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Comparative Sensitivity of Computed Tomography vs. Magnetic Resonance Imaging for Detecting Acute Posterior Fossa Infarct

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Abstract

Background—Posterior fossa strokes, particularly those related to basilar occlusion, pose a high risk for progression and poor neurological outcomes. The clinical history and examination are often not adequately sensitive or specific for detection.

Study Objectives—Since this population stands to benefit from acute interventions such as intravenous and intra-arterial tissue plasminogen activator (tPA), mechanical thrombectomy, and intensive monitoring for neurologic deterioration, this study examined the sensitivity of non-contrast head computed tomography (NCCT) for diagnosing posterior fossa strokes in the emergency department.

Methods—This study analyzed a prospectively collected database of acute ischemic stroke patients who underwent head NCCT within 30 hours of symptom onset and who were subsequently found to have a posterior fossa infarct on brain magnetic resonance imaging (MRI) performed within 6 hours of the NCCT.

Results—There were 67 patients identified who had restricted diffusion on MRI in the posterior fossa. The NIHSS scores ranged from 0 to 36, median 3. Only 28 patients had evidence of infarction on the initial NCCT scan. The timing of NCCT scans ranged from 1.2 to 28.9 hours after symptom onset. The sensitivity of NCCT was 41.8% (95% CI 30.1 – 54.4). The longest period of time between symptom onset and a negative NCCT with a subsequent positive diffusion-weighted imaging (DWI) MRI was 26.7 hours.

Conclusions—Head NCCT imaging is frequently insensitive for detecting posterior fossa infarction. Temporal evolution of strokes in this distribution, coupled with beam hardening artifact, may contribute to this limitation. When a posterior fossa stroke is suspected and the NCCT is non-diagnostic, MRI is the preferred imaging modality to exclude posterior fossa infarction.

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Keywords

Computed Tomography Scanners; X-Ray; Cranial Fossa; Posterior; Stroke; Sensitivity; Magnetic Resonance Imaging

INTRODUCTION

The timely diagnosis of a posterior fossa stroke in the emergency department (ED) can be challenging. Brainstem and cerebellar ischemic syndromes present with quite varied patterns of nonspecific signs and symptoms, including dizziness, diplopia, dysarthria, and ataxia (1–5). Often, the clinical history and examination are not adequately sensitive or specific for detection of infratentorial ischemia (6, 7). The National Institutes of Health Stroke Scale (NIHSS) is recognized to be better suited for the diagnosis of anterior circulation strokes compared with the posterior circulation (8, 9). Ensuring accuracy of diagnosis for posterior fossa strokes is crucial, as infarction in this territory is associated with a higher risk of progression and dire neurological outcomes, especially those related to basilar occlusion (10–17).

Neuroimaging, in conjunction with a careful history and physical examination, plays a key role in the ED workup of potential posterior fossa ischemia. Non-contrast computed tomography (NCCT) is currently indispensable as a means for rapidly detecting intracranial hemorrhage or mass lesions, both of which are contraindications for the administration of tissue plasminogen activator (tPA) and which may be life-threatening conditions in and of themselves. Given the widespread availability of NCCT and the time-sensitive nature of tPA administration, NCCT is an appropriate first test that patients with symptoms of posterior fossa stroke should undergo.

However, should a patient's initial NCCT be interpreted as normal, an emergency physician must then decide whether rapid magnetic resonance imaging (MRI) is warranted to ensure that a posterior fossa stroke is not missed. It is well established that MRI with diffusion-weighted imaging (DWI) is more sensitive than non-contrast computed tomography (NCCT) scan for the diagnosis of ischemic stroke in general (i.e., taking all intracranial vascular distributions as a whole) (18–19). This fact is particularly well-recognized for patients who present to the ED within 6 hours of symptom onset (i.e., the hyperacute phase) (18, 20–22). However, as MRI generally is not as readily available in most EDs as NCCT, the decision to obtain an MRI rapidly after a negative NCCT often can be challenging to make from a practical and logistical perspective, especially when patients' descriptions of their symptoms (e.g., dizziness, imbalance, difficulty with vision) are vague and nonspecific.

We would like to highlight a widely accepted theory that NCCT is particularly poor at detecting strokes in the posterior fossa, compared with its ability to diagnose acute supratentorial ischemia. Indeed, the sensitivity of NCCT for detecting acute strokes in the anterior circulation has been investigated and has approached 75% in some reports (23). However, despite the fact that many believe that posterior fossa strokes in particular are not well-visualized on NCCT, this topic has not been well studied. Strokes that occur in the posterior fossa may not be appreciated on the initial NCCT for several reasons, including the presence of beam hardening artifact due to the amount of bone locally, as well as the relative time delay for strokes to appear on neuroimaging in the white matter relative to the grey matter. The consequences of missing the diagnosis of a stroke in the posterior circulation (even after the tPA window has closed) can be great, including herniation from a large cerebellar stroke, or progressive brainstem infarction from a thrombosed vertebrobasilar system.

Prior studies that have approached the issue have compared NCCT and MRI for cerebellar strokes only, as well as for strokes in the posterior circulation only as opposed to within the posterior fossa specifically (24, 25). Other studies of the sensitivity of NCCT for detecting infratentorial ischemia have used a mix of MRI and follow-up NCCT scans as a gold-standard, as opposed to relying on DWI MRI for the determination (26).

In this study, we examined the sensitivity of NCCT for detecting stroke in patients who presented to an ED with symptoms of infratentorial ischemia, underwent NCCT within 30 hours of symptoms onset, and were subsequently found to have a definite stroke on DWI MRI. Our aim is simply to draw more attention to the potential need for advanced neuroimaging when an acute posterior fossa stroke is in question.

MATERIALS AND METHODS

We explored an existing prospective database of 836 patients who presented to an ED with stroke symptoms between 2003–2007 (27–29). Of note, the database included information from our institutions as well as from the University of California, San Francisco. This study was conducted with approval from our institutions' Institutional Review Board committees and in accord with the Helsinki Declaration of 1975.

Patients in the database were categorized according to the Oxfordshire Community Stroke Project Clinical Stroke Syndrome classification system, i.e., POCI (posterior circulation infarct), TACI (total anterior circulation infarct), PACI (partial anterior circulation infarct), and anterior and posterior lacunar infarcts (30). We reviewed the records for those patients who were classified as either POCI, posterior lacunar infarct, or not recorded, and who underwent NCCT within 30 hours of symptom onset. Examples of clinical symptoms and signs that correlate with a classification of POCI or posterior lacunar infarct include dizziness, ataxia, cranial nerve deficit, disconjugate gaze or diplopia, pure motor syndrome, and pure sensory loss. We evaluated the subset of these patients who had an MRI performed within 6 hours of the NCCT. In addition to classifying each MRI result according to the official neuroradiologist's interpretation, all scans were reviewed independently by a staff stroke neurologist blinded to the radiology reports; CT first, then MRI [DG and KF].

NIHSS scores were recorded at the time of presentation. For those missing NIHSS scores performed at that time, we calculated NIHSS scores retrospectively using medical records written by consulting neurology residents.

Means and standard deviations or medians were used to describe patient characteristics. The independent samples t-test was used to compare means between men and women. Non-parametric data were compared using the Mann-Whitney test. Categorical variables were compared with the Chi-square or the Fisher exact test.

We calculated the sensitivity of NCCT for detecting infratentorial ischemia by using brainstem and cerebellar strokes detected on DWI MRI as the gold standard. Confidence intervals were calculated using the standard methods for proportions. We selected the DWI sequence on MRI as the gold standard because in large studies DWI has been shown to be more sensitive than other sequences (e.g., T2 and FLAIR) for detecting acute infarction (9).

RESULTS

Sixty-seven patients of the total 836 patients fulfilled criteria for inclusion. Of these, 39 had NCCT scans performed within 30 hours of symptom onset that did not show evidence of posterior fossa infarction. Table 1 shows the basic characteristics of the two groups (i.e., negative versus positive NCCT). The mean age in each group was similar (63.5 ± 4.7 vs. 65

± 4.8 years, respectively), as was the range of ages (34–86 vs. 35–86 years, respectively) and the percentage female (33% vs. 32.1%, respectively).

The severity of NIHSS score on presentation did not correlate with the detection of a posterior fossa infarct on a patient's NCCT. The median NIHSS score for both groups was 3.

The mean number of hours between onset of symptoms and NCCT was greater in the positive NCCT group (12.1 ± 2.4) versus the negative NCCT group (8.6 ± 2.1) ($p = 0.03$). The median number of hours between onset of symptoms and NCCT was longer in the positive NCCT as well (9.5 vs. 6, respectively). Of note, the earliest positive NCCT performed was 2.8 hours after symptom onset; there were a total of five patients who had NCCT performed earlier than 2.8 hours after symptom onset in this study, all of whom had NCCTs negative for ischemia. Conversely, the latest head NCCT done in our study that was read as negative with a subsequent positive DWI MRI was at 26.7 hours. The number of hours between head NCCT and brain DWI MRI was roughly equal between both the negative (2.0 ± 0.42 , range 0.4–5.6) and positive (2.2 ± 0.6 , range 0.6–5.3) NCCT groups.

Table 2 shows the sensitivity data. Using DWI MRI performed within 6 hours of head NCCT as the gold standard, we calculated the sensitivity of head NCCT for detecting a posterior fossa infarction to be 41.8% (95% CI 30.1–54.4). For those patients with DWI MRIs with isolated cerebellar infarction, NCCT was more sensitive (54.8%, 95% CI 36.9–72.7) in detecting infarction. NCCT was less sensitive for brainstem infarction (sensitivity 33.3%, 95% CI 16.5–54.0).

Of note, all NCCTs that had evidence of posterior fossa infarction were recorded as being “positive.” For some patients, although head NCCT detected evidence of ischemia before DWI MRI was performed, DWI MRI detected multiple strokes or more extensive strokes outside of the region that was noted to be affected on NCCT. Ten of the 28 patients whose NCCT scans were positive for infratentorial ischemia had additional strokes on DWI MRI that were not appreciated by attending neuroradiologists on the interpretation of the NCCT.

DISCUSSION

While it is known that head NCCT is insensitive for detecting hyperacute stroke (i.e., presenting within 6 hours of symptom onset) when infarcts in all intracranial vascular distributions are analyzed as a whole, the common belief that NCCT is particularly insensitive for detecting infarct in the posterior fossa has not been previously studied in depth. Our results confirm the common perception that NCCT is insensitive (sensitivity 41.8%, 95% CI 30.1–54.4) for detecting acute strokes in the posterior fossa. This suggests that urgent brain DWI MRI is indicated when a stroke is suspected in the posterior fossa, even outside the hyperacute time window. This point is highlighted by the fact that the latest negative NCCT in our study with a subsequent positive DWI MRI was at 26.7 hours, a time when one might expect the stroke to have been visible on NCCT.

Age and sex did not correlate with detection of posterior fossa stroke. Even more notably, the median NIHSS scores on presentation for the NCCT positive and NCCT negative groups were low and equivalent. The low median score is consistent with previous observations that the NIHSS is weighted towards anterior circulation strokes (8, 9).

It is not surprising that the mean time from symptoms to NCCT was longer in the positive NCCT group (12.1 hours) versus the negative NCCT group (8.6 hours) ($p = 0.03$). However, we note that the median number of hours between symptom onset and head NCCT was 6 hours for the negative NCCT group; therefore, half (20) of the patients whose posterior fossa

strokes were not detected on head NCCT had their NCCTs performed after the hyperacute phase, during a period in which emergency physicians might be falsely reassured that a negative NCCT was adequate for “ruling out” infarction. Of these 20 patients, 9 (45%) still went on to require admission to the neuroscience intensive care unit (ICU) for complications of infratentorial ischemia.

We recognize that the longer the time from NCCT to MRI, the longer an infarct has to evolve; thus, the likelihood of an MRI detecting infarction increases. We selected 6 hours as the maximum time between NCCT and MRI for our study so that an adequate number of patients would be included. Given that the time from NCCT to MRI were very similar in each of our groups (2.0 hours in the NCCT negative group and 2.2 hours in the NCCT positive group), we believe that a delay between studies did not play a large factor in our sensitivity calculations. While DWI MRI is thought to be very sensitive for detecting infarcts in general, we also note that false-negative DWI MRI studies of posterior fossa stroke are quite possible as well (31–33).

It is interesting, but not unexpected, that there was a difference in the sensitivity of NCCT for detecting strokes in the cerebellum (54.8%) versus brainstem (33.3%). Beam hardening artifact created by bony structures obscures hypodensities in the posterior fossa (26). The brainstem is particularly susceptible to this type of artifact and thus is a particularly difficult location to image with NCCT.

Figure 1 depicts an example of a NCCT scan read by an attending neuroradiologist as possible right hemipons ischemia; subsequent DWI MRI performed within 6 hours showed bilateral pontine infarction, as well as involvement of the left cerebellum (and the bilateral posterior cerebral artery territories as well). In this example, DWI MRI was more sensitive for detecting the full extent of stroke in the posterior fossa, with the detection having implications for prognosis, even though the NCCT was technically “positive” for stroke.

Limitations

We recognize two limitations of this study that arise because of its retrospective design. First, each NCCT scan was primarily classified as positive or negative according to the attending neuroradiologist’s official interpretation at the time it was performed. Our neuroradiologists often have access to a patient’s subsequent DWI MRI result by the time an official report for the initial NCCT is documented; that is, the neuroradiologists are not always blinded to DWI MRI results when interpreting NCCT scans. Because of this potential source of bias, all scans were reviewed independently by a staff stroke neurologist blinded to the radiology reports; CT first, then MRI [DG and KF]. The interpretations from these blinded reviews did not differ from those of neuroradiology at the time of presentation. Second, documented formal NIHSS scores at the time of presentation to the ED were not available for all of our patients. While these scores were readily reconstructed based on available neurology resident consult notes in the medical records, it is possible that our retrospective calculations may have introduced a potential source of bias as well.

While this study used DWI MRI performed within 6 hours of NCCT as a reference standard for diagnosing stroke, we acknowledge again that MRI itself can be imperfect in detecting infarcts, especially in acute situations (31–33). One single center study, using final clinical diagnosis at time of discharge (as determined by a stroke neurologist) as a gold standard, estimated the sensitivity of MRI to be 83% for the detection of cerebral ischemia in patients referred to the ED for acute stroke evaluation (34). False negative rates of MRI with respect to diagnosing brainstem infarcts on presentation have been estimated to be as high as 12% when follow-up imaging at 3 days has been used as a reference (35).

CONCLUSION

The data from this study suggest that head NCCT scans are often insensitive for detecting hyperacute and acute posterior fossa infarcts, while DWI MRI is the preferred imaging modality to exclude infarction when stroke is suspected in the posterior fossa. DWI MRI should be obtained as quickly as possible after NCCT when possible infratentorial ischemia presents in the ED.

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Figure 1.

Additional strokes detected by DWI MRI for a patient whose head NCCT was interpreted as positive for posterior fossa infarct. The top and bottom left panels show two slices from the head NCCT scan of the patient, who presented initially with symptoms of dizziness and confusion. The NCCT scan was interpreted by an attending neuroradiologist as having a possible infarct in the right hemipons. The top and bottom right panels show two corresponding sections from the DWI sequence of the same patient's brain MRI. There is clear involvement of both sides of the pons, as well as infarction in the cerebellum. This particular patient also had extensive involvement of territories supplied by both the right and left posterior cerebral arteries. The patient eventually became comatose with extensor posturing in the ED.

Table 1

Comparison of groups of patients with NCCT performed within 30 hours of symptom onset interpreted as negative versus positive for posterior fossa stroke.

Group characteristic	Negative NCCT* (n = 39)	Positive NCCT* (n = 28)	p value
Average age (years)	63.5 ± 4.7	65 ± 4.8	0.68
Age range (years)	34–86	35–86	
Number of females (%)	13 (33.0%)	9 (32.1%)	0.91
Median NIHSS score	3	3	
NIHSS range	0–36	0–33	
Average number of hours between onset of symptoms and NCCT	8.6 ± 2.1	12.1 ± 2.4	0.03
Median number of hours between onset of symptoms and NCCT	6	9.5	
Range of number of hours between onset of symptoms and NCCT	1.2–26.7	2.8–28.9	
Average number of hours between NCCT and DWI MRI	2.2 ± 0.4	2.0 ± 0.6	0.59
Range of number of hours between head NCCT and brain DWI MRI	0.6–5.3	0.4–5.6	

Note: blank fields in the “p value” column are for group characteristics for which p value was not necessary because they represent median or range values as opposed to calculation of average values.

Table 2

Sensitivity of NCCT for detecting posterior fossa stroke with DWI MRI as gold standard based on location

DWI MRI infarct location	Total number	Positive NCCT	Negative NCCT	Sensitivity of NCCT
Posterior fossa	67	28	39	41.8% (95% CI 30.1–54.4)
Cerebellum only	31	17	14	54.8% (95% CI 36.0–72.7)
Brainstem only	27	9	18	33.3% (95% CI 16.6–54.0)