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Value of Alberta Stroke Program early Computed Tomography Score (ASPECTS) in the Evaluation of Middle Cerebral Artery Acute Ischemic Stroke using CT and DW-MRI

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Abstract

Background: Alberta Stroke Program Early Computed Tomography Score (ASPECTS) is a quantitative score to evaluate early ischemic changes in the middle cerebral arterial territory on Computed Tomography (CT) in addition to diffusion-weighted imaging (DWI).

Aim: To study the value of ASPECTS using CT and DWI-MRI in patients with acute stroke related to middle cerebral artery (MCA) territories and their values in predicting hemorrhagic transformation (HT).

Methods and Materials: A prospective study was done at Al-Imamain Al-Kadhmain Medical City in Baghdad, Iraq from January 2017 to January 2018 and conducted on 100 patients (62 male, 38 female) who had acute ischemic stroke related to MCA territories and imaged with CT and Magnetic Resonance Imaging (MRI) within 6 hours of symptoms onset.

Results: Male: Female ratio 1.6:1, mean age 58.7 ± 11.78 years, the mean of time between onset of symptoms and CT scan was 165 minutes. The difference between CT and DWI ASPECTS was about one point. CT scan signs of early ischemic changes were found in 58% of the patients while DWI-MRI signs of early ischemic changes were recognized in 75% patients (significance level P=0.011). The overall sensitivity and specificity of CT ASPECTS compared to MRI-DWI was 82.86% and 83.37% respectively and the accuracy was 83.00%, 70 patients had follow up by another MRI to detect HT, patients with low ASPECTS had more tendency to exhibit HT.

Conclusion: ASPECTS is a simple applicable tool for early accurate recognition and standardizing the reporting evaluation of acute ischemic stroke related to MCA territories. DWI-ASPECTS scored were roughly one point lower than CT-ASPECTS. Although CT-ASPECTS and DWI-ASPECTS were valuable in predicting symptomatic HT, DWI-ASPECTS are more sensitive.

Keywords: Alberta stroke program early computed tomography score; Computed tomography; Diffusion-weighted imaging; Acute ischemic stroke

Introduction

Stroke is a term describes the abrupt attack of a constant neurological deficit caused by partial or complete obstruction (ischemic stroke) or rupture of a cerebral blood vessel (hemorrhage) [1]. Stroke is the second most common cause of morbidity worldwide and is the primary cause of acquired disability. The middle cerebral artery (MCA) territory is the most commonly affected territory in a cerebral infarction [2]. Hemorrhagic transformation is a complication of cerebral ischemic infarction and can significantly worsen prognosis, the proportion of hemorrhagic transformation of ischemic strokes have been variably reported, but generally more than half of all cerebral infarcts at some phase develop a few hemorrhagic component, the majority (89%) are petechial hemorrhages, and a minority (11%) hematomas [3]. The overall rate of spontaneous hemorrhagic transformation (with hematoma) has been reported to be as high as 5%, the frequency of symptomatic hemorrhagic transformation is however much lower between 0.6 and 3% in untreated patients and up to 6% of patients treated with intravenous tissue plasminogen activator [4].

Non-contrast computed tomography (NCCT) of the brain remains the mainstay of imaging in the setting of an acute stroke. It is fast, inexpensive and readily available. Detection depends on the territory, the experience of the interpreting radiologist and the time of the scan from the onset of symptoms [5]. Recognition of MCA territory infarct has been shown to be approximately 60%-70% in the first 6 hours although changes in the deep grey matter nuclei (especially lentiform nucleus) can be visible within 1 hour of occlusion in up to 60% of patients [6].

Magnetic resonance imaging (MRI) has significantly higher sensitivity and specificity in the diagnosis of acute ischemic infarction

in the first few hours after onset. Within minutes of arterial occlusion, DWI demonstrates increased signal and reduced apparent diffusion coefficient (ADC) values [7]. Sequences susceptible to signal drop out due to blood products especially susceptibility weighted imaging (SWI) are useful as they are more sensitive than CT to detect hemorrhage early [3].

Alberta Stroke Program Early Computed Tomography Score (ASPECT): Developed in 2000 as a simple, reliable and systematic approach to assessing EIC on NCCT by evaluation of two standardized regions of the MCA territory (Figure 1): The basal ganglia level (which includes Caudate, Insular-ribbon, Internal Capsule, Lentiform nucleus, M1-Anterior MCA cortex, M2-MCA cortex lateral to the insular ribbon, M3- Posterior MCA cortex), and the supraganglionic level (which includes M4, M5, M6 are the anterior, lateral and posterior MCA territories immediately superior to M1, M2 and M3 cranial to basal ganglia), 1 point is subtracted from the initial score of 10 for each region shows ischemic changes [8,9].

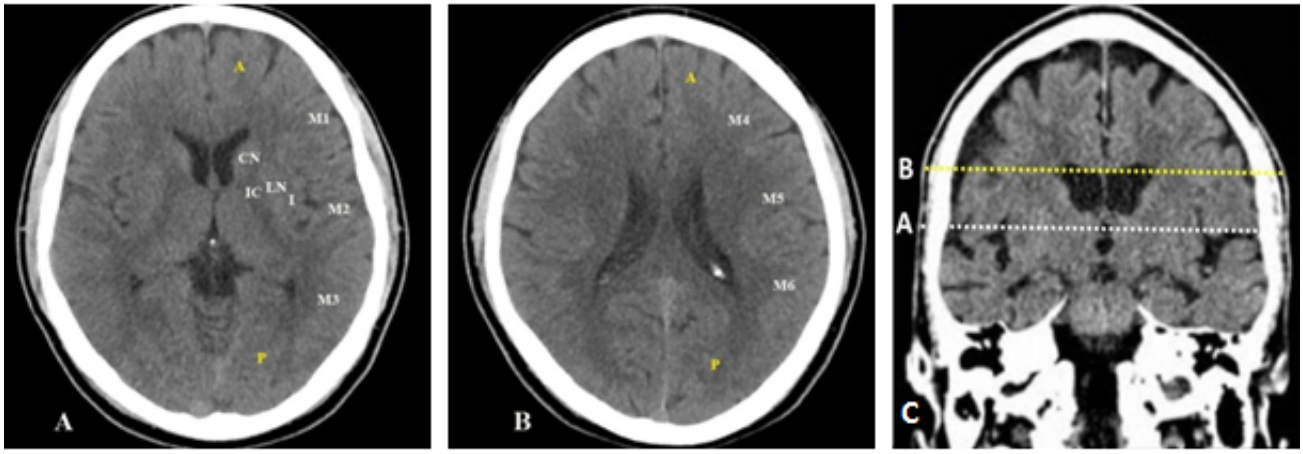

Figure 1: ASPECTS scheme (A: anterior, P: posterior). A. CT Axial slice at the level of thalamus and basal ganglion which includes 4 deep and 3 cortical territories: (M1–M3, insula (I), lentiform nucleus (LN), caudate (C), posterior limb of the internal capsule (IC)). B. CT Axial slice at the level adjacent to the most superior margin of the ganglionic structures which includes 3 cortical MCA territories: (M4–M6) (approximately 2 cm superior to M1, M2 and M3 respectively): C: lower image coronal view shows levels of image scoring.

Aim of the study

To assess the extent of acute ischemic stroke of middle cerebral artery within the first 6 hours of symptom by CT and DWI-MRI by using the Alberta Stroke Program Early Computed Tomography Score (ASPECTS).

Patients and Methods

This prospective study was done in the radiology department (CT and MRI) of Al-Imamain Al-Kadhmain Medical City/ Baghdad/ Iraq from January 2017 to January 2018. The study was conducted on 100 patients (62 male and 38 female) mean age (58.7 years).

Inclusion criteria

Patients with signs and symptoms of acute stroke and/or CT evidence of middle cerebral artery (MCA) territories ischemic infarction within 6 hours of symptoms onset.

Exclusion criteria

CT and initial MRI was not done within the first 6 hours of the onset of symptoms, patients with evidence of infarction not consistent with MCA territories, evidence of hemorrhagic stroke at initial CT or MRI, infarction due to cortical venous thrombosis, patients with previous intracranial surgery or trauma and patients who had contraindications for MRI. All the patients included in the study had brain CT and initial MRI within 6 hours of symptoms onset, only those patients who had radiological evidence of ischemic stroke of MCA were included in the study. Follow up MRI was done for 70 patients within 10 days after the initial MRI to detect hemorrhagic transformation.

CT examination

Unenhanced CT scan were performed in the emergency department using 46 multi-detector CT scanner (SOMATOM Definition AS, Siemens Medical System, Germany), the examination was carried out in supine position with 5 mm collimation, tube potential of 100 kV, and the mAs was 170.

MR Protocol

MRI was performed on 3T scanner (Achieva; Philips medical system, Netherlands), using standard head coil. Both MRI examinations (initial and follow up) was performed in supine position with the following sequences: Axial T1 weighted image (TR/TE: 600/16 ms), axial T2 weighted image (TR/TE: 3500/95 ms), coronal T2 fluid attenuated inversion recovery (FLAIR) (TR/TE: 11000/l20 ms and; TI=2600 ms), axial DWI using a single shot echo-planar imaging (b=1000 s/mm^2, 5 mm slices thickness, TR/TE: 1000/l00 ms), Apparent diffusion coefficient (ADC) values were calculated at b value of 1000s/mm^2, axial T2 gradient-echo sequence (TR/TE:600/40 ms), and axial SWI (susceptibility weighted image) (TR/TE: 500/50 ms).

Images interpretation

ASPECT Scoring: each baseline axial CT, MRI and follow up MRI was assessed for ischemic changes, all images was reviewed digitally at workstation and quantified using ASPECTS. The interpretation was done by 2 independent radiologists to decrease inter-observer error. The ASPECTS regions were marked from two standardized axial cuts: The basal ganglia level and the supraganglionic level. Segmental evaluation of the middle cerebral artery vascular territory is made and 1 point is deducted from the initial score of 10 for each region involved :l. Caudate, 2. Lentiform nucleus, 3. Internal capsule, 4. Insula, 5. M1: "anterior MCA cortex" related to frontal operculum, 6. M2: "MCA cortex lateral to Insula" related to anterior temporal lobe, 7. M3: "posterior MCA cortex" related to posterior temporal lobe, 8. M4: "anterior MCA territory immediately superior to M1, 9. M5: "lateral MCA territory immediately superior to M2" and 10. M6: "posterior MCA territory immediately superior to M3". The middle cerebral artery territories were divided into 10 points (7 cortical regions and 3 regions of the basal ganglia). A single point was subtracted for an area of EIC on CT which included any or all of: 1. parenchymal hypoattenuation, 2. loss of grey-white matter differentiation, and 3. focal brain swelling. We assumed that the extent of early signs of infarction detectable by CT is comparable to the extent of the DWI hyperintense signal (representing the restricted diffusion of water) when quantified by ASPECTS. The DWI is assessed in correlation with ADC to confirm true restricted diffusion (true restricted diffusion show increased DWI signal and low signal on ADC). A CT or MRI scan without changes in these areas, the ASPECTS score will be 10 points while score of 0 mean complete ischemia of the MCA territories. Evaluation of hemorrhage: The follow up MRI examination compared with the ischemic areas of the middle cerebral artery that was detected in the initial MRI study. We depended mostly on SWI and $T2^{*}$ in the assessment and diagnosis of possible hemorrhagic transformation.

Statistical analysis

The data of patients was entered using Microsoft office excel 2007 and the statistical analysis was performed using Minitab 17. The data are presented as mean ± standard deviation or as numbers and percentages.The categorical data was compared by applying chi-square test, Brand_Altman plot was used to point up the degree of differences between baseline CT and DWI ASPECTS. A probability (p) value of less than 0.05 was considered statistically significant.

Results

One hundred (62 male and 38 female) patients were included in the study, male: female ratio 1.6:1, mean age 58.7 (± 11.78), the mean time between onset of symptoms and CT scan in the emergency department was 165 minutes and mean time between symptoms onset and initial MRI examination was 310 minutes.

CT scan signs of early ischemic changes were found in 58% of the patients while DWI-MRI signs of early ischemic changes were recognized in 75% patients (significance level p=0.011).The overall sensitivity and specificity of CT ASPECTS compared to MRI-DWI was 82.86% and 83.37% respectively and the accuracy was 83.00%. These findings were shown in Table 1.

The frequencies of areas that show ischemic changes in CT scan are comparable to the frequency of the same areas on MRI-DWI. There was positive correlation between CT-ASPECTS and DWI-ASPECTS, the results also demonstrate statistically significant relation between CT-APECTS mean (8.43) and DWI-ASPECTS (7.60) (p=0.0243). The difference in mean between CT ASPECTS and DWI-ASPECTS was (+0.67) indicating more early ischemic changes seen on average MRI-DWI examination. The sensitivity and specificity of ischemic changes on each region of CT-ASPECTS and DWI-ASPECTS are shown in Table 2. The sensitivity of CT scan in detecting early ischemic changes was lowest in internal capsule region while specificity was lowest in lentiform nucleus region.

CT		**MRI-DWI**		**p value**
Positive	**Negative**	**Positive**	**Negative**	
58	42	75	25	0.011
Statistic	**Value**		**95% CI**	
Sensitivity	82.86%		71.97% to 90.82%	
Specificity	83.37%		65.28% to 94.36%	
Accuracy	83.00%		74.48% to 89.48%	
Positive Predictive Value	91.23%		82.58% to 95.48%	
Negative Predictive Value	67.50%		54.74% to 78.31%	

Table 1: Radiological signs of ischemia in CT and DWI-MRI with sensitivity, specificity and accuracy of CT ASPECTS compared with DWI-MRI ASPECTS.

Individual ASPECTS area	**CT lesion %**	**DWI lesion %**	**CT-ASPECTS**	
			Sensitivity %	**Specificity %**
Internal capsule	9	16	14	90
Caudate	8	11	20.1	92
Lentiform nucleus	15	12	48.5	82
Insula	12	8	54.4	85
M1	6	7	43.3	93
M2	16	12	46	85
M3	9	9	42	92
M4	4	6	35	90
M5	11	10	40	88
M6	10	9	30	96

Table 2: Sensitivity and specificity of each individual baseline CT-ASPECTS point compared with the baseline DWI ASPECTS.

Seventy patients (41 male and 29 female), mean age (59 years) had follow up MRI, of these 21 patients (30%) had hemorrhagic transformation (15 asymptomatic and 6 symptomatic), the range for follow up was 4-7 days and mean 5 days. The baseline data for follow up MRI patients presented in Table 3.

Parameters	Symptomatic +	Asymptomatic
Total	6	15
Male	4	8
Female	2	7
Mean age	57.83	61.6
Presence of risk factors*	6	7
No anticoagulant	2	5
Mean CT-ASPECTS	3	8
Mean DWI-ASPECTS	0.83	6.1
+Neurologic worsening and perhaps gradual loss of consciousness, dizziness or neck rigidity. *Older age, larger stroke size, anticoagulant use, fever, hyperglycaemia, elevated systolic blood pressure in the acute setting, thrombolytic therapy.		

Table 3: Data of patients with hemorrhagic transformation in follow up MRI.

The patients with low ASPECTS score for either CT scan or MRI-DWI had more probability to develop hemorrhagic transformation. The ASPECTS scores for both CT and MRI were much lower for symptomatic patients. The comparison between CT-ASPECTS and DWI-ASPECTS means for symptomatic and asymptomatic patients was statically significant (P=<0.0001) as demonstrated in Table 4.

Parameters	CT ASPECTS (mean ± SD)	DWI ASPECTS (mean ± SD)	p value
Asymptomatic	8 ± 2.03	6.1 ± 1.50	p=<0.0001
Symptomatic	3 ± 1.41	0.83 ± 0.75	p=<0.0001

Table 4: Comparison between CT-ASPECT and DWI-ASPECTS means in patients with hemorrhagic transformation.

In relation to original cut point the patients with hemorrhagic transformation divided into two groups ASPECTS>7 and ≤7, the results showed in Table 5.

Parameters	CT ASPECTS	DWI ASPECTS	p value
ASPECTS >7	56%	66%	p=0.4966
ASPECTS ≤7	13%	3%	p=0.0263

Table 5: Comparison between CT-ASPECTS and DWI ASPECTS in relation to the initial cut point.

Figures 2 and 3 are image of 2 patients included in the study.

Discussion

The main goal of this study was to assess early ischemic changes in simple reliable grading system and helps clinician to predict outcome and complications, thus the effectiveness of CT ASPECTS compare to DWI ASPECTS. This study shows that CT and DWI are comparable for quantifying signs of cerebral ischemia in acute ischemic stroke when assessed systemically using ASPECTS, though, this does not indicate that the two modalities are similar. ASPECTS values were lower for diffusion MR images implying that DWI is more sensitive than CT at detecting ischemic changes. Though, controversy still remains as regards whether the DWI lesion represents irreversibly ischemic tissue (the core). Some recent articles suggest that the DWI lesion includes both core and penumbra [10] and that an apparent diffusion threshold (ADC) cannot be determined within the first few hours of stroke [11,12].

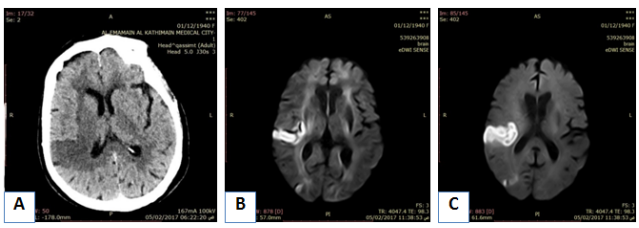

Figure 2: 77-years-old patient presented with Lt. sided weakness CT scan (A) show hypoattenuation involve insula and M2 (CT-ASPECTS=8), the MRI-DWI (B and C) show hyperintensity within same areas in addition to M5 (DWI-ASPECTS=7).

The current study showed that CT scan detected signs of early ischemic changes in 58% patients and DWI MRI in 75% patients, these results were comparable with that of Barber et al. [13] study which showed that CT scan found ischemic signs in 66% and DWI in 81%, while the difference was larger in Mitomi et al. [14] study which show ischemia detected in 30% by CT and 76.9% in DWI, this difference especially in CT scan may be related to the short mean time interval from symptoms onset to CT imaging which was 96 minutes while in our study was 165 minutes so sensitivity of CT scan ability to detect ischemic stroke increase.

In the present study the overall sensitivity and specificity of CT ASPECTS when using MRI-DWI as reference test was 82.86% and 83.37% respectively, this results were similar to that obtained by Barber et al. [13] study which showed 81% sensitivity and 88% specificity, while McTaggart et al. [15] showed 60% sensitivity and 68% specificity, the variability between our study and McTaggart et al. study was done

at larger interval duration in different centers, shorter onset to imaging time with application of National Institute of Health Stroke Scale score to the study in selection of patients.

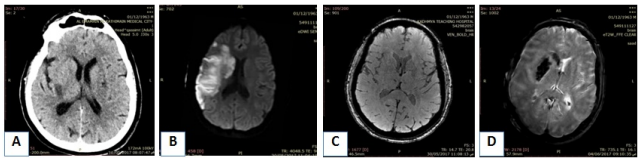

Figure 3: 54-years-old patient presented with Lt. sided weakness CT. (A) Shows hypoattenuation in Internal capsule (ASPECTS=9), initial DWI-MRI. (B) Shows hyperintensity in Caudate, Internal capsule, Lentiform nucleus, Insula, M1, M2 and M3 regions (DWI-ASPECTS=3), SWI in the initial MRI. (C) was normal, follow up MRI T2*. (D) After 5 days demonstrated hypointensity in the Caudate and Lentiform nucleus picture goes with hemorrhagic transformation.

The mean difference of ASPECTS in both methods (CT and MRI) in our study was +0.67, this result was relatively in agreement with Kawano et al. [16] which found the difference was +0.75.

An important restriction in the current study was that the analysis was referenced to DWI, which shows both reversible and irreversible ischemia. The analysis should be essentially related to follow-up imaging, which represents ultimate tissue status.

The present study showed the lowest sensitivity in the internal capsule (14%) and caudate (20.1%) which was comparable to result of Nezu et al. [17] study which show (internal capsule 18% and caudate 13%).

In the recent study symptomatic hemorrhagic transformation founded more in patients with low CT and DWI ASPECT scoring, this was in agreement with Singer et al. [18] ASPECTS providing to some extent semi-quantitative estimate of the lesion size has been shown to be simple and rapid to apply in the practical setting and may therefore be of significance for symptomatic intracranial hemorrhage (sICH) risk approximation. Given the known strengths of DWI as compared to non–contrast-enhanced CT imaging, DWI-ASPECTS may be superior to CT-ASPECTS for sICH possibility assessment. ASPECT score (CT or DWI) mostly more presides in predicting symptomatic hemorrhagic transformation in patients with ASPECTS ≤7 and this appear to be similar to the result of Barber et al. [13] study.

There are several limitations in this study first MRI examination sometimes cannot be done to the patients in the time window of our study and not available in all times, the difficulty in the follow up of some patients as some of them discharge shortly after admission and so cannot follow them to know if there is hemorrhagic transformation.

Conclusion

ASPECTS are a simple applicable tool for early accurate recognition and standardizing the reporting evaluation of acute ischemic stroke related to MCA territories by creating an easily comprehensible numerical score. Patients with acute stroke DWI-ASPECTS scored roughly one point lower than CT-ASPECTS. Although both CT-ASPECTS and DWI-ASPECTS were valuable in predicting symptomatic hemorrhagic transformation DWI-ASPECTS was more sensitive.

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