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Physicians' Risk Tolerance and Head Computed Tomography Use for Pediatric Patients With Minor Head Injury

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Objectives: Traumatic brain injury is the leading cause of death and disability in children worldwide. The objective of this study was to determine the association between physician risk tolerance and head computed tomography (CT) use in patients with minor head injury (MHI) in the emergency department (ED).

Methods: We retrospectively analyzed pediatric patients (<17 years old) with MHI in the ED and then administered 2 questionnaires (a risk-taking subscale [RTS] of the Jackson Personality Inventory and a malpractice fear scale [MFS]) to attending physicians who had evaluated these patients and made decisions regarding head CT use. The primary outcome was head CT use during ED evaluation; the secondary outcome was ED length of stay and final diagnosis of intracranial injury (ICI).

Results: Of 523 patients with MHI, 233 (44.6%) underwent brain CT, and 16 (3.1%) received a final diagnosis of ICI. Among the 16 emergency physicians (EPs), the median scores of the MFS and RTS were 22 (interquartile range, 17–26) and 23 (interquartile range, 19–25), respectively. Emergency physicians who were most risk averse tended to order more head CT scans compared with the more risk-tolerant EPs (56.96% vs 37.37%; odds ratio, 8.463; confidence interval, 2.783–25.736). The ED length of stay ($P = 0.442$ and $P = 0.889$) and final diagnosis ($P = 0.155$ and $P = 0.835$) of ICI were not significantly associated with the RTS and MFS scores.

Conclusions: Individual EP risk tolerance, as measured by RTS, was predictive of CT use in pediatric patients with MHI.

Key Words: computed tomography, risk tolerance, traumatic brain injury

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Traumatic brain injury (TBI) is the leading cause of death and disability in children around the world and accounts for approximately half of all trauma-related deaths.[1] The incidence rates of head injury (HI) for children aged 0 to 4, 5 to 9, and 10 to 14 years are 1.85, 1.1, and 1.17 per 100 children per year, respectively.[2] Most cases of TBI are minor, accounting for approximately 90% of all TBIs, and are a very common reason for presentation to the emergency department (ED).[1] In most cases of minor head injury (MHI), pediatric patients recover without any intervention. Fewer than 10% of computed tomography (CT) scans in children with MHI show intracranial injury (ICI). Furthermore, injuries needing neurosurgery are very uncommon in children with Glasgow Coma Scale (GCS) scores of 14 to 15.[3–6]

The consequences of MHI can be severe.[7] It is challenging for emergency physicians (EPs) to identify and separate the small number of patients with TBIs from the overwhelming majority of patients with benign MHI. Nonenhanced CT is the imaging modality of choice to screen patients with head trauma for neurocranial injuries, owing to its ready accessibility and diagnostic accuracy.[8,9] Patients with a normal initial head CT scan have a very low risk of developing delayed complications.[6,10] Although life-threatening sequelae occur in only a small fraction of all patients with MHI, a missed or delayed diagnosis of a potentially life-threatening disease may result in delayed initiation of treatment and may even lead to medical disputes. Accordingly, EPs must lower their testing threshold for brain imaging. In fact, the use of head CT scans has doubled in frequency from 1995 to 2003,[11] with head CT scans being performed for nearly half of all pediatric patients with blunt head trauma.[12] Unnecessary head CT examinations may lead to increased durations of ED stay,[13] medical costs,[14] and radiation exposure (a potential carcinogen), especially for children.[15,16] Some studies have tried to find specific decision rules for determining who should receive neuroimaging for pediatric MHI,[17–19] but none of these studies could achieve 100% sensitivity for detecting ICI.[20]

To the best of our knowledge, there is no widely accepted protocol for diagnosing MHI with ICI, and a consensus about the appropriate criteria for CT use is yet to be established. Previous studies revealed that variations in physician practices that are based on differences in risk tolerance could lead to suboptimal care, inefficient use of resources, and increased health care costs.[21,22] Therefore, the purpose of this study was to evaluate the association between physician risk tolerance and head CT use in the ED for pediatric patients with MHI. We hypothesized that head CT use would be higher for physicians exhibiting more risk-averse behaviors.

METHODS

Study Design and Population

A retrospective study was conducted using data collected between January 1, 2012, and December 31, 2015, in an urban tertiary hospital with an average of 60,000 ED visits per year. The medical records of trauma patients who were younger than 17 years and visited the ED with a principal diagnosis of TBI were extracted from the ED administrative database using the *International Classification of Diseases, Ninth Revision* codes 959.01 and 854.00. Electronic charts were reviewed to identify patients with MHI. Patients with MHI were defined as those with a loss of consciousness for less than 15 minutes or posttraumatic

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The study was approved by the institutional review board of the Chang Gung Memorial Hospital, Chiayi (approval no.: 201600921B0). Written informed consent was obtained from all EPs before the survey.

Disclosure: The authors declare no conflict of interest.

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amnesia for less than 1 hour and a GCS score of 13 to 15.[9] Patients with documented abnormal neurologic findings on cranial nerve examination, cerebellar function tests, or muscle power or sensory change tests were excluded. We defined ICI as finding a new lesion on head CT scans, including an intracranial hematoma, subarachnoid hemorrhage, or skull fracture or any of these findings confirmed using head magnetic resonance imaging or lumbar puncture or diagnosed as such by a neurosurgeon at discharge from the hospital. The study was approved by the institutional review board of the Chiayi Chang Gung Memorial Hospital. Written informed consent was obtained from all EPs before the survey.

Physicians' Risk Tolerance Evaluation

We used 2 scales to evaluate physicians' risk tolerance: a risk-taking subscale (RTS) of the Jackson Personality Inventory and a malpractice fear scale (MFS). These scales have been used in previous studies to evaluate the decision-making and test-ordering behaviors of Eps.[22–24] Details of the questionnaires for each survey instrument are listed in the Appendix. (Supplemental Digital Content 1, http://links.lww.com/PEC/A286).

During the study period, 16 EPs were present in the department. In June 2016, all EPs completed a survey consisting of the 2 questionnaires. The physicians were divided into quartiles based on their 2 test scores, with quartile 1 in each case being the group expected (a priori) to be the most risk averse (low-risk takers and more fearful of malpractice litigation). Our EPs were all trained in a 4-year emergency medicine residency program conducted by the Taiwan Society of Emergency Medicine in an accredited teaching hospital. None of the physicians included in this study had been deposed in a lawsuit as a defendant during the preceding 5 years. In our ED, residents help to evaluate patients, but the EPs make the final decision regarding CT examination scheduling and admissions. Emergency physicians are paid according to the number of shifts worked and not the number of patients treated; therefore, test ordering is not profit motivated.

Variables and Outcome Measures

Age, sex, triage status, risk factors, and signs of a possible ICI, including altered mental status (GCS score <15), loss of consciousness, posttraumatic amnesia, suspected skull fracture, signs of possible basilar skull fracture, and persistent vomiting were collected from the medical record charts. Other variables and measures included scalp hematomas except for frontal ones, abnormal behavior, a severe mechanism of injury, worsening headache, laceration, seizure, coagulopathy, and previous neurosurgery.[17–19] Patient disposition, ED length of stay (LOS), and the final discharge diagnosis of ICI by a neurosurgeon were also documented. The primary outcome was head CT scan use during ED evaluation, and the secondary outcome was ED LOS and final diagnosis of ICI.

Data Analysis

The results of the descriptive analyses of independent variables are reported as percentages or means ± SDs. Independent variables were analyzed using χ^2 test, Mann-Whitney *U* test, and Student *t* test. To determine whether physicians' risk scores were associated with the decision to order a head CT and admit to hospital, the EPs were categorized into 4 quartiles based on their risk tolerance scores. The relationship of risk tolerance to head CT scan use and hospital admission was analyzed using the χ^2 test, and logistic regression was used to obtain the odds ratio (OR), 95% confidence interval (CI), and *P* value for trends. $P < 0.05$ was regarded as statistically significant. SPSS version 18.0 (SPSS, Inc, Chicago, Ill) was used for all statistical analyses.

RESULTS

Characteristics of Study Participants

During the study period, a total of 231,891 patients visited the ED, and 751 (0.32%) of these patients had HI as their primary diagnosis. A total of 228 patients were excluded because their charts showed a diagnosis of moderate to severe HI or because they were treated by a physician who had left our ED, and so the questionnaires could not be completed. The remaining 523 patients comprised our study group. The patients were assessed by the 16 EPs in our department, and the median number of patients assessed by each EP was 23. Among the 16 EPs, the median scores of the MFS and RTS were 22 (interquartile range [IQR], 17–26) and 23 (IQR, 19–25), respectively. The demographic characteristics of the study group and the 233 patients (44.6%) who received head CT examination in the ED are listed in Table 1. In total, 30 patients (5.7%) were admitted. Of the 16 patients (3.06%) with a final diagnosis of ICI by a neurosurgeon at discharge, 7 had a subdural hemorrhage, 4 had a subarachnoid hemorrhage, 3 had an epidural hemorrhage, 1 had a pneumocranial hemorrhage, and 1 patient had both a subdural and subarachnoid hemorrhage. The other patients were admitted to the ward for other reasons, such as an orbital fracture or liver laceration. Three patients with epidural hemorrhage underwent surgery. One patient died because of diffuse subarachnoid hemorrhage and respiratory failure.

A univariate analysis revealed that EPs tended to order head CT scans for older patients ($P < 0.001$), as well as for patients with altered mental status ($P = 0.025$), an initial loss of conscious ($P < 0.001$), posttraumatic amnesia ($P < 0.001$), suspected skull fracture ($P < 0.001$), suspected basilar skull fracture ($P = 0.006$), persistent vomiting ($P < 0.001$), focal neurologic deficit ($P = 0.003$), abnormal behavior ($P < 0.001$), severe mechanism of injury ($P < 0.001$), worsening headache ($P < 0.001$), and triage status ($P < 0.001$). Patients who received a CT examination were also more likely to be admitted ($P < 0.001$), and the LOS was longer ($P < 0.001$).

Association Between Patient Characteristics and Decision Making

As shown in Table 2, risk tolerance based on RTS score was significantly associated with a higher likelihood of head CT use ($P = 0.022$). Physicians who were relatively risk averse were more likely to order CT examinations in pediatric patients with MHI. However, risk tolerance based on MFS scores was not associated with a higher likelihood of head CT use ($P = 0.153$). Physicians who possessed a high level of malpractice fear were less likely than EPs to order CT during the examination of patients with MHI. The ED LOS was not significantly associated with RTS and MFS scores ($P = 0.442$ in RTS, $P = 0.889$ in MFS). Moreover, the final diagnostic rate of ICI was not significantly different among RTS and MFS quartiles ($P = 0.155$ and $P = 0.835$, respectively; Table 2).

After performing a multivariate logistic regression to adjust for patient-level confounding factors (including risk factors for ICI), a significant association between RTS quartiles and head CT use was observed (Tables 2 and 3). Compared with the most risk-tolerant physicians based on RTS, the most risk-averse physicians demonstrated a significantly increased probability of ordering a CT examination (56.96% vs 37.37%, OR, 8.463; 95% CI, 2.783–25.736; Table 3). However, no significant association was observed between MFS quartiles and head CT use (Table 3).

DISCUSSION

During the study period, 231,891 patients visited the ED, 40,573 (17.5%) of whom visited the ED because of trauma; 751 (0.32%) of these patients were diagnosed with pediatric MHI.

TABLE 1. Demographic Characteristics of ED Patients

	CT Examination Performed (n = 233)	CT Examination Not Performed (n = 290)	*P*
Age, y	10.82 ± 5.802	5.58 ± 5.284	0.000
Male	148	179	0.673
Altered mental status (GCS score <15)	4	0	0.025
Initial loss of consciousness	71	0	0.000
Posttraumatic amnesia	16	1	0.000
Suspected skull fracture	13	0	0.000
Suspected basilar skull fracture	6	0	0.006
Persistent vomiting	53	8	0.000
Scalp hematoma, except in the frontal lobe	43	45	0.372
Focal neurologic deficit	7	0	0.003
Abnormal behavior	33	6	0.000
Severe mechanism of injury	54	13	0.000
Bruise, swelling, or laceration	110	129	0.534
Worsening headache	93	32	0.000
Previous neurosurgery	1	0	0.264
Seizure	3	0	0.053
Triage			0.000
1	13	1	
2	52	55	
3	160	212	
4	8	22	
5	233	290	
Final diagnosis of ICI	16	0	0.000
Admission	30	1	0.000
Length of stay, h	2.826 ± 3.985	0.684 ± 1.35	0.000

While others have reported the national incidence of TBI in patients admitted to the ED, Bazarian et al[25] were the first to issue a report focusing specifically on MHI. The incidence of MHI among patients admitted to the ED in a pooled 3-year sample during 1998 to 2000 was 878/70,900 (1.23%), and for children or teenagers aged 0 to 5, 5 to 14, and 14 to 24 years, the proportions of MHI were 16%, 21.77%, and 19.11%, respectively. The incidence of MHI was lower in our study than in a previous study that also documented a higher incidence in nonurban areas.[25] The hospital in which the study was conducted is located in an urban area, Chiayi County, with a relatively lower proportion of children, approximately 10.26% compared with 13.35% in Taiwan,[26] and might provide a reason for the relatively lower incidence of mild pediatric TBI.

Schachar et al[20] reported that of 6057 pediatric patients who presented with a chief complaint of head trauma between January 1, 2001, and September 1, 2008, only 2101 patients (34.7%) received a head CT scan after assessment by an attending physician. Another retrospective cohort study involving 9 pediatric hospitals in Canada showed that of 1164 children diagnosed with MHI from

TABLE 2. Computed Tomography Use, ED LOS, and Final Diagnosis of ICI for the RTS and MFS Quartiles

	CT Use			ED LOS			
Quartiles	CT Examination Performed n = 233	CT Examination Not Performed n = 290	*P*	Hours, Mean ± SD	*P*	ICI	*P*
RTS			0.022		0.442		0.155
1	45	34		2.12 ± 3.25		2 (1.1)	
2	71	86		1.49 ± 2.72		6 (3.6)	
3	80	108		1.66 ± 3.35		5 (6.3)	
4	37	62		1.46 ± 2.74		3 (3.1)	
MFS			0.153		0.889		0.835
1	60	72		1.79 ± 2.80		3 (2.3)	
2	38	59		1.49 ± 3.19		4 (4.1)	
3	80	76		1.66 ± 2.80		5 (3.2)	
4	55	83		1.58 ± 3.40		4 (2.9)	
Scores on the RTS and MFS for the 16 EPs were divided into quartiles							

TABLE 3. Multivariate Analysis Before and After Adjustment for Patient-Level Confounding Factors (Age, Sex, Altered Mental Status, Initial Loss of Consciousness, Posttraumatic Amnesia, Suspected Skull Fracture, Suspected Basilar Skull Fracture, Vomiting, Focal Neurologic Deficit, Abnormal Behavior, Severe Mechanism of Injury, Worsening Headache, and Triage)

	Before Adjustment			After Adjustment		
		95% CI			95% CI	
Quartiles	OR	Lower	Upper	OR	Lower	Upper
RTS						
RTS (1)	2.218	1.123	4.055	8.463	2.783	25.736
RTS (2)	1.559	0.938	2.592	9.626	3.586	25.840
RTS (3)	1.102	0.665	1.826	4.683	1.804	12.159
RTS (4)	1.000			1.000		
MFS						
MFS (1)	1.258	0.776	2.309	1.131	0.504	2.542
MFS (2)	0.972	0.571	1.654	2.142	0.866	5.296
MFS (3)	1.589	0.999	2.525	1.220	0.560	2.660
MFS (4)	1.000			1.000		

Scores on the RTS and MFS for the 16 EPs were divided into quartiles

January 1, 1995, to December 31, 1995, 171 (15%) received a CT scan.[27] In our study, of the 523 patients comprising our study group, 233 (44.6%) received a head CT scan. Thus, our proportion was higher than that reported in previous studies. One possible reason for this is that the frequency of imaging use has gradually increased over time.[28] In the United States, CT scan requests were 10 times higher in 2006 than in 1980. Another study indicated that the use of diagnostic imaging in the ED is also increasing.[29] Between 1995 and 2007, the number of ED patients who received a CT examination increased from 2.7 million to 16.2 million, constituting a 5.9-fold increase and a compound annual growth rate of 16.0%. Our study assessed visits to the ED between 2012 and 2015, and our data showed a higher usage of head CT scans, in accordance with the trend mentioned. Another reason for the higher prevalence of CT scan use may be financial. In a previous prospective observational study, two thirds of participants stated that cost should be factored into the decision to order a test and that they would not want the test if their risk were very low.[30] All of the patients included in our study were covered by national insurance and paid approximately US $23 for ED medical services, which included the CT scan. It is possible that the lower relative cost of ED medical services and high insurance coverage contributed to the high number of CT examinations in the ED. In other countries, where ordering a CT scan is expensive or inconvenient, EPs' behavior regarding the use of CT scans may be different.

Among the 16 EPs in our study, the median RTS score was 23 (IQR, 19–25), and the median MFS score was 22 (IQR, 17–26). Pines et al[22] demonstrated that among 31 EPs in an urban adult tertiary care ED in the United States the median RTS score was 20 (IQR, 18–23), and the median MFS score was 19 (IQR, 14–22). The higher RTS and MFS scores in our study may have been due to a cultural bias, resulting in different health-related preferences, legal liability, the nature of the resident training program, practice environment, and the doctor-patient relationship. To the best of our knowledge, no previous study has been designed to discuss the medical implications of variations in RTS and MFS scores between different countries with different training and practice situations. Further studies may be required to clarify this issue.

Previous studies documented that the RTS score was significantly associated with the decision to admit patients and use a CT coronary angiogram, as well as the use of cardiac markers,[22,31] whereas the MFS score was not.[22] Similar results were also recorded for imaging use in ED patients with abdominal pain and isolated dizziness or vertigo.[23,32] In addition, physicians' risk-taking behaviors are shown to be good predictors of use rates for specific laboratory procedures.[33] We arrived at the same conclusion as a previous study that the RTS score may be a fundamental characteristic that can predict physicians' use of laboratory investigations in clinical decision making.[23]

Wong et al,[34] in a study designed for 3 age-specific scenarios, claimed that members of the Michigan College of Emergency Physicians with a higher fear of malpractice score were more likely to order head CT scans for pediatric patients with minor head trauma. However, this trend was shown to be significant in only 1 of the 3 scenarios and not overall. Andruchow et al[35] found that physicians' risk-taking behavior and fear of malpractice are not correlated with the diagnostic yield of CT pulmonary angiographies in patients with suspected pulmonary embolism. The discrepancy for CT pulmonary angiography is probably because of the accepted, well-validated, evidence-based algorithms available to guide diagnostic testing for pulmonary embolism. With the uncertainty and difficulty in recognizing pediatric MHI patients, the RTS score could have a higher association with head CT utilization.

In our study, risk tolerance based on the RTS score was significantly associated with a higher likelihood of head CT use ($P = 0.022$), but the MFS score was unassociated ($P = 0.153$). To the best of our knowledge, the RTS seems to be more predictive in making medical decisions compared with the MFS.

As previously mentioned, the use of head CT scans has doubled in frequency from 1995 to 2003 and has been increasing in the past decade.[11] Studdert et al[36] studied high-risk litigation-specialist physicians in 6 specialty groups in Pennsylvania and found that ED physicians (70%, $P < 0.05$) ordered more examinations than actually necessary to avoid malpractice suits compared with other specialties. Among defensive practices to reduce the likelihood of litigation, more than half (63%) of ED physicians ordered imaging studies including radiography, CT, and magnetic resonance imaging that were not clinically indicated. Defensive medicine seems to be afflicting diagnostic-therapeutic areas and some disciplines to a greater degree, leading to a waste of economic and medical resources.[37]

In our study, EPs in the most risk-averse quartile tend to order more CT examinations than most risk-tolerant quartiles of RTS (56.96% vs 37.37%; OR, 8.463).

Therefore, if the most risk-tolerant EPs treated all the patients in our study, medical costs would have been reduced by approximately $15,573 in 4 years (523 patients × $152 CT cost in Taiwan) while maintaining the same diagnostic rate. The reduction in medical care costs would be 8 times greater in the United States, where a head CT costs $1220.[38]

Patients with longer ED LOS have lower patient satisfaction scores,[12] and unnecessary head CT examinations may lead to increased length of ED stay.[13] In our study, patients who received a CT examination had a longer ED LOS ($P < 0.001$), but this was not significantly associated with the RTS or MFS. Although ED LOS was slightly higher for patients treated by EPs with a higher RTS score compared with those with lower scores, this difference was not significant (2.12 ± 3.25 vs 1.46 ± 2.74 hours; $P = 0.442$). These results may be attributed to the fact that EPs who chose not to order CT examination may have needed to detain their patients for prolonged periods for further observation.

Several previous studies revealed that for pediatric patients with MHI with a normal neurologic examination approximately 4% to 7% might have a TBI diagnosed on CT scan, whereas 0.9% to 1.1% need surgical intervention.[6,26,39,40] Schunk et al[6] retrospectively reviewed 313 pediatric patients with a history of closed HI and a GCS score of 15 with no evidence of focal neurologic deficits and found that only 13 patients (4.2%) had ICIs, whereas 3 patients (0.96%) required neurosurgery for epidural hematoma and 1 patient (0.32%) for a complicated orbital fracture without ICI.[6] Klassen et al[27] retrospectively studied patients from 9 pediatric hospitals in Canada, including 1164 children with MHI with a GCS score greater than or equal to 13, and documented that 171 (14.7%) received a CT scan, of which 60 (35.1%) showed abnormalities, and 2 (1.2%) patients required surgery. Davis et al[40] studied 168 patients with loss of consciousness after HI and a score of 15 and found that 12 (7.14%) of them had an intracranial hemorrhage.

Among 233 patients who received a head CT scan in our study, 16 (6.87%) were diagnosed with ICI by a neurosurgeon at discharge, and 4 (1.7%) needed surgical intervention or even died because of ICI. The proportion of CT scans with positive findings in our study was similar to the average values from previous studies, but a higher percentage of patients needed surgical intervention or died.[6,26,39,40] In our study, 3 patients underwent surgery for epidural hemorrhage, and 1 died of a diffuse subarachnoid hemorrhage with respiratory failure. As only a small proportion of patients need surgical intervention for pediatric MHI, the small sample size of our study compared with those in previous studies might lead to a magnification of the difference between surgical intervention rates

Some evidence-based clinical decision-making instruments have been published to facilitate the screening and triage of minor head trauma patients. Four of the most commonly cited, independently validated decision aids, the New Orleans Criteria (NOC), the Canadian CT Head Rule (CCHR), Pediatric Emergency Care Applied Research Network (PECARN) head CT rule, and the National Emergency X-Radiography Utilization Study II (NEXUS II) head CT rule, have been introduced to provide decision-making support regarding the utilization of head CT scans, in an effort to limit their use in patients with minor head trauma.[9,17–20,41]

Applying the PECARN head CT rule[19] to our study patients, the sensitivity of CT for the prediction of brain injury is 93.8% (15/16 patients) and would reduce the number of patients who underwent CT by 17.6% (41/233 patients). The one missed from the prediction was a patient with a 15-cm laceration wound on the face without other signs, in whom the final diagnosis was a minimal subdural hemorrhage without surgical indication.

Applying the NOC head CT rule[20,41–43] to our study patients, the sensitivity of CT for the prediction of brain injury is also 93.8% (15/16 patients) and would require 15.9% (37/233 patients) of patients to undergo CT. The one missed from the prediction was a patient with a severe mechanism of injury from a road traffic accident with an initial loss of consciousness, and the final diagnosis was a falx subdural hemorrhage without surgical indication.

Applying the CCHR head CT rule[9,20,42,43] to our study patients, the sensitivity of CT for the prediction of brain injury is 81.3% (13/16 patients) and would require 46.8% (109/233 patients) of the patients to undergo CT. One patient missed from the prediction presented with a headache, another with a headache and abnormal behavior, and the other with a 15-cm laceration wound over the face. The 3 patients were diagnosed with subdural hemorrhage, and none of them required surgical intervention.

Applying the NEXUS II head CT rule[17,20] to our study patients, the sensitivity of CT for the prediction of brain injury is 56.3% (9/16 patients) and would reduce the number of patients who underwent CT by 51.1% (119/233 patients). The patients missed from the prediction presented with an initial loss of consciousness, a severe mechanism of injury, seizure, headache, or bruise and laceration wounds. One of the patients missed was diagnosed with an epidural hemorrhage and required surgery.

For the MHI patients in our study, the PECARN and NOC rules had equivalently high sensitivities for detecting any traumatic intracranial lesion on CT and clinically relevant brain injuries that might require neurosurgical intervention, but the PECARN could reduce more number of unnecessary CT examinations. Compared with the PECARN and NOC rule, the CCHR could reduce more number of unnecessary CT examinations and retain the same sensitivity for clinically relevant brain injuries that required neurosurgical intervention, but the sensitivity for detecting any traumatic intracranial lesion on CT was relatively low. Previous studies also showed similar results: that CCHR was more specific in predicting clinically relevant brain injuries than the other rules for making decisions for patients with MHI.[41,42,44] Our study also concluded that the NEXUS II rule showed the highest reduction rate for CT scans compared with the other rules, but failed to identify all those requiring neurosurgical intervention for the original cohort.[45]

To date, there is no criterion standard rule that has gained worldwide acceptance for diagnosing pediatric MHI. Some EPs consider it necessary to detect all traumatic intracranial lesions on CT, whereas others tend to focus only on detecting clinically important lesions that require a neurosurgical intervention. Moreover, many factors influence an EP's decision to order a head CT such as the doctor-patient relationship, different cultural and racial factors, financial issues, and parents' concern about the potential cancer risks associated with radiation, particularly for children who are more radiosensitive compared with adults. Hence, it is important to establish a standard evidence-based clinical decision rule to help EPs make diagnostic and therapeutic decisions during their practice, in order to identify children who are unlikely to have a clinically relevant TBI who can be safely discharged without a CT scan.

Limitations

Our study has several limitations. First, it was retrospective and relied on the accuracy and completeness of medical records. Because RTS and MFS can change over time, the scores may not reflect the characteristics that the physicians actually had during the period when they were treating the cohort of patients. In addition, a long-term follow-up could not be completely performed, so it is difficult to confirm outcomes for all patients.

Second, the study was conducted at a single institution in a single city and may not be generalizable to other practice situations. In Taiwan, the high CT utilization may be attributable to the high national health insurance penetration, and medical costs are relatively low. In our urban tertiary hospital, the ED settings may be different from a rural hospital or primary hospital.

Third, the study was conducted in a single country, but laws and regulations relating to malpractice litigation vary across countries, affecting EPs' decision to order examinations.

Fourth, only RTS and FMS were used in our study to evaluate the risk tolerance and malpractice concerns among EPs. As the measurement and self-identification of risk tolerance and malpractice concerns are difficult, additional multivariate questionnaires may be required for a more accurate analysis.

Fifth, the study sample was composed of a relatively small number of EPs. Therefore, further large-scale prospective studies involving more EPs from different countries and more multivariate measurement scales should be designed to verify our research results.

CONCLUSIONS

Individual EPs' risk tolerance measured by RTS was predictive of CT use in pediatric patients with MHI, whereas the MFS was not predictive of CT use. More studies need to be performed to create more objective and reliable guidelines in order to reduce the differences in practice among physicians with varying levels of risk tolerance and malpractice fear.

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