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ORIGINAL RESEARCH

Validity of Caregivers' Reports on Head Trauma Due to Falls in Young Children Aged Less than 2 Years

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Abstract

Objective: The clinical presentations of head trauma due to falls among young children aged less than 2 years are controversial, particularly in Japan, as the history of trauma recounted by a caretaker is not always reliable. The purpose of this study was to assess the validity of caregiver's reports on head trauma due to falls in young children aged less than 2 years in Japan.

Methods: All patients <2 years of age presenting with head trauma resulting from a fall who were admitted to 3 children's hospitals in Japan from January 2001 to December 2005 were retrospectively reviewed (N = 58). The clinical presentations were compared among groups categorized by the heights from which the patient fell (short (≤120 cm) or long (>120 cm)) and the surface on which the patient landed (carpet, tatami (Japanese mattress), hardwood floor, or concrete).

Results: Patients who suffered short falls were more likely to present with subdural hemorrhage (SDH) than those who suffered long falls (74% and 40%, respectively, $P = 0.027$). More specifically, 62% of short falls showed SDH indicative of shaken baby syndrome (e.g. multilayer SDH). Neurological symptoms, cyanosis, and SDH were more commonly observed in patients who landed on carpeted or tatami surfaces than in those who landed on hardwood or concrete floors.

Conclusions: Short falls and landing on soft surfaces resulted in the presentation of severer clinical symptoms than did long falls and landing on hard surfaces, suggesting that the validity of caretakers' reports on infant or young children's head trauma due to falls is low. Further research is warranted to investigate the cause of infant head trauma due to falls.

Keywords: head injury, child abuse, accidental falls, shaken baby syndrome, subdural hematoma

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Introduction

Clinical presentations of infant and young toddler's head trauma due to falls are controversial, as caretakers' accounts of the trauma might not to be reliable, and injury history is difficult to corroborate, particularly injury from falls that occur at home.[1,2] Falls that take place outside the home, such as in hospitals or day-care facilities, could provide a more reliable history of trauma. Previous studies on short falls in hospital or in day-care facilities have reported that no serious injuries occur in these incidents.[3–8] Furthermore, the probability of death due to short falls has been estimated to be less than one per million.[9] However, in Japan, more severe clinical presentations due to short falls, such as subdural hematoma (SDH), have frequently been reported as infantile acute subdural hematoma (IASDH) or Nakamura's hematoma type I.[10] Aoki et al reported 26 cases of SDH and attributed the frequent incidence of IASDH due to short falls to the Japanese physical environment, such as the use of tatami (Japanese mattress).[11] Fujiwara et al suggested that the difference in the characteristics of SDH in young children aged <2 years in Japan might be due to the accessibility of medical services or the credibility of the history of trauma presented by the caretaker.[12] Chadwick et al demonstrated that short falls are more fatal than long falls when they used the uncorroborated history presented by the caretaker for the categorization of falls.[1]

If the history presented by the caretaker is assumed to be true, the severity of head trauma due to falls can be attributed to the heights of the falls[3] and the surface on which the patient lands.[13] To test the validity of caregiver's reports on infant or young children's head trauma due to falls, the clinical presentation of infant or young toddlers head trauma resulting from falls categorized by the height and surface on which the patient lands must be compared. The purpose of this study, which was conducted in Japan, was to test the validity of caregiver's reports on head trauma in young children aged <2 years by comparing clinical presentations of head trauma among short and long falls and the surface on which the child landed (carpet, tatami, hardwood floor, or concrete).

Materials and Methods

Samples

All the patients with head trauma (<2 years of age) resulting from falls, as described by their caretakers, admitted in 3 children's hospitals in Japan (National Centre of Child Health and Development, Tokyo (N = 17); Kobe Children's Hospital, Hyogo (N = 31); and Saitama Children's Hospital, Saitama (N = 10)) were selected as the study sample. These patients were admitted from January 2001 to December 2005 (admissions to the National Centre of Child Health and Development were from March 2003 to December 2005, since this hospital opened only in March 2003) and were retrospectively reviewed (multicenter case series; total, N = 58). All the cases were analyzed. Cases with bleeding features (e.g. hemophilia) were excluded from the sample because the risk of developing SDH after minor injuries is higher in such cases.

Data collection

The following data were collected from each patient: demography (age in months and sex), clinical presentations (symptoms (seizure, unconsciousness, vomiting, cyanosis, and apnea) and Glasgow Coma Scale (GCS) at the time of visit, head CT findings, details regarding the history of falls as described by the caretaker (i.e. the height of fall, surface on which the patient landed)), treatment (brain surgery), outcome (Glasgow Outcome Scale (GOS)), involvement of social welfare services (report to the Child Guidance Centre (CGC; similar to the Child Protective Services in the US or UK), and decision of the CGC (separation of the child from the family or allowing the child to remain at home)). The height of falls was collected if the medical record contained the height; if not, the height was estimated depending on the type of fall. For example, if infants or young toddlers fell from a chair, the height was estimated to be 100 cm. Similarly, it was 80 cm for a bed, 60 cm for a sofa, and 20 cm multiplied by the number of steps for stairs (that is, if an infant or young toddler fell down a flight of 8 steps, the height was calculated as 8 × 20 cm, which is 160 cm. The falls were categorized into 2 groups depending on the height from which the patients fell. Falls from smaller heights (≤120 cm) were categorized as short falls, whereas those from greater heights (>120 cm) were categorized as long falls. Falls were classified as short or long falls on the basis of the results of a previous paper, which reported that serious injury can occur in the case of falls from 5 feet or more[3]; moreover, studies of hospital falls

in infants or young children (in the case of hospital falls, reliable information is available about the falling situation) reported that falls from less than 3–4 feet do not result in serious injury[7,8]. Thus, falls from a height below 4 feet (120 cm) were defined as short falls. For sensitivity analysis, falls were further categorized as very short falls (<80 cm) and very long falls (>140 cm). The falls were also categorized according to the surface on which the patients landed: carpet, tatami, hardwood floor, and concrete. This study was approved by the Institutional Review Board of the National Center of Child Health and Development.

Statistical analysis

Demography, clinical presentations, treatment, outcome, and involvement of social welfare services were compared among the patients categorized according to the height and surface of falls. Fisher's exact test was used to compare these categories, and the *t* test or ANOVA was used for continuous variable analysis. All the statistical tests were two-sided and we used an α level of 0.05 to determine significance. The data analyses were performed using STATA SE version 9.0 (Texas, USA).

Results

Among the 58 young children who suffered head trauma due to falls, 39 experienced short falls (67.2%). In half of the cases, the landing surface could not be determined from the medical records. Hardwood floor was the most frequently encountered surface, followed by concrete, carpet, and tatami (Table 1). In 9 cases (15.5%), a previous injury history was reported.

The association between the height of fall and the surface where the patient landed is shown in Table 2.

Table 1. Distribution of height of falls and surface onto which the patients landed (N = 58).

		N (%)
Height of fall	Short fall	39 (67.2)
	Long fall	15 (25.9)
	Unknown	4 (6.9)
Surface where the patient landed	Carpet	5 (8.6)
	Tatami	5 (8.6)
	Hardwood floor	11 (19.0)
	Concrete	8 (13.8)
	Unknown	29 (50.0)

Table 2. Association between the height of fall and surface where the patient landed (N = 58).

	Short falls N (%)	Long falls N (%)	Unknown N (%)
Carpet	4 (10.3)	1 (6.7)	0 (0)
Tatami	5 (12.8)	0 (0)	0 (0)
Hardwood floor	7 (18.0)	4 (26.7)	0 (0)
Concrete	6 (15.4)	1 (6.7)	1 (25.0)
Unknown	17 (43.6)	9 (60.0)	3 (75.0)

Note: Fisher's exact test: $P = 0.727$.

It was observed that short falls were more likely to happen on carpeted or tatami surfaces and long falls were more likely to happen on hardwood floors; however, these differences were not statistically significant.

Table 3 compares the symptoms at visit with the height of the fall. The symptoms at visit were not related to the type of fall (long or short). However, head CT findings significantly differed depending on the type of fall: 29 of the patients (74.4%) who suffered short falls presented with SDH, whereas only 6 of the patients (40.0%) who suffered long falls presented with SDH ($P = 0.027$). More specifically, SDH, which suggests shaken baby syndrome (SBS) or abusive head trauma (AHT) (i.e. multilayer SDH, interhemispheric SDH, subtentorial SDH, and bilateral SDH), was more frequently present in short falls than in long falls (46.2% vs. 6.7%, $P = 0.009$). Other head CT findings (skull fracture, epidural hematoma, subarachnoid hematoma, contusion, and brain edema) did not differ significantly according to the height of the fall. Retinal hemorrhage was more frequently observed in short falls, although this was not statistically significant. Sensitivity analysis confirmed the following findings: 10 SDH cases were found among 13 very short falls, while only 4 of 11 very long falls showed SDH (76.9% vs. 36.4%, $P = 0.095$). Further, SDH indicative of SBS was observed in the case of 7 of the very short falls, but none of the very long falls (53.9% vs. 0%, $P = 0.006$).

Further, associations between location and severity of injury and neurological symptoms were investigated. Seizures were more likely to be found in the case of complex skull fractures (100% vs. 16.1%, $P = 0.033$), interhemispheric SDH (50% vs. 14%, $P = 0.035$), frontal SDH (35% vs. 10.5%, $P = 0.036$), and unilateral SDH (41.2% vs. 9.8%, $P = 0.010$).

Table 3. Symptoms at visit classified according to the height of fall (N = 54).

Clinical presentations		Short falls (N = 39)	Long falls (N = 15)	*P* for fisher's exact test
Symptoms at visit, n (%)	Seizure at visit	10 (25.6)	1 (6.7)	0.153
	Unconsciousness	12 (30.8)	3 (20.0)	0.515
	Glasgow Coma Scale (mean, SD)	7.5 (3.6)	7.7 (4.2)	0.96 (*t* test)
	Vomiting	6 (15.4)	6 (40.0)	0.071
	Cyanosis	9 (23.1)	2 (13.3)	0.708
	Apnea	6 (15.4)	2 (13.3)	>0.999
Head CT findings, n (%)	Skull fracture	19 (48.7)	9 (60.0)	0.550
	SDH	**29 (74.4)**	**6 (40.0)**	**0.027**
	SDH suggestive of SBS/AHT (multilayer, interhemispheric, subtentorial, or bilateral SDH)	**18 (46.2)**	**1 (6.7)**	**0.009**
	Epidural hematoma	10 (25.6)	7 (46.7)	0.192
	Subarachnoid hemorrhage	5 (12.8)	4 (26.7)	0.244
	Contusion	4 (12.5)	0 (0)	0.566
	Brain edema	7 (22.6)	2 (22.2)	>0.999
	Metaphyseal fracture	1 (2.6)	0 (0)	>0.999
	Rib fracture	2 (5.1)	0 (0)	>0.999
	Retinal hemorrhage	11 (28.2)	1 (6.7)	0.145

Abbreviations: SDH, subdural hematoma; SBS, shaken baby syndrome; AHT, abusive head trauma.

Depressed skull fracture, subcutaneous hematoma, multi-layer SDH, SDH under the impact location, occipital SDH, subtentorial SDH, parietal SDH, temporal SDH, bilateral SDH, epidural hematoma, subarachnoid haemorrhage, and contusion were not significantly associated with seizures ($P > 0.1$). Similarly, unconsciousness was associated with not having linear skull fracture (16.7% vs. 38.2%, $P = 0.089$), multi-layer SDH (53.9% vs. 22.2%, $P = 0.040$), frontal SDH (45% vs. 21.1%, $P = 0.073$), and occipital SDH (75% vs. 25.9%, $P = 0.071$), but SDH in other locations ($P > 0.1$).

In addition, associations between the location of head fracture and SDH and length of falls were further analyzed. In short, no significant associations were found; however, complex skull fracture (5.1% vs. 0%), depressed skull fracture (10.3% vs. 0%), multi-layer SDH (28.2% vs. 6.7%), SDH under the impact location (15.4% vs. 0%), interhemispheric SDH (18% vs. 0%), frontal SDH (38.5% vs. 20%), occipital SDH (5.1% vs. 0%), subtentorial SDH (5.1% vs. 0%), parietal SDH (23.1% vs. 20%), temporal SDH (25.6% vs. 6.7%), unilateral SDH (35.9% vs. 13.3%), and bilateral SDH (20.5% vs. 6.7%) were more likely to occur in the case of short falls than long falls.

Patients who suffered short falls were more likely to undergo brain surgery (Table 4). However, the outcome was similar regardless of the type of fall: 5.1% and 6.7% of the patients died and 76.9% and 86.7% of the patients showed good recovery in the case of short and long falls, respectively. With regard to CGC involvement, 12 (30.7%) of the patients who suffered short falls were reported to the CGC as cases of suspected abuse; 3 of these patients were separated from their families by the CGC. Among the patients who suffered long falls, only 1 (6.7%) was reported to the CGC as a case of abuse; however, this patient was not separated from the family.

Table 5 presents a comparison of the symptoms at visit with the surface on which the patient landed. Interestingly, seizure at visit was more frequently observed when the subjects landed on carpeted or tatami surfaces than when they fell on hardwood or concrete floors ($P = 0.007$). Similarly, vomiting, cyanosis, and respiratory disorders were more frequently observed when the children fell on carpeted or tatami surfaces than when they fell on hardwood or concrete floors. Head CT findings revealed clear differences: SDH was more frequently observed when the patients landed on carpeted or tatami floors than when they landed on hardwood or concrete floors

Table 4. Treatment, outcome, and social welfare involvement by the height of fall (N = 54).

		Short falls (N = 39)	Long falls (N = 15)	*P* for fisher's exact test
Treatment	Brain surgery	13 (33.3)	1 (6.7)	0.080
Outcome: Glasgow Outcome Scale				0.888
	Dead	2 (5.1)	1 (6.7)	
	Vegetative state	0 (0)	0 (0)	
	Severe disability	1 (2.6)	0 (0)	
	Moderate disability	6 (15.4)	1 (6.7)	
	Good recovery	30 (76.9)	13 (86.7)	
Involvement of social welfare services				
	Report to CGC	12 (30.7)	1 (6.7)	0.083
	Separation by CGC	3 (7.7)	0 (0)	0.552

Abbreviation: CGC, child guidance centre; similar to Child Protection Service in the US or UK.

(P = 0.006). In addition, 60% of all patients who fell on carpets and 100% of all patients who fell on tatami presented with SDH suggestive of SBS/AHT. Further, skull fracture was presented more commonly when the patient landed on hardwood or concrete floors than when landing on carpeted or tatami floors (P = 0.001). Epidural hematoma, subarachnoid hematoma, and contusion were more frequently observed when the patients fell on hardwood or concrete floors than when they fell on carpeted or tatami floors, although this was not statistically significant. Retinal hemorrhage was more frequently observed when the patients fell on carpeted (40%) and tatami (40%) floors than when falling on hardwood (18.2%) and concrete (0%) floors, although the incidence was not statistically significant.

Patients who landed on tatami and concrete surfaces were more likely to undergo brain surgery (Table 6). With regard to the outcome, 40% of carpet falls resulted in death, whereas no children falling onto

Table 5. Symptoms at visit according to the surface on which the patient landed (N = 29).

Clinical presentations	Carpet (N = 5)	Tatami (N = 5)	Hardwood floor (N = 11)	Concrete (N = 8)	*P* for Fisher's exact test
Symptoms at visit, n (%)					
Seizure at visit	**3 (60.0)**	**3 (60.0)**	**1 (9.1)**	**0 (0)**	**0.007**
Unconsciousness	4 (80.0)	2 (40.0)	3 (27.3)	1 (12.5)	0.099
Glasgow Coma Scale (mean, SD)	5.3 (1.4)	9.0 (0)	5 (2.0)	9.0 (0)	0.547 (by ANOVA)
Vomiting	**1 (20.0)**	**3 (60.0)**	**1 (9.1)**	**0 (0)**	**0.044**
Cyanosis	**4 (80.0)**	**1 (20.0)**	**1 (9.1)**	**0 (0)**	**0.004**
Respiratory disorder	**3 (60.0)**	**0 (0)**	**1 (9.1)**	**0 (0)**	**0.028**
Head CT findings, n (%)					
Skull fracture	**0 (0)**	**1 (20.0)**	**9 (81.8)**	**7 (87.6)**	**0.001**
SDH	**5 (100)**	**5 (100)**	**5 (45.5)**	**2 (25.0)**	**0.006**
SDH suggestive of SBS/AHT (multilayer, interhemispheric, subtentorial, or bilateral SDH)	**3 (60.0)**	**5 (100)**	**2 (18.2)**	**1 (12.5)**	**0.004**
Epidural hematoma	0 (0)	0 (0)	5 (45.5)	1 (12.5)	0.113
Subarachnoid hemorrhage	0 (0)	0 (0)	1 (9.1)	3 (37.5)	0.241
Contusion	0 (0)	0 (0)	1 (9.1)	2 (20.0)	0.353
Brain edema	0 (0)	0 (0)	1 (12.5)	0 (0)	>0.999
Metaphyseal fracture	0 (0)	0 (0)	0 (0)	1 (0)	0.621
Rib fracture	0 (0)	0 (0)	1 (9.1)	0 (0)	>0.999
Retinal hemorrhage	2 (40)	2 (40)	2 (18.2)	0 (0)	0.186

Abbreviations: SDH, subdural hematoma; SBS, shaken baby syndrome; AHT, abusive head trauma.

Table 6. Treatment and outcome according to the surface on which the patient landed (N = 54).

		Carpet (N = 5)	Tatami (N = 5)	Hardwood floor (N = 11)	Concrete (N = 8)	*P* for fisher's exact test
Treatment	Brain surgery	**0 (0)**	**3 (60.0)**	**0 (0)**	**3 (37.5)**	**0.011**
Outcome: Glasgow Outcome Scale						0.083
	Dead	2 (40.0)	0 (0)	1 (9.1)	0 (0)	
	Vegetative state	0 (0)	0 (0)	0 (0)	0 (0)	
	Severe disability	0 (0)	0 (0)	1 (9.1)	0 (0)	
	Moderate disability	1 (20.0)	1 (20.0)	0 (0)	0 (0)	
	Good recovery	2 (40.0)	4 (80.0)	9 (81.8)	8 (100)	
Involvement of social welfare services						
	Report to CGC	2 (40.0)	3 (60.0)	3 (27.3)	1 (12.5)	0.385
	Separation by CGC	0 (0)	0 (0)	0 (0)	1 (12.5)	0.621

Abbreviation: CGC, child guidance centre; similar to Child Protection Service in the US or UK.

concrete died. Carpet and tatami falls were more likely to be reported to the CGC than concrete falls, although these differences were not statistically significant.

Discussion

By using the information of the height of fall as recounted by the caretaker at the time of the visit, we demonstrated that SDH occurred more frequently in "short" falls than in "long" falls. The percentage incidence of SDH suggestive of SBS/AHT was considerably higher in "short" falls than in "long" falls. In addition, more severe clinical presentations—more seizures, vomiting, cyanosis, and SDH—were observed in children who landed on carpeted and tatami surfaces than in those who landed on hardwood or concrete floors. However, skull fracture was more frequently observed in young children who landed on hardwood or concrete floors.

Since injured infants or young toddlers are more likely to be brought to the hospital by caregivers when they fall from long heights than short, this tendency can explain why majority of long falls showed minor injury. However, this scenario does not explain why there was a high proportion of serious head injuries in the case of short falls. Our findings can be interpreted as follows: the recounted history of the "short" falls or falls onto carpet or tatami could have been fabricated to conceal child abuse, wherein the caretaker reported a fake account at the time of the visit to cover his or her history of child abuse. It is widely known that few caretakers admit their abusive behavior at the hospital.[14] Since child abuse is a very sensitive issue in Japan, it is not difficult to imagine that caretakers provide fake accounts to hospital personnel. Alternatively, since SBS/AHT is unfamiliar in Japan, the caretakers might not have recognized the shaking of young children is a potentially dangerous activity. That is, some caretakers may have previously shaken a baby and then brought the child to the hospital when he/she had subsequently fallen. The previous head injury due to shaking was then revealed by head CT when the physician performed head CT to detect intracranial injury due to "falls" recounted by caretaker. Thus, the caretaker may have inadvertently provided an inaccurate history of the patient: he or she reported the incident, but the head CT findings revealed the trauma caused to the child within the skull. In some cases, the patient might have been brought to the hospital by a caretaker (e.g. the mother) other than the abuser, who simply reported the history of head injury that they observed, e.g. head injury caused by a short fall. Subsequently, head CT findings might reveal SDH indicative of SBS or AHT, which may have been perpetrated by another caretaker (e.g. the father).

SDH is often considered to be reported as Nakamura's hematoma in Japan.[10] The reason why Nakamura's hematoma is observed in Japan and not in Western countries might be the difference in the health system and medical equipment used. In Japan, medical services are free of cost for young children, and CT scans are commonly available,[15] whereas in the US, the availability of medical services and CT scanning is limited. Consequently, Japanese pediatricians can prescribe head CT scans with relative ease, even

for cases of minor head trauma; therefore, SDH due to short falls can also be detected. If this hypothesis is correct, frequent short falls can produce several layers of SDH, which is again suggestive of SBS/AHT. In addition, a previous study has reported that the percentage of interhemispheric SDH did not differ with the type of traumatic head injury (non-accidental or accidental), wherein short falls accounted for approximately half of all cases of accidental traumatic head injury.[16] Thus, the percentage of cases with SDH indicative of SBS or AHT might be higher among short falls. However, it is still unclear why SDH is observed more frequently in patients who landed on carpeted or tatami surfaces compared with those who landed on hardwood or concrete floors. In the case of falls in which the subjects landed on soft surfaces, the soft surfaces might absorb the energy of the fall, which might induce the tearing of the bridging vein. Further biomechanical studies are required to elucidate the mechanism by which short falls induce SDH.

This study has several limitations. First, we used a retrospective study design; not all the types of fall were represented among the admitted cases. The most significant limitation is that information regarding the surface on which the patient landed was not available in half of the cases, although data regarding the heights from which the patients fell were available for 93.1% of the cases. In addition, symptoms at the visit were not collected prospectively: the absence of symptoms was considered as a negative finding, and physicians might not have checked for or recorded all the symptoms. However, CT findings should be considered as valid information because all the patients underwent CT scans, and the findings were reported by the radiologists. Second, the criteria for admission might have varied across facilities. As an inclusion criterion, we used cases that were "admitted"; however, some patients may have been admitted on the basis of their parents' requests, although admission was not a clinical requirement. Third, fundoscopy and skeletal surveys were not completed in some cases. Thus, the percentages of retinal hemorrhage and rib fractures detected may be lower than the actual percentages in the sample. The fourth limitation is the small sample size. Further research with a larger sample size is required to replicate the study findings.

On the basis of our results, we humbly request pediatricians, emergency physicians, and nurses, who are the first to encounter children with head injury, to very carefully consider the history of falls recounted by the caretaker, as these histories might not be true. Moreover, further research on how short falls induce SDH is required. Collation of the evidence obtained from careful forensic investigations of children who died due to head injury with corroborated histories is required. In addition, experiments using animals, dummies, or computational models should be promoted to elucidate the mechanism of SDH induction by short falls. Further research on the impact of falls using a wider setting with a validated history of falls is also needed.

In Japan, it was found that there was a greater likelihood of SDH in short falls than in long falls, and that landing on carpeted or tatami surfaces resulted in severer clinical presentations than landing on hardwood or concrete surfaces. On the basis of the current evidence, to protect the life of the child in Japan, it is recommended that the history of falls presented by caretakers is treated as secondary information.

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Disclosure

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