Traumatic brain injury in high versus low falls in young children and adolescents: a retrospective analysis

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OBJECTIVE So-called low falls are gaining interest in traumatology. To date, there are no studies on low versus high falls in the pediatric population. The aim of the current analysis was to characterize the symptoms, diagnostics, and injuries associated with high versus low falls and to examine the effect of fall height on injuries and outcome in the context of current guideline-based recommendations.

METHODS After obtaining study approval from the local ethics committee, the authors reviewed the data for patients ages 5–17 years who had been consecutively treated at either hospital associated with the University Medical Center Hamburg in the period from January 2009 to August 2014 for diagnoses including traumatic brain injury (TBI). Retrospective analysis of the electronic patient charts was performed to obtain data on demographics; accident mechanism; initial neurological status with respect to consciousness, symptoms, and Glasgow Coma Scale score; radiological studies; diagnoses; length of stay; all intracranial procedures; and Glasgow Outcome Scale (GOS) score.

RESULTS Sixty-five fall-related TBIs among 380 patients were identified; 26 patients fell from a height of 3 m or more and 28 fell from a height under 3 m (height undocumented in 11 cases). Patients who fell from ≥ 3 m were 22 times more likely than those who fell from < 3 m to undergo spiral CT studies in the emergency room ($p = 0.05$). In addition, there was a 7.4 times greater chance of undergoing cranial CT ($p = 0.02$). There were significantly more noncerebral injuries requiring surgery in patients who fell from ≥ 3 m versus those who fell from < 3 m ($p = 0.007$). There was no difference in the frequency of neurosurgical procedures performed between low and high groups. Follow-up ranged from 0 to 92 months (mean 12.5 months, median 0 months). There was no significant difference in good (GOS score 4–5) and poor (GOS score 1–3) outcomes between high and low falls ($p = 0.208$).

CONCLUSIONS Low falls can be associated with intracranial hemorrhages requiring ICU monitoring and/or surgery. The authors encourage intensive monitoring and CT scans based on clinical presentation, not on fall height.

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KEYWORDS children; traumatic brain injury; falls; trauma

FALLS most commonly occur as accidents. In young children, they can be related to child abuse. In older children, they can be related to suicide attempts. Clinicians in Germany base their treatment decisions on the guidelines published by the national Association of the Scientific Medical Societies in Germany. The trauma guidelines are an interdisciplinary effort coordinated and led by the German Society of Trauma Surgery and were recently updated (<http://www.awmf.org/en/clinical-practice-guidelines/detail/11/012-019.html>). According to the guidelines,

falls from a height over 3 m should be treated in the trauma room. Cranial CT scans may be necessary for “high-velocity trauma,” which is defined as a fall from a height over 6 m, among other things (e.g., traffic accidents). Specific guidelines for children are currently being developed.

So-called low falls are gaining interest, especially in the geriatric population. The literature regarding falls, especially those from low heights, is sparse. In falls from greater heights, there is some differentiation with respect to the occurrence of traumatic brain injury (TBI). Below a

ABBREVIATIONS DAI = diffuse axonal injury; GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Scale; TBI = traumatic brain injury.

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10-m height, it is deemed unlikely that the body position changes during the fall; therefore, TBI occurrence is affected by whether someone falls head first or not. Between 10 and 25 m, the occurrence of TBI decreases as body position is altered during falls with a tendency to land feet first. From a height exceeding 25 m, the landing position has less influence on TBI occurrence as forces are strong enough to cause TBI even when a person lands feet first. For falls under 25 m, non-TBI injuries are an especially important determinant of outcome. However, few studies have further analyzed falls below 10 m.^{1,9,10,11} An analysis of high versus low falls in the pediatric population specifically is lacking.

With mounting evidence of an increased risk of cancers in children associated with CT exposure,⁷ it becomes especially important to weigh the indication for such imaging studies very carefully. Thus, the aim of this analysis was to characterize the symptoms, diagnostics, and injuries associated with high versus low falls and to examine the effect of fall height on injuries and outcome in the context of current guideline-based recommendations.

Methods

Study approval from the local ethics committee was obtained. Patients ages 5–17 years who had been consecutively treated at either hospital associated with the University Medical Center Hamburg in the period from January 2009 to August 2014 for diagnoses including TBI were included in this study. Retrospective analysis of the electronic patient charts was performed to obtain data on the following parameters: age; sex; activity leading to the accident; accident mechanism; initial neurological status with respect to consciousness, symptoms, and Glasgow Coma Scale (GCS) score; radiological studies; diagnoses including skull fractures, intracranial hemorrhage, and nonneurological injuries requiring surgery; length of stay in the hospital and ICU; all intracranial procedures including invasive intracranial pressure monitoring; and neurological status (Glasgow Outcome Scale [GOS] score) on discharge or the latest follow-up. All data were accessed and analyzed according to current data protection regulations.

Descriptive analysis was performed with Microsoft Excel and SPSS (SPSS Inc.). Statistical analysis was per-

formed with SPSS. Logistic regression was used to calculate correlations between risk factors and injuries. Parameters were analyzed with uni- and multivariate logistic regression. A p value < 0.05 was regarded as significant.

Results

Three hundred eighty children (162 [42.6%] female and 218 [57.4%] male) met the inclusion criteria within the study time frame. Mean age was 11.9 years. Sixty-five patients had suffered a fall-related TBI. Most of the remaining 315 cases were sports-related injury, including bicycling, soccer, and horseback riding accidents as well as traffic accidents. These patients with injuries unrelated to TBI served as a reference group for a portion of our analyses.

Among the 65 patients who suffered falls, 26 fell from a height of 3 m or higher and 28 fell from a height under 3 m. In 11 patients the fall height was not documented, so these cases were eliminated from further analyses. Among the 54 patients with documented fall heights, falls ranged from 0.4 to 12.5 m (median 2.65 m). The mean age among this group was 9.2 years, and 59% were male and 41% were female. Falls were the result of climbing/play (e.g., trees, jungle gyms) in 22 cases and falling down/off objects (e.g., stairs, bunk beds) in 31 cases. One case was an attempted suicide.

There was no difference between low and high fall cases with respect to concussion-related symptoms on admission, such as unconsciousness, headaches, nausea, amnesia, and focal neurological deficits (data not shown); however, low falls were associated with a 4.8 times higher risk of vomiting on admission compared to non-fall-related TBIs ($p = 0.02$, 95% CI 1.8–13).

Initial GCS scores were documented for 26 patients (Fig. 1). There was no significant difference between high- and low-fall cases with respect to a GCS score > 9 versus < 9 ($p = 0.23$, Fisher's exact test).

Patients who fell from a height ≥ 3 m were 22 times more likely than those who fell from < 3 m to undergo spiral CT studies in the emergency room ($p = 0.05$, 95% CI 2.6–188). In addition, there was a 7.4 times greater chance of undergoing cranial CT ($p = 0.02$, 95% CI 2–27.3). All CTs in children were performed with age-adapted low-dose pediatric protocols (Table 1).

FIG. 1. The initial GCS score distribution for 26 patients, according to fall height.

TABLE 1. Imaging studies performed according to fall height

Fall Height	Imaging Study							
	Spiral CT		Cranial CT		Facial Bone CT		Cranial MRI	
	No	Yes	No	Yes	No	Yes	No	Yes
≥3 m (n = 26)	14	11*	4	21†	23	2	24	1
<3 m (n = 28)	28	1*	17	12†	29	0	24	5

n = number of patients.

Low-dose CT protocols are standard for patients ages 18 years and under.

* OR = 22 for ≥ 3 m versus < 3 m (p = 0.05).

† OR = 7.4 for ≥ 3 m versus < 3 m (p = 0.02).

The frequency and types of hemorrhage as diagnosed via imaging are shown in Table 2. There was no difference between the type or frequency of hemorrhage and fall height (p = 0.77). Neither was there any difference in the frequency of neurosurgical procedures performed between low and high groups (data not shown). We did observe that the patients who required neurosurgical intervention after a low fall had fallen directly onto their head.

There were significantly more noncerebral injuries requiring surgery in patients with falls ≥ 3 m versus those < 3 m (p = 0.007; Table 3).

There was no significant difference between high and low falls with respect to length of stay in the hospital and ICU (data not shown).

The GOS score was available for 52 patients. For 56% of the patients, the GOS score was available at discharge from the hospital. Follow-up ranged from 0 to 92 months (mean 12.5 months, median 0 months). Ninety-four percent of the patients had a GOS score of 5. One death occurred (GOS score 1; described below), as did one case of severe disability (GOS score 3) and one case of moderate disability (GOS score 4), all of which were associated with high falls. After dichotomizing outcomes into good (GOS score 4–5) and poor (GOS score 1–3) categories, we found no significant difference in outcome between high and low falls (p = 0.208, Fisher's exact test).

In the one case of death, the patient was a 13-year-old male who had an accidental fall from approximately 3–4 m and suffered an isolated severe TBI including multiple skull fractures with an initial GCS score of 5. Despite maximal conservative therapy, he died within several hours of presentation in the ICU as a result of brainstem herniation.

Discussion

We analyzed low versus high falls in the pediatric population for the first time. Clinical presentation did not differ between the groups with respect to symptoms and initial GCS score. Intracranial hemorrhage and neurosurgical interventions occurred equally in the two groups. There was indirect evidence of a more severe clinical presentation with respect to vomiting on admission for low falls compared to non-fall-related TBIs. As in other series in adults, our data showed a statistically significant higher risk of noncerebral injury requiring surgery associated with high falls, although outcome was similar in the two fall groups.

TABLE 2. Intracranial hemorrhage distribution according to fall height

Type of Hemorrhage	Fall Height	
	<3 m	≥3 m
Subdural hematoma	1	1
Traumatic SAH	0	2
Epidural hematoma	1	0
Intracerebral hematoma	1	1
Multiple hemorrhages	1	1

SAH = subarachnoid hemorrhage.

A fall from a height ≥ 3 m was associated with a significantly increased risk of undergoing cranial or spiral CT, compared to a fall from < 3 m in height. In accordance with the 2011 German polytrauma guidelines, this finding was to be expected as CT scans were officially recommended as an optional indication for falls from 3 m or higher. However, the necessity of scans must be questioned as clinical presentation and initial GCS scores were similar in our two groups. One must question whether the scans were a product of the fear of medicolegal repercussions under the influence of clear guideline recommendations.

A large study in adults with low falls defined as < 2 m showed that such falls accounted for nearly half of all admissions and were associated with older, more chronically ill patients. Overall, there were fewer severely injured patients, less ICU time, and fewer deaths (except for sports-related trauma) compared to those with high falls as well as those with motor vehicle accidents, sports injuries, or assault injuries.⁴ These findings are difficult to apply to the pediatric population. In contrast, Helling et al. examined findings in adult patients who had fallen from less than 6 m.³ The most commonly sustained injury was TBI, with 35% of the included patients suffering such an injury. Head injury was also the most common cause of death. It is difficult to compare our findings to data in the aforementioned study as its authors analyzed all falls for TBI, whereas we analyzed all TBI for falls. However, their study demonstrates the potential severity of low falls in the adult population.

As mentioned above, vomiting on initial admission occurred more frequently in low-fall cases than in other non-fall-related TBIs in the present study. Vomiting as-

TABLE 3. Incidence of concomitant noncerebral injury requiring surgery, according to fall height

Parameter	Fall Height		Total
	<3 m	≥3 m	
Additional injury requiring surgery			
No	27	15	42
Yes	2	10	12
Total	29	25	54

p = 0.007, Fisher's exact test.

sociated with TBI is considered a symptom of elevated intracranial pressure, which can be related to intracranial hemorrhage or diffuse axonal injury (DAI). Dunning et al. showed that emesis was not a good predictor of substantial TBI.² While the incidence of DAI could not be assessed in the current study, intracranial hemorrhage did occur in our low-fall group. We do not have the patient numbers required to calculate risk analyses. Taken together, however, our data do not support the assumption that low falls do not require interdisciplinary trauma room care and/or may not cause serious injury requiring immediate surgery.

Thus, it was not immediately apparent why the German trauma guidelines changed their definition of high-velocity trauma from falls above 3 m to falls above 6 m, ultimately changing the threshold for a CT scan. Kohn et al., who were cited in the new 2016 trauma guidelines, found that 9.4% of patients with falls from over 6 m had severe injuries, which were defined as those requiring ICU treatment or immediate surgical treatment.⁵ Further, Yagmur et al., who were also cited, posited that death after falls was associated with a mean height of 9 m in adults.¹² However, this group also found that the mean fall height in children under the age of 15 years who had died from the fall was 4 m.¹²

There is growing evidence that CT scans are overused in the pediatric population and extremely harmful. An analysis of over 42,000 children who had presented with isolated loss of consciousness after TBI and a GCS score 13–15 revealed a very low risk of “clinically important TBI” requiring surgery, intubation, or hospitalization for 2 or more nights or resulting in death, and thus CT was not recommended.⁶

More importantly, Miglioretti et al. found an increased risk of solid cancers and leukemia in children associated with cranial CT exposure.⁷ These data indicate a palpable risk with unnecessary CT scans. However, a calculated risk model incorporating both TBI rates and cancer rates in the same population is needed to complete the picture.

The present data seem to provide arguments to override these risks. Our goal is not to increase CT rates, but rather to increase awareness of the potential serious injury associated with low falls in children. Schnadower et al. provided solid recommendations based on several meta-analyses and cited an indication to discharge an asymptomatic child without further observation if falls were below 1 m.⁸ Our observation of a relation between low falls with intracranial hemorrhage requiring surgery and an injury mechanism of falling directly onto the head must be further analyzed in larger studies with odds ratio models. We believe that regardless of the fall height, clinical presentation should dictate further diagnostics and management. We urge clinicians not to have a false sense of security when low fall heights are reported, especially if the patient has fallen directly onto the head.

As the present study showed a 22 times greater risk of cranial CT in falls from a height ≥ 3 m, in accordance with recommendations from the guidelines in place at the time, it will be interesting to see if this rate is further reduced over the next 5 years in accordance with the new trauma guidelines, especially in light of the emerging data on CT exposure-related cancer risk. The new children's hospital

at the University Medical Center in Hamburg, Germany, has only an MRI scanner; CT will be reserved for interdisciplinary trauma room emergencies. Age-adapted low-dose protocols have been the standard for our pediatric patients for several years. Our goal is to reduce unnecessary exposure without compromising patient safety.

Limitations of this study include its retrospective design. There was a surprising lack of documentation on the initial GCS score, for example. Fortunately, documentation of the initial GCS score is now an official part of the new German trauma guidelines, which will help us to better examine TBI in future studies. We also aim to extend the follow-up period in future studies and include neuropsychological assessments as we believe that the GOS is too coarse a measure of outcome, especially in children. Further, although we were able to provide a good regional overview of TBI in children in the greater Hamburg area, because the majority of pediatric patients with TBI are treated at one of our university locations, the sample size was ultimately too small to provide the necessary statistical power behind our findings. In addition, the results may not generally apply to the rest of Germany since the cohort was regional. However, we were able to identify key points for future multicenter studies.

Conclusions

The height of a fall does have influence on guidelines and clinical decisions. In comparison to the 2011 version, the 2016 version of the polytrauma guidelines indicates that a fall from over 6 m constitutes a high-velocity trauma, which may require CT diagnostics. However, our results suggested that low falls can be associated with intracranial hemorrhages requiring ICU monitoring and/or surgery. Despite falling from a lower height, a patient can suffer severe injuries, and all management decisions should be based strictly on the clinical condition of the patient. If in doubt, the patient should be monitored closely even if the fall occurred from a low height.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: all authors. Acquisition of data: all authors. Analysis and interpretation of data: Krajewski, Bandte. Drafting the article: Krajewski. Critically revising the article: Krajewski, Bandte. Reviewed submitted version of manuscript: Krajewski. Approved the final version of the manuscript on behalf of all authors: Krajewski. Statistical analysis: Krajewski. Administrative/technical/material support: Püschel. Study supervision: Püschel.

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