



Magnetic Resonance Imaging with Diffusion and Perfusion in Assessment of Patients with Cerebral Infarction

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Diffusion-weighted MR imaging is most useful for detecting irreversibly infarcted tissue, perfusion-weighted imaging may be used to identify areas of reversible ischemia as well. This work highlights the role of MR imaging in acute ischemic infarction evaluation, with particular emphasis on the importance of diffusion and perfusion MR imaging for evaluating the penumbra.

Methods: This prospective study was conducted on 30 patients who were suspected to have a cerebral infarction. All patients underwent functional MRI.

Results: 25 patients (83.3%) were isointense in T1 and only 5 patients (16.6%) were low intense, in T2 there was 25 patients (83.3%) were high intense and only 5 patients (16.6%) were isointense. In FLAIR there was 24 patients (80%) were high intense and only 6 patients (20%) were isointense. In DW1 all the cases show high signal also in ADC all the cases show low signal. As regards to Ischemic area: the mean rCBV (relative cerebral blood volume) in the core was 0.33 ± 0.30 cc while in the peripheral area was 1.24 ± 1.35 cc. There was a highly significant difference between CT and MRI in diagnosis of acute stroke with $P = 0.001$.

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Conclusion: Only depending on a single or a few parameters may not be sufficient, instead comprehensively combining the information from each MRI sequence (i.e., DWI, FLAIR and PWI) and using various mismatch parameters (DWI-FLAIR mismatch and/or PWI-DWI mismatch) may be more helpful in establishing an indication of MRI-based thrombolysis.

Keywords: Magnetic resonance imaging; diffusion and perfusion; assessment; cerebral infarction.

1. INTRODUCTION

Brain tissue is exquisitely sensitive to ischemia, because of the absence of neuronal energy stores. In the complete absence of blood flow, the available energy can maintain neuronal viability for approximately 2–3 minutes. However, in acute stroke, ischemia is more often incomplete, with the injured area of the brain receiving a collateral blood supply from uninjured arterial and leptomeningeal territories [1].

Acute ischemia constitutes approximately 80% of all strokes and is an important cause of morbidity and mortality in the United States [2].

Diffusion-weighted MR imaging is most useful for detecting irreversibly infarcted tissue, perfusion-weighted imaging may be used to identify areas of reversible ischemia as well [3].

Current imaging techniques can be used to identify hyperacute stroke and guide therapy by providing information about the functional status of ischemic brain tissue [4].

In a recent trial, intravenous desmoteplase administration at 3–9 hours after the onset of acute ischemia was associated with a higher rate of reperfusion and a better clinical outcome than placebo in patients selected because of a mismatch between findings on diffusion and perfusion MR images [5].

This work highlights the role of MR imaging in acute ischemic infarction evaluation, with particular emphasis on the importance of diffusion and perfusion MR imaging for evaluating the penumbra. A thorough evaluation of acute stroke can be performed by using a combination of conventional MR imaging, MR angiography, and diffusion- and perfusion-weighted MR imaging techniques.

2. PATIENTS AND METHODS

The present study is a prospective one that was conducted on 30 patients who were suspected to have cerebral infarction and referred to the

Radiodiagnosis Department from the Neurology Department and outpatient neurological clinics of Tanta University Hospitals after approval Ethical Committee and obtaining written informed consent.

2.1 Inclusion Criteria

Patients presented with with neurological symptoms: headache, vomiting, hemiparesis, and, clinically suspected to have a cerebral stroke.

2.2 Exclusion Criteria

2.2.1 MRI contraindications

- Brain Aneurysm Clip
- Implanted neural stimulator.
- Implanted cardiac pacemaker or defibrillator.
- Cochlear implant, Ocular foreign body (e.g. metal shavings).
- Other implanted medical devices: (e.g. Swan Ganz catheter), Insulin pump, Metal shrapnel, or bullet.
- Allergic to contrast media.
- Patients with catastrophe from MR device.

2.2.2 Each patient included in the study was subjected to

I. History taking and clinical examination

1. **Careful clinical history taking:** from the patients or their relatives including : age, smoking status, history of arterial hypertension, Diabetes Mellitus, cardiac illness or any other systemic disease as well as the history of the previous stroke. A detailed history was taken regarding the onset of the disease, present, any previous treatments and their types whether surgical or medical, any previous laboratory investigations, and any previous imaging procedures.
2. General examination and assessment of the general condition, vital signs, and, state of consciousness of the patients.

3. Neurological examination:

- Mental state: Speech, dysarthria, aphasia, dysphonia and ,phonia.
- Cranial nerves.
- Motor system: State, tone, power, fasciculation, involuntary movements, reflexes, superficial reflexes, deep reflexes and ,coordination.
- Sensory system.
- Superficial sensations.
- Deep sensations.
- Cortical sensations.
- Sphencteric disturbances.
- Gait disturbances.

Variable presentations were given by the patients with the most frequent neurological clinical presentation was hemi paralysis, disturbed conscious level and ,eadache.

4. Laboratory investigations obtained by the referring neurologist, include the routine laboratory blood investigation such as:

- Complete blood count, white blood cells count to exclude infected emboli.
- Coagulation time, prothrombin time, erythrocyte sedimentation rate.
- Blood sugar level, liver function and ,renal function tests.

II-Radiological studies

Computed Tomography (CT):

CT scan was done (at the CT unit in the Radiology department), before MR examination for all the patients to exclude hemorrhage. The patient was placed supine and positioned comfortably.

MR examination

a) Patient preparation:

- Obtaining informed consent by the patient, patient's parents or , care givers before MRI examination.
- Measuring patient body weight for calculation of the amount of contrast media.
- Checking serum creatinine before Gadolinium administration.

b) Technique

- Technique was performed using a standard 1.5 Tesla unit (GE Signa Explorer).

- A standard head coil was used.
- A baseline MRI brain was obtained from all the patients. T1- and T2-weighted images were taken and additional sequences such as fluid attenuation inversion recovery, diffusion-weighted imaging, and apparent diffusion coefficient sequences were obtained.
- PWI was then performed.
- All the perfusion-weighted images were transferred to the workstation (Advantage workstation 4.7)
- Images were post-processed using the GE software device.

2.2.3 The maps obtained were

- a) rCBV (relative cerebral blood volume) maps.
- b) rCBF (relative cerebral blood flow) maps.
- c) MTT (mean transient time) maps.
- d) Signal intensity time curve.

2.2.4 The protocol is consisting of

- Axial T1 fast spin-echo sequence (TR 450, TE 15, matrix 80 x 81, FOV 230 X177, slice thickness 6 mm): it was done for all cases to exclude hemorrhage or any other diseases i.e., tumors. Scanning time was about one minute and 20 seconds.
- Axial T2 fast spin-echo sequence (TR 3612, TE 100, matrix 208 x 127, FOV 230 X 177, slice thickness 6 mm): it was done for all cases for the staging of the infarction according to presence or absence of high signal intensity of the infarction on the images. Scanning time was about 2 minutes and 35 seconds.
- Axial Fluid Attenuated Inversion Recovery (FLAIR) (TR 6000, TE 120, matrix 240 x 111, FOV 230 X 184, slice thickness 6 mm): it was done to all patients for comparison with T2WI and DWI. Scanning time was about one minute and 50 seconds.
- Diffusion Weighted Imaging (DWI): it was done in all cases because of high sensitivity in early detection of infarction as it shows tissue with restricted diffusion. Scanning time was about one minute and 20 seconds. Sometimes, follow-up scan was obtained in patients after 72 hours of the initial scan to confirm the diagnosis and to check the final lesion volume.
- Magnetic Resonance Arteriography (MRA): does not require an exogenous contrast

agent. Time-of-flight (TOF) MRA has been the most established NCE MRA method for evaluation intracranial vessels. It was done in 10 cases.

- Magnetic Resonance Venography (MRV): Time-of-flight (TOF) MRV was used in the demonstration of a cerebral venous system. It was done in 2 cases.
- Perfusion Weighted Imaging (PWI): it was done for patients with restricted diffusion in DWI except in uncooperative irritable patients because of failure of contrast agent injection and patients of renal failure. The sequence included:

- a) Dynamic susceptibility contrast (DSC)-MRI perfusion-weighted imaging: a bolus of paramagnetic contrast agent is used to visualize the blood perfusing the capillary network in the brain; the signal change caused by the contrast agent molecules passing through the capillaries in a voxel is monitored by a repetitive MRI measures in the same region. Scanning time was 45 seconds, injection of contrast agent after passing 3 seconds (at the 42nd second). Administration of a bolus injection of Gadolinium –DTPA at a dose of 0.1cc/kg body weight (average 10 cc) followed by 10 cc of normal saline. The injection was performed by manual injection through a wide bore cannula in the antecubital fossa veins bilaterally in each limb.

Signal intensity time curves: the sequential images were obtained during the first pass through the cerebral circulation. Calculation and mapping were performed on a per-pixel basis by using the susceptibility change-versus- time curves.

2.3 Statistical Analysis

Analysis of data was done using Statistical Program for Social Science version 20 (SPSS Inc., Chicago, IL, USA). Quantitative variables were described in the form of mean and standard deviation. Qualitative variables were described as number and percent. To compare Qualitative variables were compared using the chi-square (X^2) test, the receiver operating characteristic (ROC) curve was made for MDCT, the receiver operating characteristic (ROC) curve was made for Ultrasound. P -value < 0.05 is considered significant.

3. RESULTS

This study included 30 patients; their age's ranged from (30- 93) years (mean age is 56 ± 2.5 years). Among the 30 patients included in our study, (22) patients were males (73.3%) and (8) patients were females (26.6%). The mean pulse was 82.72 ± 4.66 Beat/min, the mean systolic blood pressure at admission was 128.30 ± 5.91 mmHg while the mean diastolic blood pressure at admission was 84.60 ± 9.07 mmHg.

In the current study, 22 patients had Previous cardiac disease (73.3%), and 7 patients (23.3%) had a positive family history of cerebral infarction. Regarding to hypertension ,there were 13 patients suffering from Hypertension and 11 patients suffering from diabetes 66.6% of the studied cases were smokers, and 20% had Hyperlipidemia.

In the current study, 4 patients (13.3%) admitted to the ICU with a mean duration in ICU of about 4.9 days, the mean duration of ictus was 7.3hours. In our study, (11) patients (36.3%) had right Cerebral Infarction while (19) patients (63.3%) were with the left lesions.

As regards to the Clinical picture there were (2) Patients had Headache, 7 patients had Disturbed conscious level, 3 patients in coma, 5 patients had paralysis and 6 patients complaints of Convulsions also 2 patients had sudden vomiting and aphasia in 5 patients but 10 patients had mixed symptoms.

As regards the site affected there were (4) Patients (13.3%) who had Frontal lobe affection and 8 patients (26.6%) in the parietal lobe, 12 patients (40%) had Temporal affection and 6 patients had more than one lobe.

As regards to previous imaging modalities there were (18) Patients (60%) who had CT and 4 patients who had MRI (13.3%) and 6 patients (20%) who had not done previous imaging modalities but two patients had other imaging modalities like carotid doppler.

3.1 CT Findings of the Studied Patients

30 patients in this study with 8 surely ischemia (26.6%) and 12 possibilities of ischemia (40%) but 10 cases were normal (33.3%) (Table 1).

As regard to Previous neurological examination there were (6) Patients (20%) who had Motor

weakness and Drowsiness and disorientation, 5 patients had Language disorder (16.6%), two cases had urine incontinence, 8 cases had Seizures and convulsions and 3 cases had Memory impairment while mixed findings were in 8 cases as shown in Table (2).

Table 3 shows that 25 patients (83.3%) were isointense in T1 and only 5 patients (16.6%) were low intense, in T2 there was 25 patients (83.3%) who were high intense and only 5 patients (16.6%) were isointense .in FLAIR there was 24 patients (80%) were high intense and only 6 patients (20%) were isointense. In DW1 all

the cases show high signal also in ADC all the cases show low signal.

As regard to Ischemic area: the mean rCBV (in cubic centimeter) in the core was 0.33 ± 0.30 while in the peripheral area was 1.24 ± 1.35 as shown in Table 4.

The mean ADC in the core was 0.45 ± 0.16 , the mean rCBV in the core was 0.33 ± 0.30 , the mean MTT was 1.24 ± 1.35 , while the mean rCBV in the peripheral was 2.67 ± 1.51 and the mean MTT in the peripheral was 1.46 ± 0.59 as shown in Table 5.

Table 1. Classification of the lesions according to their nature

CT findings	N	%
surely ischemia	8	26.6%
possibility of ischemia	12	40%
normal	10	33.3%
Total	30	100%

Table 2. Previous neurological examination among 30 patients included in our study

Previous neurological examination	N	%
Motor weakness	6	20%
Language disorder	5	16.6%
Drowsiness and disorientation	6	20%
Urine incontinence	2	6.6%
Seizures and convulsions	8	26.6%
Memory impairment	3	10%
Mixed neurological findings	8	26.6%

Table 3. Different MRI sequence in acute ischemic strok

MRI sequence	Intensity	N	%
T1W1	Isointense	25	83.3%
	Low intense	5	16.6%
T2W1	High intense	25	83.3%
	Isointense	5	16.6%
FLAIR	Isointense	6	20%
	High signal	24	80%
DW1(b 1000 sec/mm ²)	High signal	30	100%
ADC	Low signal	30	100%

Table 4. Comparison of the mean rCBV (in cubic centimeter) in the core and peripheral region of ischemic area

	rCBV		Chi-squared test	
	Range	Mean ± SD	χ ²	P
Core	0.07-1.43	0.33 ± 0.30	3.164	0.003*
Peripheral	0.25-5.37	1.24 ± 1.35		

*significant, rCBV= relative cerebral blood volume

Table 5. Hemodynamic parameters in the core and in the peripheral of the lesion

	Core			Peripheral	
	ADC	rCBV	MTT	rCBV	MTT
Mean ± SD	0.45±0.16	0.33±0.30	1.24±1.35	2.67±1.51	1.46±0.59

ADC=Apparent diffusion coefficient, rCBV= relative cerebral blood volume, MTT= Mean transient time

There was highly significant difference between CT and MRI in the diagnosis of acute stroke with P= 0.001 as shown in Table 6.

3.2 Example of a Left Acute Tempo-Parietal Infarction is shown

Female patient 37 years old, clinically presented with aphasia and no body movements. MRI was done after 6 hours of the onset of the neurological deficit.

4. DISCUSSION

Stroke is a leading cause of death worldwide. Neuroimaging has become a critical tool in the evaluation and management of patients in whom acute ischemic stroke is suspected. In addition to displaying anatomical structures, the latest neuroimaging techniques can elucidate the underlying hemodynamics and pathophysiology [6].

The pathophysiology of acute stroke represents a chain of rather complex events, which can be simplified into three consecutive stages for the purpose of explaining the evolution of imaging findings: (I) flow abnormalities; (ii) cellular dysfunction; and (iii) structural breakdown [7].

(MRI) techniques play an important role in acute stroke diagnosis and management. MRI is particularly useful for identifying patients who may benefit from thrombolysis, based on the presence of potentially salvageable ischemic tissue [8].

Magnetic resonance imaging (MRI) readily allows the determination of ischemic brain lesions and thus has become an integral part of diagnostic procedures in the clinical evaluation of acute stroke. Most widely used in this setting is diffusion-weighted MRI (DWI), which has a high sensitivity to detect acute ischemic lesions [9].

Diffusion-weighted MR imaging exploits the presence of random motion (Brownian motion) of water molecules to produce image contrast, thereby providing information not available on standard T1- or T2-weighted images [10].

MR perfusion imaging exploits magnetic susceptibility effects within the brain tissue during the first pass of an intravenously injected gadolinium-based contrast agent. During its first pass through the brain, the contrast medium causes a transient signal drop on T2*-weighted (susceptibility weighted) MR images [11].

Like the composition, size, and site of clot occluding cerebral arteries are important factors for selecting the treatment strategy, SVS may be useful for treatment decisions. Initial, long-standing, platelet-rich, and well-organized white thrombi in the cerebral artery under high shear-stress are more resistant to thrombolytic therapy than fresh, fibrin-rich red thrombi formed under static conditions.

Therefore, SVS is known as a marker with a higher possibility of recanalization. Second, the location of a clot is also important. SVS of M1 is a strong predictor of recanalization failure after tPA [12].

Therefore, intra-arterial thrombolysis may be more effective than tPA in certain cases. Third, the clot length is typically used to quantify the thrombotic burden. This is important since intravenous tPA has nearly no potential to recanalize an MCA occlusion with a clot length exceeding 8 mm. Finally, irregular and tortuous clot morphologies can decrease the technical and clinical success of thrombectomies in M1 occlusions [13].

Physicians are frequently confronted with patients in whom the exact time of stroke symptom onset is not known, and attempts have been made to use signal changes in FLAIR images as a kind of "tissue clock". For example, it is known that signal intensity in FLAIR images proportionately increases with a rise in water content inside the infarcted tissue. The water content rises due to vasogenic edema as the blood-brain barrier is disrupted, and occurs within 1 to 4 hours of stroke onset. Therefore, DWI-FLAIR mismatch (i.e., lesion visible on DWI but not on FLAIR) has been used as a surrogate marker for estimating the lesion age of unknown stroke onset and can help determine the use of a thrombolytic agent.

Table 6. Sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) by MRI, CT and DWI in the studied patients

	Sens.	Spec.	PPV	NPV	Accuracy	Chi-square	
						X2	P-value
MRI	93.2	95.60	83.50	91.23	90.55	3.377	0.001
DWI	96.7	98.50	90.57	92.35	93.33		
CT	83.33	90.45	65.71	90.30	80.00		

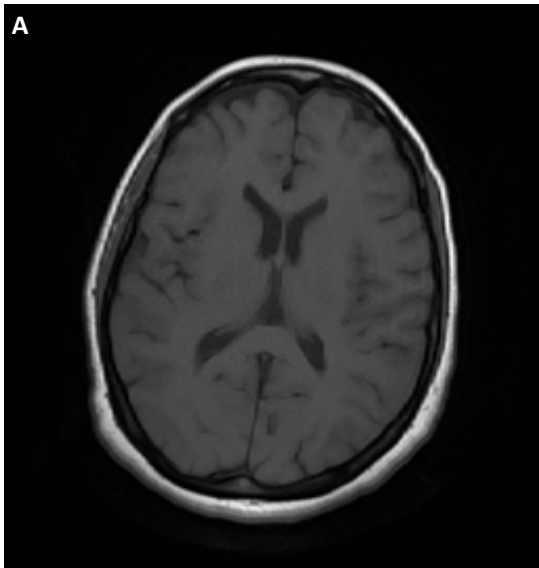


Fig. (A) T1. No abnormal signal detected

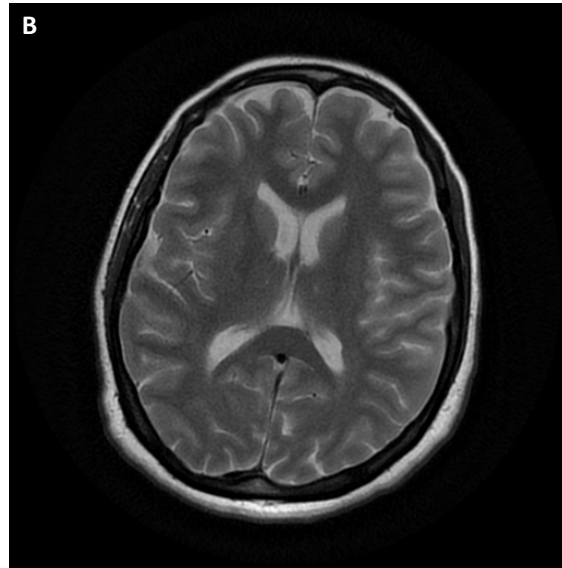


Fig. (B) T2. No abnormal signal detected

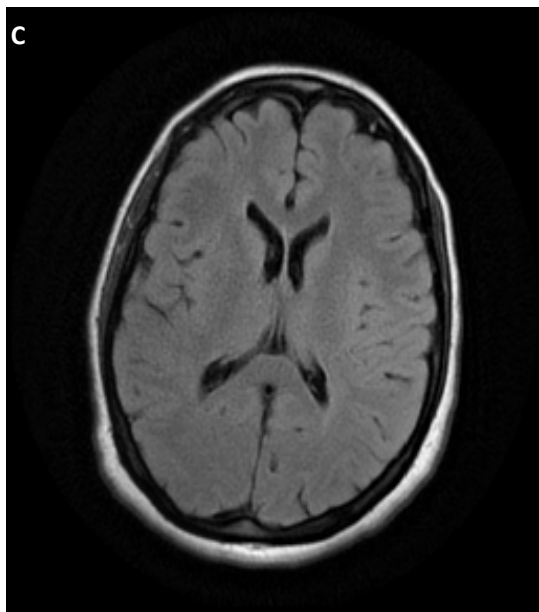


Fig. (C) FLAIR: No abnormal signal detected

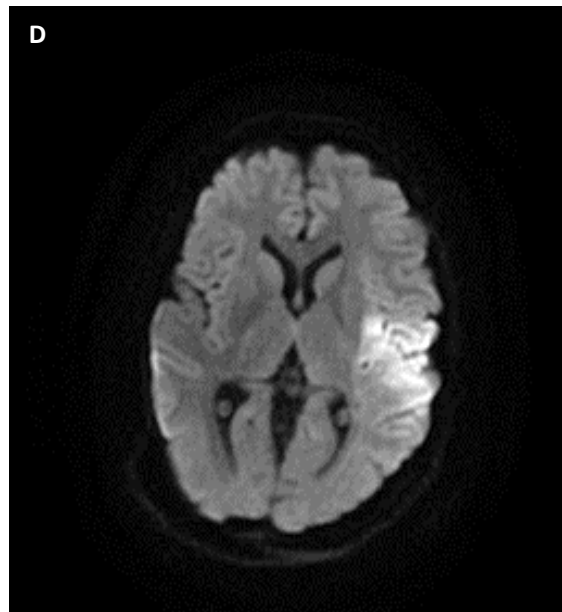


Fig. (D) Diffusion WI: High signal intensity in left parietal area

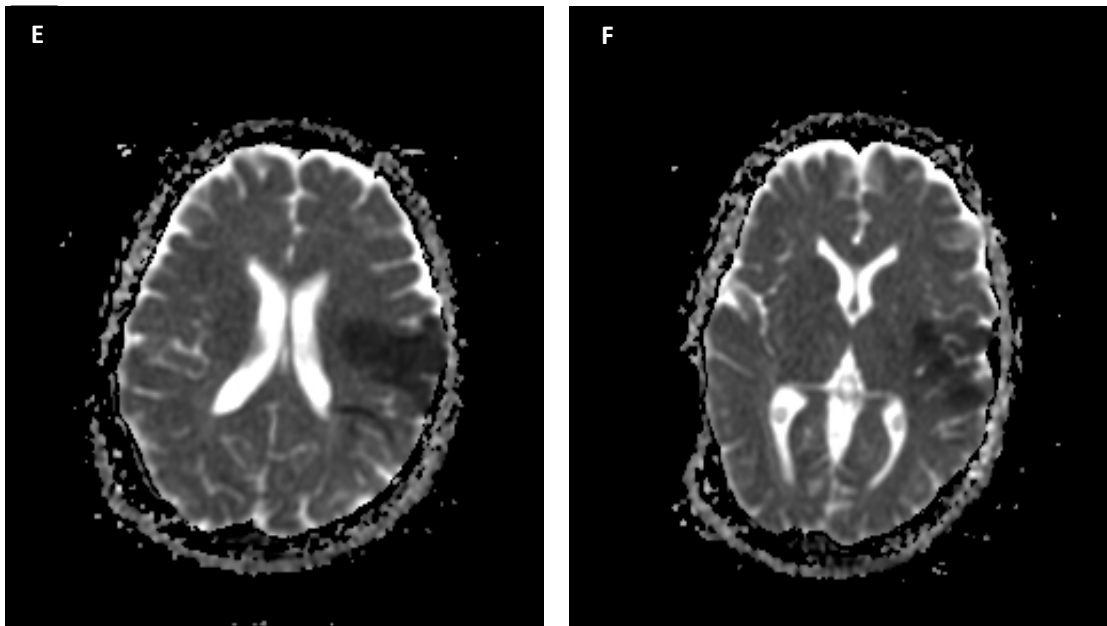


Fig. (E, F). ADC (two axial images): showing low signal intensity corresponding to the area of high intensity in DWI sequence

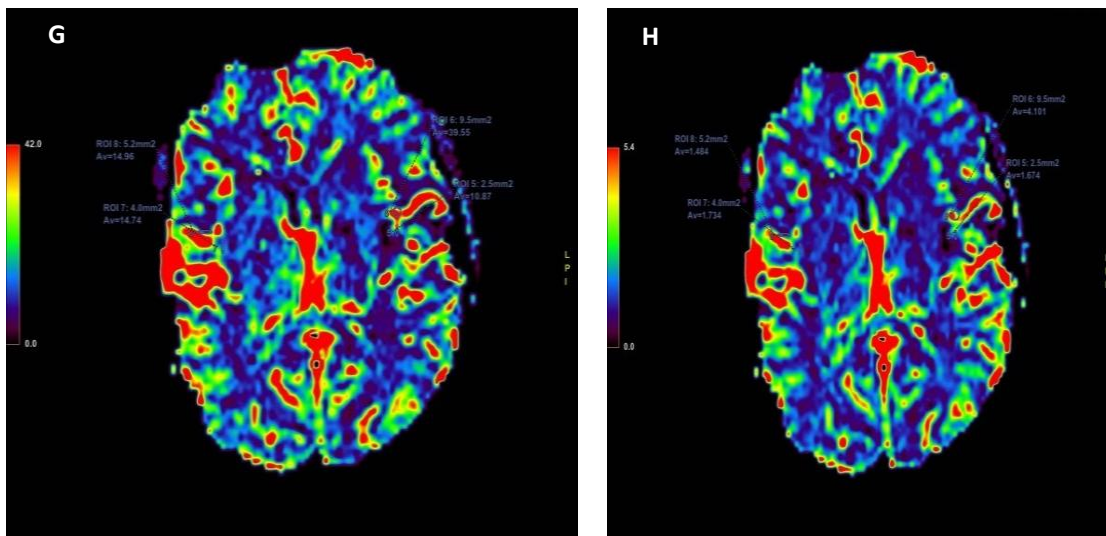


Fig. (G).

Fig. (H).

Fig. (G, H). Perfusion WI parameters (r-CBV and r. CBF) showing increasing CBV in the ischemic area than the normal contralateral side and decreasing CBF at the infarcted area corresponding to the normal contralateral side

Finally, in the reperfusion therapy in unclear-onset stroke based on MRI evaluation (RESTORE), patients with unclear stroke onset, within 6 hours of symptom detection with PWI-DWI mismatch > 20% and negative or subtle

FLAIR change, were treated with tPA or endovascular therapy, and MRI-based reperfusion therapy was found to be feasible and safe. However, potential confounding factors that interfere with the diagnostic accuracy of DWI-

FLAIR mismatch also exist. In addition to the time from symptom onset, younger age and large ischemic lesion volume have been reported to be associated with high FLAIR signal intensity. As age and lesion size alter permeability in the blood-brain barrier, these biological variations may cause altered FLAIR signal intensity. Besides, there is an issue stemming from the low inter-rater reliability of DWI-FLAIR mismatch. For example, in a previous study, it was reported that the inter-rater reliability of FLAIR change was only moderate, based on visual rating [14].

One-third of acute ischemic strokes that have occurred within the therapeutic time window has been excluded because of mild or rapidly improving symptoms. However, the poor outcome in patients who did not receive tPA because of minor stroke symptoms has been reported with up to 30% of these patients at risk of death and dependence [15].

Moreover, a subgroup of patients with minor stroke and proximal vessel occlusion was found to be at higher risk of neurological deterioration. Clinical criteria, such as NIHSS scores, are poorly predictive of proximal intracranial occlusion and underestimate the risk of subsequent neurological deterioration [16].

Clinical trials evaluating the success of thrombolysis have relied on various outcome parameters to measure how well an ischemic vascular bed responds to treatment. Usually, clinical parameters based on the severity of neurological deficits (NIHSS scores) or functional disability (modified Rankin Scale or Barthel Index) are used. However, as these clinical parameters are influenced by various confounders, including the lesion location or patient age, they do not directly demonstrate the treatment effect of salvaging the penumbral tissue. On the other hand, imaging parameters have an advantage in quantitatively measuring the effect of treatment by demonstrating the initial infarction core, penumbra, and the final infarction volume [17].

The three main categories used in outcome measures by MRI are, 1) DWI lesion volume change, 2) PWI lesion volume change, and 3) recanalization of the occluded vessel on MRA. Currently, there is no consensus on how to determine infarct growth. This measure has been based on the change in lesion volume between baseline and follow-up MRIs (DWI at 24 hours and FLAIR at 5 days).⁹⁰ In the EPITHET study,

various measures of infarction volume were suggested, such as geometric mean and the difference in cube-root volumes [18].

However, measurement tools in the clinical setting should be easy to use, and PWI parameters used in the previous clinical trials differ from study to study. Thus, there are some difficulties in comparing the results of each study. For example, in the DEFUSE study, early reperfusion was defined as a more than 50% reduction in the volume of the PWI lesion (Tmax > 6 seconds). On the other hand, reperfusion in the EPITHET study was defined as > 90% reduction between baseline and day-3 PWI lesion volumes [19].

The aim of work of the current study was to evaluate the role of diffusion and perfusion MRI in the assessment of patients with cerebral infarction. To elucidate this aim 30 patients were included in the study.

In the current study, the mean age was 56±2.5years, their age ranged from (30 -93) years. This was also almost similar to a study made by Ritzl, et al [20] where age ranged from 31 to 87 years old with a mean age of (57 ±14 years).

In the present study, (22) patients were males (73.3%) and (8) patients were females (26.6%) which in agreement with the study done by Nil et al. [21] who stated that there was male predominance (77%).

Regarding to the risk factors, 22 patients had Previous cardiac disease (73.3%), and 7 patients (23.3%) had a positive family history of cerebral infarction. Regarding to Hypertension, there were 13 patients (43.3%) suffering from Hypertension and 11 patients (36.6%) suffering from diabetes. 66.6% of the studied cases were smokers, and 20% had Hyperlipidemia.

Assessment of atherosclerosis, an important risk factor for cerebrovascular ischemic events, has recently shifted from lumen measurement to the evaluation of the plaque structure and composition Naghavi et al. Saba et al. [22, 23].

The presence of the cerebrovascular disease is strongly associated with the presence of symptomatic and asymptomatic cardiac disease. Besides, myocardial infarction is associated with the development of atrial fibrillation and is a common source of cariogenic emboli [24]. However, acute myocardial infarction is infrequently associated with stroke, the majority

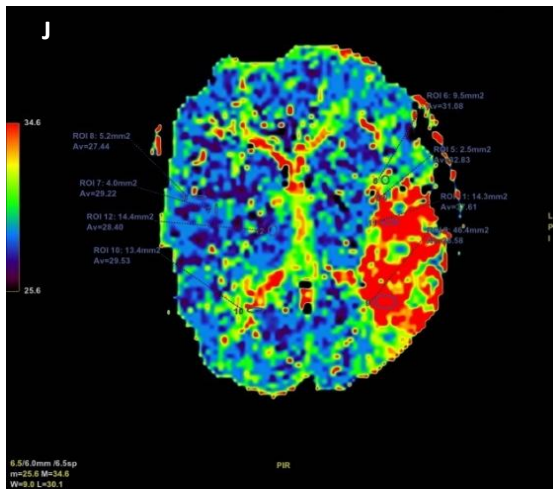


Figure (J): MTT map shows larger lesion denotes area at risk (penumbra) than obtained by DWI with prolongation of the MTT involving the left parietal region.

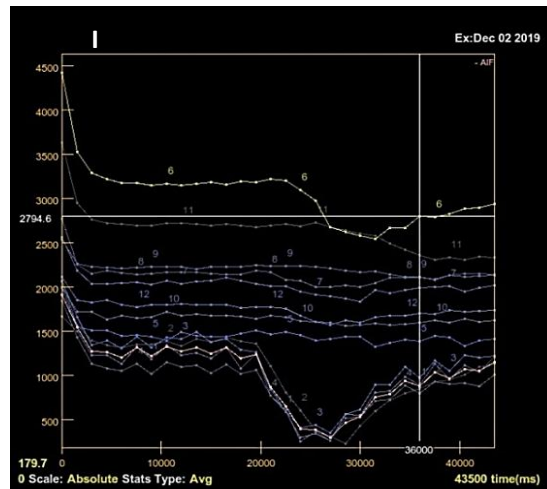


Figure (I): Signal intensity /time curve shows flattened curve that represented ROI which means absence of CBF.

of those strokes are ischemic. [25] That agrees with our results as 22 patients had Previous cardiac disease (73.3%) .

In the current study, Regarding to Hypertension, there was 13 patients (43.3%) suffering from Hypertension and 11 patients (36.6%) suffering from diabetes which in line with previous studies [26] which confirmed an independent effect of diabetes on ischemic stroke with an increased relative risk in diabetes ranging from 1-8 folds.

Also, Chalela et al. [27] found that high blood pressure is common in patients with type 2 diabetes and the combination of hyperglycemia and hypertension has been long believed to increase the frequency of diabetic complications including stroke.

In the current study, as regards to previous neurological examination, there were (6) Patients (20%) who had Motor weakness and Drowsiness and disorientation, 5 patients had Language disorder (16.6%), two cases had urine incontinence, 8 cases had Seizures and convulsions and 3 cases had Memory impairment while mixed findings were in 8 cases. Age and early neurological statuses are reasonable predictors and risk factors of stroke [28].

In general, patients with less initial impairment have better functional outcomes, but the prognosis for patients with more severe motor impairment is far more difficult to predict [29].

The story is similar for those with moderate to severe aphasia, suggesting that important factors for predicting the functional outcome [30].

A recent meta-analysis by [31] found that initial upper limb impairment and function, and the integrity of ascending and descending white matter pathways measured with neurophysiological and neuroimaging techniques, were the strongest predictors of subsequent recovery of upper limb function.

In our study, 25 patients (83.3%) were isointense in T1 and only 5 patients (16.6%) were low intense, in T2 there were 25 patients (83.3%) were high intense and only 5 patients (16.6%) were isointense. in FLAIR there were 24 patients (80%) were high intense and only 6 patients (20%) were isointense and DW1 all the cases show high signal also in ADC all the cases show low signal that was near to the results by Stinear and Ward 2012 [32].

The mean rCBV in the core was 0.33 ± 0.30 , the mean MTT was 1.24 ± 1.35 , while the mean rCBV in the peripheral was 2.67 ± 1.51 and the mean MTT in the peripheral was 1.46 ± 0.59 .

Kim et al. [33] initially studied patients in the first 10 h and showed abnormalities on MTT maps to be more extensive than on rCBV maps. Jahng et al., 2011 [34] showed that the size of the final infarct was grossly over-estimated on MTT maps, but correlated well with the extent of abnormality shown on rCBV maps.

In the present study, there was a highly significant difference in between CT, MRI, DWI in the diagnosis of acute stroke with $P= 0.001$. the sensitivity and specificity for DWI was 96.7, 98.5% respectively Balam et al. [35] demonstrated the very high sensitivity and specificity of DWI for the diagnosis of acute ischemia using the final clinical and imaging diagnoses as gold standards Tong et al. [36] demonstrated 100% sensitivity to ischemia with DWI versus 75% with CT within 6 hours. Because there was a time delay between the CT and MR studies in that project Kim et al. [33] undertook a randomized crossover comparison of DWI and CT within 6 hours of symptom onset, which demonstrated a sensitivity/specificity for DWI of 91%/95% versus 61%/65% for CT.

Its sensitivity in detecting ischemia is reported as 99% with a high specificity of 92%. Brazzelli et al. [26] Chalela et al., [27] Jauch et al. [37] Within minutes of vessel occlusion, failure of the sodium-potassium pump leads to an influx of water from the extracellular space to the intracellular space. Cytotoxic edema restricts diffusion of water molecules and appears as increased signal intensity on DWI [2].

Thus, DWI has emerged as the most sensitive and specific imaging technique for acute ischemia, far beyond NECT or any of the other MRI sequences.

There are a few anecdotal papers describing negative DWI studies when cerebral perfusion is decreased enough to produce infarction, as well as the reversal, partial or complete, of DWI abnormalities with restoration of perfusion [38]. Thus, DWI is not a simple indicator of irreversible infarction but a complex variable that requires more study. In addition, other conditions can produce restricted diffusion, such as infection (eg, abscesses, aggressive viral infections) and other inflammatory conditions (eg, aggressive demyelination), and certain tumors with either little cytoplasm (eg, lymphoma, meningioma) or with a complex internal architecture (epidermoid, some metastases) [39].

5. CONCLUSIONS

Both CT and MR imaging are useful for the comprehensive evaluation of acute stroke and can provide important and necessary information for therapy planning. Multimodal imaging provides information that is useful for diagnosing ischemic stroke, selecting appropriate patients

for thrombolytic therapy, and predicting the prognosis of ischemic stroke. Only depending on a single or a few parameters may not be sufficient, instead comprehensively combining the information from each MRI sequence (i.e., DWI, FLAIR, and PWI) and using various mismatch parameters (DWI-FLAIR mismatch and/or PWI-DWI mismatch) may be more helpful in establishing an indication of MRI-based thrombolysis.

CONSENT AND ETHICAL APPROVAL

The present study is a prospective one that was conducted on 30 patients who were suspected to have cerebral infarction and referred to the Radio diagnosis Department from the Neurology Department and outpatient neurological clinics of Tanta University Hospitals after approval Ethical Committee and obtaining written informed consent.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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