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ORIGINAL ARTICLE

# Injury from falls in infants under one year

Christopher S Mulligan,[1,2,3,4] Susan Adams,[1,3,4] Dimitra Tzioumi[1,3] and Julie Brown[4,5]

[1]School of Women's and Children's Health, [2]Prince of Wales Clinical School, and [5]Medical Sciences, University of New South Wales, [3]Sydney Children's Hospital and [4]Neuroscience Research Australia, Sydney, New South Wales, Australia

**Aim:** Falls in infants are a common cause of injury. Compared to older children, infants under age one are likely to have distinctive causation and injury patterns, as they are pre-mobile or have limited independent mobility and falls are more directly the responsibility of the care giver. There is little known about the mechanistic factors, predictors of injury and injury patterns in this age group.

**Methods:** We conducted a retrospective review of infants under age one who presented after a fall to a paediatric trauma centre in Sydney, Australia. Circumstances and mechanisms of the fall, injury patterns, burden of investigations and outcomes were analysed.

**Results:** Over a 3-year period (2011–2013), 916 infants presented following a fall. One hundred and six (11.6%) were admitted and there was one death. Head injury was the most common reason for admission (85%). While there were severe and critical head injuries (Abbreviated Injury Scale 4–5) these were infrequent (2% of presentations). All admitted cases involved a short distance fall. Patients dropped by others were three times more likely to be admitted than infants presenting following other fall types (95% CI 1.9–4.8). Compared to other mechanisms, patients who fell from furniture had significantly longer hospital stays.

**Conclusions:** Fall mechanisms involving infants being dropped by adults, and falls from beds or couches carry the highest clinical burden. These mechanisms should be targets for injury prevention and inform the design of safe equipment and environments for babies.

**Key words:** falls; infant; injury; prevention.

**What is already known on this topic**

1 Falls are the leading cause of injury in infants under one.
2 Infants under one are pre-mobile or have limited independent mobility and are likely to have different injury patterns and mechanisms compared to older children.
3 Non-accidental causes of injury should be considered in cases of serious injury in pre-mobile infants.

**What this paper adds**

1 The most common falls in infants under one are short distance falls from being dropped by an adult or falling from furniture or bedding or through the use of purpose built baby equipment.
2 Head injuries are the most common cause of fall-related hospital admissions.
3 A small proportion of these injuries are the result of non-accidental injury.

Falls represent the leading cause of non-fatal injury and fourth leading cause of death in infants under 1 year of age[1,2] and, in Australia, account for almost 50% of hospitalised injury in this age group.[3]

Infants under 1 year generally have limited independent mobility. Younger infants are largely pre-mobile, while older infants progressively attain developmental milestones including the ability to roll, crawl, cruise and ambulate. Infants' activities are also mainly determined by their care giver. Mechanisms of injury and injury patterns associated with falls are therefore likely to be different from those observed in older children. Previous studies have included infants under one in broader studies of falls in childhood, or in reference to a specific injury type or mechanism, such as falls from prams, beds and bouncers or during care-activities on change tables.[4–8]

To prevent serious injury, there is a need to identify how falls occur in infants who are pre-mobile or have only limited mobility and what factors predict injury outcome. This information is critical to development of preventative strategies. This study aimed to assess fall mechanisms in infants under one and relate this to injury patterns and severity.

## Methods

### Study design and setting

We conducted a retrospective review of emergency department (ED) presentations and admissions to the Sydney Children's Hospital (SCH) from January 1, 2011 to December 31, 2013. SCH is a state-wide referral centre for paediatric trauma. Patients were eligible for inclusion if they were aged under 1 year on presentation and primary cause for presentation was injury due to a fall. Cases were identified from the ED triage database, SCH trauma database

**Correspondence:** Dr Christopher Mulligan, Neuroscience Research Australia, c/o Brown Group, Margarete Ainsworth Building, Barker Street, Randwick, NSW 2031, Australia; email: c.mulligan@neura.edu.au

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and child protection unit (CPU) database, which records cases referred for child protection assessment. Cases were identified if triage information, ED admission, discharge summary or hospital coding data included 'fall' as a reason for presentation. Each case was reviewed to eliminate non-eligible and duplicate entries and data were manually entered into a separate data file. The study was approved by the Sydney Children's Hospitals Network Human Research Ethics Committee.

### Variables and data sources

A dataset was created including variables described in Table 1. Qualitative descriptions of each index fall were grouped into fall type categories using likely biomechanical patterns.

As head injury was the predominant injury type in admitted patients, pattern of injury was grouped as head injury yes/no, and type of head injury, based on presence of skull fracture, an intracranial bleed or non-skull fracture or soft tissue injury.

### Analysis and statistical methods

Data were analysed using IBM Statistical Packages for the Social Sciences for Windows version 22 (IBM Corp, Armonk, NY, USA). Descriptive techniques were used to characterise the sample and examine frequencies of different mechanisms and injury outcomes. Contingency tables and $\chi^2$ (or Fisher's exact where necessary) were used to assess for differences between categorical variables and outcome variables. Analysis of variance with *post hoc* Tukey tests were used to assess relationships between continuous variables and outcome variables. Logistic regression was used to examine relationships between mechanism of injury and outcome when other variables were controlled.

## Results

Over a 3-year period, 916 patients under age one, presented following a fall, representing almost one patient a day, including 504 males and 412 females.

**Table 1** Study variables and data sources

| Variables | Data type | Category/Units | Data source |
|---|---|---|---|
| Age | Continuous | Months | Electronic medical record |
| Gender | Binary | Male<br>Female | Electronic medical record |
| Mechanism of Injury | Categorical | Dropped by another person<br>Fall from cot/bed/couch<br>Fall from or out of seat/pram/bouncer<br>Fall from table<br>Fall from child's standing height<br>Other | Admission notes, medical records and ICD-10 hospital codes |
| Injury type for admitted patients | Categorical | Skull fracture<br>Skull fracture plus intracranial bleed<br>Intracranial bleed without skull fracture<br>Other head injury (extra-cranial haematoma)<br>Non-head injury | Consultant reported radiological imaging (CT, MRI or ultrasound), ICD-10-AM codes, discharge summaries, medical records |
| Intracranial injury | Categorical | EDH<br>SDH<br>SAH<br>ICH<br>Cerebral contusion | Consultant reported radiological imaging (CT, MRI or ultrasound), ICD-10-AM codes, discharge summaries, medical records |
| Clinical management | Categorical | Main treatment modality (non-operative or operative management) | Medical records, operation reports |
| Injury severity (AIS) | Categorical | AIS 1–5 | Coded from data sourced from electronic medical record, hospital coding data |
| Injury severity score | Ordinal | Minor (1–8)<br>Moderate (9–14)<br>Serious (15–24)<br>Severe (25–75) | Constructed from AIS codes. Electronic medical record, hospital coding data |
| Child protection unit referral | Categorical | Referral to CPU for assessment<br>CPU assessment confirms NAI concern | CPU confidential database |

AIS, Abbreviated Injury Severity score, 2008 revision; CPU, child protection unit; CT, computed tomography; EDH, extradural haemorrhage; ICD-10, International Statistical Classification of Disease and Related Health Problems, version 10; ICD-10-AM, International Statistical Classification of Disease and Related Health Problems, version 10, Australian modification; ICH, intra-cerebral haemorrhage; MRI, magnetic resonance imaging; NAI, non-accidental injury; SAH, subarachnoid haemorrhage; SDH, subdural haemorrhage.

**Table 2** Mechanism of injury reported for all presenting patients ($n$ = 916)

| Mechanism | Number of presentations | Percentage of total (%) |
|---|---|---|
| Fall from cot, bed or couch | 253 | 27 |
| Fall from baby seat, pram, bouncer | 193 | 21 |
| Dropped by adult | 143 | 16 |
| Fall from table | 106 | 12 |
| Trip or fall from standing height | 98 | 11 |
| Other (including falls from other furniture, toys and baby equipment not otherwise listed and falls down stairs) | 123 | 13 |

## Mechanism of fall

The most common mechanism of injury was falling from a bed or couch (27%) (Table 2). The second most common were falls from baby equipment such as baby seats, prams or bouncers (21%), some of which were being misused, such as bouncers on the kitchen table, or babies falling from prams without being buckled in. The third most common mechanism was being dropped by another person (16%), such as being dropped when the care giver tripped and fell, or when the adult attempted to do something else with their free hand. Our data do not record whether any adult was affected by drugs or alcohol at the time. Other mechanisms included fall from other furniture and equipment, fall or trip from the infant's standing height and fall down stairs ($n$ = 45), though our data did not record the distance fallen or number of stairs involved.

## Hospital admission

Of all presentations, 110 patients (12%) were admitted to hospital. Nine patients (8%) were admitted to the intensive care unit. There were significant differences in hospital admissions by fall mechanism ($P < 0.001$). Controlling for age, infants dropped by other people were three times more likely to be admitted than infants presenting from other mechanisms (OR 3.1, 95% CI 1.9–4.8), and infants who fell from a bed, or couch were significantly less likely to be admitted (OR 0.6, 95% CI 0.4–0.9). There was also a significant difference in age between those admitted and those not ($P < 0.001$). Admitted infants were younger (mean 5.3 months, SD 3.5, range 0–12 months) than those not admitted (mean 7.5 months, SD 3.4, range 0–12 months).

## Admitted patients

Of the 110 admitted patients, 20 (18%) were referred to the CPU, based on the concerns of treating clinicians. There was no difference in initial recorded mechanism or injury severity between those that were and were not referred. However, pattern of injury varied ($P$ = 0.014, see Fig. 1). Children were less likely to have been referred to CPU when there was a skull fracture without intracranial bleed, than when there was an intracranial bleed or no head injury.

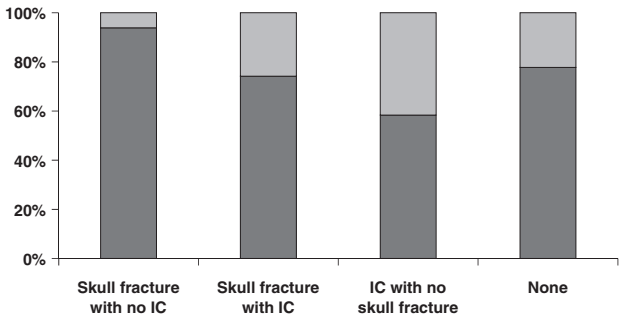


**Fig. 1** Child protection assessment referral patterns by head injury type. (■), Not referred; (□), referred. IC, intracranial haemorrhage.

Of the 20 children referred to the CPU, four (20%) were found to have proven child protection concerns and were assumed into care by social services. Notably none of these children sustained skull fracture. Two sustained intracranial bleeds without fracture. This included one child with bilateral extradural hematomas in isolation and one child with a subdural hematoma and multiple arm/hand fractures. The other two sustained fractures of the upper extremity (the clavicle in one child, and the humerus in the other). Three of the four had multiple occult injuries or injuries of different ages. The history of the fall or falls could not account for the injuries. The history changed or was vague and not specific. All four children came from families with multiple psychosocial risk factors. These four cases with identified child protection issues were removed from further analysis.

Among the remaining 106 infants admitted, 18 (17%) had an injury severity score (ISS) of 15 or greater, there were a 31 (29%) with an ISS between 9 and 14. There was one death. Of these 106 admitted patients, nearly all of the injuries ($n$ = 100) occurred within the child's home.

## Clinical investigations

On average, admitted infants underwent 1.3 (SD 0.8) imaging investigations. Computed tomography scan of the brain was the main initial diagnostic modality in the context of head injury, with an additional small number of progress computed tomography scans performed. Skeletal survey and nuclear medicine bone scan to look for other injuries were reserved for use where there were concerns regarding non-accidental injury, in line with local protocols and American Academy of Pediatrics recommendations.[9,10]

## Injury

The reason for most admissions was head injury, with 90 patients (85%) admitted under the neurosurgical service, and most head injuries involved skull fracture ($n$ = 80, 75.5%), either in isolation ($n$ = 49, 46.2%) or in combination with an intracranial bleed/s ($n$ = 31, 29.2%). Ten (9.4%) had an intracranial bleed without any skull fracture. Other non-head injuries included long bone fractures, soft tissue injuries and lacerations requiring formal washout or repair.

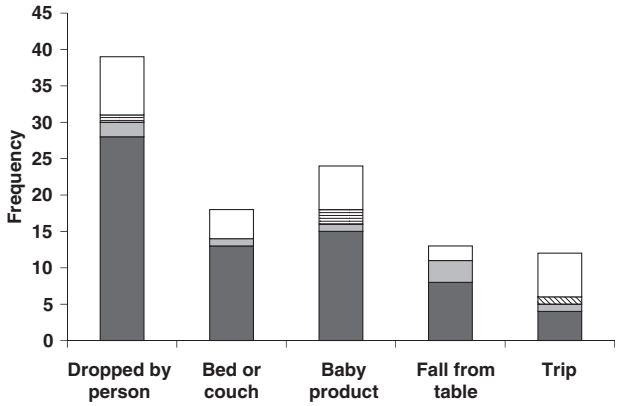


**Fig. 2** Fracture location by mechanism of fall. (■), Parietal; (▤), occipital; (▧), frontal; (▤), multiple; (□), no skull fracture.

Most skull fractures involved one parietal bone (66/80). Two children sustained bilateral parietal fractures, and two children sustained fractures to both parietal and occipital bones. Nine children sustained fractures to just the occipital (8/80), or frontal bone (1/80). One child had fractures of the frontal and orbital bones. There was no difference in fracture location by mechanism (see Fig. 2).

Most intracranial bleeds occurred in a single location (36/41), however multiple intracranial bleeds occurred in five children. Intracranial bleeds were most commonly extradural haemorrhage (EDH, $n = 19$), followed by subdural haemorrhage (SDH, $n = 11$) and subarachnoid haemorrhage (SAH, $n = 8$, six in isolation and two in combination with other types). Three were intra-cerebral haemorrhages (ICH, two in isolation and one in combination with other types) and four were cerebral contusions (three in isolation and one in combination with other types). EDH occurred equally among children dropped (32% of EDH), who fell from beds or couches (32% of EDH) and from baby equipment (37%). SAH and SDH occurred most often among children dropped (66.7% of SAH, and 45.5% of SDH). ICH and contusions occurred only among children dropped or who fell from baby equipment. Table 3 presents details of intracranial bleeds.

Among the five children with multiple intracranial bleeds, three occurred with parietal fracture and two without fracture. All multiple bleeds occurred when the child was dropped. One child sustained bilateral EDH, one child sustained a combination of EDH and ICH, two sustained a combination of SAH and SDH, and one sustained an SAH and cerebral contusion.

There was no difference in pattern of head injury by fall mechanism, or by gender. However, there was a difference by age ($P < 0.001$) (Fig. 3). Children with skull fracture (mean 5.3, SD 3.2, range 1–11 months), or skull fracture with an intracranial bleed (mean 3.9, SD 3.4, range 0–11 months) were on average younger than those with no head injury (mean 8.3, SD 3.3, range 1–12 months).

## Pattern of injury by age and mechanism

Mechanism of fall varied by age. Figure 4 demonstrates increased involvement of the youngest children in falls when dropped and from baby equipment, as well the preponderance of head injury among these children. Conversely there was increased involvement of older children in falls from a bed or couch and trips, with increased proportions of non-head injury.

**Table 3** Location, size and severity of intracranial bleeds

| Intracranial haemorrhage type | Size/Severity (AIS) | Number (% of type) |
|---|---|---|
| Extradural | AIS 2; <0.6 cm thick (tiny) | 2 (10.6) |
| | AIS 4; ≤25 cc; 0.6–1 cm thick (moderate) | 6 (31.5) |
| | AIS 5; ≥25 cc; 1 cm thick (large) | 7 (36.8) |
| | AIS 3; not further specified | 4 (21.1) |
| Subdural | AIS 2; <0.6 cm thick (tiny) | 0 (0) |
| | AIS 4; ≤15 cc; 0.6–1 cm thick (moderate) | 4 (36.4) |
| | AIS 5; ≥15 cc; 1 cm thick (large) | 0 (0) |
| | AIS 3; not further specified | 7 (63.6) |
| Subarachnoid | AIS 2; NFS/not associated with coma >6 h | 6 (100) |
| Intra-cerebral | AIS 4; ≤15 cc; ≤1 cm | 1 (50) |
| | AIS 3; not further specified | 1 (50) |
| Cerebral contusion | AIS 2; <1 cm diameter (tiny) | 1 (33.3) |
| | AIS 3; not further specified | 2 (66.6) |

AIS, Abbreviated Injury Severity score, 2008 revision.

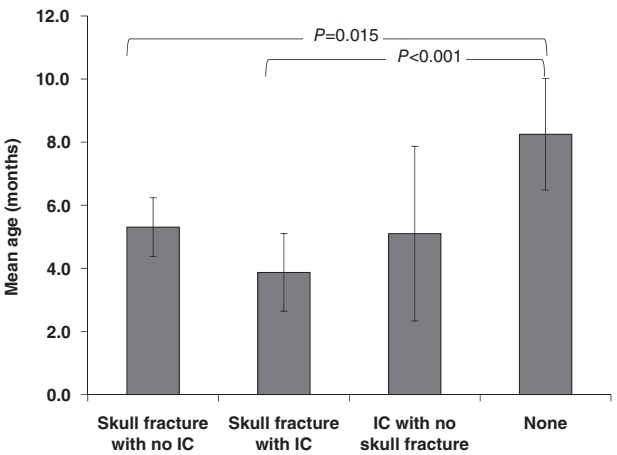


**Fig. 3** Age of patients by head injury pattern. Vertical error bars represent 95% confidence interval. IC, intracranial haemorrhage.

## Head injury severity

There was no difference in head injury severity by mechanism. Head injuries were most commonly abbreviated injury scale (AIS) 2 and AIS 3 injuries (77.7%, see Fig. 5). AIS 3+ head injuries occurred in all fall types, while AIS 4 injuries occurred in all but 'trip' falls. AIS 5 occurred when the child was dropped, fell from a bed or couch or baby equipment.

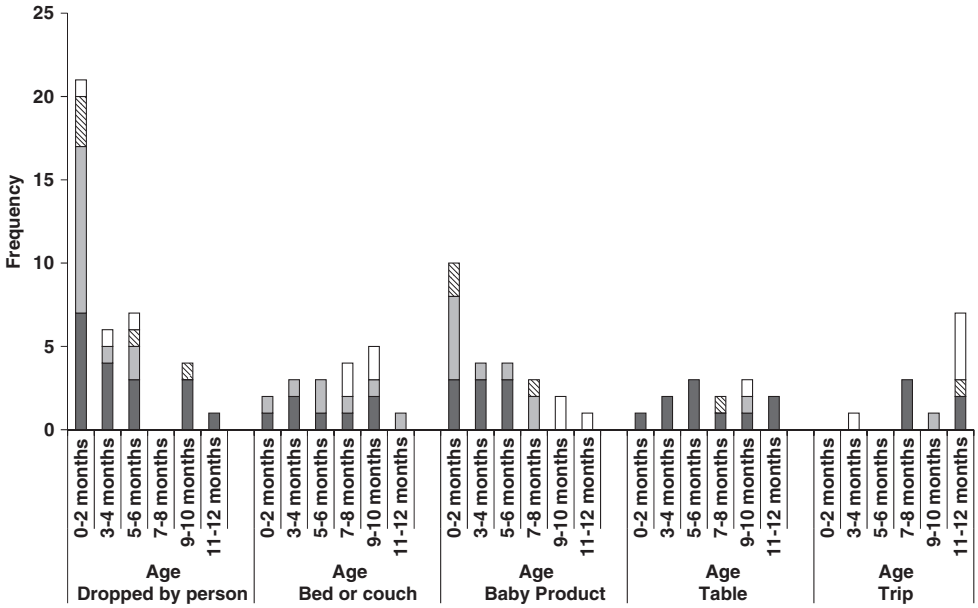


**Fig. 4** Fall mechanism and patterns of head injury by age. (■), Skull fracture with no ICH; (▤), skull fracture with ICH; (▧), ICH with no skull fracture; (□), non-head injury. ICH, intra-cerebral haemorrhage.

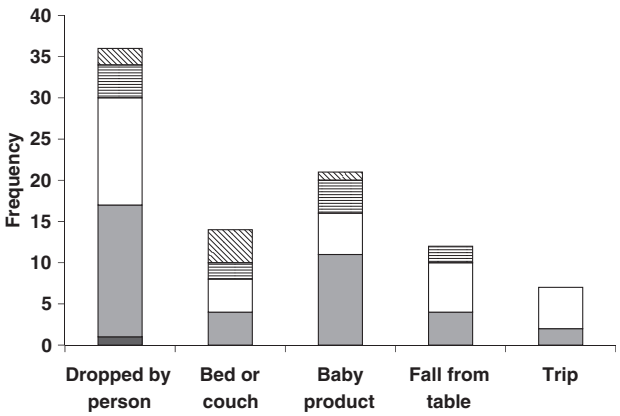


**Fig. 5** Head injury severity by mechanism. (■), AIS 1; (▤), AIS 2; (□), AIS 3; (▤), AIS 4; (▧), AIS 5. AIS, Abbreviated Injury Severity score, 2008 revision.

Table 4 presents key information from the 19 cases where children sustained AIS 4+ head injuries.

### Injury outcome

Of the 90 admitted patients with head injury, most ($n$ = 85) were managed non-operatively with clinical observation. There were five neurosurgical procedures performed, including four craniotomies for evacuation of extradural haematomata and one operation to elevate a depressed parietal skull fracture. All neurosurgical procedures occurred in infants admitted after being dropped ($n$ = 1) or after a fall from a bed or couch ($n$ = 4). Other operations performed were application of a spica cast for femoral fracture ($n$ = 4), repair of facial laceration ($n$ = 5) and one removal of impacted teeth.

Among the admitted children, there was one death. This was a 5-month-old who fell from a cot onto a hard floor and sustained a skull fracture with EDH, dying 5 days after injury.

## Discussion

Falls in infants under one are influenced by the child's developmental milestones, and injury prevention strategies need to target the most common mechanisms (falling from bed/couch) and those most likely to require hospital admission (being dropped). This analysis has demonstrated variations in the mechanisms leading to hospitalisation following a fall among children under one, as well as differences in the pattern of injury by age of infant. This likely reflects the developmental non-homogeneity of this cohort.

Falls from significant heights, such as from windows or balconies, defined as >4.7 m, or 15 ft, represent an important mechanism of injury in older children,[8,11–14] but there were no falls from such heights in our cohort of infants. In this study we have grouped fall mechanism by activity and did not attempt to estimate the specific fall height. Some falls that occurred when the infant was dropped may have involved heights >1 m, as falls from the arms of carers may be from a height >1.5 m. However, it is likely that the majority of falls occurred from <1 m. Our data therefore support the conclusion by Hughes *et al.*[14] that for the youngest infants, shorter falls from lower heights under a metre are common and important to address. Our data also supports the findings of Burrows *et al.*[15] who reported more complex head injury occurring among the youngest children, and children who fall when dropped or from beds and couches, and baby equipment. This further highlights the need to prioritise prevention of these fall types.

Whilst the reported mortality rate for short falls is low (0.48 per million),[16,17] our series highlights a significant number of serious injuries, with 11.6% of presentations requiring hospitalisation, in whom 14% required operative management and 17% had an ISS of 15 or greater – slightly below a similar cohort of infants reported by Unni *et al.* of 39%.[18] Similar to published patterns of injury in all children, head injury represented the primary reason for admission in our cohort.[19–23] This finding suggests that, counter to the view of some that short distance falls

**Table 4** Characteristics of AIS 4+ head injuries

| Age | Gender | Mechanism | Injury | Management | LOS, days | CPUA | CPISS |
|---|---|---|---|---|---|---|---|
| 10 | F | Dropped | Parietal no., SGH | Observation | 1 | Y | N |
| 10 | M | Dropped | EDH | Craniotomy for extradural | 5 | N | N |
| 7 | M | Bed/Couch | Parietal no., EDH | Craniotomy for evacuation of extradural | 8 | N | N |
| 11 | M | Bed/Couch | Parietal no., EDH | Craniotomy for epidural | 5 | Y | N |
| 6 | F | Baby product | Parietal no., EDH | Observation | 2 | N | N |
| 8 | M | Baby product | Parietal no., EDH, SGH | Observation | 6 | N | N |
| 5 | M | Bed/Couch | Parietal no., EDH | Craniotomy for evacuation of extradural | 13 | N | N |
| 7 | F | Baby product | Parietal no., occipital no., EDH, SGH | Observation | 3 | Y | N |
| 2 | M | Dropped | Bilateral parietal no., bilateral EDH, SGH | Observation | 2 | Y | N |
| 1 | F | Baby product | Parietal no., EDH | Observation | 1 | N | N |
| 3 | F | Baby product | Parietal no., EDH, SGH | Observation | 2 | N | N |
| 6 | F | Bed/Couch | Parietal no., EDH | Observation | 6 | Y | N |
| 10 | M | Bed/Couch | Parietal no., EDH | Observation | 7 | N | N |
| 1 | F | Dropped | Parietal no., EDH | Observation | 3 | N | N |
| 10 | F | From table | Occipital no., SDH, SGH | Observation | 5 | N | N |
| 1 | M | Bed/Couch | Occipital no., SDH | Observation | 5 | Y | N |
| 7 | F | From table | SDH | Observation | 6 | Y | N |
| 6 | F | Dropped | Parietal no., SAH | Observation | 2 | N | N |
| 2 | F | Dropped | Occipital no., Parietal no., ICH | Observation | 3 | N | N |

AIS, Abbreviated Injury Severity score, 2008 revision; CPUA, child protection unit assessment undertaken; CPISS, child protection issue identified; EDH, extradural haemorrhage; ICH, intra-cerebral haemorrhage; LOS, length of stay; SAH, subarachnoid haemorrhage; SDH, subdural haemorrhage; SGH, sub-galeal haematoma.

do not generally cause severe or life-threatening injury,[17,19,24–26] serious head injuries are possible from this mechanism. As reported by a number of other authors,[15,26–28] we saw intracranial injury, with and without skull fracture in this sample and this was primarily associated with falls when dropped and from beds and couches. However, also as reported by others,[28] serious injuries (AIS 4+) are infrequent, accounting for only 2% of the 916 presentations.

Nearly all of the injuries occurred in the home, which is consistent with previous reports.[3] Furthermore, our data demonstrated a relative rate of falls by gender of males to females of 1.2:1, just below rates of 1.5:1 reported in older children.[1,12,29,30] Gender differences in older children are explained by greater risk taking behaviours in males,[31] however, this explanation is unlikely to be applicable to infants under age one. It is possible that differences in gross motor development and in care giver attitudes or supervision to male and female infants may be potential factors.[32]

The relationship between short distance falls and inflicted injury is one of ongoing contention. In this study just under 20% of admitted patients were referred for child protection multidisciplinary assessment and 5% were found to have inflicted injuries. The presence of multiple and occult injuries, or injuries of different ages with vague and/or changing description of injury history differentiated these cases from accidental injuries and not the severity of injury.

### Limitations

Our single-centre, retrospective study contains only limited detail on biomechanics, fall height and risk factors underlying these falls. Caution must be exercised in interpreting results in relation to forces involved. While the fall mechanism categories used attempts to group similar fall types, there is likely to be significant non-homogeneity in forces within these categories. Our sample may also be skewed towards more seriously injured patients as data were collected from a paediatric tertiary referral hospital. Furthermore, details of neurological status of the children on presentation were not collected, nor were details about the specific location of fractures and intracranial blood collections. This latter omission prevents presentation of details related to the relationship between fracture location and intracranial bleed.

## Conclusions

This is the first study to look exclusively at falls in children under one. The findings indicate short distance falls are the most common type of fall in this age group and mechanisms where infants are dropped by adults, or fall from beds or couches carry the highest clinical burden. These mechanisms should therefore be priority targets in injury prevention programs.

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