

CASE REPORT

PATHOLOGY/BIOLOGY

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Fatal Acute Intracranial Injury, Subdural Hematoma, and Retinal Hemorrhages Caused by Stairway Fall*

ABSTRACT: We describe an infant with an acute subdural hematoma, a fatal head injury, and severe hemorrhagic retinopathy caused by a stairway fall. His cerebral and ocular findings are considered diagnostic of abusive head trauma by many authors. Our literature search of serious injuries or fatalities from stairway or low-height falls involving young children yielded 19 articles of primary data. These articles are discrepant, making the classification of a young child's death following a reported short fall problematic. This case report contradicts the prevalent belief of many physicians dealing with suspected child abuse that low-height falls by young children are without exception benign occurrences and cannot cause fatal intracranial injuries and severe retinal hemorrhages. The irreparable harm to a caregiver facing an erroneous allegation of child abuse requires physicians to thoroughly investigate and correctly classify pediatric accidental head injuries.

KEYWORDS: forensic science, retinal hemorrhages, subdural hematoma, shaken baby syndrome, child abuse, accidental fall, abusive head trauma, stairway fall, short fall

Extensive multilayered retinal hemorrhages (RHs), an acute subdural hematoma (SDH), and brain injury—recognized manifestations of abusive head trauma (shaken baby syndrome)—reportedly do not occur from an accidental head injury when an infant falls downstairs or from a low height (1–31). If a young child dies from a stated short fall, a few authors assert that the caregiver(s) falsified the history (32–35). We present an infant with a fatal traumatic brain injury, acute SDH, and severe hemorrhagic retinopathy. A thorough investigation corroborated witness accounts that the injuries resulted from an accidental fall (<1.5 m) down carpeted steps, which has important medico-legal implications.

Case Report

Transported in extremis by ambulance, a 7 $\frac{3}{4}$ -month-old male infant had a modified Glasgow Coma Scale of 3 and a rectal temperature of 35°C on arrival at our medical center's emergency department. Resuscitative measures restored a labile heart rate and blood pressure after he experienced pulseless electrical activity (PEA). Axial cranial computed tomography (CT) revealed a left acute SDH of mixed low attenuation suggestive of active bleeding (Fig. 1). Associated findings included a left to right midline shift with early subfalcine and uncal herniation, mild edema of the left cerebral hemisphere, plus blood layering along the tentorium and

falx cerebri. The cranial, cervical, thoraco-abdominal, and pelvic CT images revealed no other injuries. He had an initial hemoglobin of 76 g/L, a hematocrit of 0.228, a prothrombin time of 17.6 sec,

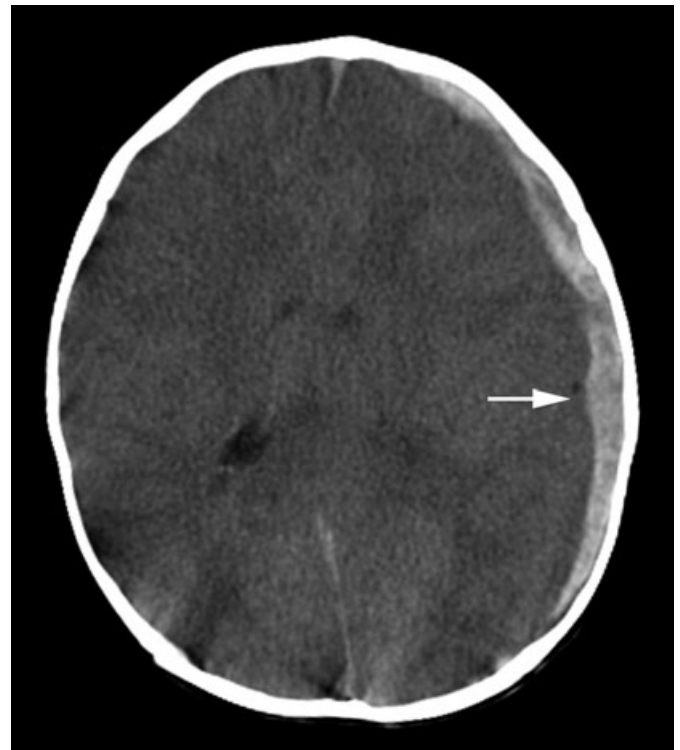


FIG. 1—An axial cranial computed tomography image shows an acute mixed low attenuation subdural hematoma (arrow) compressing the left cerebral hemisphere with a resultant 0.7–0.8 cm left to right midline shift.

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a partial thromboplastin time of >200 sec, a platelet count of $247 \times 10^9/L$, an arterial blood pH of 6.884, and a lactic acid of 12.5 mmol/L. In the operating room, progressive bradycardia and hypotension preceded a final episode of PEA. Resuscitative efforts continued for 20 min during exploration for a bleeding source and evacuation of the compressive subdural blood that had increased to about 2 cm in thickness. At 9:27 PM, he was pronounced dead.

Separate interviews with the mother and maternal grandparents revealed that immediately before the incident, he was active, playful, and crawling on the floor. In adjacent rooms, the mother and grandmother heard a loud thud. Finding him supine on the basement steps' landing (the stairway door had inadvertently been left open), the grandmother comforted him but did not move him while the mother called emergency medical services (dispatch time: 6:45 PM). He cried for about 2 min, started to gasp, and then became unresponsive. Paramedics arrived at 6:52 PM, immediately began resuscitative measures and transported him to the hospital (arrival time: 7:15 PM).

Delivered vaginally at term following an uncomplicated pregnancy, he weighed 4.0 kg and had Apgar scores of 8 and 9 at 1 and 5 min, respectively. Physical examination in the nursery noted cranial molding, a caput succedaneum, and a head circumference of 38.1 cm. He received vitamin K, and no hemostatic complications occurred following circumcision. He attended all scheduled well-child checkups (WCCs) and received all of his routine immunizations. His head circumference was at the 75th percentile when he was 5 weeks old and was at the 90th percentile at his 6-month WCC. According to the mother, grandparents, and family friends, he had been crawling since he was about 6½ months old.

His autopsy weight and length were at the 70th and 97th percentile, respectively, for his age. External injuries included a superficial 1.5-cm pale tan abrasion on the right shoulder and two small pale blue nonpatterned bruises on his lower extremities. Indirect

ophthalmoscopy revealed bilateral RHs (left > right). A large preretinal hemorrhagic cyst and vitreal blood obscured most of the left macula (Fig. 2). Ocular examination disclosed bilateral acute perineural soft tissue extravasated blood, optic nerve sheath hemorrhages, and multilayered RHs (left > right). Peripheral RHs were focally <0.1 cm from the right ora serrata, whereas the left globe contained vitreal blood and extensive multilayered RHs extending 360° to the ora serrata (Fig. 3). Blood had extravasated within the subcutaneous tissue near the surgical incision, but a definite impact site on the scalp or underlying soft tissue was not evident. No bony, ligamentous, or soft tissue injury involved the cervical spine, and his osseous survey revealed no acute or healing fractures. Neuropathological examination of the brain and spinal cord verified the radiological findings of an acute intracranial injury with compressive effects from a left acute SDH. A focal microscopic contusion of the right inferior cerebellar hemisphere had overlying acute subarachnoid hemorrhage (SAH). Immunohistochemical staining of the brain for β -amyloid precursor protein exhibited a vascular axonal injury pattern except for focal axonal staining of the midline pons and lateral upper cervical spinal cord.

The upper half of the stairway (hallway to the landing) consisted of a carpeted flight of six oak steps and landing (total units of rise = 7). The riser height measured 0.2 m, contributing to a total

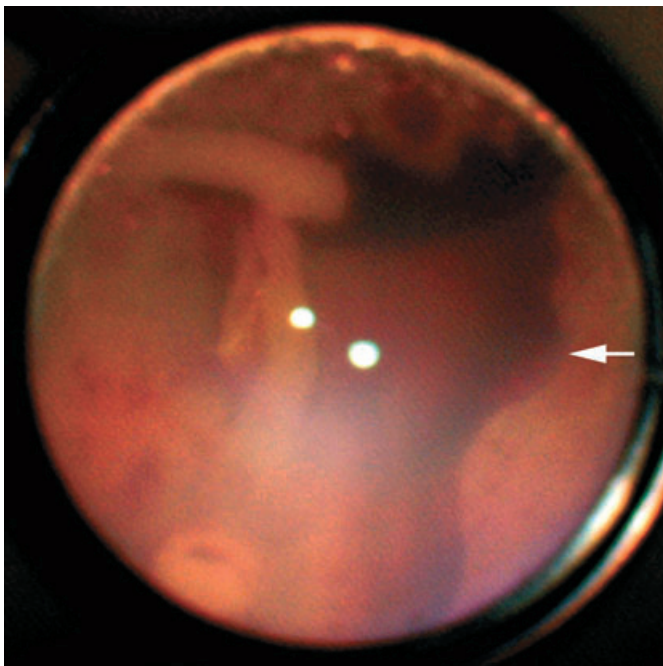


FIG. 2—The indirect ophthalmoscopic projected aerial image reveals a subinternal limiting membrane hemorrhagic cyst (arrow) covering most of the left macula plus thin wisps of vitreal extravasated blood characteristic of Terson syndrome.

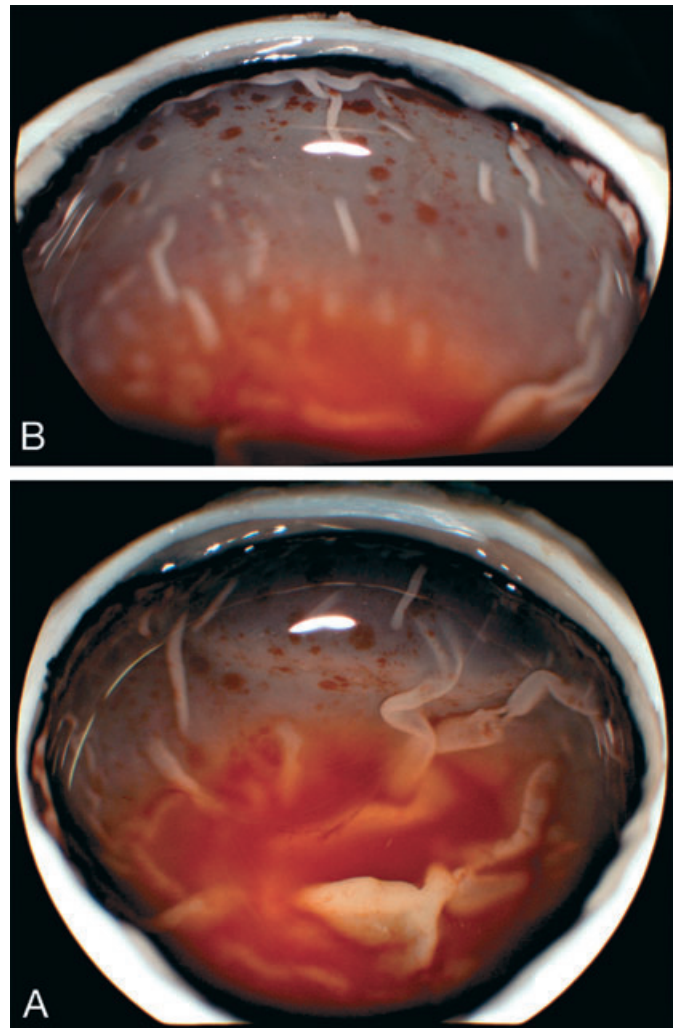


FIG. 3—The left globe exhibits extensive hemorrhagic retinopathy with vitreal blood (A) and has peripheral retinal hemorrhages abutting the ora serrata (B). The retinal folds are postmortem artifacts.

vertical height from the landing to upstairs floor of 1.42 m and a stairway pitch of 37°. The treads and landing measured 2.7 cm thick, and the synthetic carpet and pad had a combined thickness of 1.9 cm.

The mother and grandparents provided detailed, credible, and repeated unchanging accounts of the incident to the emergency medical services dispatcher, paramedics, emergency department personnel, neurosurgeon, detectives, and medical examiner. Medical professionals, law enforcement personnel, and the multidisciplinary child fatality prevention team found no contradictory evidence or risk factors after their evaluation of the medical and investigative findings.

Discussion

The missed diagnosis of an abusive head injury in an infant or toddler can have catastrophic consequences (36). Conversely, the mistaken diagnosis of abusive head trauma can cause irreparable harm with devastating medical, social, and legal ramifications (37). To systematically find the reports of original data about serious injuries or fatalities from stairway or low-height falls involving young children, we searched the National Library of Medicine through September 2010. The terms and medical subject headings (MeSHs) included:

- accidents/mortality [MeSH] OR child abuse/diagnosis [MeSH] OR craniocerebral trauma/etiology [MeSH] OR retinal hemorrhage [MeSH] OR intracranial hemorrhages [MeSH]
- accidental falls [MeSH] OR fall OR falls OR stair*
- #1 and #2.

Setting the English language search strategy to “Limit to All Child (0–18 years)” recovered 906 articles. We reviewed pertinent abstracts and articles on serious childhood injuries or fatalities related to stairway and low-height falls, plus cited references and correspondence to identify related reports. We also examined citations from two recent review articles discussing short-fall deaths in young children (35,38). After excluding review articles, commentaries, position papers, technical reports, and consensus guidelines, we identified 19 articles of original data. The authors of nine of these studies did not discuss RHs.

Falls Downstairs

In a retrospective review encompassing April 1985 to October 1985, Joffe and Ludwig (39) found no evidence of intracranial hemorrhage in 363 children, 1 month to 18.7 years of age (mean and median age: 55 and 38 months, respectively), with a history of a fall downstairs. Concussions occurred in three children and six sustained skull fractures; however, the percentage of children having radiographic imaging was not stated. The authors maintained that falls downstairs seldom result in serious injury and are much less severe than free falls of the same total vertical distance.

In contrast, Chiaviello et al. (40) reported on 69 children <5 years of age (median age: 2 years) who had fallen downstairs and presented to their pediatric emergency department from November 1990 through October 1992. The majority of children (84%) were injured at home while unsupervised (71%). Significant injuries occurred in 22% of the children including 11 concussions, five skull fractures, two cerebral contusions, one SDH (the child fell while being carried), and one cervical fracture. Of the eight children hospitalized, two were admitted to the intensive care unit. The authors concluded that stairway-related injuries in young children are most often superficial but that severe head injury can occur.

In a retrospective review of extensive cerebral hemispheric hypodensities on CT imaging, <5 h after traumatic events, Steinbok et al. (41) identified five infants and children (ages: 4 months–14 years) with well-documented accidental head injuries that caused death within 48 h. A 7-month-old infant had an acute SDH, mild intraventricular hemorrhage, and parenchymal hypodensities associated with bilateral preretinal hemorrhages and RHs, considered consistent with nonaccidental trauma. However, on the basis of corroborating eyewitness accounts, the child protection team concluded that the fatal injury was the result of a fall downstairs as described by the family. The child protection team also determined that a 2-year-old child with tentorial and convexity SDHs, parenchymal hypodensities, and normal funduscopy died after falling from a stool.

A retrospective analysis of medical records for 24 months (2005–2007) by Docherty et al. (9) revealed 239 children <15 years of age (median age: <1 year) with a history of having fallen downstairs. Injuries occurred in 90% of the patients with 69% (165 of 239) sustaining minor head and facial injuries. The authors reported that 2% (five of 239) had skull fractures; however, only 18 children had skull radiographs (one child had a skull fracture diagnosed on a cranial CT without having skull radiography). All the skull fractures occurred when children were dropped while being carried on stairs. The authors concluded that children who fall downstairs are typically toddlers and generally only sustain minor injuries (mainly minor head injuries) and infants who fall downstairs with a caregiver or are dropped while being carried downstairs require an especially careful evaluation.

Low-Height Falls

In the pre-CT era, Gutierrez and Raimondi (42) described 27 neonates, infants, and toddlers they treated from 1968 to 1972 with posttraumatic acute SDHs. The authors stated that falls and child abuse caused 33.3% and 29.6% of the injuries, respectively. RHs occurred in 40% of the newborns, 63.1% of the infants, and 33.3% of the toddlers. Of the five children who died, three were ≤3 months of age, while the other two were 3 and 4 years of age. The authors did not characterize the circumstances associated with the RHs or deaths.

From medical examiner’s files from January 1983 through December 1986, Hall et al. (43–45) identified 18 children (mean age: 2.4 years) who died from accidental falls of <0.9 m (eight witnessed by two or more people in public places). Intracranial injuries included 15 SDHs (five with linear skull fractures), one epidural hematoma (EDH), one cerebral edema, and one cerebral laceration. Fall circumstances consisted of two dropped on ice, five while playing, eight off an object, and three down steps. Two fatal SDHs occurred in medical facilities. Delays in recognition and treatment of head injuries were identified as contributing factors in these deaths. According to the authors, investigations by law enforcement and the medical examiner’s office ruled out child abuse.

During a 2-year period from a children’s hospital emergency department, Williams (30) prospectively studied the fall height necessary to cause severe injury or death in infants and young children. Inclusion criteria included children <3 years of age, a description of injuries and outcome, and a free unobstructed fall from stationary object witnessed by two or more people or by a nonrelated person uninvolved in care of the child. The fall height was estimated to the nearest foot. Of the 106 children in the witnessed group, no injuries occurred in 15 including seven who fell <3.05 m. Mild injuries (bruises, abrasions, lacerations, and simple fractures) occurred in 77 children including 43 who fell >3.05 m.

Severe injuries including intracranial hemorrhages, cerebral edema, depressed skull fractures, and compound or comminuted fractures occurred in 14 children falling between 1.52 and 12.19 m. Three children who fell between 1.22 and 1.52 m onto edged surfaces had small, depressed skull fractures, and one infant died after falling 21.34 m. A comparison group consisted of 53 children <3 years of age who had a free fall that was not witnessed or was witnessed by a single caretaker only. In this latter group, 18 had severe injuries and two died after falling <1.52 m. The author did not describe the fall circumstances or surfaces fallen onto and conceded that falls of >1.83 m generally occurred outside accounting for the frequency that independent observers corroborated higher falls. Because severe injuries and deaths from falls ≤ 1.52 m occurred only in the uncorroborated group, the author assumed that many if not all of the severe injuries attributed to low-height falls represented child abuse.

Chadwick et al. (33) retrospectively classified 317 children presenting to a trauma center between August 1984 and March 1988 with a history of a fall. Seven of 100 children died from short falls (0.3–1.22 m). No deaths occurred in the 65 children who fell 1.52–2.74 m, and one death occurred in 118 children who fell 3.05–13.72 m. Fatal short-fall histories included two from standing height, two from bed/table, one downstairs, and two from arms of an adult. Head injuries in these seven consisted of one skull fracture, seven SDHs, and five SAHs, and all had cerebral edema. Five had RHs (severity and location not specified). The authors inferred that if the histories of short falls were accepted as correct, this would mean that the risk of death is, counterintuitively, eight times greater for children who fall from <1.22 m than for those who fall from 3.05 to 13.72 m. They therefore surmised that when children incur fatal injuries from falls of <1.22 m, the history was incorrect; however, they did not validate their assumption with the medical examiner's certification.

Duhaime et al. (10) prospectively studied 100 consecutively admitted head-injured children ≤ 24 months of age (mean age: 9 months). All had an ophthalmological examination within 36 h of admission. The authors developed an algorithm that incorporated the specific injury type, best history available, and associated physical and radiological findings, so that their determination of inflicted injury was purportedly independent of the ophthalmological examination. Their algorithm indicated presumptive or suspicious inflicted injury if a history of forces was considered by the authors to be mechanically insufficient to cause a particular injury, designating falls of <0.91 m as "trivial." For the 73 children with a history of a fall, the reported height or mechanisms for those falls were 34 <1.22 m, 21 >1.22 m, 10 downstairs, and eight downstairs in a walker. Three EDHs occurred in accidental falls <4 feet. Of the 24 children meeting criteria for presumed inflicted injury, eight had a history of a fall of <1.22 m. Ten children in the study had RHs (all with SDHs); nine of 10 had inflicted injuries (two with a history of a trivial fall). The authors concluded that RHs can occur in severe accidental head trauma but were never seen in trivial accidental head injuries. After their study was completed, the authors identified three children with accidental head injuries who had RHs—a nonfatal traffic accident, a fall downstairs in a walker, and a fatal three-story fall.

Reiber (46) evaluated coroner's records from 1983 to 1991 and identified 19 pediatric fatal head injuries (age: <5 years) with fall histories of <1.83 m. Manner of death determinations were 14 homicides, three undetermined, and two accidents. Six children, including two of the three children in his undetermined category, had RHs or axonal injury that the author considered indicative of accelerative injury. Accidental deaths included a 21-month-old

child who fell 1.52–1.83 m from a top bunk, sustaining an SDH plus cerebral edema, and a 17-month-old toddler who fell backward 0.61–0.91 m from a rocking chair, causing an SDH, an SAH, and a cerebral contusion. The author determined that while children on occasion suffer fatal head injuries from short falls, such events are extremely rare.

From an administrative database (Washington State Comprehensive Hospital Abstract Reporting System), Rivara et al. (47) reported the incidence and characteristics of fall-related injuries in children and adolescents (≤ 19 years of age) occurring in 1989 and 1990. Data on fatalities came from the state of Washington vital statistics tapes for the same years. Fall-related injuries accounted for 2658 hospital admissions. Head injuries including concussions, skull fractures, and intracranial bleeding occurred in 586 (22%) of the children. Head trauma was more common in preschool children (42.1%) compared with 14.4% of adolescents (15–19 years of age). The circumstances of the 11 fall-related deaths were not characterized; however, eight were because of head injuries. Only one child <10 years of age died.

From medical records of 287 children with head injuries that occurred from January 1986 through December 1991, Reece and Sege (25) categorized 54 as definite abuse and 233 as accidents. The authors conceded that funduscopic examinations were not recorded in all 287 children, even though they reported the presence of RHs in 18 of 54 definite abuse cases and in five of 233 accidents. The abuse and accident groups had mean and median ages of 0.7 and 0.3 versus 2.5 and 2.3 years, respectively. Of those children with a history of a short fall (<1.22 m), the authors classified 62 cases as accident and eight as abuse. The short-fall accident group had five complex skull fractures, 12 concussions, two brain contusions, five SDHs, one SAH, and no RHs, whereas in short-fall histories characterized as abuse, there were three SDHs, three SAHs, one complex skull fracture, and two RHs. They commented that short falls seldom cause SDHs and SAHs, while RHs are virtually never seen.

Reviewing more than 75,000 reports of playground-related head/neck injuries in the United States Consumer Product Safety Commission National Injury Information Clearinghouse databases from January 1988 through June 1999, Plunkett (48) found 18 fatal fall-related traumatic brain injuries. Ages ranged from 12 months to 13 years (mean and median ages: 5.2 and 4.5 years, respectively) with fall heights estimated between 0.6 and 3 m. Five children were 12–24 months of age, but none in the study were <1 year old. Noncaregivers witnessed 11 incidents, and one was videotaped. In the six fundal examinations by nonophthalmologists, four children had bilateral RHs. Cerebral findings included one EDH, two cerebral infarcts, 10 SDHs, and 12 with cerebral edema. The author reasoned that an infant or young child might sustain a fatal head injury and RHs from a fall of <3 m.

Wang et al. (49) retrospectively examined 729 charts of pediatric patients (<15 years of age) treated for accidental fall-related trauma from 1992 through 1998. Twelve children died, eight from heights ≥ 4.57 m and four from <4.57 m. The four children who died of falls <4.57 m did not have stigmata of abuse according to the Suspected Child Abuse and Neglect team. A 3-year-old girl died after tripping, sustaining an orbital fracture, ocular injury, and SDH. The authors concluded that children suffering low-level falls (<4.57 m) had a similar risk for intracranial injuries compared with those who fell from greater heights (>4.57 m), although triage may have overrepresented low-level falls with significant clinical signs.

Denton and Mileusnic (50) described a 9-month-old infant who had a witnessed fall off a bed and then was reportedly asymptomatic for 72 h before being found dead. Autopsy findings included a

linear nondisplaced parietal skull fracture, occipital sutural diastasis, subgaleal hemorrhage, a small posterior SDH, marked cerebral edema, and a small tear in the corpus callosum but no diffuse axonal injury or RHs.

From a retrospective 6-year medical record review (1994–1999), Park et al. (51) described fall-related head injuries and outcomes in children <7 years of age at a pediatric trauma center. Child abuse and motor vehicle accidents were excluded from the study. The authors identified 52 children <3 years of age and 16 children who were 4–6 years old; all had cranial CTs. Falls were classified as low (<1 m) or high (>1 m) level based on witness or paramedic narratives. Typical low-level falls were from a chair, bed, table, or sofa, while high-level falls usually occurred from a window, balcony, or stairs. Of the 68 children, five (four <3 years of age) died because of intracranial injuries (three SDHs and two severe contusions). Of the 38 low-level falls, 19 children had a skull fracture without an intracranial injury, seven had an intracranial injury, six had an extracranial injury (extremity fracture or viscus injury), and one (2.6%) died. The authors did not characterize the fall circumstances but concluded that children sustaining low-level falls are at risk of intracranial injury and death.

In a prospective study, Trenchs et al. (28) reported no SDHs or deaths in 154 children, 15 days to 2 years of age (mean age: 10.1 months), hospitalized from May 2004 to May 2006 with head injuries from vertical falls. Eighty-three percent of the falls were from heights ≤ 1.2 m. Seven children fell downstairs from a standing position. One hundred twenty-two children had skull fractures, and 16 (10.4%) had intracranial injuries including 14 EDHs, one SAH with parenchymal contusion, and one cerebral contusion. Unilateral RHs (confined to the posterior pole) occurred in three children with an EDH and midline shift, but RHs were not evident in children who had no intracranial injuries. The authors contended that diffuse, bilateral RHs indicated trauma other than a fall.

Falls from household furniture and staircases accounted for 21.3% and 6.9%, respectively, of the 174 fatal accidental falls in infants and children analyzed by Behera et al. (52). Their retrospective study of medical records and autopsy reports covered a 10-year period (January 1998–December 2007). Ages ranged from 4 months to 14 years (mean age: 4.87 years) with 7.5% ≤ 1 year old. Intracranial injury was the most common cause of death with SDHs documented in 60 of 147 of the fatal head injuries. The average fall distance was 5.38 m, and the lowest fall height occurred with a 6-month-old infant who fell from a bed. The authors did not correlate fall circumstances with intracranial injuries.

Stray-Pedersen et al. (53) characterized the clinical findings of an 11-month-old infant, who according to her parents, was standing, fell backward, and struck her head on a carpeted wooden floor. Shortly thereafter, she stiffened and became less responsive. On admission to the hospital, she had a decreased level of consciousness and a dilated left pupil. Following emergency surgery to evacuate a compressive left SDH, an ophthalmological examination disclosed numerous bilateral, multilayered RHs. Because of the putative inconsistency between the history and the severity of the SDH and RHs, the case was reported to law enforcement and the parents were charged with child abuse. Initial coagulation testing was normal; however, subsequent analyses uncovered mild von Willebrand disease Type I. As such, the medical conclusions were modified and the allegation of child abuse was withdrawn. The authors indicated that repeat laboratory testing might be necessary to reveal minor coagulation disorders and emphasized that coagulopathies are extremely difficult to diagnosis in fatalities.

Conclusions

These published reports of original data are discordant and controversial, making the correct classification of a young child's death following a reported short fall a diagnostic challenge. Most childhood stairway and low-level falls do not cause serious head injuries. Nevertheless, not all seemingly minor falls are minor. This case report refutes a pervasive belief that childhood low-height falls are invariably trivial events and cannot cause subdural bleeding, fatal intracranial injuries, and extensive multilayered RHs. The harmful and potentially devastating consequences for a caregiver or family facing a false allegation of child abuse obligate physicians to thoroughly investigate and accurately classify pediatric accidental head injuries.

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