The Value of Magnetic Resonance Susceptibility-Weighted Imaging in the Early Detection of Hemorrhagic Transformation in Acute Stroke

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ABSTRACT:

BACKGROUND:

Stroke is rapidly increasing clinical signs of focal (or global) disturbance of cerebral function that last more than 24 hours. Magnetic Resonance Susceptibility-Weighted Imaging (MRI-SWI) is especially helpful in the detection of calcifications and micro-hemorrhages, which are both characterized by low signal. Thus allowing a significant improvement compared with T2* GE and other MRI sequences.

OBJECTIVE:

Study the value of MR SWI in the early detection of hemorrhage in an acute ischemic stroke and compare the findings of SWI with Gradient and conventional MR sequences.

PATIENTS AND METHODS:

This is a cross sectional analytic study was conducted between October 2016 to October 2017, at the MRI and Computed tomography (CT) units at Al-Imamian Al-Kadhimyian medical city, Baghdad, Iraq, 100 patients (64 males and 36 females) with signs and symptoms of acute stroke within 72 hours of attack and positive findings in Diffusion-weighted magnetic resonance imaging (DWI MRI). The ages ranged between 42 and 83 years (mean age 62.8 years old). Exclusion Criteria: patients with evidence hemorrhagic infarction in CT, patients with stroke-like symptoms but CT and MRI finding show findings not consistent with signs of stroke, patients with previous intracranial surgery or trauma that distort brain anatomy, patients with history of >72 hours, or show normal DWI sequence (no restriction), patients with unstable vital signs and the general MRI contraindication. CT was done in the emergency department, then an MRI study was done for all patients. MRI examination was done with the following sequences: T2 Weighted axial, Fluid attenuated inversion recovery (FLAIR) T2 coronal, T1 Weighted axial and sagittal, Diffusion-Weighted Image (DWI) Axial, Gradient Echo 2D axial T2*, and Venous Bold (SWI) in axial plane were done for all patients. Hemorrhagic transformation was diagnosed on the basis of the hypo intense blooming region in the infarct area on SWI. Statistical Analysis using SPSS 16.00 Statistical significance was considered whenever the p-value was equal or less than 0.05.

RESULTS:

In CT 90 patients (90%) have abnormal CT finding consistent with ischemia, 10 patients (10%) have normal CT, in all cases no hemorrhage nor calcification was detected. In MRI SWI 23 patients (23%) show areas of hemorrhage. In MRI GRADIENT sequence 20 patients show areas of hemorrhage (20%). In MRI T2 sequence 8 patients show areas of hemorrhage (8%). In MRI T1 sequence 3 patients show areas of hemorrhage (3%). SWI demonstrated 100% relative sensitivity.

CONCLUSION:

Susceptibility-Weighted Imaging (SWI) is an important and sensitive technique that permits early and accurate detection of hemorrhagic transformations within an area of acute cerebral infarction. SWI is more sensitive than 2D GRE T2WI, T2WI and T1WI.

KEYWORDS: Susceptibility-Weighted Imaging, hemorrhagic transformation, acute stroke

INTRODUCTION:

Stroke is rapidly increasing clinical signs of focal (or global) disturbance of cerebral function that last more than 24 hours [1]. There are two main types after excluding a subarachnoid hemorrhage, ischemic and hemorrhagic.

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Ischemic strokes are far more common (85%) than hemorrhagic strokes. Spontaneous hemorrhagic transformation occurs within the first few days in up to 15% of ischemic strokes. The incidence of symptomatic hemorrhagic transformation is, however, much lower, between 0.6 and 3% in untreated patients and up to 6% of patients treated with the antithrombotic agent [2]. The appearance of hemorrhagic transformation can be broadly classified as either infarction with petechial hemorrhage (89%) or intra infarct hematoma (11%) and this latter type can be confused with intracerebral hemorrhage (ICH) radiologically [3]. If hemorrhagic transformation complicates infarction, this follows secondary bleeding into areas of reperfused ischemic tissue; it is often seen within basal ganglia and cortex (with possibly a gyriform pattern [4].

Gradient echo (GRE) MRI has been demonstrated to be more sensitive than CT in detecting intracerebral hemorrhage (ICH), which is characterized as hypointensity on T2* weighted GRE magnitude images [5]. Susceptibility-weighted imaging (SWI) is a relatively new magnetic resonance (MR) technique that provides innovative sources of contrast enhancement visualizing the changes in magnetic susceptibility [6]; it offers information about any tissue that has a different susceptibility from its surrounding structures such as deoxygenated blood, hemosiderin, ferritin, and calcium [7]. Susceptibility-Weighted Imaging is therefore especially helpful in the detection of calcifications and micro-hemorrhages, which are both characterized by a low signal. Thus allowing a significant improvement compared with T2* GE sequences [6]. The susceptibility information adds valuable data to what is already available with conventional T1, and T2 weighted imaging [7]. Susceptibility-Weighted Imaging has continued to develop into a powerful clinical tool to visualize venous structures and iron in the brain and to study diverse pathologic conditions [8].

Susceptibility-Weighted Imaging may be used as an adjunct to localize the affected vascular territory further.

Susceptibility-Weighted Imaging, as a complementary sequence, can provide additional information by the following: Detecting acute thrombo-embolic that occlude arteries, Detecting a hemorrhagic component within the region of infarction, further helping to distinguish ischemic and hemorrhagic stroke, predicting the probability of hemorrhagic transformation before thrombolytic treatment by counting the number of microbleeds and early detection of hemorrhagic complication after intra-arterial thrombolysis, demonstrating areas of hypo perfusion [8].

AIMS OF THE STUDY:

Study the value of magnetic resonance (MR) susceptibility-weighted imaging (SWI) in the early detection of hemorrhage in an acute ischemic stroke and compare the findings of SWI with Gradient and conventional MR sequences.

PATIENTS AND METHODS:

3.1 Study Design: cross sectional analytic study was conducted in the period from October 2016 to October 2017, at the MRI and CT units of Al-Imamian Al-Kadhimyian medical city, Baghdad, Iraq, 135 patients were examined by MRI, 35 of them were excluded because no sign of acute stroke was seen in DWI MR Examination. The remaining 100 patients were included in the study; they constitute 64 males and 36 females, their ages ranged between 42 and 83 years with a mean age of 62.8 years old. Informed consent was obtained from all patients or their relatives.

Inclusion Criteria: patients with signs and symptoms of acute stroke within 72 hours of the attack and proved to have an acute ischemic stroke by finding abnormal DWI (restricted diffusion.

Exclusion Criteria: patients with positive finding of hemorrhage in the infarcted area in CT, patients with stroke-like symptoms, but CT and MRI finding show no signs of stroke and show other lesions like (neoplasm, abscess that cause mass effect with vasogenic edema and enhancing components, hemorrhagic stroke (hematoma), demyelinating disease … etc.), patients with previous intracranial surgery or trauma that distort brain anatomy, patients with history of >72 hours, or show normal DWI sequence (no restriction) on MRI examination, patients with unstable vital signs and the general MRI contraindication. All patients had signs and symptoms suggestive of acute stroke, CT was done in the emergency department, then MRI study was done for all patients and only those with positive DWI (high signal and low ADC) were included in this study.

3.2 MRI Examination: the MR examinations were performed using Achieva 3 Tesla MR Scanner (Phillips medical System the Netherlands) using a 16 element phased array encoding (SENSE) head coil. All patients were examined in the supine position; the examination was done without the use of Intravenous contrast with the following sequences: T2 Weighted imaging in axial plane (field of view 230mm, matrix 256, slice thickness 5mm, voxel size 0.9/0.9/5, Turbo factor 16, Repetition Time 4400 millisecond (m sec), Echo Time 100 m sec, number of signal- averaged 1, bandwidth/ pixel (Hertz) 184, flip angle 90 degree, acquisition time 2 minutes (min) plus 20 seconds (sec)), Fluid-attenuated inversion recovery (FLAIR) T2 in coronal plane with the following parameters: (TR/TE = 11000/120ms and; TI, 2600 m s), T1 Weighted imaging in axial and sagittal planes (Field of view 230 mm, Matrix 256, Slice Thickness 5mm, Voxel size 0.9/0.9/5 mm/turbo factor 16, Repetition Time 600 m sec, Echo Time 15 m sec, number of signal-averaged 1, Bandwidth/pixel (Hertz) 184, Flip angle 69 degrees, acquisition time of 3 min 23 s,).

Diffusion-weighted Image (DWI) Axial DWI which obtained using a single shot echo-planar imaging (b=1000 s/mm2, 5mm slices thickness, TR/TE=1000/100ms), Apparent diffusion coefficient (ADC) values were calculated at b value =1000s/mm2. Gradient Echo 2D axial T2*-weighted images (Field of View 230mm, Repetition time 500 m sec, Echo Time 18 m sec (TR/ TE _ 500/18 m sec), flip angle (FA) _ 15°, Slice thickness 4 mm, matrix 256, acquisition time of 4 min 23 sec, with FOV varying according to patient basically 230mm). Venous Bold (SWI) in the axial plane (Field of View 230mm, Matrix 256, slice thickness 2mm, repetition time 17 m sec; echo time 24 m sec, flip angle 15, acquisition time 5min and 32 sec).

3.3 Image Interpretation: the images were viewed by two independent radiologists. The diagnosis of acute infarction as a hypo dense region in CT scan, a hypo intense region in T1WI, a hyper intense region in T2WI, a hyper intense region in DWI and low intense region in ADC. The hemorrhagic transformation was diagnosed on the basis of a Hypo intense blooming region in the infarct area on SWI, ISO to the hyper intense areas on T1-weighted sequence, heterogeneous increased signal intensity in the infarct area on T2-weighted and FLAIR was considered hemorrhage. Although SWI images are often displayed as maximum intensity projections, only source images were used in this study because they provided greater conspicuity of the white matter lesions including hemorrhage, the majority of the small veins are easily distinguishable from hemorrhages by their homogeneous curvilinear pattern. This is further aided by several contiguous images are reviewed to follow a vessel. It should be noted that the examination was done at 3Tesla power field of the magnet because at high fields, such as 3T the coverage can be immediately doubled, in the same scanning time, with an improvement in signal-to-noise ratio (SNR) of 2.

3.4 Statistical Analysis: the collecting data were tabulated and analyzed using an available package of SPSS 16.00 (Statistical Package for Social Sciences version 16), ChiSquare Test was used to compare the number of a positive finding of hemorrhage among MRI sequences (SWI, T2W1, T2 FLAIR, and GRE-T2* WI). Statistical significance was considered whenever the probability of (p-value) was equal or less than 0.05 and the calculation of sensitivity for each sequence.

RESULTS:

This study included 100 patients, 64 were male and 36 were female with a male: female ratio of 1.8:1. Age range from 42-83 years, mean age 62.8 years.

In CT: 90 patients (90%) have abnormal CT finding consistent with ischemia and represented as hypo dense regions, 10 patients (10%) have normal CT. In all cases, no hemorrhage nor calcification was detected. In MRI SWI: 23 patients (23%) show areas of hemorrhage as hypointense region within the area of infarction (16 patients were male (25%) and 7 patients were female (19.4%)). In MRI GRADIENT sequence: 20 patients show areas of hemorrhage (20%) as hypointense regions within the area of infarction. In MRI T2sequence: 8 patients show areas of hemorrhage (8%) as hypointense area within the region of infarction. In MRI T1 sequence: 3 patients show areas of hemorrhage (3%) as ISO to the hyperintense area in the region of infarction. All these findings were shown in table I.

Table I: Incidence of hemorrhagic transformation in different MRI sequences in the 100 patients with acute stroke.

	SWI	GRADIENT	T2 W1	T1
Hemorrhage	23	20	8	3
No Hemorrhage	77	80	92	97
Total	100	100	100	100

SWI demonstrated 100% relative sensitivity, as it identified hemorrhage in positive cases. SWI detected hemorrhage in 3 additional cases that were not positively identified in 2D-GRADIENT T2*, and 15 Additional cases were not positively identified in conventional SE T2WI and 20 cases were not identified by T1, comparing GRADIENT, T2, T1 to SWI in the sensitivity was 87%, and 34%,13% respectively, in the detection of hemorrhage in these 23 patients within acute infarct.

Figures 1 and 2 show some cases of this study:

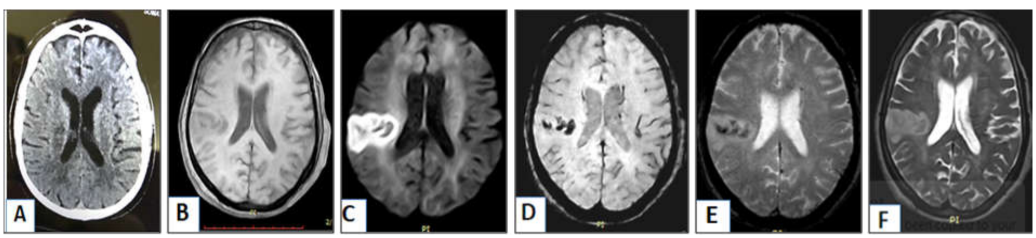

Figure (1): 60 years old female presented with left-sided weakness.
A: axial brain CT scan showing: loss clarity and hypo density of the right lentiform nucleus.
B: MRI axial T1 hypo intense signal.
C: MRI DWI showing restricted diffusion in the right parietal lobe.
D: MRI axial SWI showing a blooming effect in the infarcted region
E: MRI axial Gradient mild hypo intense signal.
F: MRI axial T2 hyper intense signal.

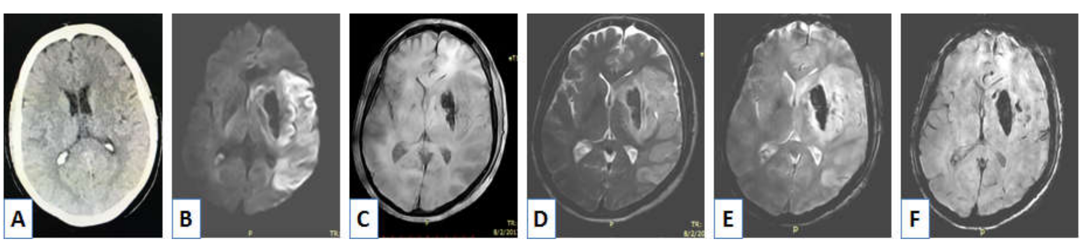

Figure (2): 53 years old male presented with right-sided weakness.
A: axial brain CT scan shows a loss of clarity of the left lentiform nucleus.
B: MRI axial DWI show restricted diffusion and central part showing hypo intense signal,
C: MRI axial T1WI shows hypo intense region in the left parito-temporal region,
D: MRI axial T2WI there is hyper intense area in the left parietal region with central low signal area,
E: MRI axial Gradient sequence with a blooming effect in the region of infarction,
F: MRI axial SWI sequence with larger area of a blooming effect denoting hemorrhagic transformation in the region of infarction.

DISCUSSION:

Imaging studies can confirm the diagnosis of acute infarction and differentiate hemorrhage from ischemia with high accuracy. This distinction is extremely important, as the treatment decisions are dependent on this [7]. On another hand, accurate detection of hemorrhage in ischemic stroke is crucial because hemorrhage is a contraindication to the use of anticoagulant, antiplatelet and thrombolytic agents in the acute stroke setting [9]. MRI is sufficient in the initial workup of stroke patients for evaluation of possible thrombolytic therapy [8], [10].

Indeed, many studies show that SWI can detect hemorrhagic transformation earlier than CT [11], [12]. SWI sequence was used to detect the presence of micro bleeds or hemorrhagic transformation of infarctions in order to prevent the use of a conventional dose of anti-platelets and anticoagulants aiming to avoid serious hemorrhage [7], [13], [14]. Characterization of the hemorrhage by the signal changes seen on T1-weighted, T2-weighted, Gradient, and SWI was done. In this study hemorrhagic transformation detected in acute infarction is seen in 23 (23%) of 100 patients using SWI, male was more commonly affected than female (25%and 19.4% respectively), while the T2 WI detected hemorrhagic transformation in 8 patients (8%), this was in agreement with many reported studies, Wycliffe et al. [15] shows that SWI is more sensitive than T2WI in the detection of hemorrhagic transformation (SWI 42% and T2WI 21%). Another study was done by RanojiShivaji Mane et al [16] detected hemorrhagic transformation by SWI more than T2WI (34% versus 12% in T2WI). This higher number of patients with hemorrhagic transformation in the above two studies can be attributed to the inclusion of patients with positive hemorrhage in CT scan which were excluded in our study.

Susceptibility-Weighted Imaging is more sensitive in detecting hemorrhagic transformation than 2D GRE T2* weighted imaging which detects only 20 patients (20%). This was in agreement with a previous study done by Wycliffe et al. (15) shows that SWI detect hemorrhagic transformation compared to 2D GRE T2WI (58% versus 41% of their patients), the higher number of patients with hemorrhagic transformation in this study because their patients receive intravenous thrombolytic agent in the first aid of stroke. Another study was done by Shams et al [17] shows similar results in which SWI is more sensitive compared to GRE (20% versus 17%). Cheng et al [18] showed similar results in which SWI was more sensitive compared to GRE (40% versus 23%). The higher percentage of micro bleed in the last study may be related to sampling bias because their sample included some of the patients with Alzheimer and the incidence of cerebral amyloid angiopathy in patients with Alzheimer disease is up to 98% [19].

Hyper intense areas seen on a T1-weighted sequence that is suggestive of hemorrhage in acute infarction was seen in 3 patients and so SWI was significantly superior to the T1-weighted. This result is in agreement with a study was done by RanojiShivaji Mane et al [16] that detects hemorrhagic transformation in the ischemic region in 34% by SWI compared to 4.8%in T1WI. In our study, there is an increased incidence of hemorrhagic transformation among the male gender compared to females. This increase was similar to a previous study done by L_Shao et al [13] that shows the same according to age group. We found that there is an increase in the number of cases with hemorrhagic transformation in the old age group mainly detected by SWI at the age group of (70-79 years). A previous study was done by L_Shao et al [13] showed the same result in that old age and male gender are risk factors for increase cerebral micro bleed and hemorrhagic transformation in the infarcted region and their result mainly in aged 57-77 years. The main limitation of our study is that discrimination between calcification and hemorrhage is not straightforward with SWI as both of them demonstrate blooming. SWI image is a combined magnitude image with phase filtered image, the differentiation between the two (calcium and iron) is by using filtered phase image alone, Filtered phase images are not uniformly windowed or presented by all manufacturers and as such care must be taken to ensure correct interpretation. Another limitation of SWI techniques is that it is difficult to differentiate small venous structures from small hemorrhages and thrombosis because the signal characteristics are similar. However, sequential SWI imaging pre- and post-contrast agent administration, or analysis of the phase pattern (patent venous vessels show unique phase characteristics) can mitigate this disadvantage.

CONCLUSIONS:

Susceptibility-weighted imaging (SWI) is an important and sensitive technique that permits early and accurate detection of hemorrhagic transformations within an area of acute cerebral infarction. SWI is more sensitive than 2D GRE T2WI, T2WI and T1WI in the detection of early hemorrhagic transformation within an area of acute cerebral infarction. Males and Older age group (>70 years old) susceptible to develop hemorrhagic transformation.

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