# Non-contrast Computed Tomography in Acute Ischaemic Stroke: A Pictorial Review

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**SUMMARY**

**Non-contrast computed tomography (NCCT) remains a widely used imaging technique and plays an important role in the evaluation of patients with acute ischaemic stroke. However, the task of identifying the signs of acute ischaemia and quantifying areas of brain involvement on NCCT scan is not easy due to its subtle findings. The reliability of early ischemic sign detection can be improved with experience, clinical history and the use of stroke window width and level on viewing the images. The Alberta Stroke Program Early CT Score (ASPECTS) was developed to overcome the difficulty of volume estimation in patients eligible for thrombolysis. It is a systematic, robust and practical method that can standardized the detection and reporting of the extent of acute ischaemic stroke. This article serves as an educational material that illustrates those findings which are important for all clinicians involved in acute stroke care.**

**KEY WORDS:**

*Acute stroke, computed tomography, thrombolysis, cerebral infarction, cerebral ischaemia*

## INTRODUCTION

Stroke is a global health problem and is one of the leading causes of mortality and morbidity in adult[1]. In Malaysia, it was the top two leading causes of death reported by Malaysian National Burden of Disease Study[2]. There is no comprehensive database on the incidence or prevalence of stroke in Malaysia[3,4].

The introduction of brain imaging with computed tomography revolutionized the treatment of patients with acute stroke.Majority of acute stroke patients (80%) are due to ischaemic stroke[3]. Visual differentiation of haemorrhagic stroke from ischaemic stroke has made thrombolytic therapy became feasible. In developed countries, thrombolytic therapy is available in most hospital and the aim is to achieve early revascularization in eligible patients to improve clinical and functional outcomes[5]. In Malaysia, steps have been taken in the right direction to establish this service in all Ministry of Health hospitals[4,6].

Introduction of thrombolysis therapy in acute ischaemic stroke management has proven to be beneficial to patient. However, due to the associated risk of bleeding, patients must be carefully screened. Non-contrast computed tomography (NCCT) remains the most widely used imaging due to its wide availability, fast acquisition of images and being easily performed. The goal of early CT scan is used to differentiate ischemic stroke from cerebral haemorrhage and to identify stroke mimics. Patients with infarct of more than one third of middle cerebral artery (MCA) territory and those with intracranial haemorrhage should not be given thrombolytic therapy[3,7].

Physicians managing acute stroke are expected to recognize early signs of cerebral infarction on NCCT. However, signs of early infarction on CT are subtle. The mean sensitivity and specificity of observer reliability in detecting these early radiological signs were reported as 55% (range 20-87%) and 87% (range 56-100%) respectively[8,9]. Furthermore, there is considerable lack of agreement in recognizing and quantifying such early CT changes[8]. To improve the detection rate, clarification and simplification of signs to be look for and focused training of doctors on recognizing these signs are important[10,11]. Although interpretation by the neuroradiologist may be optimal, an appropriately trained neurologist or general radiologist is able to read the CT brain with a similar degree of accuracy [12].

## MATERIALS AND METHODS

We retrospectively traced NCCT images of patient presented with acute ischaemic stroke for thrombolysis in a two-year period from 2010 to 2011. A total of 44 cases were reviewed. Final diagnosis of stroke were made with clinical correlation, subsequent imaging findings such as a repeat NCCT, CT angiography and CT perfusion.

For all patients, the CT scans were acquired using a multislice CT scanner (Siemens 64-Sensational). Images obtained in axial plane, contiguous 5-mm sections from base to vertex. Imaging parameters were the following: 120kVp, 320 mA, FOV of 195 mm, 1s/rotation and table speed of 15mm/rotation.

### CT features in Acute Ischaemic Stroke

Early radiological signs seen in acute stroke relate to sequalae of cellular hypoperfusion and cytotoxic oedema[9]. The manifestation of this compartmental water shift is focal mass effect, cortical/gyral swelling and sulcal effacement[13]. The signs of acute ischaemic stroke on NCCT are loss of basal ganglia (lentiform nucleus) outline, loss of insular ribbon,

*This article was accepted:*

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hemispherical effacement of the sulci, hypodensity or hypoattenuation area and hyperdense vessel (MCA) sign. Delineation of these changes may be improved by using variable window width and centre level settings to accentuate the contrast between the normal and oedematous tissue (Figure 1)[14].

**Loss of basal ganglia (lentiform nucleus) outline**
This is one of the earliest sign that can be seen in acute stroke patient, in some, as soon as one hour after clinical onset. This sign is defined as decreased attenuation involving the basal ganglia (lentiform nucleus) and inducing loss of the precise delineation of this area[9] (Figure 2). It was found in 73-92% of cases when scan was obtained within 6 hours of stroke onset[15,16].

The lentiform nucleus is fed by the lenticulostriate arteries from M1 segment of MCA without collateral flow from cortical anastomoses, thus this sign is seen in patient with M1 or ICA infarction. However, if the embolic occlusions had been in more distal part of the MCA or in other arteries, CT may not show abnormality in the basal ganglia at all. Presence of this sign in 16% of patients with branch occlusion resulted from variation in lenticulostriate arteries, which arise from middle cerebral artery branch in around 20% of cases[17].

**Loss of insular ribbon**
Loss of insular ribbon sign is defined as decreased precision in delineation of gray-white matter interface at lateral margin of insula[9] (Figure 3). It is a very common early sign of infarction of the MCA (or internal carotid artery) territory and reported to be present in 75-100% of the cases[16].

The insular segment of the MCA and its claustral branches supplies the insular ribbon. In MCA (or internal carotid artery) infarction, with cessation of flow, the insular ribbon becomes the region most distal from the anterior and posterior cerebral collateral circulation. Consequently, the insular ribbon effectively becomes a watershed arterial zone[16].

Loss of insular ribbon sign hardly ever appeared alone and more than half of the patients with this sign also had obscuration of basal ganglia and effacement of the hemispherical sulcus. The concomitant presence of these three signs seemed to have a strong correlation with internal carotid artery occlusion and showed poor arterial recanalization after thrombolysis[17].

**Hemispherical (cortical) sulcal effacement**
This sign is defined as decreased contrast, loss of precise delineation of the gray white interface in the margins of cortical sulci corresponding to localized mass effect[9] (Figure 4). It reflects cortical ischaemia and isolated sulcal effacement was highly indicative of branch occlusion and a partial superficial infarct[17]. This sign in isolation is a good indicator for intravenous thrombolysis with 47% rate of renacalization[17].

**Focal hypoattenuation (hypodensity)**
Subtle changes of cerebral ischemia include hypoattenuation of the x-ray signal, due to increase tissue water content by cytotoxic oedema (Figure 5). Slight hypoattenuation of gray matter may manifest as loss of the distinction between gray and white matter. More marked hypoattenuation may appear as tissue hypodensity[8]. This is observed on CT scan as increased radiolucency of brain structures relative to other parts of the same structures or to contralateral counterpart[9].

This sign is found in 20% to 60% of acute stroke cases[8,15]. The identification of this sign during early stroke is difficult and the quantification of involvement whether it involved more or less than one third MCA territory is even more difficult. In comparison, physicians who are involved in providing acute stroke care, the sensitivity for recognizing hemorrhage on CT was 82% but the sensitivity of these physicians for identifying acute infarction involving more than one third MCA territory is 78%[18]. Inter-observer agreement for this sign was worst compared to other signs of early stroke with k value ranging from 0.30 to 0.58[9].

**Hyperdense MCA sign**
The hyperdense MCA sign has been reported to have high specificity and positive predictive value for thromboembolic occlusion of the MCA (Figure 6). It is associated with severe neurological deficit, extensive brain damage and poor clinical outcome. On CT, it is seen as MCA vessel with attenuation higher than that in any other visualized artery or vein[9]. Abnormal MCA above 43HU and a ratio of dense abnormal MCA to normal appearing vessel of more than 1.2 correctly identified all hyperdense MCA associated with acute ischemic stroke[19]. The incidence of this sign greatly varies and reported to be ranging from 5%-41% in patients with acute ischemis stroke[20].

However, MCA may appear hyperdense without intraluminal thrombosis in few conditions such as in patients with raised hematocrit, partial volume averaging artifact from vascular wall calcification and due to relative hypodensity of adjacent parenchymal hypodensity (Figure 7)[21,22].

MCA dot sign is hyperdensity of the distal MCA and its branches seen in the sylvian fissure (Figure 8). Some authors proposed that it is more likely to represent embolic material as larger intracranial vessel such as the main MCA are more likely to be affected by atherosclerotic changes; thus having atheromatous plaque that can influence its appearance on CT scan[23].

**Alberta Stroke Program Early CT Score (ASPECTS)**
Extent of early ischaemic changes is an important predictor for the response to thrombolysis. Thrombolysis benefits patients with a small (less than 1/3 of the MCA territory) hypoattenuation area on NCCT scan[24]. However, volume estimation with this one-third rule is difficult in routine practice. To standardized the detection and reporting of the extent of ischaemic hypodensity, the ASPECTS was developed[25]. This CT score is simple, reliable and identifies stroke patients unlikely to make an independent recovery despite thrombolytic treatment[26,27].

ASPECTS is a topographic scoring system applying a quantitative approach that does not ask physician to estimate volumes from two-dimensional images. The score divides the MCA territory into 10 regions of interest (Figure 9).

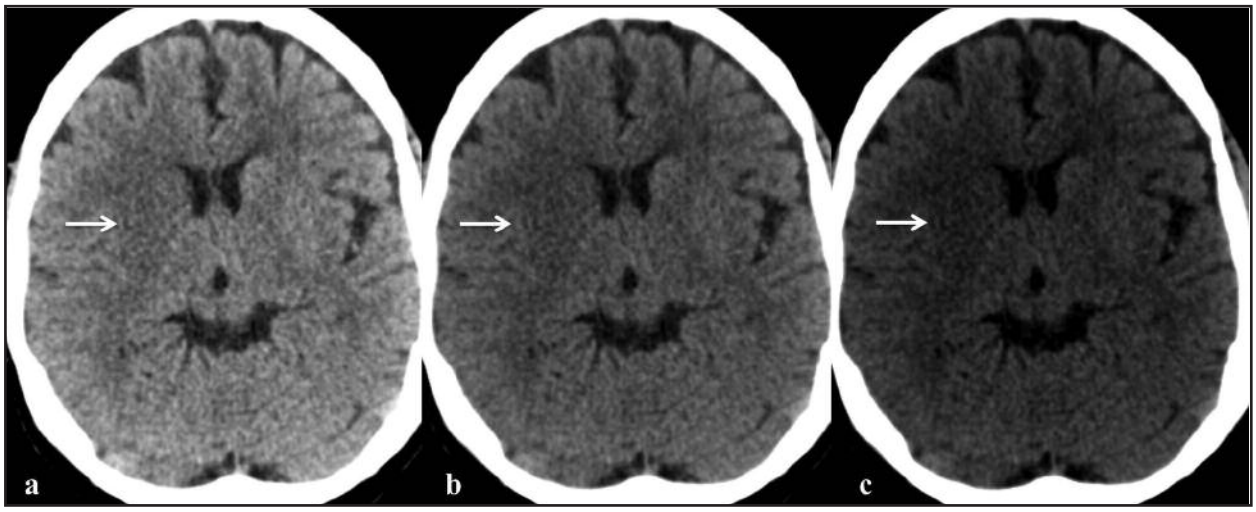


**Fig. 1:** Optimal window settings. (a) Standard window setting for soft tissue or brain is approximately 60-80HU width and 40HU level (virtual hard copy). (b, c) Use of nonstandard, variable soft copy, narrow window and level settings showed more conspicuous findings of early ischaemic changes (arrows).

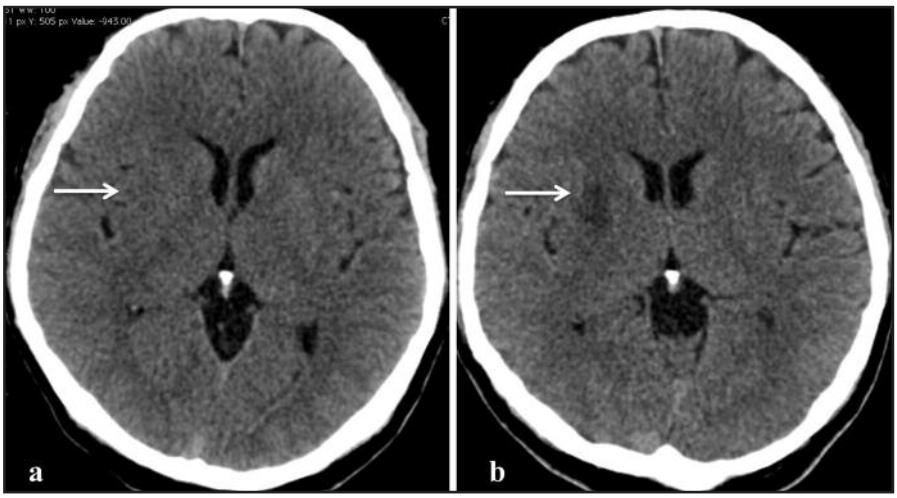


**Fig. 2:** Loss of basal ganglia (lentiform nucleus) sign. (a) Initial NCCT done 2 hours after clinical presentation showed loss of right basal ganglia outline (arrow). Compare with normal-outlined left basal ganglia. (b) Repeat NCCT scan one day later showed more conspicuous hypodensity at the right basal ganglia region.

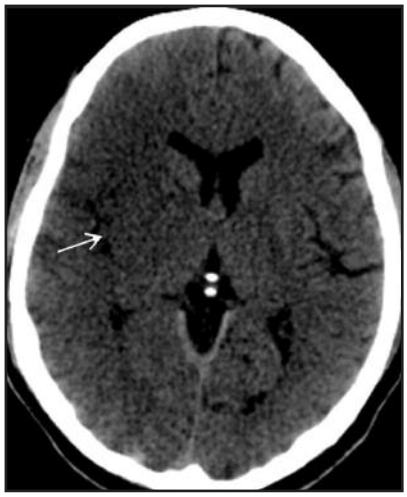

**Fig. 3:** Loss of insular ribbon sign. NCCT showed loss of grey white matter differentiation at right insular region (arrow). Compare with the normal insular at the left side. Note that this patient also had loss of basal ganglia outline and effacement of the adjacent cortical sulci.

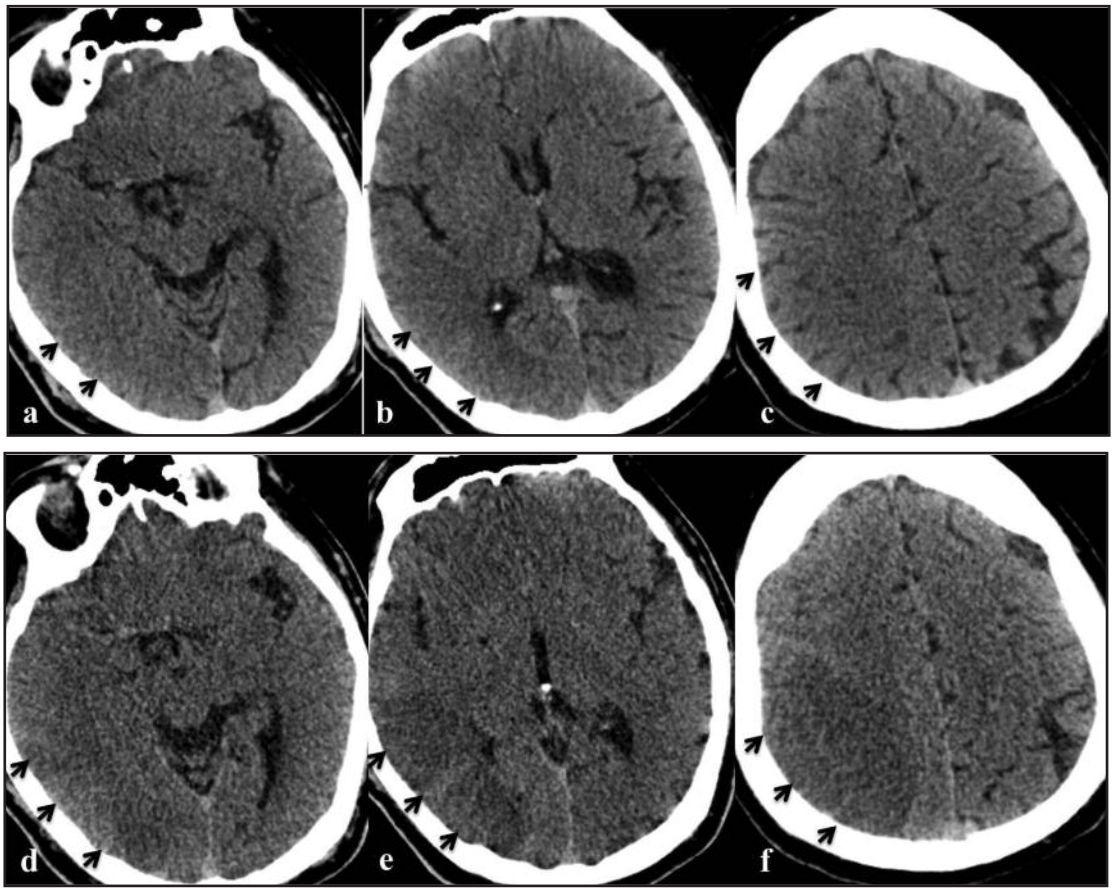


**Fig. 4:** Effacement of the cortical sulci sign. (a-c) Initial NCCT done in patients presented 2 hours after clinical event showing the effacement of cerebral sulci on the right hemisphere (black arrowheads). Repeat NCCT after 24 hours (d-f) showed more conspicuous infarction area (arrows).

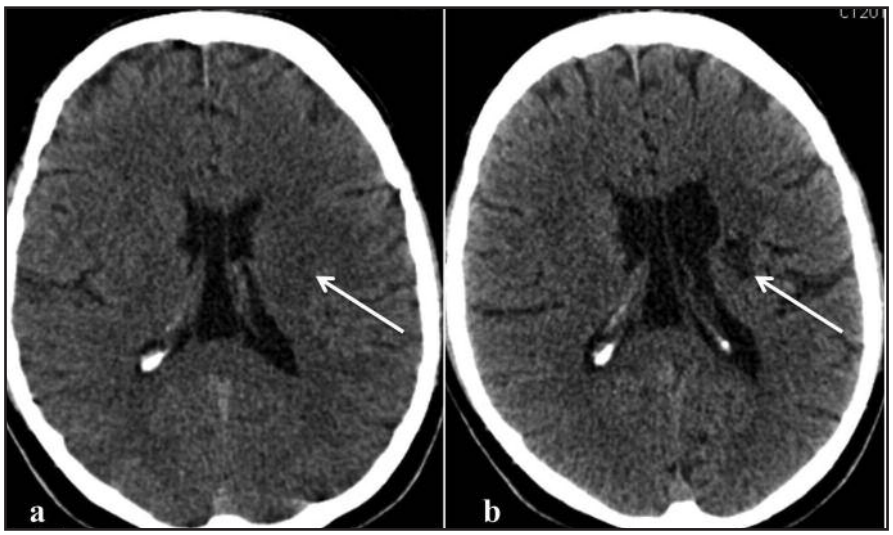


**Fig. 5:** Hypoattenuation sign. (a) NCCT done 2 hours after clinical onset showed subtle hypodensity at the left corona radiata (arrow). (b) A repeat scan 2 months later showed the infarction area to be more conspicuous than before.

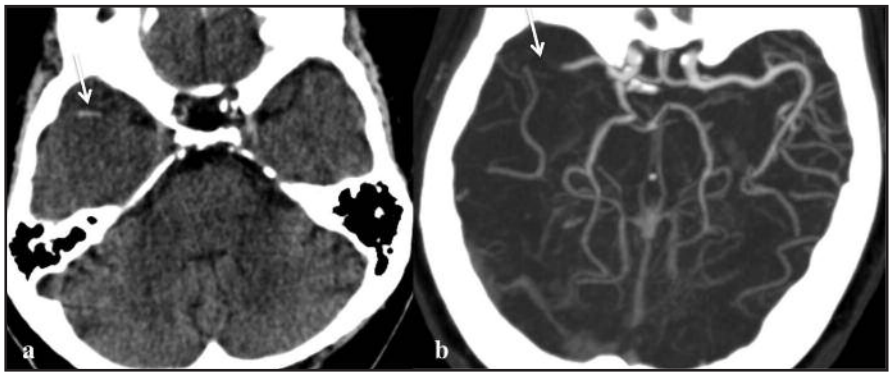


**Fig. 6:** Dense MCA sign. (a) Initial NCCT in a 69-year-old female presented with left-sided body weakness showed hyperdensity along the right MCA (arrow). (b) Right MCA occlusion was confirmed with CT angiography (arrow).

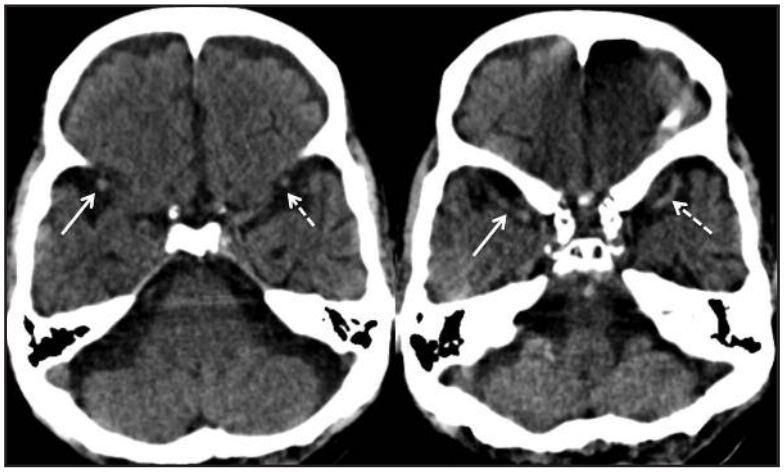

**Fig. 7:** False hyperdense vascular sign. NCCT in an 86-year old man with left sided weakness showing hyperdense right MCA (arrow). However comparison with the other side of the vessel (dotted arrow) and the length of involvement suggested that the hyperdensity was due to calcification of vessel in this elderly patient. No thrombosis was seen on CT angiography (images not shown).

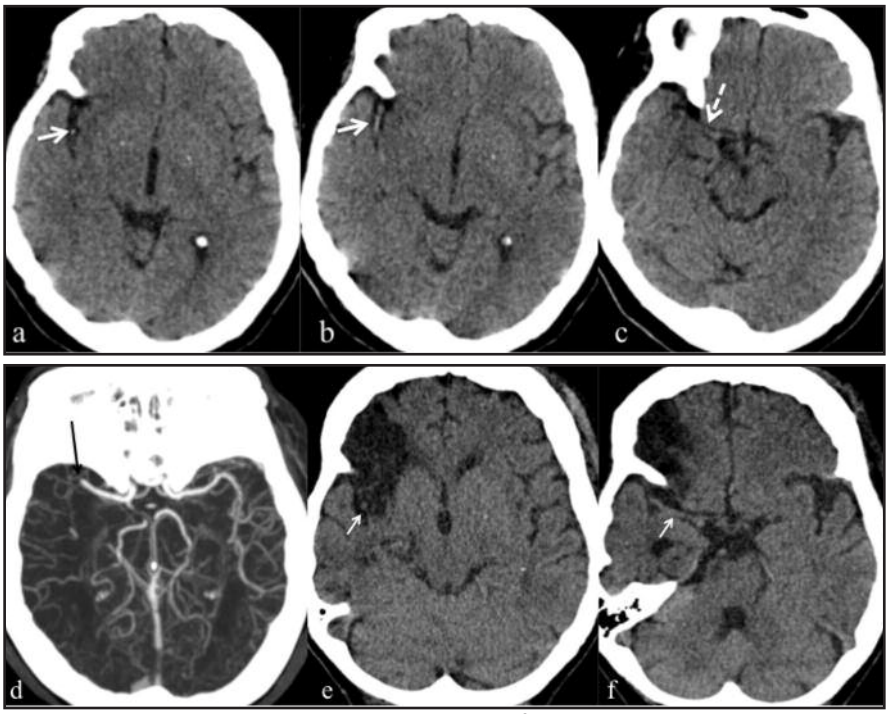


**Fig. 8:** Dot sign. (a,b) NCCT showed hyperdense MCA in the right Sylvian fissure during acute ischaemic phase in a 69-year-old man 3 hours after clinical event. (c) Proximal MCA (dotted arrow) showed normal density almost similar to brain tissue. (d) Presence of thrombosis within the MCA was confirmed with CT angiography. (e, f) A repeat NCCT 5 months later showed normal density of distal right MCA which is almost similar to brain parenchyma and proximal part of the vessel (arrow). Note the volume loss due to previous insult.

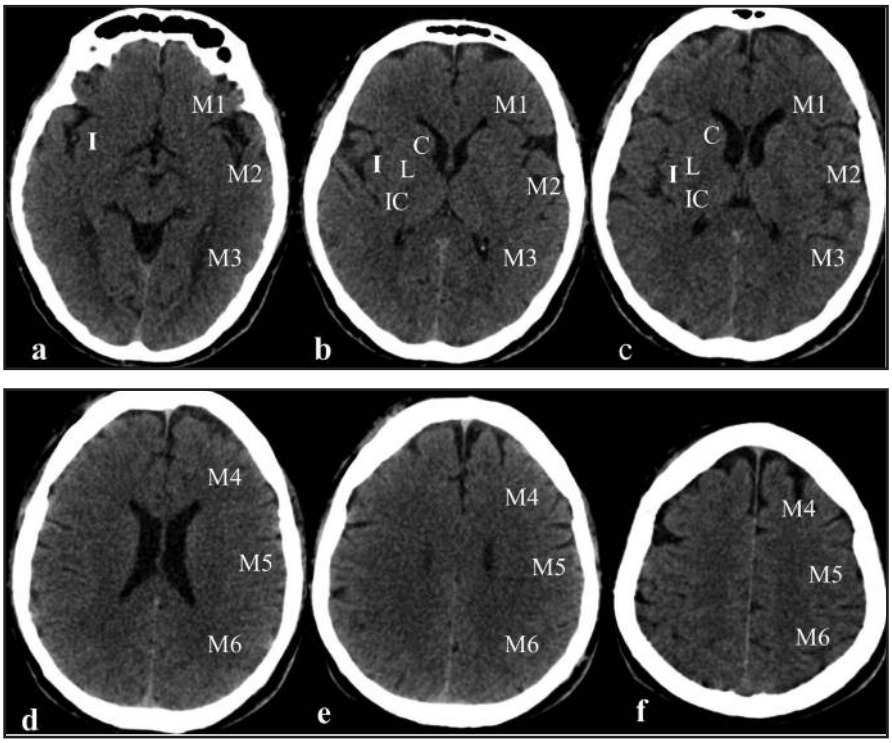


**Fig. 9:** ASPECT score system. (a-c) Ganglionic region referred to any ischaemic lesion on axial cuts at the level of the caudate head or below. M1=anterior MCA cortex, M2= MCA cortex lateral to the insular ribbon, and M3= posterior MCA cortex. Caudate head (C), lentiform nucleus (L), internal capsule (IC) and insular ribbon (I) are other areas marked as different area. (d-f) Supraganglionic region is referred to ischaemic lesions above the caudate head. M4=anterior, M5=lateral and M6=posterior MCA territories which are superior to M1, M2 and M3 respectively.

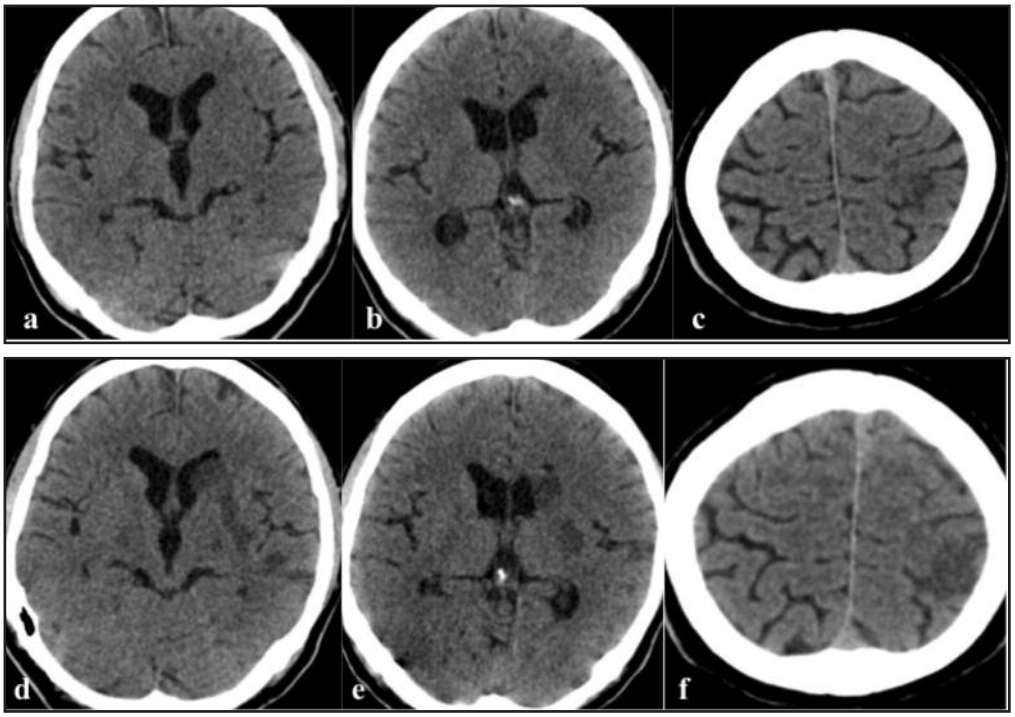


**Fig. 10:**(a-c) A 69-year old man with right sided weakness. Initial NCCT 2.6 hours after clinical event showed subtle hypodensity in the left basal ganglia and parietal cortex, volume estimation of less than one third MCA territory involvement. Using ASPECTS scoring system, this patient was graded as ASPECTS 6 (Ten minus caudate nucleus, lentiform nucleus, internal capsule and M6). This patient received thrombolysis but showed no improvement of clinical signs. (d-f) A repeat NCCT 24 hours after later demonstrate the infarcted area more clearly.

It was determined from ganglionic and supraganglionic levels. The ganglionic level is the region of MCA territory where the thalamus, basal ganglia and caudate are visible, and the supraganglionic level is the region which includes the corona radiata and centrum semiovale. It can be used on all commonly used axial baselines and a change of baseline would have no significant effect on the interpretation[28].

A normal CT scan received an ASPECT score of 10-points. To compute the ASPECTS, one point is subtracted from ten for an area of early ischaemic change, such as focal swelling or parenchymal hypoattenuation, for each of the defined region. A score of zero indicated diffuse ischaemic involvement throughout the MCA territory (Figure 10).

Previous studies showed reliable and reproducible results with ASPECTS score with low inter and intraobserver reliability[25]. Baseline ASPECTS score correlates inversely with the severity of NIHSS and with functional outcome. Scores of 7 or less, indicating more extensive MCA involvement are correlated with both poor functional outcome and symptomatic intracerebral haemorrhage. A higher ASPECTS value (ASPECTS 8-10) were associated with a greater extent of benefit from intravenous thrombolysis[29,30].

There are a few limitations of ASPECTS scoring sytem. It is limited to only MCA territory infarction. ASPECTS scoring is difficult in M2 region in the presence of streak artifacts in the base of skull and in patients having extensive age-related periventricular changes. Poor quality scan like motion artifact or tilt can lead to incorrect ASPECT scoring.

## CONCLUSION

Non-contrast CT of the brain remains the modality of choice for initial assessment in patients with acute ischaemic infarction intended for thrombolysis. The findings are usually subtle and not easy to be interprete but, it can be improved with exposure and focused training in recognizing the features. The ASPECTS scoring system is a useful clinical tool and an important method of baseline risk stratification of acute stroke therapy.

## ACKNOWLEDGEMENT

We would like to thank all members of the *Kuala Lumpur Regionalised Intergrated Stroke Intervention Strategy (KRISIS)* for their involvement in acute stroke care. We would like to thank Mr Safwan Hashim for the technical assistance in this manuscript preparation.

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## Multiple Choice Questions

1. The following statements are regarding acute stroke:
a. Haemorrhagic stroke is more common than ischaemic stroke.
b. Thrombolytic therapy should be considered after a contrast-enhanced CT scan has been performed.
c. In cases considered for thrombolysis, non-contrast CT scan should not be performed if the onset is too acute (less than 2 hours)
d. Thrombolytic therapy is contraindicated if non-contrast CT scan is normal.
e. Early signs of acute ischaemic stroke demonstrated on CT scan are due to cytotoxic oedema.

2. The following are signs of acute ischaemic stroke on non-contrast CT scan:
a. loss of basal ganglia outline
b. area of hypoattenuation
c. hyperdense vessel sign
d. better visualization of insular ribbon
e. effacement of the cerebral sulci

3. Which of the following statements are true?
a. Loss of basal ganglia outline can only be seen after 4 hours of stroke onset
b. Visualization of CT changes in acute ischaemic stroke can be improved using contrast-enhanced CT scan
c. Thrombolysis should not be given to patient with infarction involving more than one quarter of MCA territory
d. Non-contrast CT scan can differentiate stroke from stroke mimics
e. Haemorrhagic stroke shows subtle findings on non-contrast CT scan

4. Which of the following statements are true?
a. Delineation of CT changes can be improved using fixed window width and level.
b. Identifying focal hypottenuation is more difficult than the quantification of brain involvement in acute ischaemic stroke.
c. Hyperdense MCA sign is commonly seen in patients with acute ischaemic stroke.
d. MCA dot sign is more specific than hyperdense MCA sign to represent embolic material in the affected vessel.
e. Bilateral hyperdense MCA seen in elderly patient with hemiparesis are more probably due to calcification rather than acute thrombus.

5. The followings are true regarding ASPECT
a. It is a clinical-based scoring system for acute ischaemic stroke.
b. It is a simple but unreliable method to identify acute ischaemic stroke patients likely to benefit from thrombolysis.
c. A change in axial baseline scanning technique and protocol would not have significant effect on image interpretation.
d. A lower score showed worse involvement of brain parenchyma
e. Motion artifact does not influence ASPECT scoring