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Original Article

Indications for computed tomography use and frequency of traumatic abnormalities based on real-world data of 2405 pediatric patients with minor head trauma

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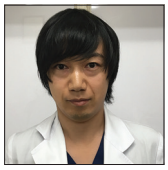

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ABSTRACT

Background: In pediatric patients with minor head trauma, computed tomography (CT) is often performed beyond the scope of recommendations that are based on existing algorithms. Herein, we evaluated pediatric patients with minor head trauma who underwent CT examinations, quantified its frequency, and determined how often traumatic findings were observed in the intracranial region or skull.

Methods: We retrospectively reviewed the medical records and neuroimages of pediatric patients (0–5 years) who presented at our hospital with minor head trauma within 24 h after injury.

Results: Of 2405 eligible patients, 1592 (66.2%) underwent CT examinations and 45 (1.9%) had traumatic intracranial hemorrhage or skull fracture on CT. No patient underwent surgery or intensive treatment. Multivariate analyses revealed that an age of 1–5 years (vs. <1 year; $P < 0.001$), Glasgow Coma Scale (GCS) score of 14 (vs. a score of 15; $P = 0.008$), sustaining a high-altitude fall ($P < 0.001$), using an ambulance ($P < 0.001$), and vomiting ($P < 0.001$) were significantly associated with the performance of CT examination. In addition, traumatic abnormalities on CT were significantly associated with the combination of an age of under 1 year ($P = 0.042$), GCS score of 14 ($P < 0.001$), and sustaining a high-altitude fall ($P = 0.004$).

Conclusion: Although slightly broader indications for CT use, compared to the previous algorithms, could detect and evaluate minor traumatic changes in pediatric patients with minor head trauma, over-indications for CT examinations to detect only approximately 2% of abnormalities should be avoided and the indications should be determined based on the patient's age, condition, and cause of injury.

Keywords: Computed tomography, Intracranial hemorrhage, Minor head trauma, Pediatric patients, Skull fracture

INTRODUCTION

Children with minor head trauma commonly present to the emergency department.[14] When attempting to detect severe traumatic intracranial abnormalities in such cases, the parsimonious use of computed tomography (CT) examinations based on empirically-established algorithms is recommended to avoid unnecessary exposure to radiation.[3,5,10] However, in clinical practice,

CT may be performed more often because parents are often concerned about their child's intracranial condition and request a radiation examination, or clinicians may recommend CT to prevent oversight. Alternatively, as children with minor head trauma rarely demonstrate CT abnormalities, most CT examinations may be unnecessary.

Thus, the aims of this study were to (1) evaluate the frequency of CT examinations; (2) identify demographic, historic, and diagnostic trends among pediatric patients with minor head trauma who received a CT examination; and (3) determine how often traumatic abnormalities occurred in the intracranial region or skull.

MATERIALS AND METHODS

We retrospectively reviewed the medical records and neuroimages of pediatric patients (0–5-years-old) who presented to our hospital for minor head trauma within 24 h after head injury between January 2017 and February 2020. Excluded patients were those admitted for more than 24 h following an injury, those who were older than 5 years, and those with insufficient documentation in their medical records. Specifically analyzed parameters were age, Glasgow Coma Scale (GCS) scores, the cause of injury, use of ambulance services, assessment with CT, traumatic abnormalities shown on CT, vomiting, and the necessity for wound sutures. As the participants were 0–5 years of age, the medical history of headache or loss of consciousness at the time of injury was often unclear; therefore, these data were not included in our analyses.

Univariate and multivariate Cox proportional hazards regression models were used to evaluate putative prognostic factors in terms of the frequency of CT examinations and associated traumatic abnormalities. The level of statistical significance was set at $P < 0.05$. JMP Pro (version 13; SAS Institute, Cary, NC, USA) was used for all statistical analyses.

The present study was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments. The Institutional Review Board of our institution approved the present study and waived the requirement for informed consent due to the retrospective study design.

RESULTS

A total of 2405 pediatric patients were eligible for the present study. These patients' characteristics are summarized in [Table 1]. The frequency of CT examinations increased with the age of the patients, and the rate of high-altitude falls decreased with age. Due to its nature, pediatric patients with severe trauma were not transported to our hospital; therefore, the GCS scores of all participating patients were either 14 or 15, indicating negligible to mild brain injury. CT examinations were performed in 1592 (66.2%) patients, and 44 (1.8%) patients had traumatic abnormalities on a CT, such as intracranial hemorrhage or skull fracture [Figure 1]. Among these patients, there were presentations of acute subdural hematoma (ASDH, $n = 9$), traumatic subarachnoid hemorrhage ($n = 4$), brain contusion ($n = 3$), acute epidural hematoma ($n = 2$), and linear skull fracture alone ($n = 26$; Figure 2). Aside from these 44, one patient with a CT abnormality did not receive radiological examination on the day of injury; however, CT was performed the following day due to a reported headache, revealing a minor ASDH. All patients with CT abnormalities ($n = 45$) had a good prognosis and underwent observation or conservative treatment, with none requiring surgery.

Next, we performed univariate and multivariate analyses to better understand when to perform CT examinations [Table 2]. The results revealed that an age of 1–5 years (vs. <1 year; $P < 0.001$), GCS scores of 14 (vs. a GCS score of 15; $P = 0.008$), the experience of a high-altitude fall ($P < 0.001$), using an ambulance ($P < 0.001$), and experiencing vomiting ($P < 0.001$) were significantly associated with a CT examination being performed. In the multivariate analysis, traumatic abnormalities on CT were significantly associated with the combination of an age <1 year ($P = 0.042$), GCS score of 14 ($P < 0.001$), and the experience of a high-altitude fall ($P = 0.004$) [Table 3]. The requirement for wound sutures was not a significant factor for performing a CT examination or demonstrating abnormal findings on a CT.

CT examinations for minor head trauma rarely reveal brain abnormalities unrelated to the trauma. Of the 1592 patients who underwent CT examinations in the present study, 26 cases presented with an arachnoid cyst and two presented with ventricle enlargement; however, none required treatment. No brain tumors or cerebrovascular diseases were observed on the CT scans.

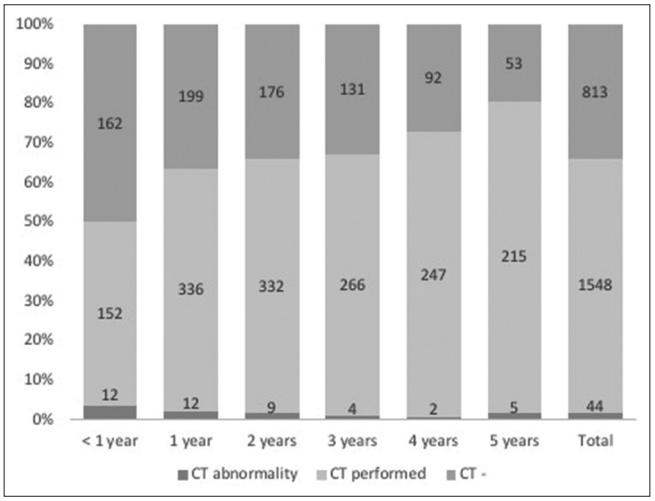

Figure 1: Frequency of CT examinations and abnormal findings for pediatric patients with minor head trauma. CT: computed tomography

Table 1: Summary of pediatric patients with minor head trauma.

Age	GCS score 14/15	CT performed	CT abnormalities present	Ambulance use	Vomiting present	Wound sutures required	Cause of injury: High-altitude fall
<1 year	5/321	164	12	16	19	1	193
n=326		(50.3%)	(3.7%)	(4.9%)	(5.8%)	(0.3%)	(59.2%)
1 year	5/547	348	12	43	43	36	248
n=547		(63.6%)	(2.2%)	(7.9%)	(7.9%)	(6.6%)	(45.3%)
2 years	12/505	341	9	52	41	71	197
n=517		(66.0%)	(1.7%)	(10.0%)	(7.9%)	(13.7%)	(38.1%)
3 years	8/393	270	4	39	39	81	116
n=401		(67.3%)	(1.0%)	(9.7%)	(9.7%)	(20.2%)	(28.9%)
4 years	5/336	249	2	28	30	50	89
n=341		(73.0%)	(0.6%)	(8.2%)	(8.8%)	(14.7%)	(26.1%)
5 years	7/266	220	5	23	30	50	58
n=273		(80.6%)	(1.8%)	(8.4%)	(10.1%)	(18.3%)	(21.3%)
Total	42/2363	1592	44	201	202	289	901
n=2405		(66.2%)	(1.8%)	(8.4%)	(8.4%)	(12.0%)	(37.5%)

Data are presented as *n* (%). GCS: Glasgow Coma Scale, CT: Computed tomography.

Table 2: Univariate and multivariate analyses regarding the indication of computed tomography examinations.

	Univariate			Multivariate		
	Hazard ratio	95% CI	*P*-value	Hazard ratio	95% CI	*P*-value
Age 1–5 years versus <1 year (ref.)	2.17	1.71–2.74	<0.001*	2.74	2.14–3.60	<0.001*
GCS 14 versus 15 (ref.)	21.46	2.95–156.3	0.003*	15.5	2.06–116.5	0.008*
Cause of injury: high-altitude fall versus others (ref.)	2.03	1.69–2.44	<0.001*	2.40	1.97–2.93	<0.001*
Ambulance versus walk-in (ref.)	3.01	2.04–4.47	<0.001*	2.75	1.82–4.14	<0.001*
Vomiting: yes versus no (ref.)	8.29	4.69–14.64	<0.001*	7.44	4.17–13.30	<0.001*
Wound suture: necessary versus unnecessary (ref.)	0.91	0.75–1.18	0.482	0.90	0.68–1.18	0.448

GCS: Glasgow Coma Scale, CI: Confidence interval. *Statistical significance at $P<0.05$

Table 3: Univariate and multivariate analyses regarding the presence of traumatic abnormalities on computed tomography.

	Univariate			Multivariate		
	Hazard ratio	95% CI	*P*-value	Hazard ratio	95% CI	*P*-value
Age 1–5 years versus <1 year (ref.)	0.41	0.21–0.80	0.009*	0.48	0.24–0.97	0.042*
GCS 14 versus 15 (ref.)	10.20	4.06–25.6	<0.001*	7.73	2.89–20.76	<0.001*
Cause of injury, high-altitude fall versus others (ref.)	3.00	1.60–5.54	<0.001*	2.55	1.34–4.83	0.004*
Ambulance versus walk-in (ref.)	1.10	0.39–3.10	0.859	0.95	0.32–2.80	0.929
Vomiting, yes versus no (ref.)	2.89	1.37–6.10	0.005*	2.18	0.97–4.90	0.060
Wound suture, necessary versus unnecessary (ref.)	0.34	0.08–1.43	0.142	0.61	0.14–2.64	0.506

GCS: Glasgow Coma Scale, CI: Confidence interval. *Statistical significance at $P<0.05$

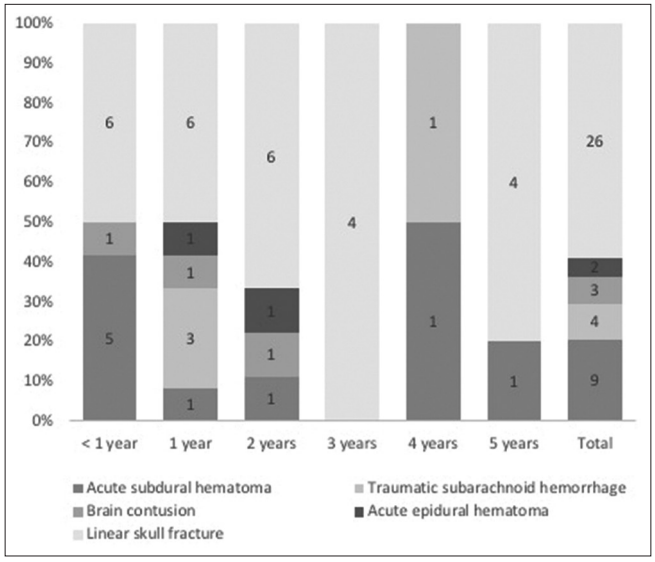

Figure 2: Traumatic findings on computed tomography images of pediatric patients with minor head trauma.

DISCUSSION

The present study involved a large sample of 2405 pediatric patients with minor head trauma and revealed that CT examinations were performed in 1592 (66%) patients; and 45 (1.9%) patients presented with traumatic intracranial hemorrhage or skull fracture. CT was most commonly performed in patients aged 1–5 years with unusual neurological symptoms and in severe cause of injury which was defined as a high-altitude fall. Moreover, traumatic abnormalities on CT were observed in patients <1 year of age, with a GCS score of 14, and whose cause of injury was a high-altitude fall. The results of this study provide important suggestions on the indications for CT use and assessment in pediatric patients with minor head trauma.

It has been recommended in the literature to avoid radiological examinations in children, unless necessary, because of the increased risk of developing brain tumors, leukemia, and malignancies as a result of radiation exposure.[7,11,15] In addition, unnecessary CT examinations should be avoided due to the associated financial expenses.[9,13] At our institution, clinicians fully inform the parents of pediatric patients with minor head trauma about the benefits of CT examination and the risks of radiation exposure, and will perform CT if the parents still wish for their child to undergo the examination. The frequency of CT examinations in the present study sample was relatively high compared to the previous reports.[6,8] The previous reports in the United States suggest that an increase in the availability of CT scanners contributed to an increase in CT examinations.[1] Thus, we reckon that the relatively high frequency of CT examinations in this study may be related to availability, because there are approximately 97.4 CT scanners per million people in Japan, which is the highest rate globally, making it relatively convenient to perform a CT at any medical institution at any time. Moreover, parents often request a CT examination because they worry about their child's health. Although CT examinations are costly, since the subsidy system for medical expenses for children has become widespread in Japan, patients are only required to pay 500 yen ($4.6 USD), regardless of medical examinations or treatments at our institution. Thus, parents are often willing to pay for a CT examination due to the low medical cost, and the low co-payment on medical expenses is considered to be one of the reasons for the high frequency of CT examination. Finally, if the clinician does not perform a CT examination despite the parents' request and subsequent intracranial traumatic changes are revealed, it can be considered medical negligence. Therefore, clinicians may recommend CT examinations to prevent oversight and to avoid the risk of medicolegal litigation. In contrast, the frequency of CT examinations in the present study was significantly lower compared with a previous study that reported a frequency of 94.4% in a sample of 739 children.[4] This may be largely because the present study was focused on patients who were 0–5-years-old, whereas the previous study sampled participants who were 0–17-years-old. Therefore, the difference in frequency may allude to the fact that radiological examinations may be more dangerous for younger children. However, it would be over-indications for CT performance in as many as 66% of patients to detect only approximately 2% of abnormalities as in this study.

In the present study, patients who were 1–5-years-old, had a GCS score of 14, experienced a high-altitude fall, used an ambulance, and presented with vomiting received a CT scan significantly more frequently. We suggest that these results were obtained because clinicians tended to avoid radiological examinations for patients younger than 1 year of age for the same reasons as mentioned previously. Considering that the risk of lethal malignancy associated with radiation examination is inversely proportional to the patient's age,[2] avoiding CT in younger children is reasonable. Furthermore, clinicians tended to perform CT examinations in patients with abnormal neurological symptoms or serious causes of injury. In addition, traumatic abnormalities on CT scans were significantly more common in patients younger than 1 year. We suggest that this is because CT examinations among patients younger than 1 year were performed mainly in those who were at a high risk of traumatic changes due to their consciousness, neurological symptoms, or severity of the cause of injury. Of the 164 patients younger than 1 year who underwent CT examinations, six (3.7%) presented with intracranial hemorrhage and six (3.7%) presented with skull fracture only. These percentages were relatively

high compared to other age groups, as a previous report documented that patients under 2 years of age were more likely to end up with skull fractures due to their thin skull.[12] Alternatively, one of the reasons that patients aged 3–4 years presented with a relatively low frequency of traumatic findings on CT could be due to the low percentage of high-altitude falls in this age group.

Only 0.8% and 1.1% of the patients in this study presented with intracranial hemorrhage and skull fracture, respectively; however, they were observed or were given conservative treatment and had good prognoses. These results suggest that pediatric patients with minor head trauma rarely show intracranial hemorrhage or skull fracture; however, 1–2% of the patients presented with CT abnormalities that did not require surgery or resulted in a poor prognosis. Moreover, patients with CT abnormalities typically demonstrated unusual consciousness or serious causes of injury. The previous algorithms have been primarily intended to detect patients who require surgery or intensive treatment, which excludes those with minor traumatic findings that do not require treatment.[3,5,10] Minor intracranial hemorrhage or linear skull fracture is rarely an indication for surgery or intensive treatment; however, it is crucial for parents to understand that these abnormalities are caused by head trauma, because it is necessary for the parents to observe the patient's condition and avoid re-bruising. Thus, as a preventive measure, it might be clinically important to detect not only abnormalities requiring surgery or intensive treatment but also those that do not require treatment. However, significantly over-indications for CT examinations to detect only 2% of abnormalities should be avoided in viewpoint of radiation exposure and financial expenses, and the indications should be determined based on the patient's age, condition, and cause of injury.

Study strengths and limitations

The present study is based on a large sample of pediatric patients with minor head trauma. Studies that analyze large sample sizes of patients aged 0–5 years at a single institute are very rare. The real-world data used in the present study provide important information and practical suggestions for the consultation of pediatric trauma patients. It should be noted that the scope of this study is limited by certain factors. First, since this study did not include patients with severe head trauma or severe disturbances in consciousness due to the nature of the participating hospital, this might potentially distort the facts regarding overall head trauma in pediatric patients. Moreover, as the results of this study were based on the cultural characteristics and medical system of Japan, the results may not be universally applicable. In addition, the retrospective, non-randomized, and non-blinded design of this study rendered sample size differences among the patients' age, and potential selection biases. These factors must be considered when attempting to generalize the study results and when designing future research.

CONCLUSION

Approximately 2% of the patients in this study, aged 0–5-years-old, with minor head trauma, demonstrated traumatic intracranial hemorrhage or skull fractures on CT examination. Traumatic findings were significantly more frequent in patients younger than 1 year of age, those with a GCS score of 14, and those whose cause of injury was a high-altitude fall. Therefore, slightly broader indications for CT use could detect and evaluate minor traumatic changes in pediatric patients with minor head trauma. However, over-indications for CT use to detect only 2% of abnormalities should be avoided and the indications should be determined based on the patient's age, condition, and cause of injury.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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