Effect of Clinical History on Interpretation of Computed Tomography for Acute Stroke

The Neurohospitalist
2019, Vol. 9(3) 140-143
© The Author(s) 2019
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/1941874418825179
journals.sagepub.com/home/NHO

Peter Hung, BA¹ , Caitlin Finn, BS¹, Monica Chen, BA¹, Ashley Knight-Greenfield, MD², Hedyeh Baradaran, MD², Praneil Patel, MD², Iván Díaz, PhD, MS³, Hooman Kamel, MD^{1,4}, and Ajay Gupta, MD^{1,2}

Abstract

Objective: We assessed whether providing detailed clinical information alongside computed tomography (CT) images improves their interpretation for acute stroke. **Methods:** Using the prospective Cornell Acute Stroke Academic Registry, we randomly selected 100 patients who underwent noncontrast head CT within 6 hours of transient ischemic attack or minor acute ischemic stroke and underwent magnetic resonance imaging (MRI) within 6 hours of the CT. Three radiologist investigators evaluated each of the 100 CT studies twice, once with and once without accompanying information on medical history, signs, and symptoms. In random sequence, each study was interpreted in one condition (ie, with or without detailed accompanying information) and then after a 4-week washout period, in the opposite condition. Using MRI diffusion-weighted imaging (DWI) as the reference standard, we classified CT interpretations as correct (true positives or negatives) or incorrect (false positives or negatives). We used logistic regression with sandwich estimators to compare the proportion of correct interpretations. **Results:** In patients with DWI-defined infarcts, acute ischemia was called on 20% of CTs with detailed history and 18% without history. In patients without infarcts, the absence of ischemia was called on 77% of CTs with history and 77% without history. The proportion of correct interpretations of CTs accompanied by detailed clinical history (49%) did not differ significantly from those without history (47%; odds ratio: 1.1; 95% confidence interval: 0.8-1.4). **Conclusions:** Reported findings on head CT for evaluation of suspected acute ischemic stroke were similar regardless of whether detailed clinical history was provided.

Keywords

stroke, cerebrovascular disorders, anatomic imaging, techniques, neuroradiology, clinical specialty, ischemic attack, transient, cerebrovascular disorders

Introduction

Computed tomography (CT) is the primary imaging modality for the assessment of acute ischemic stroke due to widespread availability and expedience. Computed tomography is vital in deciding whether to administer thrombolytic agents or perform endovascular therapy. However, CT has only 10% to 25% sensitivity for hyperacute or acute infarction.^{1,2} Magnetic resonance imaging (MRI) with diffusion-weighted imaging (DWI) achieves >90% sensitivity within 30 minutes after infarction,³ but longer acquisition times and limited availability relative to CT have prevented widespread incorporation of MRI into acute stroke evaluations.

In a typical workflow of a stroke team activation, the radiologist may be required to interpret an expedited head CT without direct patient contact and minimal communication with the referring clinicians providing acute stroke care. Radiologists often receive limited clinical information in the form

of a “clinical indication” transmitted along with the images through the picture archiving and communication system (PACS). Although they often receive vague or incomplete information, radiologists typically prefer more clinical

¹ Clinical and Translational Neuroscience Unit, Feil Family Brain and Mind Research Institute, New York, NY, USA

² Department of Radiology, Weill Cornell Medical College, New York, NY, USA

³ Department of Healthcare Policy and Research, Weill Cornell Medical College, New York, NY, USA

⁴ Department of Neurology, Weill Cornell Medical College, New York, NY, USA

Corresponding Author:

Peter Hung, Greenwich Hospital, 5 Perryridge Road Greenwich, CT 06830, USA.

Email: phung@post.harvard.edu

information in order to focus on regions corresponding to given symptoms and to adjust their indices of suspicion.⁴⁻⁶ However, it is also possible that providing information biases radiologists to overcall ambiguous findings or overlook findings elsewhere. Few data exist to guide practice in this common clinical scenario. We hypothesized that providing detailed clinical information alongside head CTs improves their interpretation for acute stroke.

Methods

We performed a crossover study comparing interpretations of head CTs in 2 different conditions: one in which they were accompanied by detailed clinical history and one in which they were not. The institutional review board at Weill Cornell Medical College approved this study and waived the requirement for informed consent.

Case Selection

The cases for our study were drawn from the Cornell Acute Stroke Academic Registry (CAESAR), a prospective registry of patients hospitalized with stroke or transient ischemic attack (TIA) at New York–Presbyterian Hospital/Weill Cornell Medical Center.⁷ Among patients registered in CAESAR between 2011 and 2015, we first selected cases of TIA or minor ischemic stroke (NIH Stroke Scale score ≤ 3). Minor strokes present similarly to TIAs, and identifying less obvious imaging findings of smaller strokes would potentially be more significantly assisted by clinical information. Among these patients, we selected those who had a noncontrast head CT study within 6 hours of symptom onset and an MRI study within 6 hours of CT. The CT studies were 2.5 or 5 mm axial acquisitions and may have included coronal and sagittal reconstructions. Using the interpretation of the MRI study, including Fluid-Attenuated Inversion Recovery (FLAIR) and DWI sequences, by the attending neuroradiologist at the time of stroke presentation as the reference standard for the true presence or absence of acute infarction, we randomly selected 50 patients with infarction (ie, acute stroke) and 50 patients without infarction (ie, TIA). This 1:1 ratio was chosen because approximately 50% of stroke codes at our center are ultimately diagnosed with stroke. The sample size of 100 patients was chosen based on a power estimation showing that 92 cases would be required for 80% power to detect a 15% effect size using a test for paired proportions assuming that 25% of the CTs would be interpreted differently in the condition with versus without detailed clinical information (see “Statistical Analysis” section below). However, given our lack of robust pilot data to guide power estimates, we assigned each of the 100 CT studies to be read by 3 different radiologists in order to ensure adequate sample size for detecting a meaningful difference between groups.

Computed Tomography Interpretations

Three radiologist investigators served as readers for this study: a radiology resident (A.K.-G.), neuroradiology fellow (H.B.), and neuroradiology faculty member (P.P.). These readers were blinded to the overall study rationale and hypothesis until the conclusion of their reading sessions. The readers used their usual workflow in GE Centricity PACS (General Electric, Chicago, Illinois) to review the initial head CT obtained at the time of patients’ presentation with stroke or TIA. Each of the 3 readers reviewed all 100 CT studies twice to adjudicate the absence or presence of acute infarction. The cases were presented in different random sequences to each reader, with each case being first presented randomly with or without accompanying clinical history. The same cases were then presented in the opposite condition (with or without clinical history) in a new random sequence after a 4-week washout period.

A single investigator (P.H.) abstracted relevant history from the attending neurologist’s admission note in the electronic medical records, including age, gender, medical risk factors, neurological deficits, and symptom time course. For the reading condition with accompanying history, this information was provided in standardized prose format (eg, “74-year-old man with a history of hypertension, atrial fibrillation, and prior stroke presents with left hemiparesis and expressive aphasia for 3 hours”). For the condition with no accompanying history, only the patient’s age, gender, and the prompt “rule out stroke” were provided (eg, “74-year-old man, rule out stroke”). No other information or imaging was provided to the readers.

Statistical Analysis

We used counts and frequencies for descriptive reporting. Given the multiple levels of clustering (ie, each scan was read twice by each radiologist, and this occurred for 3 different radiologists), we used logistic regression with sandwich estimators to compare the proportion of correct interpretations (true positives or negatives) in the scenario with versus without detailed clinical information. Statistical analysis was performed using Stata/MP (version 14.2, College Station, Texas).

Results

Among 1721 patients registered in CAESAR for acute ischemic stroke between 2011 and 2015, 583 had an NIHSS ≤ 3 , of whom 506 demonstrated acute diffusion restriction on MRI. From among 118 patients in this cohort who had a CT study within 6 hours of symptom onset and an MRI study within 6 hours of CT, 50 were randomly selected. Furthermore, from among 540 patients registered in CAESAR for TIA between 2011 and 2015, 50 were randomly selected. Thus, our final cohort included 100 patients, half of whom had acute infarction as detected by MRI and half of whom were infarct-free on MRI (Table 1).

Table 1. Characteristics of Patients Meeting Inclusion Criteria.

Characteristic	Patients With Stroke, NIHSS ≤ 3 (N = 50)	Patients With TIA (N = 50)	P Value
Age, mean (SD), years	67.0 (16.5)	73.5 (12.9)	.03 ^a
Female	22 (44)	22 (44)	1.00
Comorbidities			
Hypertension	27 (54)	26 (52)	.84
Hyperlipidemia	20 (40)	22 (44)	.69
Atrial fibrillation	6 (12)	7 (14)	.77
Diabetes	6 (12)	12 (24)	.12
Coronary artery disease	5 (10)	10 (20)	.16
History of stroke	8 (16)	10 (20)	.60
Symptom onset to CT, mean (SD), hours	2.4 (1.3)	2.3 (1.3)	.74
CT to MRI, mean (SD), hours	2.6 (1.5)	2.2 (1.4)	.18
Transient deficit Symptoms	10 (20)	14 (28)	.35
Motor deficit	21 (42)	19 (38)	.68
Sensory deficit	15 (30)	9 (18)	.16
Dysarthria	13 (26)	11 (22)	.64
Aphasia	6 (12)	18 (36)	.005 ^a
Visual disturbance	6 (12)	3 (6)	.30

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; NIHSS, National Institutes of Health Stroke Score; SD, standard deviation; TIA, transient ischemic attack.

Data are presented as number (%) unless otherwise specified.

^aA P value that met our set α of .05 as the cutoff for significance.

Table 2. Interpretation Outcomes of CTs for Acute Stroke and TIA Cases Performed Without and With Detailed Clinical History.^a

Case Type	No History	With History
Acute stroke, NIHSS ≤ 3 (n = 150)		
Infarct	27 (18)	30 (20)
No infarct	123 (82)	120 (80)
TIA (n = 150)		
Infarct	35 (23)	34 (23)
No infarct	115 (77)	116 (77)

Abbreviations: CT, computed tomography; NIHSS, National Institutes of Health Stroke Score; TIA, transient ischemic attack.

^aData are presented as number (%) unless otherwise specified.

In patients with DWI-defined infarcts, acute ischemia was called on 20% of CTs with detailed history and 18% without history. In patients without infarcts, the absence of ischemia was called on 77% of CTs with history and 77% without history (Table 2).

When a detailed history was present, 26 (9%) of 300 interpretations changed from incorrect to correct, while 22 (7%) of 300 interpretations changed from correct to incorrect. The proportion of correct interpretations of CTs accompanied by

Table 3. Concordance of Paired CT Interpretations of Acute Stroke and TIA Cases Performed Without and With Detailed Clinical History.^a

Case Type	No History	
	Correct	Incorrect
All cases (n = 300)		
With history		
Correct	120 (40.0)	26 (8.7)
Incorrect	22 (7.3)	132 (44.0)
Acute stroke NIHSS ≤ 3 (n = 150)		
With history		
Correct	20 (13.3)	10 (6.7)
Incorrect	7 (4.7)	113 (75.3)
TIA (n = 150)		
With history		
Correct	100 (66.7)	16 (10.7)
Incorrect	15 (10.0)	19 (12.7)

Abbreviations: CT, computed tomography; NIHSS, National Institutes of Health Stroke Score; TIA, transient ischemic attack.

^aData are presented as number (%) unless otherwise specified.

detailed clinical history (49%) did not differ significantly from those without history (47%; odds ratio: 1.1; 95% confidence interval: 0.8-1.4; Table 3).

Discussion

Using data from a prospective stroke registry, we found that the diagnostic accuracy of head CT for acute brain ischemia was not significantly influenced by the presence or absence of accompanying clinical history. The sensitivity and specificity of CT in our study was consistent with previously published reports.^{1,2} The low sensitivity of CT seen in our study and others highlights the challenge of detecting acute ischemia on this imaging modality. The provision of detailed medical history did not substantially address this limitation of CT.

Few data exist on how detailed clinical information influences the comparative accuracy of diagnostic imaging. One case series with 12 patients suggested that CT interpretation in acute stroke does not change significantly upon repeat reading with additional clinical knowledge.⁸ This significantly larger multireader study suggests that investing substantial time to write a detailed clinical history in the emergency setting may not benefit read accuracy. There are several potential explanations for this counterintuitive finding. First, radiologists may be accustomed to operating without detailed history, and thus, our radiology investigators may have discounted or ignored the provided clinical information when reading scans. Second, compared to other cross-sectional diagnostic radiology studies, head CT studies contain a smaller region of anatomic coverage, and thus, radiologists may be able to thoroughly review the study without needing clinical information to narrow their focus to a particular organ system. Third, given that neuroanatomical localization based on symptoms and signs is

an imperfect art, detailed clinical information may help draw attention to the right anatomical area in some cases but distract in others.

Our study had several limitations. First, the simulated study conditions differed from real-life practice. The readers were asked to perform 100 abbreviated evaluations of CTs in relatively rapid succession and provide binary interpretations with no gradation in reporting certainty. Reading was performed “in a void” with a lack of prior studies for comparisons and no actual clinicians to consult. The lack of prior comparisons was especially limiting for the differentiation of small acute and chronic infarcts which can appear similarly on CTs. Second, the 600 interpretations analyzed in this study were drawn from repeated readings of only 100 cases, 50 in each subgroup. The radiologists may have been biased by recall of prior interpretations, though we concealed that the cases were being repeated and instituted a 4-week washout period. Among the random selection of strokes with NIHSS ≤ 3 , some of the strokes were lacunar in nature or so small that they could not be feasibly detected on CT studies even if the clinical information had drawn the radiologists’ attention to the correct anatomical region. Third, the effect of other types of histories, such as incomplete or even incorrect histories, was not studied.

Although the read outcomes did not differ significantly between our 3 readers of varying experience, our data may not be fully generalizable to other stroke centers. Additionally, the inherently low sensitivity of CT in the setting of subtle strokes prevents the generalization of our findings to other imaging modalities or other indications.

It is important to note that there are many benefits of close integration of diagnostic radiologists into the workflow of acute stroke management. Our study focuses on only one aspect of read accuracy and does not assess the other benefits of close referring clinician–radiologist collaboration in advanced imaging modalities recommended by the radiologist as follow-up studies. These caveats notwithstanding, in the setting of suspected acute stroke, our results suggest that the diagnostic accuracy of head CT interpretations may not be adversely affected by a lack of clinical history.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study is funded by NIH grant KL2 TR000458. Hooman Kamel is supported by NIH grants K23NS082367, R01NS097443, and U01NS095869 as well as by the Michael Goldberg Research Fund. Ajay Gupta is supported by NIH grants KL2TR000458, R01NS090464, R01NS092802, and R21EB024366.

ORCID iD

Peter Hung <https://orcid.org/0000-0003-0522-8795>

References

1. Lin K, Do KG, Ong P, et al. Perfusion CT improves diagnostic accuracy for hyperacute ischemic stroke in the 3-hour window: study of 100 patients with diffusion MRI confirmation. *Cerebrovasc Dis*. 2009;28(2):82-79.
2. Das T, Settecasse F, Boulous M, et al. Multimodal CT provides improved performance for lacunar infarct detection. *AJNR Am J Neuroradiol*. 2015;36(6):1069-1075.
3. Simonsen CZ, Madsen MH, Schmitz ML, Mikkelsen IK, Fisher M, Andersen G. Sensitivity of diffusion- and perfusion-weighted imaging for diagnosing acute ischemic stroke is 97.5%. *Stroke*. 2015;46(1):98-101.
4. Fatahi N, Krupic F, Hellstrom M. Quality of radiologists’ communication with other clinicians—as experienced by radiologists. *Patient Educ Couns*. 2015;98(6):722-727.
5. Obara P, Sevenster M, Travis A, Qian Y, Westin C, Chang PJ. Evaluating the referring physician’s clinical history and indication as a means for communicating chronic conditions that are pertinent at the point of radiologic interpretation. *J Digit Imaging*. 2015;28(3):272-282.
6. Pack JR, Yuh WT, Sonnad JR, et al. Request form history, clinical indication, and yield of brain magnetic resonance studies. *J Magn Reson Imaging*. 2004;20(2):228-232.
7. Gupta A, Gialdini G, Lerario MP, et al. Magnetic resonance angiography detection of abnormal carotid artery plaque in patients with cryptogenic stroke. *J Am Heart Assoc*. 2015;4(6):e002012.
8. Wardlaw JM, Dorman PJ, Lewis SC, Sandercock PA. Can stroke physicians and neuroradiologists identify signs of early cerebral infarction on CT? *J Neurol Neurosurg Psychiatry*. 1999;67(5):651-653.