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Head CT for Nontrauma Patients in the Emergency Department: Clinical Predictors of Abnormal Findings[1]

Xi Wang, MD
John J. You, MD, MSc

Purpose: To identify predictors of clinically important abnormal findings in computed tomography (CT) images of the head among emergency department (ED) patients without a history of trauma.

Materials and Methods: Approval was obtained from the institutional research ethics board, and informed consent from patients was not required. This study was a retrospective review of consecutive unenhanced head CT examinations in patients aged 18 years or older who did not have trauma or known intracranial pathologic processes in ED from January 2004 through June 2006. Multivariable logistic regression was used to identify predictors of clinically important abnormal CT findings in the derivation cohort (CT examinations from January 1, 2004, through August 15, 2005), and the reproducibility of findings in a validation cohort (all subsequent CT scans through to June 30, 2006) was assessed. The strength of association of each variable was expressed with clinically important abnormal CT findings as adjusted odds ratio (OR) and 95% confidence interval (CI).

Results: Of 29469 consecutive head CT images performed at a single institution between January 1, 2004, and June 30, 2006, 3967 were eligible for this study. Of the CT images in these patients, 548 (13.8%) revealed clinically important abnormalities. Six independent clinical predictors of important abnormal findings on head CT were identified: age (adjusted OR per 10-year increase: 1.17; 95% CI: 1.08, 1.28), focal neurologic deficit (adjusted OR: 5.39; 95% CI: 3.90, 7.47), altered mental status (adjusted OR: 2.32; 95% CI: 1.66, 3.25), history of malignancy (adjusted OR: 4.11; 95% CI: 2.28, 7.42), nausea and/or vomiting (adjusted OR: 2.22; 95% CI: 1.14, 4.33), and derangements in coagulation profile (adjusted OR: 1.91; 95% CI: 1.07, 3.41).

Conclusion: This study identified several potential clinical predictors of abnormal head CT findings in ED patients who did not sustain trauma. Prospective validation of a clinical prediction rule in this population is warranted.

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[1] From the Departments of Radiology (X.W.), Medicine (J.J.Y.), and Clinical Epidemiology & Biostatistics (X.W., J.J.Y.), McMaster University, 1280 Main St West, Room HSC-2C8, Hamilton, ON, Canada L8S 4K1. Received March 28, 2012; revision requested June 4; revision received July 27; accepted August 9; final version accepted August 22. Supported by the Regional Medical Associates and the McMaster University Department of Radiology. J.J.Y. supported by a Hamilton Health Sciences Research Early Career Award and a McMaster University Department of Medicine Internal Career Award. **Address correspondence to** J.J.Y. (e-mail: *jyou@mcmaster.ca*).

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Computed tomography (CT) revolutionized radiology and medicine as a whole (1). Current CT scanners are capable of acquiring submillimeter-resolution images of the entire body in seconds (2). Since its inception in 1972, the use of CT has increased exponentially. Approximately 70 million CT examinations are performed annually in the United States (3,4). In 2007 in the United States, 14% of all patients in the emergency department (ED) underwent CT, a sixfold increase compared with 1995 (5). The majority (80%) of the annual increase in CT use in the ED can be explained by increased frequency of CT scanning, while only 20% are attributable to increased numbers of patients in the ED (5). Factors that promote the increased use of CT in the ED include its availability, efficiency, image resolution, noninvasive nature and the higher ED patient throughput it allows, patient expectations, and providers' fear of medicolegal repercussions (5–9).

Because of this growth in utilization of CT, policy makers are increasingly concerned about the increase in both costs and the exposure that occurs during CT acquisition (10). Unenhanced head CT examinations account for approximately 70%–80% of all CT requests from our institution's ED, at the cost of approximately Can$700 per test. As a comparison, charges at a typical hospital in the United States for an unenhanced head CT scan range from $400 to $800 (11,12). According to the National Center for Health Statistics, in 2008 there were a total of 123.8 million ED visits in the United States (13). If we assume a 14% utilization rate of CT among ED patients (5), and that approximately 70% of these CT examinations consist of unenhanced head CT and cost $500 (conservative estimate) per study, this equals annual expenditures of $6.1 billion for unenhanced head CT in the ED. Even a small reduction in the number of requests from the ED for head CT could potentially translate into substantial savings for the health care system.

While many (approximately 60% at our institution) head CT scans in the ED are requested for patients without trauma, few studies have examined the utility of head CT in this population. The existing studies, though typically small, suggest that head CT scans in this population are of low diagnostic yield and range from 0% to 15%, depending on the population that is studied (eg, patients with delirium or cognitive impairment, dizziness or vertigo, or syncope) (14–22). These studies also suggested that almost all nontrauma patients with abnormal head CT findings have abnormal findings on neurologic examinations, and that the majority of patients who had abnormal findings would be over 65 years of age (20–22); however, robust data that identify independent predictors of abnormal head CT findings in this population are lacking. More selective use of CT in the ED has the potential to substantially reduce health care costs, and there is a need for valid and reliable clinical decision guidelines to support physicians' decisions to order head CT for these patients. Accordingly, the objective of this study was to identify clinical predictors of abnormal imaging findings among patients in the ED with no history of trauma who underwent head CT.

Advances in Knowledge

- The following six clinical variables were independent predictors of abnormal head CT findings among patients in the emergency department (ED) who were referred for nontrauma-related indications: age over 70 years, focal neurologic deficit, altered mental status, history of malignancy, nausea and/or vomiting, and derangements in coagulation profile.
- Although prospective evaluation will be required, data suggest that if these clinical predictors been applied, the number of CT examinations performed could have been reduced by approximately 20%, while a sensitivity of 96%–98% is maintained.
- There is potential for more selective use of head CT in ED patients who have not sustained trauma.

Implication for Patient Care

- This study identified several potential clinical predictors of abnormal head CT findings in ED patients who did not sustain trauma; prospective validation of a clinical prediction rule in this population is warranted because a clinical decision rule would potentially reduce head CT utilization in the ED and optimize the use of limited health care resources.

Materials and Methods

Study Population

We used data from three academic tertiary care centers. Approval was obtained from our institutional research ethics board and informed consent from patients was not required.

We used our institution's picture archiving and communication system (Centricity; GE Healthcare, Little Chalfont, UK) to conduct a systematic search of consecutive patients who underwent unenhanced head CT from January 1, 2004, through June 30, 2006. We excluded patients who

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Abbreviations:
CI = confidence interval
ED = emergency department
OR = odds ratio
SAH = subarachnoid hemorrhage

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Guarantor of integrity of entire study, X.W.; study concepts/study design or data acquisition or data analysis/interpretation, X.W., J.J.Y.; manuscript drafting or manuscript revision for important intellectual content, X.W., J.J.Y.; approval of final version of submitted manuscript, X.W., J.J.Y.; literature research, X.W., J.J.Y.; clinical studies, X.W.; and manuscript editing, X.W., J.J.Y.

Conflicts of interest are listed at the end of this article.

were not from the ED, were younger than 18 years of age, were referred for CT because of a history of trauma (eg, motor vehicle accident, assault, falls), had known current or recent intracranial pathologic process (eg, intracranial hemorrhage, neurosurgery, ventricular shunt), or had a known history of a primary or metastatic brain tumor. We also excluded patients whose requisition did not contain information regarding any of the clinical predictors of interest. Patients with known malignancy but no known metastatic diseases of the brain were still eligible for inclusion.

Interpretations of CT studies were rendered by board-certified radiologists, not by trainees. Interpretations of CT scans were performed by staff neuroradiologists at a neurosurgical center. The other hospitals in this study were not neurosurgical centers, and interpretations were rendered by general staff radiologists or radiologists in other areas of subspecialization.

Data Collection

We categorized demographic and clinical data from the CT requisitions into the following candidate predictor variables of abnormal CT findings: age; sex; headache, neck stiffness, photophobia, and/or phonophobia; nausea or vomiting; altered mental status; focal neurologic deficit, including cranial nerve abnormality, dysarthria, and aphasia; ataxia, tremors, gait or balance abnormality, vertigo or dizziness, or other posterior fossa pathologic abnormalities; seizure; known seizure disorder; history of malignancy; history of drug use, including alcohol; fever or leukocytosis; hypertension or hypotension; derangements in coagulation profile (eg, warfarin therapy, thrombocytopenia, or hemophilia); general weakness, fatigue, or other nonspecific symptoms.

Primary Outcome

The primary outcome was abnormal findings on a head CT image, defined by one or more of the following: hemorrhage, acute or subacute infarction, mass lesion, or other clinically important abnormality that required intervention or follow-up.

Table 1

Demographics and Findings from Head CT Examinations

Parameter	Derivation Cohort (n = 1926)	Validation Cohort (n = 2041)
Mean age (y)	63.2 ± 19.1	64.5 ± 18.8
Men:Women (%)	49:51	49:51
Abnormal CT findings	275 (14.2)	273 (13.4)
Prevalence of hemorrhage	79 (4.1)	81 (4.0)
Prevalence of acute ischemia	139 (7.2)	136 (6.7)
Prevalence of mass lesion	44 (2.3)	47 (2.3)
Other pathologic entities*	13 (0.1)	16 (0.1)

Note.—Data in parentheses are percentages. Mean age is reported plus or minus standard deviation.

* Cavernoma, epidermoid cyst, aneurysm, arteriovenous malformation, hydrocephalus, encephalitis, neurocysticercosis, posterior reversible encephalopathy syndrome, acute disseminated encephalomyelitis, multiple sclerosis, and one case of Fahr disease.

We obtained information regarding the primary outcome from staff radiologists' reports on head CT examinations. In cases where the CT diagnosis was reported as equivocal, we reviewed all follow-up scans and clinical notes to classify the CT findings as either healthy or abnormal. When such follow-up data were unavailable, we assumed that the abnormal finding was present (ie, a worst-case scenario).

Sample Size Determination

To avoid derivation of an over-fitted model, approximately 10 outcome events (ie, abnormal head CT findings) were required for every independent variable that was entered into a multivariate logistic regression model (23,24). In our study, we wanted to examine the association of 15 candidate independent variables with abnormal findings on head CT scans. Therefore, we required at least 150 CT findings that showed an abnormality in both the derivation and the validation cohorts.

Data Analysis

The total data set was partitioned into two subsets. The first (derivation data set) contained all data from January 1, 2004, to August 15, 2005. The second (validation data set) contained all subsequent data to the end date of June 30, 2006. August 15, 2005, was chosen as a cutoff date because this provided two data sets that each had the required 150 head CT images showing an abnormality.

We used multivariate logistic regression analysis to identify which of the 15 candidate variables were independent clinical predictors of abnormal head CT findings and expressed the strength of association of each variable with the primary outcome as an adjusted odds ratio and 95% confidence interval. We assessed the reproducibility of our findings by using the validation cohort. A P value of .05 indicated statistical significance. All statistical analyses were performed with statistical software (SPSS version18.0; IBM, San Jose, Calif).

Results

Between January 1, 2004, and June 30, 2006, a total of 29469 head CT examinations were identified on our picture archiving and communication system. Of these, 20544 (69.7%) were not from the ED. After we excluded 252 pediatric patients (0.9%) and patients who had insufficient clinical information on the CT requisition (796 patients, 2.7%), had a history of trauma (3246 patients, 11.0%), or had a known intracranial pathologic process (664 patients, 2.3%), 3967 CT examinations met eligibility criteria.

The frequency of CT images showing abnormalities was similar in the derivation data and the validation data set (P = .43), and the patient demographics of these two groups were not significantly different ($P > .05$), as described in Table 1. In addition to age and sex, we assessed the distribution of

Table 2

Frequency of Clinical Indications for Head CT Examinations

Indication	Derivation Cohort (n = 1926)	Validation Cohort (n = 2041)
Headache, neck stiffness, and/or photophobia	529 (27.5)	481 (23.6)
Nausea and/or vomiting	89 (4.6)	101 (4.9)
Altered mental status	484 (25.1)	636 (31.2)
Focal neurologic deficit	830 (43.1)	917 (44.9)
Posterior fossa symptoms	297 (15.4)	314 (15.4)
Seizure	237 (12.3)	244 (12.0)
History of seizure disorder	20 (1.0)	15 (0.7)
History of malignancy	61 (3.2)	79 (3.9)
History of drug use	22 (1.1)	37 (1.8)
Fever and/or leukocytosis	35 (1.8)	34 (1.7)
Derangement in blood pressure	32 (1.7)	50 (2.4)
Derangement in coagulation profile	77 (4.0)	111 (5.4)
General weakness/fatigue	37 (1.9)	57 (2.8)

Note.—Cohorts are nontrauma patients from the ED. Data in parentheses are percentages.

Table 3

Independent Predictors of Abnormal Head CT FIndings

Variable	Adjusted Odds Ratio
Age	1.17 (1.08, 1.28)*
Nausea and/or vomiting	2.22 (1.14, 4.33)
Altered mental status	2.32 (1.66, 3.25)
Focal neurologic deficit	5.39 (3.90, 7.47)
History of malignancy	4.11 (2.28, 7.42)
Derangement in coagulation	1.91 (1.07, 3.41)

Note.—Numbers are from 1926 patients in the derivation cohort, with 95% confidence intervals in parentheses. The predictor variables listed in this table are those that were significant (P = .05) in a multivariate regression model that included the following candidate predictor variables: age; sex; headache, neck stiffness, and/or photophobia; nausea and/or vomiting; altered mental status; focal neurologic deficit; posterior fossa symptoms; seizure; history of seizure disorder; history of malignancy; history of drug use; fever and/or leukocytosis; derangement in blood pressure; derangement in coagulation profile; and general weakness and/or fatigue.

* Adjusted odds ratio per 10-year increase in age.

13 clinical variables in our study population (Table 2).

In the derivation cohort, we identified six independent predictors of abnormal head CT findings (Table 3). Patients with abnormal findings on their CT images were significantly older than patients without those findings ($P <$ .001) (Figs 1, 2).

Presentation at an ED with seizure was not predictive of abnormal head CT findings. In fact, in the derivation cohort, abnormal findings on the CT images were less frequent (18 of 237 [7.6%]) in patients who presented with a seizure than in patients who did not present with seizure (257 of 1689 [15.2%]) ($P <$ .002). No patients who presented with a seizure and who had a known history of seizure disorder had abnormal CT findings.

If patients in our study had been scanned only if they had one or more of the five independent clinical predictors (focal neurologic deficit, altered mental status, history of malignancy, nausea and/or vomiting, and derangements in coagulation profile) with no regard for patient age, a sensitivity of 94.2% (259 of 275 images with positive findings) would have been achieved, while reducing the number of examinations to 69.9% of the original number (1346 of 1926). Had any patient older than70 years been scanned regardless of whether one of the other independent predictor variables was present, a marginal increase in sensitivity to 96.0% (264 of 275) would have been achieved. This comes at the cost of having to scan nearly 10% more patients, which would bring the total scanned to 79.3% (1528 of 1926). Although presentation with seizure was not independently associated with an abnormal CT finding, such patients did account for some of the remaining 11 CT examinations with abnormal findings that were not identified by using the latter combination of predictor variables. If all patients in our study who presented with a seizure had also been scanned, sensitivity would increase to 98.5% (271 of 275). The cost of this increased sensitivity would be an increase in the percentage of patients scanned to 85.7% of the original number (1651 of 1926).

Four patients would have been missed with this last paradigm. The first patient was a 57-year-old man who presented with headache and no other symptoms who most likely had a small cavernoma. It is uncertain whether this was related to the patient's headache. He underwent no follow-up or treatment. The second patient was a 52-year-old man who also presented with only a headache and was found to have a small amount of subarachnoid hemorrhage (SAH) in the prepontine space. No aneurysm was found, and a conventional angiogram showed no abnormalities. The SAH resolved without intervention, and no subsequent hemorrhages were ever documented on our picture archiving and communication system. The patient most likely had benign perimesencephalic SAH. Every other case of SAH that was documented in our patient cohort had additional neurologic symptoms other than headache. The third patient was a 45-year-old woman who presented with only headache, which later resolved. She had equivocal CT findings, but the reporting staff radiologist questioned whether the patient had a mild degree of hydrocephalus. The patient was assessed at neurosurgery, and no intervention was required. The fourth patient was a 61-year-old man who presented with sudden headache, dizziness, and fever and was found to have a lacunar infarct in the left corona radiata. No specialist referral was documented, and the patient did not receive any follow-up or specific treatment, which implied that the lacunar infarct may have been an incidental finding that was unrelated to the patient's clinical presentation.

Figure 1

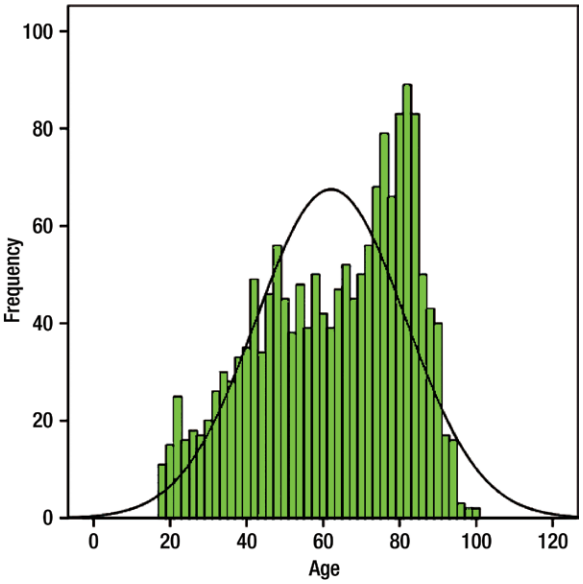

Figure 1: Graph shows age distribution for patients without abnormal head CT findings.

Figure 2

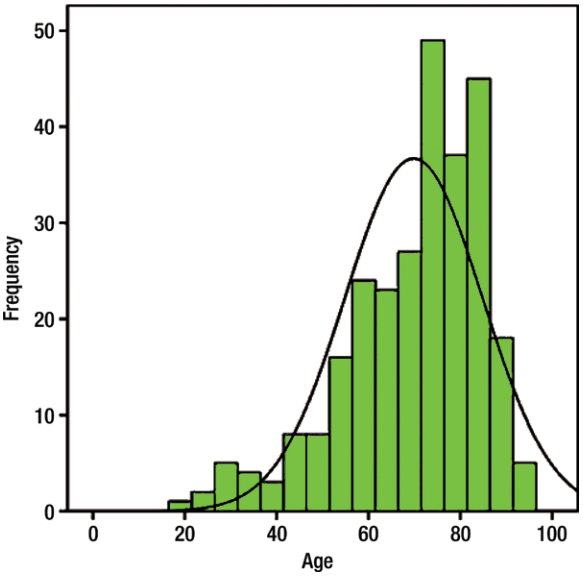

Figure 2: Graph shows age distribution for patients with abnormal head CT findings.

When tested in our validation cohort, the presence of one or more of the six clinical predictors had a sensitivity of 98.2% (268 of 273) for the prediction of abnormal head CT findings. This translates to a false-negative rate of 1.8%, in other words, five of 273 patients with abnormal head CT findings had none of these six clinical features (Table 4).

Discussion

In this retrospective study of ED patients without a history of trauma who underwent head CT, we identified the following independent clinical predictors of abnormal CT findings: age older than 70 years, focal neurologic deficit, altered mental status, history of malignancy, nausea and/or vomiting, and derangements in coagulation profile. Although prospective evaluation would be required to find the true effect of a clinical prediction rule on CT utilization, an exploratory analysis of our data suggested that if these clinical predictors had been applied among the patients included in our study, the number of CT examinations performed could have been reduced by approximately 20% while maintaining a sensitivity of 96%–98%. Thus, our findings suggest that there is potential for more selective use of head CT in ED patients who have not sustained trauma.

This compares favorably with similar clinical decision rules, such as the Canadian Assessment of Tomography for Childhood Head injury (CATCH) clinical decision rule for head CT in child with minor head injury (25) or the Canadian CT head rule developed by Papa et al (26). Sensitivity for the CATCH clinical decision rule ranges from 98.1% to 100%, depending on whether the patient has medium-risk or high-risk factors for brain injury. The work by Stiell et al was able to achieve 100% sensitivity for a cohort of 431 patients, in whom 22 patients had evidence of intracranial trauma on CT images; it is acknowledged that a larger cohort will be required to validate these findings (26).

The results of our exploratory impact analysis with the validation cohort demonstrated that these variables were able to predict the majority of patients with positive findings on unenhanced head CT examinations (sensitivity 97.4%–100%; Table 4). Our study does not support the routine use of brain CT for the investigation of solely headache or migraine-like symptoms, vertigo, dizziness, drug use, blood pressure abnormality, or generalized symptoms such as diffuse weakness in patients under the age of 70 years. In the absence of a focal neurologic deficit, altered mental status, or high-risk history such as malignancy or coagulation profile derangement, these CT examinations were of very low diagnostic yield.

Most studies of head CT utilization in the ED focus on trauma patients.

Table 4

Clinical Variables for Prediction of Abnormal Head CT Findings

Parameter	Deviation Cohort		Validation Cohort	
	Sensitivity	Patients Who Would Be Scanned	Sensitivity	Patients Who Would Be Scanned
One or more of five clinical predictors*	259 of 275 (94.2)	1346 of 1926 (69.6)	266 of 273 (97.4)	1517 of 2041 (74.3)
One or more of five clinical predictors, or age > 70 y	264 of 275 (96.0)	1528 of 1926 (79.3)	268 of 273 (98.2)	1682 of 2041 (82.4)
One or more of five clinical predictors, age > 70 y, or presentation with seizures	271 of 275 (98.5)	1651 of 1926 (85.7)	273 of 273 (100)	1815 of 2041 (88.9)

Note.—Numbers in parentheses are percentages.

* Focal neurologic deficit, altered mental status, history of malignancy, nausea and/or vomiting, and derangements in coagulation profile.

Comparatively few studies examine nontrauma patients, who are in fact more likely to have undergone noncontributory head CT and among whom exists the greatest potential for more selective use of CT. These studies are typically smaller but demonstrate that head CT examinations in this population are of low diagnostic yield. Moreover, nearly all patients with abnormal CT findings also had abnormal neurologic examination findings. For example, in a study of 279 patients with delirium or impaired consciousness, Naughton et al (20) determined that only 15% had positive findings on CT. Of these, 95% had positive neurologic examination findings, and the two patients who did not were not delirious and had experienced a fall. Authors of another study (21) of 200 patients who presented with acute dizziness or vertigo found no acute abnormal findings on head CT, and no head CT showed a lesion that could explain the patient's symptoms. The diagnostic yield was zero, at an estimated cost of $60 000. Another study (22) that examined the use of CT for syncope found that only five of 113 (4%) prospectively enrolled patients had an abnormal finding that was related to their presentation. In that study, post hoc examination revealed that two patients had focal neurologic findings, one patient had a new headache, two had outward signs of trauma, and all patients were over 65 years of age. The authors suggested that the use of CT in this population could potentially be reduced by 56%. A recent case-control study by Lai et al (29) examined 300 elderly patients who presented with delirium and found three predictors of abnormal head CT findings: new neurologic deficits, deterioration in consciousness, and recent history of a fall. Several other studies echo these conclusions (14–19,27–28).

The problem of patients who present to the ED with headache deserves further mention. In the derivation cohort, there were several patients who presented with headache and who would not have met criteria for further CT by using our prediction model, but one of these patients did have SAH (albeit nonaneurysmal, and it required no intervention). All other patients with SAH had other neurologic findings and would have merited a CT examination by using the prediction model. Because of the retrospective nature of our study and the heterogeneity of the requisitions, all headaches were grouped into a single category because no reliable distinction could be made between a headache that had been present for days versus a headache that was severe and of sudden onset.

There is preliminary evidence that certain features of headache may be predictive of SAH, such as time to peak (30). The American College of Emergency Physicians recommends that patients who present to the ED with headache and new abnormal findings in a neurologic examination (eg, focal deficit, altered mental status, altered cognitive function) should undergo emergent head CT without a contrast agent (31), which is in agreement with our current study. However, the same consensus policy also recommends that patients who present with new sudden-onset severe headache should undergo emergent head CT. Clearly, there are a minority of patients with SAH who present with only headache and are neurologically intact, which presents a tremendous challenge. At the time of this writing, Perry et al (32) are conducting a prospective validation of a clinical decision rule regarding the triage of patients with sudden severe headache who may have SAH.

The routine use of CT in patients who already have a known history of seizures was not supported in our study, although there is conflicted evidence of this in the literature. The vast majority of patients who have seizure and intracranial pathologic processes will also have focal neurologic findings or a high-risk history, such as malignancy or focal seizure onset (33,34).

Our work adds to this field because, to our knowledge, it is the first study to systematically examine a comprehensive set of clinical features that are associated with abnormal head CT in this patient population. On the basis of our study results, we therefore report independent predictors, whereas authors of other studies have only presented unadjusted associations. While there certainly are inherent limitations owing to our study's retrospective nature, the strengths of our study include its large sample size

and use of a validation cohort. This work, therefore, sets the stage for the development and prospective evaluation of a clinical decision rule.

We acknowledge some limitations of our work. First, our study was retrospective and did not include ED patients who did not undergo head CT. Therefore, it must be stressed that the true effect of applying these clinical predictors cannot be assessed. There is need for prospective validation of the clinical predictor variables that we identified in this consecutive series of ED patients with nontraumatic neurologic symptoms who did undergo head CT. We believe that our findings can directly inform the development and prospective evaluation of such a clinical prediction rule in a subsequent study.

Second, as a result of the retrospective nature of our study, patient assessment and documentation of clinical findings were not standardized. In Table 2, we list the frequency of 13 clinical features in our sample, but this does not mean that each requisition actually contained explicit information about the presence or absence of each of these features. Rather, if a clinical feature was not mentioned on the requisition, we assumed it was not present.

Finally, owing to the retrospective design of our study, there was no standardization of the terminology contained within the CT requisitions. For example, some CT requisitions only state "LOC," and it is unclear whether this means "loss of consciousness" or alteration in "level of consciousness." We attempted to mitigate some of these limitations through the employment of broad definitions for certain clinical predictors, such as "altered mental status" (which could include loss of consciousness and/or syncope, confusion, delirium, amnesia, or somnolence), to err on the side of caution. This likely lowered model specificity.

In conclusion, six variables obtainable from the bedside clinical assessment were independent predictors of abnormal findings among patients in the ED who were referred for head CT for nontrauma-related indications: age over 70 years, focal neurologic deficit, altered mental status, history of malignancy, nausea and/or vomiting, and derangements in coagulation profile. Our study has identified several potential clinical predictors of abnormal head CT findings in ED patients who have not sustained trauma, and prospective validation of a clinical prediction rule in this population is warranted. Such a clinical decision rule has the potential to reduce head CT utilization in the ED and to optimize the use of limited health care resources.

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