a 'trivial fall' (<3 feet) or 'remote trauma' (remote in time), and the history was changing or developmentally incompatible. (The height of fall specified the arc through which the head travelled.) Third, if there were clinical or radiographic findings of focal impact, but no history of trauma. Regarded as suspicious (but not presumptive) was any case with no history of trauma. Dr Duhaime's algorithm does not use retinal haemorrhage (RH) as a criterion.

Our population incidence used the merged numbers as numerator, and as denominator census data for 'less than 1 year', and '1 year and under 2' (http://www.stats.govt.nz/census/2001-census-statistics/default.htm. Accessed 18 June 2006). The 'minimum' estimate included only cases diagnosed as child abuse by one or other dataset, and the 'maximum' estimate included indeterminate cases. Ethnic distribution was derived from those aged <5 years in the census, assuming this held true for infants. Ninety-five per cent confidence intervals were derived using a Poisson approximation.[22] We present other results as percentages, median (range) or odds ratios. Comparisons were done using $\chi^2$for categorical variables (with Fisher's exact for small samples), and for continuous variables with non-parametric data, Wilcoxon signed-rank.

Results

Figure 2 shows the number of cases identified. Eighty-six cases were identified from NZHIS alone, of which 37 were coded P528 (see below). Most P528 were probably not SDH. This left 49 cases of SDH not detected through the NZPSU, only two of which were deaths. The NZPSU detected 77 cases: 20 in 2000, 27 in 2001 and 30 in 2002. The combined total was 126.

SDH from birth trauma (12). Three deaths

NZHIS identified four cases from birth trauma unknown to the NZPSU. One died. Of the eight known to NZPSU, six were known to NZHIS but mis-coded as P528. From the NZPSU, three were breech, two Ventouse, one Kiellands rotation, one 27/40 with a difficult delivery and one 'birth injury/asphyxia'. Two died – one breech delivered at home, the other the 27-week infant.

Other neonatal intracranial bleeding (46). No deaths

Of the 39 NZHIS cases labelled 'other neonatal' in Figure 2, only two had a code specific for SDH (I620). One was also coded as meconium aspiration, one as 'other perinatal'.

Thirty-seven NZHIS cases were coded P528. Seventeen had complications of prematurity (extremely low birth weight, sepsis, intraventricular haemorrhage); nine had combinations of birth asphyxia, hypoglycaemia and convulsions; four had coagulopathies; two had hydrocephalus; two had complex congenital heart disease; one had hypoplastic lung; one was septic

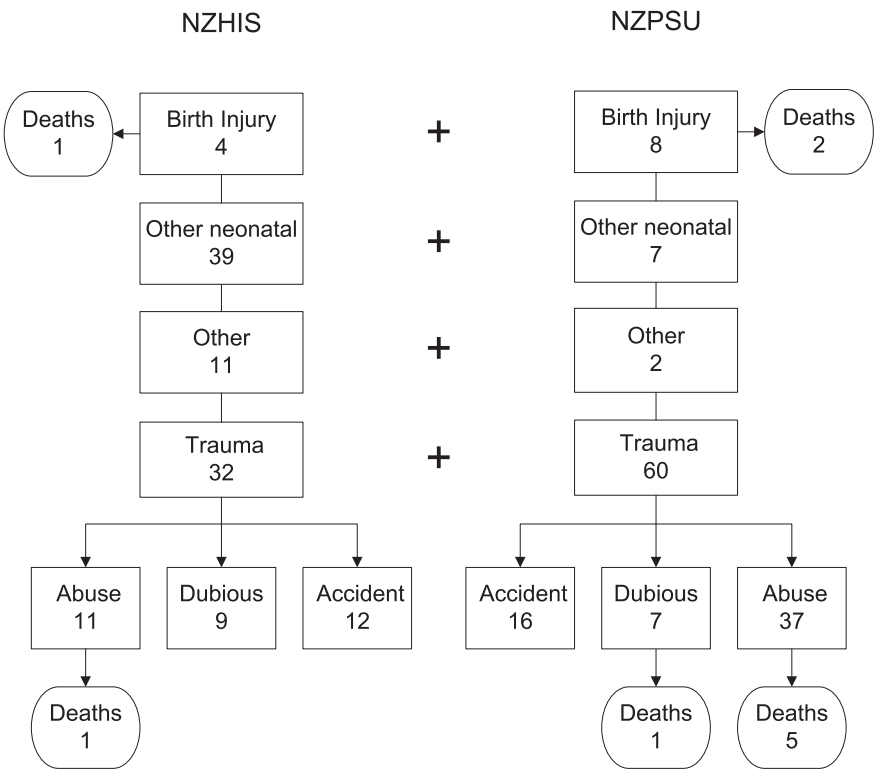

Fig. 2 Summary of cases identified by the two methods.

and one a Ventouse. Given the use of P528 in NZHIS for cases we know had SDH from birth trauma, some may have had SDH. However, it is more likely (given their other diagnoses), that most were not SDH.

Seven cases of non-traumatic neonatal SDH were reported to the NZPSU. Five had contributing factors (24 weeks with intraventricular haemorrhage, haemorrhagic disease of the newborn, neonatal sepsis, birth asphyxia and a 6-day old with complex congenital abnormalities). In another case the mother was assaulted before delivery. One case had unexplained SDH after normal delivery. None had left hospital. There was no case ascribed to antenatal massage.[23]

Other causes of SDH (13). No deaths

The NZHIS coded 11 infants with I620. Causes were meningitis (3), complicated hydrocephalus (2), and one case each of congenital malformation of the corpus callosum, haemophilia, macrocephaly and convulsions, malignancy, septicaemia and 'Sudden Infant Death Syndrome' with RH, multiorgan failure and coagulopathy. NZHIS had no death record for this infant, who may have presented as a 'near-miss' but survived. No case of glutaric aciduria was reported.

The NZPSU identified two infants with non-traumatic causes of SDH outside the neonatal period (arteriovenous malformation, meningitis).

Traumatic SDH

SDH resulting from accidental trauma (28). No deaths

Sixteen were notified to the NZPSU, but 12 (43%) were not. The accidental mechanisms are shown in Table 1. NZHIS data on mechanism was limited to E codes. In the absence of more detail (e.g. the height of falls 'from one level to another'), we chose to accept these as plausible.

Table 1 SDH resulting from accidental trauma

Nature of accident	NZPSU	NZHIS	Total
Motor vehicle accident	3	6†	9
Fall stairs	4	2	6
Fall being carried	5‡	1	6
Fall one level to another		3	3
Fall 2nd story to ground	1		1
Fall from go-cart	1		1
Fall <1 m§	2		2
Total	16	12	28

†Includes 1 car versus pedestrian. ‡Includes 1 fall from arms of a sibling. §One fell onto a fire hearth, the other onto a concrete floor. NZHIS, New Zealand Health Information Service; NZPSU, New Zealand Paediatric Surveillance Unit; SDH, subdural haemorrhage.

Further details of the findings in accidental trauma are presented alongside abuse (see below).

SDH resulting from 'dubious' accidental trauma (16). One death

Seven were notified to the NZPSU, nine (56%) were not. Table 2 lists coded mechanisms and types of additional injury, in the indeterminate NZHIS cases. Table 3 provides fuller data on the indeterminate NZPSU cases.

Table 2 SDH resulting from questionable accidental mechanisms and associated injuries (NZHIS)

Age	Nature of accident	*n*	Fracture Skull vault	Other codes
<1	Fall involving bed	2	1	
<1	Fall chair	1	1	
1–2	Fall same level, unspecified place	1	1	
<1	Fall same level, home, unspecified activity	1	1	brief loss of consciousness (<30 min)
<1	Fall other furniture, sports area	1	1	
<1	Striking against or struck other object, unspecified place	1	1	traumatic cerebral oedema, contusion head
<1	Fall involving chair home, unspecified activity	1		Anaemia, contusion head and thorax, retinal haemorrhages, seizures
<1	Exposure unspecified factor at home	1		Fracture one rib, seizures, 'spontaneous ecchymoses'

Table 3 SDH resulting from questionable mechanisms, assessed using Duhaime's criteria (NZPSU)

Age (months)	Soft tissue injury	Poor history, trivial fall	No history, focal impact	Other comments	Category (after Duhaime)
0.2	Yes		Yes		Abuse
3				7 year old fell on bouncer. No RH	Indefinite
6		Yes			Abuse
7				Fell from arms. SDH of 2 ages	Indefinite
8	Yes			High chair fell back. No RH	Indefinite
9				'Almighty thump'. Bilateral RH.	Indefinite
11	Yes		Yes		Abuse;

NZPSU, New Zealand Paediatric Surveillance Unit; RH, retinal haemorrhage; SDH, subdural haemorrhage.

Three of the seven NZPSU cases could be regarded as presumptive for abuse, using Duhaime's criteria. None had fractures. One 6-day old found dead at home had external bruising, bilateral SDH and sub-arachnoid haemorrhage, cerebral oedema and bilateral RH. The pathologist was very suspicious, but another pathologist queried a minor venous anomaly.

The uncertainties of assessment are illustrated by the 8-month infant who allegedly 'fell backwards in his high chair' after a care giver got entangled in the vacuum cleaner cord. He struck his head on the floor, sustaining a bruise to the forehead and SDH. Both datasets recorded this event. NZHIS coded the mechanism as W0709 ('fall involving chair, home, after unspecified activity'), and also coded for traumatic cerebral oedema and loss of consciousness of uncertain duration. NZPSU recorded 'no definite conclusion'. He was not reported to statutory authorities. Two months later, he died at home from multiple blows to the head, and returned to the study on a death certificate via NZHIS.

SDH from child abuse (48). Six deaths

Thirty-seven were notified to the NZPSU, 11 (23%) were not. Combining both datasets, there was no difference in age or gender. The median age in abuse was 33.3 weeks (range 5.4–113.4), and in accidents 39.4 weeks (range 1.3–101) ($P = 0.93$, Wilcoxon). The only significant difference was the over-representation of Maori among the abused (European 14/48 vs. 15/28, odds ratio (OR) 1.0; Maori 27/48 vs. 6/28, OR 4.8, 95% confidence interval (CI) 1.6–14.8; Pacific Nation 6/48 vs. 6/28, OR 1.1, 95% CI 0.3–4.0; other 1/48 vs. 1/28). Analysing NZPSU data separately, the findings were the same. Table 4 shows the 'minimum' and 'maximum' population-based incidence from this data.

All subsequent analysis was perforce restricted to NZPSU data.

In the 37 cases of abuse, there was no history of injury at all in 14. In 15 cases, the infant allegedly fell <1 m (two care givers later confessed: one to shaking, one to slapping the infant in the face). In three cases, the infant allegedly fell 1–3 m. There were no reports of falls >3 m. There was one other confession to shaking. Four other mechanisms were suggested: a 6-year old shaking a 14-month old; a 2-year old hitting a 6-month old on the face; a father bouncing a 2-month old on his knee; an 11-month infant pulling a video cassette recorder onto himself (he died).

In contrast (the NZPSU accidental group in Table 1), all 16 accidental cases had a history. There were three motor vehicle accidents, three falls >3 m, six falls 1–3 m, and four falls <1 m. One of these had momentum (an infant fell out of a go-kart under a trailer and hit his head, corroborated by a 12-year-old witness), one fell from a 7-year old's arms and struck his occiput on a wooden floor (presenting immediately), one fell from a mattress onto a concrete fire-hearth, and one had a witnessed fall on a concrete floor. Two of these had bruising to the head at site of impact. None of the four had injuries outside the head, and all were neurologically normal 7 days after admission.

Table 4 Population-based incidence of SBS

		Rates per 100 000			
Age	Ethnicity	'Minimum'	95% CI	'Maximum'	95% CI
<2 years (all)	All	14.7	10.8–19.4	19.6	15.1–25.0
	Non-Maori	8.6	5.3–13.2	13.1	9.0–18.5
	Maori	32.5	21.4–47.3	38.5	26.3–54.4
1–2 years	All	7.3	3.8–12.9	8.0	4.2–13.6
	Non-Maori	4.9	1.8–10.7	5.7	2.3–11.8
	Maori	14.6	5.3–31.8	14.6	5.3–31.8
<1 year	All	22.0	15.4–30.4	31.1	23.1–40.9
	Non-Maori	12.3	6.9–20.3	20.5	13.3–30.3
	Maori	50.0	31.0–76.4	61.9	40.5–90.7

CI, confidence interval; SBS, shaken baby syndrome.

Table 5 documents all damage to the head (external bruising, fracture, intracranial injury) in the two diagnostic groups. Injuries to the head were the only injuries found in 14 (87.5%) accidental cases, and in 24 (64.9%) cases of abuse, so in this respect there was no difference between the groups ($P = 0.09$). All 16 accidental cases, and 35 of the 37 abusive cases, had a CT head. One abused infant was dead on arrival, so had no CT. One abused infant had no CT because SDH was discovered on outpatient MRI for sixth nerve palsy. Abused infants more often had MRI (26/37 (70.3%) vs. 5/16 (31.3%) accidents, $P = 0.01$). There was no difference in the rate of surgical evacuation of SDH (9 (24.3%) cases of abuse vs. 3 (18.8%) accidental cases, $P = 0.66$).

External bruising away from the head was almost exclusive to abuse: seven of 37 (19.4%) versus one of 14 (7%) accidents. Skeletal survey occurred more often in abuse: 33 (89.2%) versus five(31.3%) accidents ($P = 0.0$). No accidents were bone-scanned, but five (13.5%) cases of abuse were. Fractures outside the head were seen only in abuse (eight cases, 21.6%), namely rib fractures in two infants (5.4%) (both also had metaphyseal fractures, one had sub-periosteal tibial bleeding), metaphyseal fractures (without other skeletal fractures) in two infants, and isolated long bone fractures in four others.

Data on family demographics are poor. Information not noted here, was not provided.

Information on care giver at time of injury was available in 12 accidents. In six cases the care givers were the mother and father, in four the mother, in one the father, and in one multiple. Of the 35 cases of abuse where information was available, in 14 the care givers were the mother and father, in five the father, in five multiple, in four the mother, in four other family members, and in four the mother and her partner. These numbers were not significantly different ($P > 0.05$). Cohabital status of the mother was recorded in 14 accidents (two single, 12 not) and 36 cases of abuse (16 single, 20 not) ($P = 0.05$). The number of previous live-born children to the mother was noted in 12 accidents (four none, four had one, two had two, and two had >2), and in 26 cases of abuse (seven none, nine had one, 10 had two, and three had >2). Full antenatal care was noted in four accidents, and in 12 cases of abuse. Data on parental age (13 mothers, eight fathers) and educational status (two mothers, no fathers) were too poor to present. Whether the family was already known to child protective services is documented in 28 cases of abuse (24 were not), and in seven cases of accident (five were not).

Table 5 Head injuries

Finding	Abuse	Accident	Odds ratio (95% CI)
Bruising to head			
Yes	17 (46.0%)	13 (81.3%)	0.2 (0.1–0.8)
No	20 (54%)	3 (18.7%)	
Skull fracture			
Yes	5 (13.5%)	13 (81.3%)	0.0 (0.0–0.2)
No	32 (86.5%)	3 (18.7%)	
Complex			
Yes	3 (60%)	5 (38.5%)	2.4 (0.3–16.9)
No	2 (40%)	8 (61.5%)	
Bilateral SDH			
Yes	19 (52.8%)	3 (18.7%)	4.6 (1.2–17.4)
No	17 (47.2%)	13 (81.3%)	
Chronic SDH			
Yes	19 (51.4%)†	0	∝ (3.3–∝)
No	18 (48.6%)	13 (100%)	
SAH			
Yes	7 (20%)	5 (31.3%)	0.6 (0.1–2.0)
No	28 (80%)	11(68.7%)	
Contusion			
Yes	8 (21.6%)	8 (50%)	0.3 (0.1–0.9)
No	29 (78.4%)	8 (50%)	
Oedema			
Yes	7 (18.9%)	5 (33.3%)	0.5 (0.1–1.7)
No	30 (81.1%)	10 (66.7%)	
RH			
Yes	25 (67.6%)	1 (14.3%)	12.5 (1.7–86.2)
No	12 (33.3%)	6 (85.7%)	

†11 of the 19 had both chronic and acute SDH. CI, confidence interval; RH, retinal haemorrhage; SAH, sub-arachnoid haemorrhage; SDH, subdural haemorrhage.

In 23 cases of abuse (62%), no perpetrator was identified at notification. In eight cases it was thought to be the father (three confessions), in three the mother (one confession), and in three an unrelated care giver.

Neurological status at 1 week was normal in 12 of 16 accidents (75%), but in only 12 of 37 cases of abuse (32%) ($P = 0.01$). Of those neurologically abnormal at 1 week, two (12.5%) of the accidental group were able to feed orally, and two (12.5%) were nasogastrically fed. In the abusive group, 16 (43%) were able to feed orally and three (8.1%) were nasogastrically fed. There were no deaths in the accidental group, but the mortality in the abusive group was five (13.5%).

Discussion

International population-based studies on the incidence of NAHI yield relatively consistent results.

Jayawant *et al*.[16] studied South Wales and south-west England retrospectively over a 3-year period, surveying ICD-9 codes, paediatric wards, neurosurgeons, coroners and expert witnesses. They also conducted a 2-year prospective study through the Welsh PSU. Their retrospective method yielded a SDH rate of 12.8 (95% CI, 5.4–20.2) per 100 000 under 2, and of 21 (95% CI, 7.5–34.4) under 1. Most were abusive, giving rates of non-accidental SDH of 10.1 (95% CI, 5.3–19.2) under 2 (retrospective), or 12.45 (95% CI, 6.4–24.1) (prospective). Barlow and Minns[17] briefly described an 18-month prospective study of NAHI in Scotland, surveying paediatric wards, paediatric intensive care units (PICU), neurosurgeons, the Death Register, and the Scottish Health Information System. There were no cases over 1. Their incidence was 24.6 (95% CI, 14.9–38.5) cases per 100 000 under one. Keenan *et al*.[19] conducted a 2-year prospective study in North Carolina, surveying PICU and medical examiners, including any intracranial injury, and using births as a denominator. Their rate was 17.0 (95% CI, 13.3–20.7) per 100 000, under 2. The rate was 29.7 (95% CI, 22.9–36.7) in infants 1 year or less, and 3.8 (95% CI, 1.3–6.4) in infants 1–2 years old. Finally, Hobbs *et al*.[18] conducted a 12-month prospective study through the British PSU (paediatricians, neurosurgeons and pathologists), and the Office of National Statistics. His overall rate of 'SDH/effusion' was 12.5 (10.3–14.6) under 2. The rate was 24.1 (95% CI, 20.9–28.2) in infants under 1, and 1.3 in infants from 1 to 2. However, the rate of NAHI was lower: 7.1 (95% CI, 6.4–9.3) under two, and 14.2 (95% CI, 12.1–17.8) under 1.

There is no single completely reliable diagnostic test for abusive head injury.[24] Not all forms of abusive head injury cause SDH, and the presence of SDH does not necessarily prove that an infant was abused. Responsible practice will always yield cases where we are sure the injury was accidental, cases where we are sure it was abusive, and cases where we just don't know.[3] The 'minimum' and 'maximum' figures in our analysis reflect the realities of clinical practice. However, even by our 'minimum' figure, our overall incidence of NAHI is similar to that obtained by Jayawant, Barlow and Keenan, and higher than that obtained by Hobbs.

The 'minimum' and 'maximum' figures were also forced upon us by the surprising number of cases not reported through the NZPSU, making it impossible to apply Duhaime's algorithm to all cases. Other studies through the NZPSU have not encountered this problem,[25] which suggests issues particular to the questionnaire or the condition. Our poorest rates of notification involved non-traumatic SDH (15%), neonatal SDH (36%) and SDH caused by accidental or equivocal trauma (52%), whereas 79% of cases of NAHI were notified. It is likely a paediatrician did see the 21% coded as NAHI but not notified, because our experience is that almost no one else commits themselves to a codeable diagnosis of abuse in infants. Among the other categories, if neonatal P528 codes were not SDH, the 'low' rate of neonatal notification may well be artefact. Some paediatricians may have assumed we were only interested in those cases where NAHI was in the differential. Some accidental or equivocal cases may have come through trauma services and not been referred to a paediatrician, although including neurosurgeons did not alter the reporting rate.

For clinical practice, the last possibility worries us most. Many cases of abusive head injury are missed.[26,27] In the absence of evidence of a thorough investigation, we regard many of the cases in Table 2 as suspicious. It is possible that inexperienced clinicians may have been falsely reassured by the absence of injuries outside the head. However, as this study shows, abusive injury (like accidental injury) may be confined to the head alone. In our view, except for cases of corroborated major accidental trauma, all cases of infantile traumatic head injury should be reviewed by a paediatrician with expertise in child protection. We suggest that this may not be the case with as many as 20% of New Zealand infants admitted with traumatic SDH.

It is reasonable to suggest that our 'minimum' incidence is less than the true incidence. The 'maximum' incidence may overestimate NAHI causing admission or death, but is still likely to underestimate infantile NAHI in New Zealand. First, our study did not look at head injuries without SDH. Second, studies suggest that up to 5.6% of parents and care givers smother, slap or shake their baby at least once in the first 6 months of life,[28] and that only one in 150 cases of NAHI end in intensive care.[29] The spectrum of damage from abuse to the head in diagnosed cases is widely variable,[30] and not all babies suffer evident brain injury. In the last 10 years in Auckland we have seen at least three babies who were shaken but showed no symptoms, and sustained no injury on detailed assessment (one mother walked in on a shaking incident, and two mothers sought help after shaking an infant). Even if brain injury occurs, it may not be recognised or help-sought. Many babies admitted have evidence of previous head injury, and of symptoms that were, in retrospect, symptoms of concussion.[26] Unrecognised or undisclosed NAHI may be a hidden contributor to many developmental and behavioural problems.[31]

The high rate of NAHI among Maori is extremely concerning, replicating an earlier study in Auckland.[1] This study, unfortunately, provides no more information as to why this should be so. Some dubious literature has suggested racial susceptibility to accidental SDH in non-Caucasian infants,[32,33] but it is more likely that ethnicity has been confounded by factors such as poverty, social isolation, young parenthood, family violence and drug and alcohol dependency.[18,19,34,35] It is noteworthy that other Pacific peoples are not over-represented, despite higher rates of physical abuse of older children.[36,37] Further research is

necessary, because even the 'minimum' incidence among Maori is one of the highest in the world.

The mortality from NAHI requiring admission is high. Our figures probably underestimate the death rate, because of delays in death certification. Only one of eight deaths notified to the NZPSU by December 2002, appeared in NZHIS data in July 2005. The other seven cases dated back to July 2000.

Our data on morbidity are limited. Neurological status at 1 week is a poor outcome measure. Delayed morbidity is common[38] and many survivors have long-term disability.[39–42] These infants are at the beginning of their lives, and cumulatively are likely to be a significant lifelong challenge for their families and communities. There have been attempts to quantify the social and economic costs of child abuse,[43,44] but few have focused on NAHI.[45]

It was disappointing, but not unexpected, that the demographic information available through the NZPSU was so poor. This replicates our earlier study on the limitations of medical records.[1] Despite the literature on risk analysis in child protection, there is little on factors particular to NAHI.[19,21,46] We cannot assume that factors affecting children old enough to disclose (in cases of family violence, neglect, physical assault or sexual abuse), will necessarily govern infantile NAHI. Abused infants are disadvantaged by the fact that data collection is spread between health, child protection and law enforcement. We will only make progress in understanding when data are collected uniformly, and prospectively, on all infants with abusive head trauma. In order to avoid selection bias and circular reasoning, a strong case can be made that all infants admitted with traumatic SDH (whatever the aetiology) become part of an ongoing clinical research project, collecting demographics, data about the injury and ongoing neurodevelopmental progress.

Death or permanent brain damage is an extremely high price for infants, their families and society to pay for the effects of a few seconds or minutes of uncontrollable rage. It would be far better, if possible, to try and prevent these injuries. Focused education of both parents in the neonatal period may be effective, for an estimated cost of $US10.00 per infant.[47] This evidence is derived from a dedicated continuing programme of nurse-led parent education, not a one-hit media campaign. It is our opinion that it is time for such an intervention to be implemented in New Zealand. Such an intervention should be evidence-based and prospectively evaluated.

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