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Fatal Falls in Childhood

How Far Must Children Fall to Sustain Fatal Head Injury? Report of Cases and Review of the Literature

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The question of whether fatal head injuries may occur from short-distance falls is one that continues to cause controversy. The records of the Sacramento County Coroner's Office from 1983 to 1991 were reviewed for cases of fatal head injury in children aged ≤5 years, where a history of a fall was initially given. During this 9-year period, three cases of witnessed falls from heights of >10 ft (3 m) were found. At autopsy, all children had multiple complex calvarial skull fractures, basal fractures, or both; subdural and subarachnoid hemorrhage was found in all cases, and two showed severe cerebral contusion. None had retinal hemorrhage or axonal injury. These are compared with 19 fatalities initially alleged to have occurred from short falls of ≤5–6 ft (1.5–1.8 m). As others have found, most of these "minor fall" fatalities occurred under circumstances where there were no unrelated witnesses to corroborate the initial history. Autopsy findings in these cases tended to be of unexpected severity for the initially proposed mechanism of injury, and a number of cases showed evidence of accelerative injury (retinal hemorrhage and/or diffuse axonal injury) where no such mechanism was accounted for by initial history. After sufficient investigation, most of these cases (74%) have ultimately been proven to represent inflicted trauma. A thorough literature review on the subject identifies two major viewpoints. One is that short falls have a significant potential for fatality. The other, more widely espoused view is that short falls rarely, if ever, cause serious injury or death. These two views, and the data upon which they rest, are compared and contrasted.

Key Words: Child abuse—Head injury—Falls from heights.

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At times, medical examiners may be confronted with cases of severe head injury that present with a history of a minor accidental fall. Histories of falls down stairs, against pieces of furniture, in bathtubs, or from beds or couches are common examples. The suspicion of child abuse arises when the injuries do not correspond with the history. This necessitates critical comparison of the severity of the injury and the adequacy of the explanation. Additionally, one may be confronted in the courtroom with medical literature or expert opinion that attributes "severe head injury" to mechanisms typically held to be minor.

To address this question more fully, childhood fatalities from falls in Sacramento County, California, between 1983 and 1991 are reviewed. The related literature is also reviewed, exposing two apparently contradictory viewpoints. The first, more prevalent view is that major trauma does not result from minor falls. The other "minority" viewpoint is that, on occasion, fatal injury to children results from short falls. These two views, and their foundations, are explored and compared.

CASE PRESENTATION

Major-Fall Cases

In the period from January 1983 through December 1991, three cases of accidental injury in children under the age of 5 years, involving falls from heights of between 10 and 25 ft (3 and 7.5 m), were identified in the records of the Sacramento County Coroner's Office.

Case 1

Y.K., a 14-month-old girl, fell from a second-story window onto a concrete sidewalk after a screen came loose. The fall was witnessed by an unrelated bystander. The exact distance of the fall was not

measured, but is estimated at ~15 ft (4.5 m). The child was obtunded at the scene and had right otorrhea. The pupils were fixed but unequal. Aside from an area of right parietal swelling, no external trauma was seen.

The child was stabilized at a local hospital before transfer to the trauma center within an hour of injury. On admission, multiple skull fractures and an acute subdural hematoma were found. After a left parietal craniotomy, the child developed malignant brain swelling. She died ~1 week after injury.

An autopsy performed at the Sacramento County Coroner's morgue found no external injuries of note. Internal examination revealed a large left parietal craniotomy defect, through which softened hemorrhagic brain tissue had herniated. A left frontal skull fracture extended into the orbital plate. Residual subdural hematoma and focal subarachnoid hemorrhage were present.

Case 2

R.D., a 4-year-old girl, had allegedly climbed onto a heating/air-conditioning unit in a motel room and then fallen from the third-story room when a loose screen, covering the window above the unit, gave way. She struck a sheet-metal canopy over a first-story window before falling further to a concrete walkway. The total distance of the fall was estimated at 25–30 ft (7.5–9 m). The fall was not directly witnessed, but the desk clerk recalled hearing a "thump" at the time of the incident. Police investigation revealed several aspects of the scene that confirmed the story and uncovered no contradictory evidence.

The child was rushed by ambulance to the nearest hospital and survived for ~8 h after the injury, following laparotomy with repair of splenic lacerations. She ultimately died from complications of severe head trauma. External findings at autopsy included marked swelling of the head, bilateral periorbital ecchymoses, and facial contusions and abrasions. Superficial abrasions were found on both upper extremities. Internally there was severe subgaleal hemorrhage and multiple complex depressed skull fractures of the left frontotemporal region. Linear basal fractures were present, as were bilateral linear occipital fractures.

The brain showed extensive left temporal and parietal lacerations, deep contusions, and bilateral cerebral and cerebellar subarachnoid hemorrhages. Bilateral pulmonary contusions were also found.

Case 3

J.L., a 22-month-old boy, was in the care of his mother, who was working as a motel maid. The mother was cleaning a third-floor room when the child escaped her attention, crawled under a metal railing, and fell ~20 ft (6 m) onto a concrete surface. He lost consciousness after the impact, but awoke briefly and cried before paramedics arrived.

The child was unresponsive when emergency medical personnel arrived and was hospitalized within 1 h of the injury, with a Glasgow coma score of 6. Computed tomographic scan showed a right frontal acute subdural hematoma, underlying cerebral cortical contusion, and cerebral swelling with a right-to-left shift of ~1 cm. Multiple cranial fractures were present.

He was rushed to neurosurgery for evacuation of the subdural hematoma and partial right frontal lobectomy, but died 32 h after injury, with severe cerebral edema, diabetes insipidus, and disseminated intravascular coagulopathy. The body was transported to the Sacramento County Coroner's Office for postmortem examination.

The head had a 5-cm area of contusion above the right eye. Bilateral periorbital ecchymoses were present, with greater severity on the right. No scalp abrasions or lacerations were seen. Scalp reflection revealed extensive frontoparietal subgaleal hemorrhage. The frontal skull showed multiple basal and calvarial fractures. The midcoronal suture and anterior sagittal suture were diastatic. Basal fracture extended into the right lesser and greater sphenoid wings.

Clot and softened brain matter replaced the right frontal pole; an adjacent frontal subdural hematoma was present. Bilateral uncal and tonsillar herniation and mild right cingulate herniation were found. Microscopic examination revealed acute anoxic damage, but evidence of diffuse axonal injury was absent. Other autopsy evidence of trauma included dislocation of the left wrist and hip, and scattered bruises and abrasions of the back and lower extremities.

Minor-Fall Cases

During the 9 years covered by this report, the records of the Coroner's Office contain 19 fatalities with an initial history of a short fall, usually between 1 and 5 ft (0.3–1.5 m). The reason for a higher number of short-fall fatalities during this period is unclear. It could simply be a reflection of a much higher prevalence of minor falls as compared with higher-distance falls in the community as a whole. However, close examination of individual cases suggests other explanations.

The minor-fall cases break down into three groups: (a) cases with clear evidence of homicidal assault; (b) cases with inconsistencies between history and injury, but where gaps in the investigation or pau-

city of autopsy findings prevent one from reaching a conclusion; and (c) cases where the history and injuries appear consistent.

The first group includes 14 cases (74%) that investigation and injury analysis have shown to be homicides involving either blunt impact (eight cases) or a combination of shaking and blunt impact (six cases). These cases show vast inconsistencies between initial history and spectrum of injury. In nearly all cases, the histories were ultimately amended, either with additional inconsistencies or with a confession of what actually happened.

The second group includes three cases (15.5%). Two have highly inconsistent findings, such as unexplained retinal hemorrhages, but for various reasons cannot be classified as homicides. A third case shows clear evidence of battering, but the cause of death is uncertain and the manner of death remains undetermined.

The third group includes two cases (10.5%) where the histories appear genuine. In one case, a 21-month-old child fell from a top bunk to a carpeted floor. This history suggests a height of fall of between 5 and 6 ft (1.5–1.8 m)—certainly the farthest of the short-fall group. As a result, the child sustained an acute subdural hemorrhage accompanied by severe brain swelling. There was no skull fracture.

In the second case, a 17-month-old child fell backwards from a rocking chair and sustained acute left subdural hemorrhage, subarachnoid hemorrhage, and a left parietal cerebral contusion, without scalp contusion or skull fracture. The fall was perhaps 2–3 ft (0.6–0.9 m), but there may have been an initial angular velocity from movement of the rocking chair. Recalling the formula for free-fall velocity, one of the assumptions is zero initial velocity. If there is, in fact, a significant initial velocity, then the final speed at impact is significantly higher than distance alone might suggest.

CASE ANALYSIS

Presence of Skull Fracture (Fig. 1)

All of the major-fall cases included skull fracture. Of the minor-fall cases, six (31.5%) showed skull fracture. These included three depressed fractures, two complex (one of which was also depressed), one linear but gaping, and one narrow linear. Fewer than one third of the "minor fall" deaths involved skull fracture.

Landing Surface (Fig. 2)

All of the major-fall deaths resulted from falls onto concrete surfaces. Only three (16%) of the 19 minor-fall cases had initial histories of landing on a hard surface such as concrete; two of these cases included skull fractures. In one case (5%), the child reportedly fell onto a semihard surface and had a complex depressed fracture. Fifteen cases (79%) involved a carpeted surface; only one such case included skull fracture.

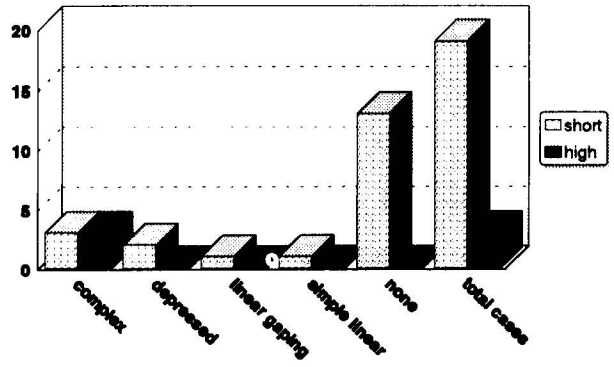

FIG. 1. Skull fractures in fatal falls to children <6 years of age, SAC county, 1983–91.

Unexpected Anatomic Findings (Fig. 3)

The most commonly encountered unexpected finding in the minor-fall group involved unexplained bruises of the trunk and/or extremities. These were found in 13 (68%) of 19 cases. One major-fall case (33%) had significant extremity injury, one (33%) had no extremity injury but had major internal abdominal trauma, and one (33%) had only minimal injury to one hand.

The next most common unexpected finding was retinal hemorrhage and/or diffuse axonal brain injury. None of the major-fall cases had evidence of retinal hemorrhage or diffuse axonal injury. Six (32%) of the minor-fall cases had autopsy evidence of either retinal hemorrhages, diffuse axonal injury, or both, although none of the presenting histories suggested acceleration injury.

FIG. 2. Landing surfaces in fatal falls to children <6 years of age, SAC county, 1983–91.

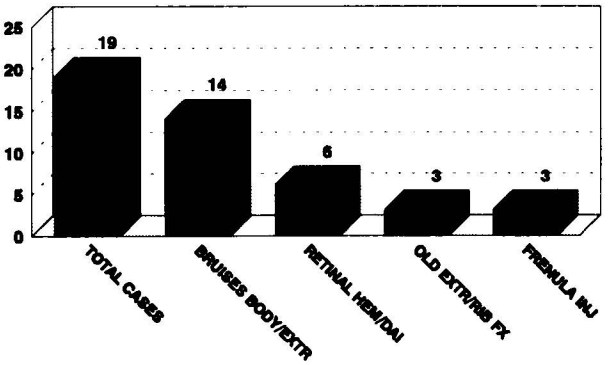

FIG. 3. Unexpected findings in alleged short falls, SAC county, 1983–91.

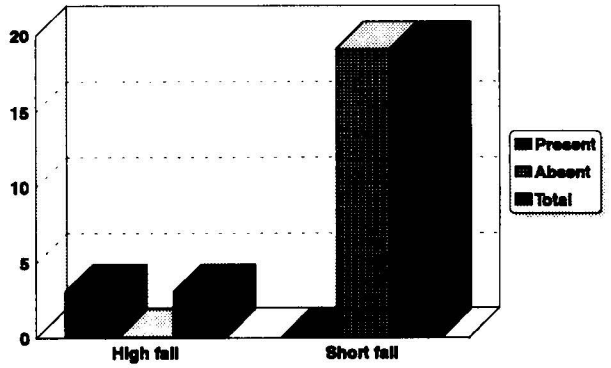

FIG. 4. Fatal falls in children <6 years of age, SAC county, 1983–91, observed by unrelated witnesses.

Torn or bruised frenula were absent in the major-fall cases and were found in only three (16%) of the minor-fall group. Old rib or extremity fractures were also found in three cases (16%).

Presence of Witnesses (Fig. 4)

Two of the three major-fall cases were directly witnessed by unrelated parties. One was indirectly witnessed. None of the 19 minor-fall cases were witnessed by an unrelated party.

LITERATURE REVIEW

A fairly large body of literature presents the concept that children do not typically sustain major injury from minor falls. This concept appears in studies based on series of only short falls without injury, or on series of falls from various heights but with serious injury only at substantial height. There is seeming contradiction in a smaller body of literature that presents cases of serious injury and death in children falling short distances.

The "Major Injury–Major Fall" Literature

This body of literature can be roughly separated into three major subgroups: (a) articles presenting the concept of minor injury from minor falls, (b) articles presenting the concept of major injuries from major falls, and (c) articles that contrast cases of major injury from alleged minor falls with cases of major injury from major falls.

The first subgroup presents the view, on a clinical basis, that short falls rarely, if ever, result in serious intracranial pathology. Helfer et al. (1), though sometimes criticized, represent an oft-quoted vanguard of this position. They present a group of 161 children with histories given by parents, and a second group of 85 children whose falls were witnessed in hospitals. Of the group reported by parents, only two had skull fractures; of the hospital-based cases, there was only one skull fracture. None of the fractures resulted in neurologic sequelae.

Nitimyongskul and Anderson (2) also conclude that minor falls lead to relatively minor injuries. In a series of 76 children who fell from low heights, there was only one questionable occipital skull fracture. Most injuries were cutaneous or soft tissue bruises or lacerations. No fatalities were encountered.

The second subgroup presents fatalities resulting from major falls. Barlow et al. (3) reviewed a series of 61 children aged ≥15 presenting with injuries from falls and found no fatalities from heights of three stories or less. The 50% mortality rate occurred between the fifth and sixth floors; most fatalities were from brain trauma.

Cummins and Potter (4) studied falls of ≥10 ft (3 m) by children and adults and found three fatalities—all adults falling onto concrete. Serious but nonfatal injuries, including four depressed compound skull fractures, were also found among children who had fallen onto hard surfaces from similar heights. Skull fractures in the group as a whole were more frequent in children of ≤5 years of age, but brain trauma was more frequent in older patients. Severity of brain injury was more significant in predicting outcome than was the presence or absence of skull fracture.

The third subgroup compares mortality and injury rates from alleged minor falls and from witnessed major falls. This group is represented by two recent studies. Chadwick et al. (5) address the issue from the standpoint of mortality rates. In their series, there was one death in 118 children who fell from between 10 and 45 ft (3–13.5 m; mortality rate, 0.85%), whereas seven of 100 children died whose caretakers gave a history of a fall of ≤4 ft (1.2 m; mortality rate, 7%). This would imply, if

most of the short-fall histories are accepted, that falls of <4 ft are not only dangerous, but are more than eight times as dangerous as falls from 10 to 45 ft. The odd results are attributed to falsification of history in the short-fall group, a conclusion that gains support from the high frequency of retinal hemorrhage in this group. The overall findings by Chadwick et al. generally correspond with the present author's analysis of Sacramento County cases.

Williams (6) echoes Chadwick et al. in comparing injury rates in falls of approximately known heights, and witnessed by unrelated parties, with injury rates in allegedly short falls (<5 ft or 1.5 m) where no independent verification was obtainable. The findings are quite similar to those reported by Chadwick et al.

The "Major Injury–Short Fall" Literature

Reichelderfer et al. (7), in discussing playground injuries, state that serious head injury may occur in falls where gravity (*g*) forces exceed 50 *g*. The authors list tabular data which indicate that a drop of 0.25 ft—a "fall" of 3 in. (7.5 cm)—onto a concrete surface may generate a force of 150–200 *g*. A drop of 1 ft (0.3 m) onto concrete produced a 475–525 *g* impact.

Weber (8) dropped infant cadavers and found that, in free-fall situations, skull fractures may occur in young (<1 year) infants at changing-table and countertop heights, especially with a hard landing surface. Most injuries were linear parietal fractures; complex fractures were rare.

Root (9) implies that, if skull fractures may occur with falls from relatively low heights, then *perhaps* serious head injury does not require a "serious" event or mechanism. He presents the image of someone running headlong into a brick wall, which would most certainly result in discomfort and could produce serious injury. Unfortunately, since no hard data result, it is difficult to compare such a mental "experiment" with the clinical and laboratory studies on children who fall or infant cadavers that are dropped.

A recent study of autopsied children by Hall and colleagues (10) reveals a potential for mortality from minor falls of ≤3 ft (0.9 m). Over a 4-year period, 18 children died after allegedly falling <3 ft. Two of the cases were witnessed by medical personnel. The remaining 16 were not independently witnessed, but the histories were never disproved.

Whereas the medical examiner's office involved in the study autopsied eight children who died after falls from five stories or higher, 18 children were autopsied who died after allegedly falling ≤3 ft. This could be simply a function of frequency of major versus minor falls in the community. There is also the possibility of falsified history, as our analysis of Sacramento cases indicated.

While the study by Hall and colleagues does not contain our type of case analysis, the lack of concurrent injuries to other parts of the body in their series contrasts with the high incidence of such unexpected trauma in our series. While not settling the issue, this may indicate a higher likelihood that his short-fall histories were true than in our cases.

DISCUSSION

Superficially, there is clear conflict in the literature on the subject of fatalities from childhood falls. On closer examination, however, the conflict is less than it initially seems. Much of the apparent contradiction arises not so much from the data contained in the literature as from the use of differing approaches to the data and the inherent strengths and weaknesses of those approaches. Table 1 summarizes these differences.

While there is disagreement, there is also much consensus in the literature on the subject. The major areas of consensus form a core of concepts that contain useful guidelines for the evaluation of one's individual cases.

One point of consensus is that the presence of skull fracture *alone* is not evidence of nonaccidental trauma, particularly when only a simple linear parietal fracture is present. Several clinically based studies (11,12) illustate the not uncommon occurrence of linear skull fractures from minor falls in children. While the greatest incidence involves infants of <1 year of age, a lower incidence is also seen in older children. Such fractures are usually uncomplicated and result in no neurologic sequelae. Other types of fracture, however, are more problematic. Complex fracture patterns and large depressed fractures, especially when combined with severe intracranial pathology, are generally inconsistent with minor falls (13–15). Unless there is history of a major fall or road accident, the possibility of abuse must be investigated in these cases. Small depressed fractures, however, have been seen in accidental short falls against edged surfaces (6).

Another important point over which there is no contradiction is the lack of major nonhead trauma in short falls. When falls of significant magnitude occur, injuries to parts of the body other than the head may be present and may be of major significance (3,4). However, such collateral trauma is not expected from a short fall (10). If severe trauma to

TABLE 1. *Comparison of literature on childhood falls*

Helfer et al. (1)	
Viewpoint	Clinical pediatrics; need for routine x-rays
Strengths	Size of series; use of clinical data
Weaknesses	Fall mechanics limited to landing surface and relative height; partial reliance on questionnaires may add reporting bias
Nitimyongskul and Anderson (2)	
Viewpoint	Orthopedic surgery (clinical study)
Strengths	Statistical analysis of direct clinical observations
Weaknesses	Little information on mechanics of falls; primary focus on skeletal trauma, not head trauma
Barlow et al. (3)	
Viewpoint	Pediatric surgery/injury prevention (clinical study)
Strengths	Includes some autopsy data; includes variety of distances
Weaknesses	Addresses only free-falls; small series
Cummins and Potter (4)	
Viewpoint	Neurosurgery/outcome oriented (clinical study)
Strengths	Cases well analyzed
Weaknesses	Small database
Chadwick et al. (5)	
Viewpoint	Pediatrics/child abuse (clinical study)
Strengths	Reasonably sized database; more detailed case analysis
Weaknesses	Overt orientation to child abuse diagnosis may lead to exclusion of some valid short-fall cases
Williams (6)	
Viewpoint	Pediatric pathology (clinical study)
Strengths	Reasonably sized database; good statistical analysis
Weaknesses	Many histories uncorroborated
Reichelderfer et al. (7)	
Viewpoint	Pediatrics/injury prevention (laboratory data presented)
Strengths	Laboratory-based "hard" data; tabular presentation clear
Weaknesses	Experimental technique not discussed leaves question of comparability to real-world falls
Weber (8)	
Viewpoint	Forensic science (laboratory study)
Strengths	Lab study with some control; varying heights and contact surfaces; used actual infants (cadavers)
Weaknesses	Use of cadavers prevents full injury evaluation; comparability with older children questionable
Root (9)	
Viewpoint	Forensic pathlogy (discussion article only)
Strengths	Appeal to conceptual framework
Weaknesses	No data; limited to discussion and opinion
Hall et al. (10)	
Viewpoint	Pediatric surgery/prevention (clinical study)
Strengths	Includes clinical and autopsy data
Weaknesses	Case breakdown unclear; autopsy findings abbreviated; evaluation of some histories may be too noncritical

Note: All of the articles except those by Weber (8) and Root (9) relied largely on hospitalized cases. This selects for the most serious cases and may overemphasize the commonality of injuries from falls of any height.

head *and* body is found, a presenting history of a minor fall is suspect.

One clear area of remaining uncertainty concerns the infant skull itself. The pliability and thinness are considered by some (4) to provide greater protection to the brain by virtue of a greater degree of shock absorption. Others (10) feel that the child's skull provides less protection. The true role of the child's skull in either lessening or exacerbating the magnitude of internal injury is a question that deserves additional study.

CONCLUSIONS

In our series, all fatalities from bona fide short falls resulted from intracranial hemorrhage without skull fracture or significant external head trauma. Hall et al. (10) also emphasize the possibility of potentially

lethal intracranial hemorrhage from seemingly "minor" falls. Cases of fatal malignant cerebral edema may also occur without signs of major mechanical trauma to the scalp or skull (16–20).

In contrast, cases with extensive skull fracture and brain contusion or laceration, or with major head *and* body injury, render a short-fall history highly questionable. Findings of retinal hemorrhage, interhemispheric subdural hemorrhage, and diffuse axonal injury indicate accelerative injury. Without a history of a major fall or high-speed motor vehicle accident, these findings typically point to shaking or shaken/impact syndrome.

The height from which children must fall to sustain fatal head trauma is a question that lacks a single, easy answer. One has to consider the possible mechanics of the fall, the age and condition of the child, and the shape and consistency of the contact surface. Correlation of fall mechanics and injury pattern should be considered.

The bulk of the studies on head injuries in children, regardless of viewpoint, are based on hospitalized cases. This selects for the most serious cases and is likely to give the impression that fatalities from short falls are more prevalent than they actually are. The conclusion that appears best at this time, with our current state of information, is that, while children on occasion suffer fatal injury from short falls, such events are an extreme rarity. Major injuries nearly always result from major impacts and serious falls. □

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