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Modified decision-making rule supported by scheduled telephone follow-up reduces head computed tomography utilization in children with mild traumatic brain injury

A cohort study

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Abstract

Unnecessary computed tomography utilization is common in children with a mild traumatic head injury. It is valuable to find a reasonable strategy for the patient's management.

The aim of this study was to investigate the effect of scheduled telephone follow-up on computed tomography utilization in children with a mild head injury.

A 2-year cohort study was performed. Children diagnosed with mild traumatic brain injury (TBI) were evaluated with a scoring system upon their arrival and during 1 month of scheduled telephone follow-ups by nurses. The rates of head computed tomography utilization, delayed imaging, and delayed diagnosis were analyzed.

The rate of computed tomography utilization was 64.3% and 46.1% ($P = .00$) in the retrospective and prospective study periods, respectively. During the prospective study period, there were no differences in the rates of delayed imaging (2.3% vs. 2.2%, $P = .814$) or the rates of delayed diagnosis of significant radiological findings (0.1% vs 0.2%, $P = .672$) in cases with versus without immediate computed tomography.

Adoption of a modified decision-making rule supported by scheduled telephone follow-up can reduce head computed tomography utilization without increasing the rate of missed or delayed diagnosis of clinically significant TBI in children with mild TBI.

Abbreviations: CATCH = Canadian Assessment of Tomography for Childhood Head Injury, CHALICE = the Children's Head Injury Algorithm for the Prediction of Important Clinical Events, CT = Computed tomography, ED = Emergency department, GCSs = Glasgow Coma Scale score, NEXUS II = the National Emergency X-Radiography Utilization Study II, PECARN = the Pediatric Emergency Care Applied Research Network, TBI = traumatic brain injury.

Keywords: children, computed tomography, mild traumatic brain injury, telephone follow-up

1. Introduction

Blunt head trauma is a common cause of emergency department (ED) visits by children.[1,2] Although very few children have a clinically significant traumatic brain injury (TBI), up to 70% have received a computed tomography (CT) scan.[3–7] Many studies have indicated that exposure to ionizing radiation increases the lifetime incidence of cancer.[8–11] In recent decades, clinical decision rules have been published to improve clinical decision making concerning the recognition of injuries and the reduction

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of unnecessary radiation exposure.[4–6] However, nonindication CT scans are still popular, especially in China.[12–16]

For these patients, observation in the emergency department for several hours instead of ordering an immediate CT scan became a reasonable method of lowering the rate of overall CT use without delayed diagnosis or increasing the rate of significant injuries.[17–19] However, in many emergency departments, patient overcrowding could be a more challenging issue, and admitting most of the children with mild head injury to the ED for observation is not always feasible.[20–22]

To this end, a prospective observation was performed to study children with mild head trauma visiting the emergency department of a tertiary academic teaching hospital. Our goal was to determine how scheduled telephone follow-up affects CT scan utilization for children with mild head injuries (Glasgow Coma Scale score [GCSs] of ≥14). We hypothesized that scheduled telephone follow-up could reduce the use of CT for children without delaying the diagnosis of a clinically important TBI.

2. Methods

2.1. Study design

A retrospective study and a prospective cohort study were performed successively in 2 years. Ethical approval for this study was provided by the Institutional Research Ethics Committee of West China Hospital (No. 20140117). A written informed consent to participate was taken from all participants.

2.2. Setting

We performed a retrospective study of all cases of children with an initial diagnosis of mild blunt head trauma in our ED from January 1, 2013, to December 31, 2013. Then, a routinely used evaluation scale in our emergency department for years which derived from several published clinical decision rules (Table 1) was simplified and incorporated into a follow-up protocol (Table 2)[4–6] and implemented in the prospective cohort study, which enrolled all children who presented to our ED for the evaluation of mild head trauma during the following 12 months (from January 1, 2014 to December 31, 2014).

2.3. Participants

All emergency physicians and nurses participating in this study were trained on the evaluation criteria and follow-up form. Once the patients were included, nurses were assigned to follow them via telephone calls at a set of scheduled time points over 1 month.

Children younger than 14 years with a GCSs of 14 or 15 who visited the ED for evaluation of blunt head trauma sustained within 24 hours of presentation were included. Patients with a GCSs of <13, neurologic comorbidities such as brain tumors, ventricular shunts, or coagulopathy were excluded. Patients who had received neuroimaging before arriving at our ED or injured beyond 24 hours from the presentation were also excluded.

2.4. Variables

Once included, the patients were evaluated by the emergency physician with the above-mentioned standardized study form. The patients classified into the low-risk group were discharged for observation at home without a CT scan. If the low-risk patients did not follow the physician's suggestion and insisted on receiving the CT scan, their medical data, such as the results of the physician's evaluation, CT results, and ED disposition, were recorded just as the other 2 groups (high- and intermediate-risk). All patients discharged after the initial ED visit with or without immediate CT scan, or with CT scan but no clinically important findings, were referred to a nurse for a scheduled telephone follow-up. According to the protocol, the followed-up patients received telephone surveys at scheduled time points, from 1 hour to 30 days after their discharge from the ED. During the follow-up period, patients with a new onset of abnormal symptoms were requested to come back to the ED and receive a reevaluation. The following-up management and results were also recorded.

A positive computed tomography result was defined as either a depressed skull fracture or a TBI (eg, cerebral edema, traumatic infarction, intracranial contusion or hemorrhage, signs of brain herniation, pneumocephalus or diffuse axonal injury). In our study, a clinically important TBI was defined as a head injury resulting in hospitalization (≥2 days), intubation, neurosurgery, or death.[6] Time from injury was defined as the time from a head injury to the initial evaluation by an emergency physician.

We stratified patients into 3 groups of risk levels (low, intermediate, and high) according to our modified TBI prediction rules based on the Pediatric Emergency Care Applied Research Network (PECARN) rule, the Canadian Assessment of Tomography for Childhood Head Injury (CATCH) and the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE) (Table 1). For each group, physicians explained the patient's condition to the patient's parents or guardians and made the decision on the subsequent management strategies, including immediate neuroimaging examination, observation, or discharge without a CT scan.

The performance of a CT scan (yes or no) in the study period was recorded and compared with the data in the retrospective study. Those receiving cranial MRI were included in the CT group for this study. The follow-up results of all included patients were recorded for safety analysis.

2.5. Statistical analysis

Statistical analysis was performed by using Statistical Package for Social Sciences for Windows, version 20. Descriptive statistics were calculated by using means ± SDs, frequencies, and percentages. χ^2 tests (Pearson χ^2 test, Yates' correction for continuity) or Fisher exact tests were used to compare proportions among different groups. A P value of <0.05 was considered as a statistically significant result.

3. Results

In the 2-year study period, a total of 3326 eligible patients were enrolled in our study. Of these patients, 1602 were retrospectively collected from January 1, 2013 to December 31, 2013, via an electronic medical records system, and 1724 were enrolled prospectively from January 1, 2014 to December 31, 2014. However, 11 cases were lost during our follow-up process, and were excluded from the analyses (Fig. 1). Of the 3315 recorded children, 809 (50.5%) and 907 (52.9%) ($P=.153$) children were older than 2 years in the retrospective and prospective study periods respectively, whereas 947 (59.1%) and 1020 (59.5%) children ($P=.801$) were boys in the retrospective and prospective study periods respectively. According to our scoring system, 1195 (74.6%), 306, (19.1%) and 101 (6.3%) patients in the retrospective study period were classified as low-risk, intermediate-risk,

Table 1

Evaluation and decision for CT scan.

Levels	Clinical symptoms	Decisions
High risk	✧ Focal neurological deficit ✧ Skull fracture: depressed fracture, basal fracture ✧ Bulging fontanel ✧ Altered mental status (e.g., Irritability, drowsiness，lethargic fatigue, raving, slurred speech) ✧ Recurrent vomiting ✧ Seizure (convulsion) ✧ Loses consciousness for several seconds ✧ High energy injury	CT scan is recommended
Intermediate risk	✧ Vomiting ✧ Headache ✧ Suspected or transient LOS ✧ Recovered from irritability or drowsiness after injury ✧ Injured with high risk factors ✧ Scalp hematoma ✧ Skull fracture ✧ Presence of other substantial (non-cranial) trauma ✧ Parental report of abnormal acting	CT scan is recommended in intermediate risk group if with: ✧ Any one of intermediate risk factor ✧ Delayed vomiting or ⩾2 times ✧ ⩾3cm scalp hematoma, non-frontal, especially age⩽ 12months ✧ Trauma in infants（age⩽3months） If immediate CT scan not performed, patients should be observed for 4-6 hours and re-evaluated for further decision.
Low risk	✧ Normal mental status ✧ No Scalp hematoma ✧ No LOS ✧ Parental report of normal acting ✧ No high-risk factors injury ✧ No vomiting ✧ No evidence of skull fracture ✧ No obvious headache	Avoiding CT scan
High risk factors including children (⩽2-year old) fall from 0.9 meters height or 2-year old more children fall from 1.5 meters height, head struck by high speed object, motor vehicle crash (with documentation of ejection, rollover, death of other passenger), pedestrian struck by vehicle, bicycle rider struck by automobile (with documentation of helmet use)		
Risk levels decision： ☐high risk ☐Intermediate risk ☐Low risk **Decision of CT scan:** ☐Yes, result：☐Normal ☐Abnormal：_____ ☐No, reason：☐Parents refused ☐Low risk ☐Observation **Further management**：☐Discharge for home observation ☐Observation in ED ☐In hospital treatment ☐Others		

and high-risk, respectively, whereas 1301 (75.9%), 318, (18.6%) and 94 (5.5%) patients in the prospective study period were classified as low-risk, intermediate-risk, and high-risk, respectively (Table 3).

In the retrospective study period, 64.3% (1030/1602) of patients received a CT scan, and in each month, the rate of CT scan utilization was consistent. By contrast, only 46.1% (789/1713) received a CT scan in the prospective study period ($P=.00$), and the rate of CT scan use remained <50% (Fig. 2, Table 3). However, the rates of positive CT findings were similar between the 2 groups: 4.7% and 5.3%, respectively ($P=.405$). In addition, there were no significant differences in the rate of clinically important TBI between the 2 study periods (Table 3).

In the prospective study period, 924 (53.9%) patients were discharged directly from the ED without an immediate CT scan after a physician's evaluation. A total of 771 (45%) children were discharged for follow-up without clinically important TBI after receiving a CT scan (Fig. 1). For the 2 groups of patients who were discharged from the ED with or without immediate CT scan, there were no significant differences in the incidence of unscheduled ED re-visits, delayed/repeated CT scans, and new positive CT findings (Table 4).

For patients receiving immediate CT scans in the prospective study period, 377 (47.8%), 318 (40.3%), and 94 (11.9%) patients were classified into the low-risk, intermediate-risk, and high-risk groups, respectively. This finding indicates that approximately one-third (377/1301, 29.0%) of the patients evaluated as low risk did not follow their physician's suggestion and insisted on receiving a CT scan. But there were no differences between these 2 subgroups (contrary to the physician's recommendation or not) in repeated CT scan rates but unscheduled ED re-visits (Table 5). Accordingly, the rates of

Table 2

Follow-up form.

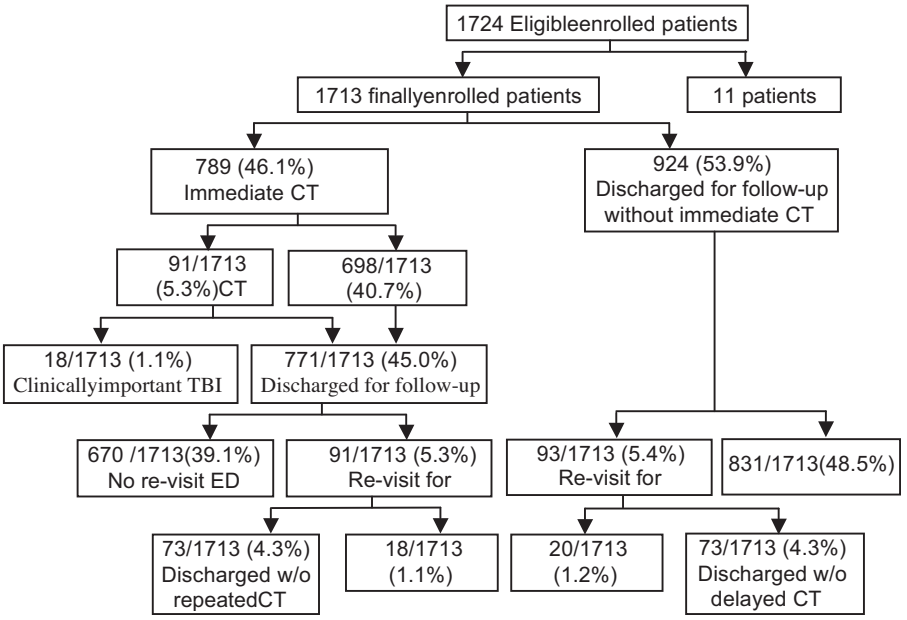
Time point	Clinical Information	Management
☐1 hour ☐6 hours ☐12 hours ☐24 hours ☐3 days ☐7 days ☐30 days	☐Normal ☐Disturbance of consciousness ☐Drowsiness ☐Irritability ☐Excessive crying ☐others mental status abnormality ☐Convulsion/seizure ☐Focal neurological abnormality ☐Vomiting ☐Headache ☐visual abnormality ☐amnesia	☐Keep on following ☐Back to ED for re-evaluation

Other information: _____

positive CT findings and unscheduled ED re-visits were significantly different between the 3 groups. Interestingly, there were no differences among the 3 groups in repeated CT scan rates (Table 6). Also, during the follow-up period, most of the patients re-visited the ED and repeated the CT scan in 3 days (Fig. 3).

4. Discussion

Mild head injury is a common reason for children to visit the ED.[1–2] The use of pediatric cranial CT scan has increased significantly during the last several decades.[13–15] Applying clinical decision rules can improve clinical decision making concerning the recognition of injuries and the reduction of unnecessary radiation exposure.[4–6] In the recent decade, a number of clinical decision rules have been published, including PECARN, CATCH, CHALICE, and the National Emergency X-Radiography Utilization Study II (NEXUS II), and so on.[4–6,23] In our study, a modified decision-making rule was used in the prospective study period, and more than half of the patients who were evaluated as low-risk were discharged from the ED and avoided unnecessary CT scanning. Therefore, implementing clinical evaluation and decision-making strategies can efficiently help reduce unnecessary radiation exposure for children with a mild head injury.



CT: Computed tomography

TBI: Traumatic brain injury

ED: Emergency department

Figure 1. Patient flow diagram in prospective study period.

Table 3

Comparison of characteristics between children in 2 study periods.

Characteristics	Retrospective study period, N = 1602, n/N (%)	Prospective study period, N = 1713, n/N (%)	P
Sex (male)	947 (59.1%)	1020 (59.5%)	.801
Age ≥2 y	809 (50.5%)	907 (52.9%)	.153
Risk classification			
Low	1195 (74.6%0	1301 (75.9%)	.366
Intermediate	306 (19.1%)	318 (18.6%)	.693
High	101 (6.3%)	94 (5.5%)	.318
CT performed	1030 (64.3%)	789 (46.1%)	.000
Positive CT findings	75 (4.7%)	91 (5.3%)	.405
CT efficiency	75/1030 (7.3%)	91/789 (11.5%)	.002
Clinically important TBI*	16 (1.0%)	18 (1.1%)	.882

*Traumatic brain injury resulting in death, neurosurgical intervention, intubation for >24 hours, or hospital admission for ≥2 nights.
CT = computed tomography, TBI = traumatic brain injury.

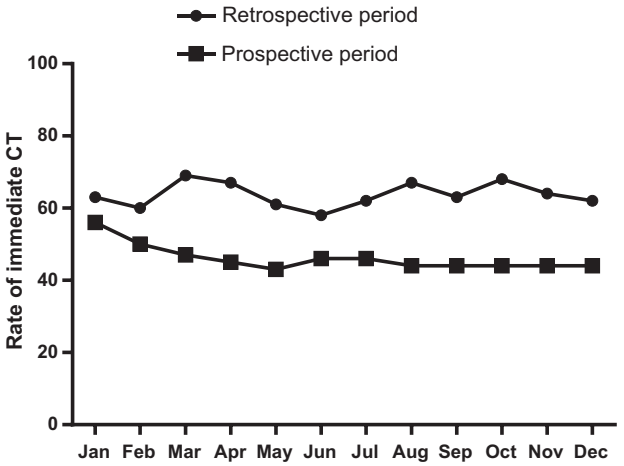


Figure 2. Immediate computed tomography (CT) scan rate in 2 study periods.

However, PECARN was the only rule to identify all clinically important TBIs, whereas the rest were incompletely sensitive.[24] And a recent study reported that in a setting with high clinician accuracy and a low CT scan rate, these clinical decision rules had limited potential to increase the accuracy of detecting clinically important TBI and may increase the CT scan rate.[25] Furthermore, the simple application of decision-making rules could not wholly eradicate unnecessary CT scanning for many reasons. We performed a survey to determine the factors that might influence decision-making for CT scans not only for emergency physicians but also for the children's parents (data not shown in this article). The first factor of concern for both physicians and parents was safety. In addition, the solution they preferred was not a CT scan but rather professional medical care.

The reasonable explanation for the preference to professional medical care was of relatively insufficient medical resources and poor communication between doctors and patients in China. Overcrowding, poor physician–patient communication, and declined patient–physician trust made it difficult for both physicians and parents to make the right decision.[26–28] Over-reliance on radiological examinations became a routine practice that led to tremendously unreasonable radiation exposure in children with a mild head injury. In our study, it was understandable that patients who were classified into higher-risk groups displayed a higher incidence of positive CT findings, clinically important TBIs, and unscheduled ED re-visits. However, there were no significant differences in repeated CT rates among the different-risk groups. A possible reason for this finding was that parents with children in higher-risk groups would be more nervous and more inclined to return for help even

Table 4

Comparison of patients with or without immediate CT scan in prospective study period.

Characteristics	Immediate CT performed, N = 789, n/N (%)	No Immediate CT, N = 924, n/N (%)	P
Discharged for follow-up	771/789 (97.7%)	924/924 (100%)	—
Unscheduled re-visit ED	91/771 (11.8%)	93/924 (10.1%)	.252
Delayed/repeated CT	18/771 (2.3%)	20/924 (2.2%)	.814
CT new positive findings	1/771 (0.1%)	2/924 (0.2%)	.672

CT = computed tomography, ED = emergency department.

Table 5

Comparison of characteristics among patients in low risk group.

Characteristics	Low risk, w/o immediate CT N = 924, n/N (%)	Low risk, with immediate CT N = 377, n/N (%)	P
Unscheduled re-visit	93/924 (10.1%)	20/377 (5.3%)	.006
Repeated CT	20/924 (2.2%)	8/377 (2.1%)	.962

CT = computed tomography.

Table 6

Comparison of characteristics among patients in different risk levels.

Characteristics	Low risk N = 1301, n/N (%)	Intermediate risk, N = 318, n/N (%)	High risk, N = 94, n/N (%)	*P*
Positive CT findings	6/377 (1.6%)	49/318 (15.4%)	36/94 (38.3%)	.00
Clinically important TBI	1/377 (0.3%)	5/318 (1.6%)	12/94 (12.8%)	.00
Unscheduled Re-visit	113/1301 (8.7%)	40/318 (12.6%)	31/94 (33.0%)	.00
Repeated CT	28/1301 (2.2%)	7 /318 (2.2%)	3/94 (3.2%)	.396

CT = computed tomography, TBI = traumatic brain injury.

without actual evidence of worsening. For this reason, regular and consistent medical care might get them out of their predicament.

Some researchers have reported that observation was associated with a reduction in cranial CT scan rates without delaying the diagnosis of clinically important TBI in children presenting to the ED for evaluation of head trauma.[18,19] Since the risk of a clinically significant TBI for children evaluated as low risk is very low and since a longer length of ED stay for observation was associated with the occupation of unaffordable emergency care resources, it might be reasonable and safe to discharge most of these children for home observation.[6] The rest of the question to be considered is how to provide continuous professional medical care and obtain parents' adherence and trust.

In our study, with the support of scheduled follow-up phone calls, most of the patients did not stay in the ED for observation but rather were discharged directly from the ED after evaluation, with or without an immediate CT scan. During the 30-day follow-up period, there was no increase in the rate of repeated CT scan or the risk of delayed diagnosis of clinically important TBI. The further subgroup analysis in the low-risk group found no difference in the rate of repeated CT scan but that of unscheduled re-visit, which indicates that these low-risk patients undergoing CT scan had no demonstrable benefit from the CT performed. Besides, the CT scan some of the low-risk children received proved to be unnecessary in the end. Therefore, these findings indicate that we should continue to make an effort to improve decision-making by providing feasible and reliable medical care, such as professionally scheduled follow-ups by nurses.

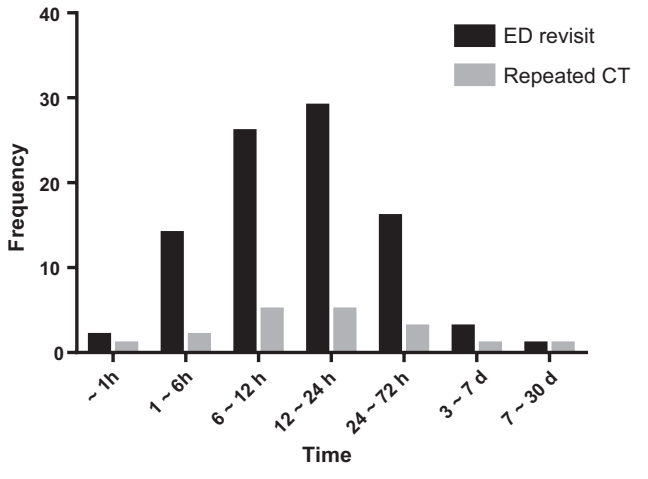


Figure 3. Frequency and distribution of emergency department re-visit and repeated computed tomography (CT) performing.

The optimal time for cranial CT scans in children with a mild head injury is unknown. Previous studies have demonstrated that at least 4 hours of observation after the injury is reasonable because a delayed presentation (>6 hours after injury) of a significant TBI is rare.[17] In our study, most of the ED re-visits and repeated CT scans occurred in the first 24 hours after patient's discharge. Therefore, we believe that a decision made after 24 hours of home observation with professional follow-up would be more acceptable and advisable.

5. Conclusion

In summary, the adoption of a modified decision-making rule supported by scheduled telephone follow-up can reduce head computed tomography utilization without delaying the diagnosis of clinically important TBI in children with mild TBI. This strategy should be considered as an additional method in the management of children with minor head trauma.

6. Limitations

Our study has several limitations. First, this study was conducted at a single hospital. The protocol is just a preliminary one and needs to be validated in larger number of patients in our country and may not be applicable in countries with different health care systems. Second, due to ethical considerations, we did not design this study as a randomized control study, which should include randomized groups with or without scheduled follow-up. Many factors, such as the understanding of injury or the social or economic conditions and educational backgrounds of the parents, influence the decision-making for an immediate CT scan and ED re-visit. Third, the data for the retrospective study period came from electronic medical records. The lack of follow-up information made it difficult to further compare the 2 study periods.

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