Original Article

Diagnostic Accuracy of Cerebral CT Perfusion in Acute Ischemic Stroke

Asim Shaukat, Nosheen Ahmad, Aamir Shaukat

ABSTRACT

Objectives: To determine the diagnostic accuracy of CT Perfusion brain over Non contrast CT for patients presenting with stroke symptoms in the 12-hour window. **Design:** Cross-sectional study. **Setting:** Department of Radiology Allied Hospital, Faisalabad. **Period:** From July 2014 to December 2014 **Patients and Method:** We studied 60 patients of 45-70 years of age of both genders (mean 55.13±5.54) (42 (70%) males and 18 (30%) females) with initial clinical symptoms suggestive of acute ischemic stroke. All patients had an initial non-contrast head CT, CT Perfusion (CTP), and follow up brain diffusion MRI at 7th day. The obtained CT perfusion images were used for image processing. Cerebral blood volume, cerebral blood flow and mean transit time were visually estimated and manually traced and the results were compared to diffusion MRI lesions. **Results:** Follow-up DWI for confirmation of acute infarct revealed true recent infarcts in 36 patients. NCCT revealed 23 (38.3%) true acute infarcts, 10 (16.7%) false positive infarcts, 14 (23.3%) true negative and 13 (21.7%) false negative yielding diagnostic accuracy of 61.66%. CTP revealed 30 (50%) true positive acute infarcts with two (3.3%) false positive, 22 (36.7%) true negative and 6 (10%) false negative yielding sensitivity of 83.3%, specificity of 91.67%, PPV=93.75%, NPV=78.57% and diagnostic accuracy of 86.7%. CTP was significantly more sensitive (83.3 vs. 64.2%, $p < 0.0001$) and accurate (86.7 vs. 61.7%, $p < 0.0001$) and had a better negative predictive value (78.57 vs. 52.2%) than NCCT. **Conclusions:** Dynamic PCT provides more sensitivity and accuracy than no enhanced CT in detecting acute strokes in the 12-hour window.

Keywords: Acute ischemic stroke, Diffusion MRI, CT perfusion imaging

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INTRODUCTION

Early detection of acute stroke helps to reduce the mortality and morbidity by rapid treatment decision.[1]

Most primary stroke centers use brain non-contrast computed tomography (NCCT) as the initial imaging modality for the evaluation of acute stroke patients due to its 24 hours a day availability. CTP is an imaging modality used in acute stroke settings and is designed to determine the severity and potential reversibility of neuronal damage and predict which brain tissue can be salvaged with reperfusion.[2]

CBF and CBV in combination can differentiate between the infarction core and ischemic penumbra more accurately than CBF or CBV alone, with a sensitivity, specificity, and accuracy higher than 97%.[3]

Infarction core shows significant reduction of CBF accompanied by a matched decrease of CBV with increased MTT. In ischemic penumbra, tissue at risk, the CBV is maintained despite a reduction of CBF which can be salvaged with early treatment.

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Computed tomography angiography (CTA) and CT perfusion (CTP) of the brain are two imaging procedures which are reported to be of significant importance in the evaluation of acute ischemic stroke apart from non-contrast CT for emergency situation.[4,5,6]

With CT and MR-diffusion we can get a good impression of the area that is infarcted, but we cannot preclude a large ischemic penumbra (tissue at risk).With perfusion studies we monitor the first pass of an iodinated contrast agent bolus through the cerebral vasculature. So Perfusion will tell us which area is at risk of infarct.

The CT- CBV hypovolemic lesions that reflect the infarct core in the acute ischemic phase of stroke are similar to diffusion weighted imaging (DWI) lesions on brain MRI.[7] Similarly, the CT - MTT is thought to be a surrogate marker of the ischemic penumbra. The mismatch between CBV and MTT is the target for cerebrovascular reperfusion therapies.[7]

The aim of the study was to assess the use of cerebral CTP imaging for the diagnosis of areas of decreased perfusion, which is at risk of infarct, detection of infarct and the estimation the ischemic penumbra. Patients are usually diagnosed with CT brain which detects infarction at irreversible stage. CTP detects brain tissue at risk at an earlier stage before infarction occurs. Brain lesion at this stage is potentially reversible by revascularization therapy which help in better patient survival, secondary stroke prevention and rehabilitation and to compare the accuracy of CTP with native CT in the detection of early stroke.

MATERIALS & METHODS

This was a Cross-sectional study undertaken in Department of Radiology, Allied Hospital Faisalabad. Study was carried out over a period of six months from July 2014 to December 2014 and the patients were collected from emergency department of Allied Hospital Faisalabad. All the patients who ranged from 45-70 years of age(mean age 55.13±5.54) of both genders showing the symptoms of ischemic stroke of no more than 12 hours duration were recruited for non-enhanced CT and CTP and the patients who underwent follow-up diffusion MR imaging to confirm or rule out ischemic hemispheric stroke. Reasons for not performing CTP were the patients who had known kidney disease with deranged renal function test, established infarct or hemorrhage on NCCT, the patients who did not remain on follow up with diffusion MRI and patient motion/instability.

All selected patients were examined by 128 slice CT scanner that included a NCCT, CTP and a follow up brain diffusion MRI was performed at 7th day.

The CT stroke protocol included conventional non contrast CT of 3- or 4-mm-thick basal sections and 5- or 8-mm-thick supratentorial sections, the acquisition parameters were 80 kVp and 120 mAs and dynamic CT perfusion was performed with 4 cm plane coverage. CTP image was acquired as a cine series 45 seconds, beginning 5 seconds after 40 to 50 mL of non-ionic iodine contrast injection through a peripheral intravenous catheter.

Commercially available software (CT perfusion; GE optima 660) was used to calculate parametric maps of CBV and MTT by using baseline CT perfusion data. Arterial input and venous output time-attenuation curves were created, with regions of interest manually drawn by the experienced CT technologist performing the study, mostly in the anterior cerebral artery ipsilateral to the side of the infarct and the superior sagittal sinus, respectively.

Follow up MRI was performed on all patients at 7^{th} day with a 1.5 Tesla Philips MRI scanner. MRI protocol included axial isotropic DWI spin echo sequences and ADC images of 5mm slice thickness, TR (time to repeat) of 2824msec, and TE (time to echo) of 89msec at b value of 1000mm2/sec, MR images were post-processed with the use of extended MR Workspace R1.0 (view forum R 6.1 V5) software and a workstation. NCCT were assessed by a radiologist for early ischemic changes. CTP was assessed for time to peak (TTP) and cerebral blood flow (CBF) and cerebral blood volume (CBV).Final DWI lesion was considered as a surrogate of final infarct.

Data was analyzed on SPSS version 17. In each patient, follow-up MR results were considered the standard criteria for the calculation of the sensitivity, specificity, PPV, NPV and accuracy for the detection of stroke for both non enhanced CT and for dynamic PCT.

RESULTS

The statistical data obtained were 23 true-positive, 10 false-positive, 14 true-negative, 13 false negative cases for non-contrast CT (Table 1) and were 30 true-positive, 2 false-positive, 22 true-negative, 6 false negative results for PCT (Table 2). Comparison of sensitivity, specificity, PPV, NPV and accuracy in detecting stroke among non-enhanced CT and PCT and the accuracy was significantly greater with PCT than with no enhanced CT (Table 3).

Table 1: Non enhanced CT-pathology correlation

	Frequency	Percentage (%)
True positive	23	38.3
False positive	10	16.7
True negative	14	23.3
False negative	13	21.7
Total	60	100

Table 2: Dynamic PCT-pathology correlation

	Frequency	Percentage (%)
True positive	30	50
False positive	2	3.3
True negative	22	36.7
False negative	6	10
Total	60	100

Table 3: Comparison of sensitivity, specificity, accuracy in detecting stroke among non-enhanced CT and PCT

	Nonenhanced CT	PCT
Sensitivity (%)	64	83.3
Specificity (%)	58.3	91.67
PPV (%)	70	93.75
NPV (%)	52	78.57
Diagnostic accuracy (%)	61.66	86.67

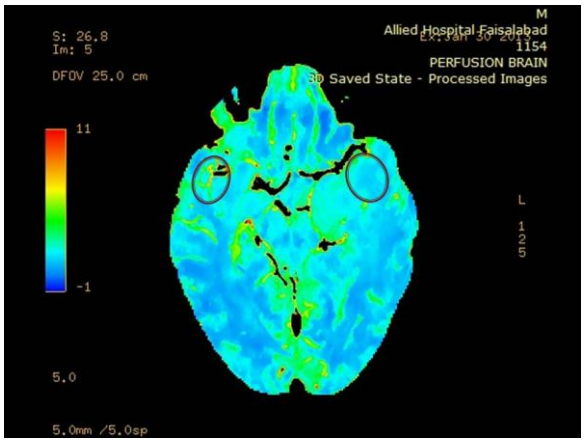

Figure 1: Decreased CBF and CBV on left side as compared to the right side – Ischemic area

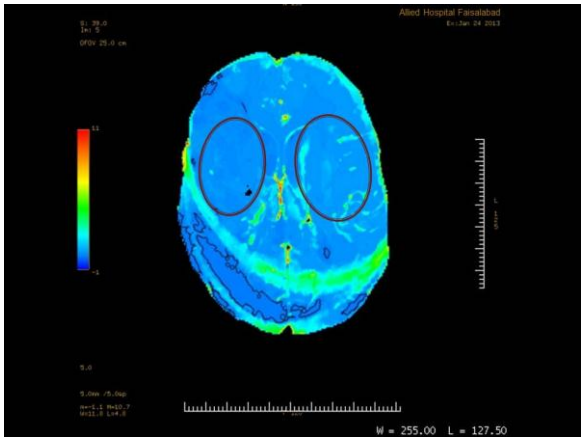

Figure 2: Reduced CBV and CBF on right as compared to healthy contralateral left side – ischemic area

DISCUSSION

The modalities used for evaluation of acute stroke are non-contrast CT scan brain, CTA, CTP, diffusion MRI and MR perfusion. However plain CT scanning of all patients with suspected stroke is the most cost-effective strategy.

CTA procedure has high diagnostic accuracy for detection of the site of occlusion and tells about its severity while CTP procedure provides high diagnostic accuracy to detect ischemic lesion of brain tissue and distinguish between infarcted and ischemic penumbra. In fact, the ability to precisely differentiate the ischemia from infarction definitely helps in the decision making for performing thrombolytic therapy.[4]

DWI offers high sensitivity and specificity for acute stroke diagnosis and is the best surrogate of final brain ischemia.[8] However the sensitivity of DWI decreases with small stroke lesions[8-10] and in patients with early reperfusion, showing false negative results.[11]

The sensitivity of non-enhanced CT to detect acute stroke ranges between 45%[12] and 55%,[13] Kloska et al found sensitivity for CTP of 76%,[13] whereas Koenig et al reported 89%.[14] Mayer et al found a sensitivity of 93% with a follow-up study.[15]

Sabarudin A et al found the sensitivity, specificity, PPV, NPV and accuracy for CTP is 69.9%, 87.4, 76.4%, 78.2% and 89.8% respectively.[16]

PCT maps were significantly more accurate in detecting stroke when compared with non-enhanced CT (75.7–86.0% vs. 66.2%).[17]

The sensitivity of Diffusion weighted imaging (DWI) in showing signs of recent brain ischemic is 52% patients with a normal CT scan.[18]

In our study the diagnostic accuracy was significantly higher than non-enhanced CT brain (86.67% vs. 61.66%), in detecting acute infarct and the results are comparable with the results of Wintermark M et al[17] and Sabarudin A et al[16]

Of the 6 infarcts missed on dynamic PCT, 3 (50%), were related to lack of anatomical coverage. In two (33.3%) cases, hyperemia (high rCBF and rCBV, low MTT and TTP) rather than oligemia at the site of infarct led to false-negative results in which follow-up diffusion imaging showed infarct. In one (16.7%), case, follow-up diffusion MRI demonstrated acute lacunar infarct that was too small to be detected on PCT maps.

False-positive results with PCT occurred in two cases of TIA, in which TTP and MTT maps suggested ischemia that were negative for stroke on follow-up MRI examination.

The limitation of CT-perfusion in our study was the limited anatomical coverage. This may compromise the diagnostic sensitivity of CTP, with special concern of decreased sensitivity for small cortical, or lacunar infarcts. Furthermore, non-availability of expertise and interpretation of CTP studies could potentially delay the time of decision making and treatment in acute ischemic stroke patients leading to worse patient outcomes.

CONCLUSION

Computed tomography perfusion provides effective tools in the diagnosis of acute ischemic stroke that helps in directing the treatment by detecting lesions within minutes instead of hours and the sensitivity and accuracy to detect acute cerebral infarction is significantly higher than plain CT.

REFERENCES

1. Grotta JC, Chiu D, Lu M, Patel S, Levine SR, Tilley BC, Brott TG, et al. Agreement and variability in the interpretation of early CT changes in stroke patients qualifying for intravenous rtPA therapy. Stroke 1999;30:1528-33.
2. Meuli RA. Imaging viable brain tissue with CT scan during acute stroke. Cerebrovasc Dis. 2004;17 Suppl 3:28-34]
3. Murphy BD, Fox AJ, Lee DH, et al. Identification of penumbra and infarct in acute ischemic stroke using computed tomography perfusion-derived blood flow and blood volume measurements. Stroke. 2006;37:1771-1777.
4. Schramm P. CT angiography and perfusion CT in acute stroke: principles and applications. Imaging Decisions MRI 2003;7:31-41.
5. Mousa AE, Elrakhawy MM, Zaher AA. Multimodal CT assessment of acute ischemic stroke. Egypt J Radiol Nuc Med 2013;44:71-81. Available online: http://www.sciencedirect.com/science/article/pii/S0378603X12001234
6. Scharf J, Brockmann MA, Daffertshofer M, Diepers M, Neumaier-Probst E, Weiss C, Paschke T, Groden C. Improvement of sensitivity and interrater reliability to detect acute stroke by dynamic perfusion computed tomography and computed tomography angiography. J Comput Assist Tomogr 2006;30:105-10.
7. Wintermark M, Flanders AE, Velthuis B, Meuli R, van Leeuwen M, Goldsher D, et al. Perfusion-CT assessment of infarct core and penumbra: receiver operating characteristic curve analysis in 130 patients suspected of

acute hemispheric stroke. Stroke; a journal of cerebral circulation.2006;37:979–85.
8. Chalela JA, Kidwell CS, Nentwich LM, Luby M, Butman JA, Demchuk AM, et al. Magnetic resonance imaging and computed tomography in emergency assessment of patients with suspected acute stroke: a prospective comparison. Lancet. 2007;369:293–8.
9. Ay H, Buonanno FS, Rordorf G, Schaefer PW, Schwamm LH, Wu O, et al. Normal diffusion-weighted MRI during stroke-like deficits. Neurology. 1999;52:1784–92.
10. Sylaja PN, Coutts SB, Krol A, Hill MD, Demchuk AM. When to expect negative diffusion-weighted images in stroke and transient ischemic attack. Stroke; a journal of cerebral circulation. 2008;39:1898–900.
11. An H, Ford AL, Vo K, Powers WJ, Lee JM, Lin W. Signal evolution and infarction risk for apparent diffusion coefficient lesions in acute ischemic stroke are both time- and perfusion-dependent. Stroke; a journal of cerebral circulation. 2011;42:1276–81.
12. Gonzalez RG, Schaefer PW, Buonanno FS, et al. Diffusion-weighted MR imaging: diagnostic accuracy in patients imaged within 6 hours of stroke symptom onset. Radiology. 1999;210:155–162.
13. Kloska SP, Nabavi DG, Gaus C, Nam EM, Klotz E, Ringelstein EB, Heindel W. Acute stroke assessment with CT: do we need multimodal evaluation? Radiology 2004;233:79-86.
14. Koenig M, Klotz E, Luka B, et al. Perfusion CT of the brain: diagnostic approach for early detection of ischemic stroke. Radiology. 1998;209:85–93.
15. Mayer TE, Hamann GF, Baranczyk J, et al. Dynamic CT perfusion imaging of acute stroke. AJNR Am J Neuroradiol. 2000;21:1441– 1449.
16. Sabarudin A, Subramaniam C , Sun Z. Cerebral CT angiography and CT perfusion in acute stroke detection: a systematic review of diagnostic value. Quant Imaging Med Surg 2014;4(4):282-290.
17. Wintermark M, Fischbein NJ, Smith WS, et al. Accuracy of dynamic perfusion CT with deconvolution in detecting acute hemispheric stroke. AJNR Am J Neuroradiol. 2005;26:194-112.
18. Totaro P, Toni D, Durastanti L, Bozzao L, Gualdi GF, Raz E, et al. Diffusion-weighted MRI in patients with non-diagnostic CT in the post-acute phase of cerebral ischemia. Eur Neurol 2010;63:94-100.

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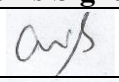
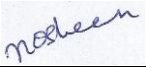
Dr. Asim Shaukat	1st Author	
Dr. Nosheen Ahmad	2nd Author	
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