

Clinical predictors of intracranial injuries on CT in infants younger than 2 years old with mild traumatic brain injury

Guangfu Di^{1,2,*}, Hua Liu^{1,3,*}, Xinhua Hu^{1,*}, Sansong Chen², Zhichun Wang² and Hongyi Liu¹

¹Department of Neurosurgery, The Affiliated Brain Hospital, Nanjing Medical University, Nanjing, China

²Department of Neurosurgery, Yijishan Hospital, Wannan Medical College, Wuhu City, China

³Department of Neurosurgery, The First People's Hospital of Kunshan, Jiangsu University, Suzhou, China

*These authors have contributed equally to this work

Correspondence to: Hongyi Liu, email: DGFYJSYY@163.com

Keywords: intracranial injury, mild traumatic brain injury, infants

Received: June 14, 2017

Accepted: August 28, 2017

Published: October 04, 2017

Copyright: Di et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License 3.0 (CC BY 3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

ABSTRACT

Purpose: Mild traumatic brain injury (TBI) is common in children. The aim of this study was to identify clinical predictors of intracranial injuries on computed tomography (CT) in infants younger than 2 years old with mild TBI, which allow reducing number of imaging.

Results: Of 214 enrolled infants with complete data, 30 (5.8%) sustained intracranial injuries. Younger age in months, severe injury mechanism and scalp hematomas were associated with traumatic intracranial injuries on CT. 71 had scalp hematomas and 143 had no scalp hematoma. Within infants with scalp hematomas, 26 sustained intracranial injuries and 45 presented normal. Intracranial injuries were significantly correlated with larger scalp hematomas and different scalp hematoma locations. Logistic regression analysis showed that scalp hematoma and mechanism of injury in infants younger than 2 years old with mild TBI was related to intracranial injuries (hazard ratio=38.291, P=0.0001; hazard ratio=0.174, P=0.001). In subgroup of mild TBI infants with scalp hematomas, logistic regression analysis showed age, scalp hematoma size and mechanism of injury were independently associated with intracranial injuries (hazard ratio=0.299, P=0.032; hazard ratio=5.272, P=0.006; hazard ratio=0.312, P=0.030).

Methods: Between 2014 and 2016, we retrospectively enrolled infants <2 years old with mild TBI. Data recorded included age, sex, mechanism of head injury, size and location of scalp hematoma, fracture and intracranial injuries on CT.

Conclusion: The characteristics of scalp hematomas and mechanism of injury were associated with intracranial injuries. These factors should be considered when making decisions on radiologic examinations of infants < 2 years old with mild TBI and alternative procedures, which do not involve ionizing radiation, should be used if appropriate.

INTRODUCTION

Traumatic brain injury (TBI) remains the important cause of both morbidity and mortality in

children. With more than 700,000 reported pediatric TBI occurring annually, and many more unreported, this represents a major pediatric health problem [1, 2]. Fortunately, most TBI in children are classified

as mild TBI, require no specific therapy and leave no sequelae. However, a small proportion of pediatric patients might present as having mild TBI but resulting in intracranial injuries that need to be identified rapidly and treated in a timely way. Neurological examination of infants younger than 2 years old is very difficult. Besides, concern of the parents for their children and fear of malpractice litigation may force the physicians to request radiological imaging, especially the CT scans. Although radiologic examination can effectively identify TBI, more selective use of CT in the youngest children would induce the number of children exposed to the risk of radiation-induced malignancy [3–5]. The aims of this study were to identify clinical predictors of intracranial injuries on CT in infants younger than 2 years old with mild TBI and identify clinical factors using radiologic examination.

RESULTS

Between January 1, 2014, and December 30, 2016, 214 infants younger than 2 years old presented to Yijishan Hospital of Wannan Medical College with mild TBI. Patient demographics are presented in Table 1. Among them, 30 (5.8%) intracranial injuries occurred, 83 (16.1%) were girls, and the mean age was 14.7 ± 7.2 months. Intracranial injuries on CT were observed in 3 of 7 (42.9%) of those younger than 3 months, 4 of 18 (22.2%) of those aged 3 to younger than 6 months, 8 of 37 (21.6%) of those aged 6 to younger than 12 months, and 15 of 152 (9.9%) of those aged 12 to 24 months. There was significant correlation between age in months and number of incidents ($P=0.016$). In 30 patients with intracranial injuries, the most common mechanism of injury was fall from elevation ($n=26$; 86.7%), and intracranial injuries were significantly correlated with mechanism of injury ($P=0.0001$). Compared with scalp hematoma group, the prevalence of intracranial injuries on CT was significantly lower in the patients without scalp hematoma (26/71, 36.6% vs. 4/143, 2.8%, $P=0.0001$).

In 71 infants with scalp hematomas, the age was classified into 4 groups (Table 2). The prevalence of intracranial injuries differed significantly between the groups and was higher in the younger age groups ($P=0.003$). In 26 scalp hematoma patients with intracranial injuries, the most common mechanism of injury was fall from elevation ($n=23$; 88.5%). The size of scalp hematomas was classified as large (>6 cm) in 15 (21.1%) infants, medium ($>3, \leq 6$ cm) in 29 (40.8%) infants, and small (≤ 3 cm) in 27 (38.0%) infants (Table 2). Intracranial injuries were significantly correlated with a larger scalp hematoma ($P=0.0001$). We assessed intracranial injuries according to the location of the scalp hematoma (frontal,

temporal, parietal, occipital, ≥ 2 locations). There was a significant difference among the scalp hematoma locations ($P=0.0001$) (Table 2).

Multivariate logistic regression analysis revealed that independent predictors of intracranial injuries were scalp hematoma and mechanism of injury in infants younger than 2 years old with mild TBI (hazard ratio=38.291, $P=0.0001$; hazard ratio=0.174, $P=0.001$) (Table 3). In subgroup of mild TBI infants with scalp hematomas, multivariable analysis showed age, scalp hematoma size and mechanism of injury were each associated with intracranial injuries on CT, whereas scalp hematoma location was not (hazard ratio=0.299, $P=0.032$; hazard ratio=5.272, $P=0.006$; hazard ratio=0.312, $P=0.030$). The prognosis of all injured infants was good.

DISCUSSION

Children patients are particularly susceptible to TBI because of their anatomy [6]. Children's heads are disproportionately larger than those of adults, and their skulls are more compliant. Children also have weaker neck muscles and, most importantly, their neurons are less myelinated. Therefore, the children brain is not only more likely to sustain shearing forces when a force is applied but also, because of the decreased myelination, is more prone to axonal damage [6, 7]. Because the central nervous system is immature, it has typically been considered to be more difficult to detect clinical signs of intracranial lesions in infants <2 years old [8]. As a result, the rates of CT use have increased rapidly in children, however, the relatively high radiation doses associated with CT have raised health concerns [4, 9]. Thus, in the present study, we focused on mild TBI and intracranial injuries on CT in infants ranging in age from birth to 2 years old.

Similar to previous studies, infants younger than 3 months had a substantially higher prevalence of intracranial injuries on CT than infants in older age groups, and the age remained a substantial risk factor for intracranial injury in infants <2 years old [10, 11]. For infants aged 3 to 12 months, the incidence of intracranial injuries was 21.8% (12/55), emphasizing the importance of maintaining a low threshold for obtaining skull radiographs or cranial CT scans if there is a concern for intracranial injuries.

Falls are a common cause of traumatic injuries in children, and we have shown that intracranial injuries differ significantly between fall injury patterns. The most common mechanism of intracranial injuries in children with mild head trauma was a fall from elevation. Previous studies including children <5 years old reported the highest number of falls from a window, balcony, stairs, and furniture, and intracranial injury was a major cause of

Table 1: Characteristics of infants < 2 years old with mild traumatic brain injury

Characteristic	Intracranial injuries		Total	P Value
	Yes	No		
Age (months)				0.016
0-<3	3	4	7	
3-<6	4	14	18	
6-<12	8	29	37	
12-<24	15	137	152	
Sex				0.105
Female	16	67	83	
Male	14	117	131	
Mechanism of injury				0.0001
Fall from elevation	26	70	96	
Fall from standing/walking	2	79	81	
Traffic accidents	2	13	15	
Collision	0	12	12	
Object struck head-accidental	0	10	10	
Scalp hematoma				0.0001
Yes	26	45	71	
No	4	139	143	
Total	30	184	214	

fall-related deaths in children [12, 13]. Our results suggest that parents should always be careful when there is a risk for fall from elevation.

A previous investigation reported that subcutaneous hematomas were observed in 28.7% of infants <24 months old, and a correlation with TBI was noted [14]. In the present study, subcutaneous hematomas were observed in 33.2% (71/214) of patients. We found that the scalp hematoma is a useful predictor of intracranial injuries in infants <2 years old with mild TBI. Furthermore, we investigated the characteristics of 71 mild TBI infants with scalp hematomas and revealed a close relationship between the size and location of the scalp hematoma and intracranial injuries in infants younger than 24 months with mild TBI. Scalp hematomas >3 cm in size might be determined to be a risk factor for intracranial injuries. The hematomas \geq 2 locations was associated with a very high risk of intracranial injuries.

In accordance with previous investigations, the scalp hematoma and mechanism of injury were independent predictors of intracranial injuries on CT in our study [14, 15]. The literature indicates that a

severe mechanism independently increases the risk of intracranial injuries, and falls from greater heights increase the prevalence of skull fractures traumatic brain injury [16], which suggests that clinicians should closely observe children with scalp hematomas after more severe mechanisms of injury in the emergency department. The multivariate logistic regression analysis in the subgroup of 71 infants with scalp hematomas also revealed that the age, mechanism of injury and scalp hematoma size were independent prognosticators of intracranial injuries. This suggests that the younger infants with larger scalp hematomas are more prone to suffer intracranial injuries.

The available research literature indicates that few pediatric patients with mild TBI require surgical intervention (0-1%) [8]. In our series, all injured infants had a good outcome. Although CT scan can identify intracranial injuries with high-level sensitivity, we should carefully select candidates for CT, the effects of radiation exposure must be considered. Use of CT scans in children to deliver cumulative doses of about 50 mGy might almost triple the risk of leukaemia and doses of about 60 mGy

Table 2: Characteristics of 71 mild traumatic brain injury infants with scalp hematomas

Characteristic	Intracranial injuries		Total	P Value
	Yes	No		
Age (months)				0.003
0-<3	3	0	3	
3-<6	4	1	5	
6-<12	6	6	12	
12-<24	13	38	51	
Sex				0.205
Female	12	14	26	
Male	14	31	45	
Mechanism of injury				0.0001
Fall from elevation	23	8	31	
Fall from standing/walking	1	27	28	
Traffic accidents	2	2	4	
Collision	0	6	6	
Object struck head-accidental	0	2	2	
Scalp hematoma				
Size (cm)				0.0001
0-≅3	1	26	27	
3-≅6	13	16	29	
>6	12	3	15	
Location				0.0001
Frontal	4	20	24	
Temporal	1	1	2	
Parietal	8	10	18	
Occipital	2	12	14	
≅2 locations	11	2	13	
Total	26	45	71	

might triple the risk of brain cancer [3]. According to another study, infants <2 years old undergoing cranial CT had a higher risk of developing cancer compared with older children [17]. Otherwise, unnecessary tests with high costs and wasted time would also result. The results of this study are useful in determining whether to perform CT for infants with mild TBI.

The present study has some limitations. Clinicians obtained CT scans for the minority of patients, with selection bias likely toward those with more severe findings. Because this bias would be expected to inflate the prevalence of intracranial injuries on CT, the actual

prevalence of intracranial injuries in infants with scalp hematomas is likely lower than that reported here.

CONCLUSION

We found that the age, mechanism of injury and size of scalp hematomas were independently correlated with intracranial injuries on CT in TBI infants <2 years old with scalp hematoma. These factors should be considered as indications for radiologic examination in this subgroup.

Table 3: Logistic regression analysis for independent factors

214 infants < 2 years old with mild traumatic brain injury			
Factor	HR	95% CI	P Value
Age	0.518	0.264-1.018	0.056
Mechanism of injury	0.174	0.060-0.506	0.001
Scalp hematoma	38.291	10.632-137.908	0.0001
71 mild traumatic brain injury infants with scalp hematomas			
Factor	HR	95% CI	P Value
Age	0.299	0.099-0.900	0.032
Mechanism of injury	0.312	0.109-0.894	0.030
Scalp hematoma location	1.602	0.863-2.973	0.135
Scalp hematoma size	5.272	1.627-17.078	0.006

HR, hazard ratio; CI, confidence interval.

MATERIALS AND METHODS

This retrospective study was approved by the Institutional Ethical Board of the Yijishan Hospital of Wannan Medical College. All medical records of infants younger than 2 years old who had been hospitalized for mild TBI between January 1, 2014, and December 30, 2016, were reviewed. Data collected included sex, age, mechanism of head injury, scalp hematoma size, scalp hematoma location, neurologic examination and CT presentation.

Frequencies and descriptive statistics were used to characterize the study population. Either χ^2 test or Fisher exact test was used to determine differences between large and small scalp hematomas. In multivariable logistic regression analysis, we assessed the association between intracranial injuries with age, sex, scalp hematoma size and location.

ACKNOWLEDGMENTS

The authors thank Sansong Chen for his diligent record keeping. Hua Liu and Zhichun Wang did all data sorting and statistical analyses. Because Guangfu Di, Hua Liu and Xinhua Hu contributed equally to this work, they are considered as co-first authors.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

GRANT SUPPORT

This study was supported by Medical science and technology development fund of Jiangsu University (JLY20160047).

REFERENCES

- Caskey RC, Nance ML. Management of pediatric mild traumatic brain injury. *Adv Pediatr.* 2014; 61:271-86.
- Schneider AJ, Shields BJ, Hostetler SG, Xiang H, Smith GA. Incidence of pediatric traumatic brain injury and associated hospital resource utilization in the United States. *Pediatrics.* 2006; 118:483-92.
- Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, Howe NL, Ronckers CM, Rajaraman P, Sir Craft AW, Parker L, de González AB. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. *Lancet.* 2012; 380:499-505.
- Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. *N Engl J Med.* 2007; 357:2277-84.
- Frush DP, Frush KS. The ALARA concept in pediatric imaging: building bridges between radiology and emergency medicine: consensus conference on imaging safety and quality for children in the emergency setting, Feb. 23-24, 2008, Orlando, FL - Executive Summary. *Pediatr Radiol.* 2008; 38:S629-32.
- Pinto PS, Poretti A, Meoded A, Tekes A, Huisman TA. The unique features of traumatic brain injury in children. Review of the characteristics of the pediatric skull and brain, mechanisms of trauma, patterns of injury, complications and their imaging findings--part 1. *J Neuroimaging.* 2012; 22:e1-1e17.
- Master CL, Gioia GA, Leddy JJ, Grady MF. Importance of 'return-to-learn' in pediatric and adolescent concussion. *Pediatr Ann.* 2012; 41:1-6.
- Schutzman SA, Greenes DS. Pediatric minor head trauma. *Ann Emerg Med.* 2001; 37:65-74.

9. Rehani MM, Berry M. Radiation doses in computed tomography. The increasing doses of radiation need to be controlled. *BMJ*. 2000; 320:593-4.
10. Greenes DS, Schutzman SA. Clinical indicators of intracranial injury in head-injured infants. *Pediatrics*. 1999; 104:861-7.
11. Greenes DS, Schutzman SA. Clinical significance of scalp abnormalities in asymptomatic head-injured infants. *Pediatr Emerg Care*. 2001; 17:88-92.
12. Kim KA, Wang MY, Griffith PM, Summers S, Levy ML. Analysis of pediatric head injury from falls. *Neurosurg Focus*. 2000; 8:e3.
13. Pomerantz WJ, Gittelman MA, Hornung R, Husseinzadeh H. Falls in children birth to 5 years: different mechanisms lead to different injuries. *J Trauma Acute Care Surg*. 2012; 73:S254-7.
14. Dayan PS, Holmes JF, Schutzman S, Schunk J, Lichenstein R, Foerster LA, Hoyle J, Atabaki S, Miskin M, Wisner D, Zuspan S, Kuppermann N. Risk of traumatic brain injuries in children younger than 24 months with isolated scalp hematomas. *Ann Emerg Med*. 2014; 64:153-62.
15. Ohbuchi H, Hagiwara S, Hirota K, Koseki H, Kuroi Y, Arai N, Kasuya H. Clinical Predictors of Intracranial Injuries in Infants with Minor Head Trauma. *World Neurosurg*. 2017; 98:479-83.
16. Gruskin KD, Schutzman SA. Head trauma in children younger than 2 years: are there predictors for complications. *Arch Pediatr Adolesc Med*. 1999; 153:15-20.
17. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. *AJR Am J Roentgenol*. 2001; 176:289-96.