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The Role of Susceptibility Weighted Imaging (SWI) in Evaluation of Acute Stroke

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ABSTRACT

Background and Objectives: SWI provides information about blood oxygenation levels in intracranial vessels. Prior reports have shown that SWI focusing on venous drainage can provide noninvasive information about the degree of brain perfusion in arterialischemic stroke. We aimed to evaluate the influence of the SWI venous signal pattern in predicting stroke evolution.

Materials and Methods: a semiquantitative analysis of venous signal intensity on SWI and diffusion characteristics on DTI was performed in 2o adult patients with acute stroke of MCA vascular territories. The mismatch between areas with SWI-hypointense venous signal and restricted diffusion was correlated with stroke progression on follow-up.

Results: we included 2O patients with a confirmed diagnosis of arterial ischemic stroke. Follow-up images were available for. MCA stroke progression on follow-up was observed in 11/12 patient with DWI -SWI mismatch. Initial SWI hypointense venous signal and areas of restricted diffusion on DTI. This mismatch showed a statistically significant association (P _ 0.00188) for infarct progression.

Conclusion: SWI-DWI mismatch predicts stroke progression in arterial ischemic stroke.

Keywords: stroke, MRI, Susceptibility weighted imaging (SWI), (PWI), DWI.

INTRODUCTION

A stroke is caused by the interruption of the blood supply to the brain, usually because a blood vessel bursts or is blocked by a clot. This cuts off the supply of oxygen and nutrients, causing damage to the brain tissue [(1)]. The effects of a stroke depend on which part of the brain is injured and how severely it is affected. A very severe stroke can cause sudden death, so predicting the risk of further infarct growth in stroke patients is critical to therapeutic decision making [(2)]. Contemporary therapy for acute ischemic stroke is based on the concept of penumbra, which is an area with reduced blood flow but not to such a level that causes irreversible cell membrane failure. Although challenged by several limitations, mismatch between larger abnormal areas on MR perfusion-weighted imaging (PWI) and smaller restricted areas on diffusion-weighted imaging (DWI) is a widely accepted approach to detecting penumbra, predicting stroke evolution and determining patients with the greatest potential to benefit from thrombolytic therapy. However, PWI requires administration of a contrast agent, which is contraindicated in a variety of clinical conditions, such as renal insufficiency and previous reactions to contrast agents [(3)]. Susceptibility-weighted imaging (SWI) which is a high-resolution, three-dimensional, gradient-echo T2* MR technique with enhanced sensitivity for paramagnetic substances is a potential alternative for detecting ischemic penumbra and thus predicting infarct growth. In the ischemic brain, the increased oxygen extraction fraction and slow flow contribute to a higher level of deoxyhemoglobin and vein dilatation, which increases the conspicuity of vessels on SWI. As a result, SWI can show asymmetric prominent hypointense vessels potentially from different concentrations of deoxyhemoglobin between ischemic and normal brain areas. This potential metabolic information on SWI may help to delineate penumbra without contrast agent administration [(4)]. Recently, a study on pediatric arterial ischemic stroke has reported that SWI/DWI mismatch is useful in detecting penumbra in middle cerebral artery (MCA) infarct, thus predicting progression of infarction on follow-up images [(5)].

AIM OF THE WORK

This study aims to assess the diagnostic value of SWI-DWI mismatch in detecting ischemic penumbra, and predicting early infarct growth in patients with acute MCA territory ischemic stroke.

PATIENTS AND METHODS

Patients: During a period of 8 months duration from October 2017, twenty patients were enrolled in the study. All patients presented clinically with acute stroke. **The study was approved by the Ethics Board of Ain Shams University and an informed written consent was taken from each participant in the study.** ***Inclusion criteria:*** Patients with radiological evidence of acute non-lacunar ischemic infarct in the territory of the middle cerebral artery presenting within not less than 6 hours and not

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more than 24 hours of symptom onset, both sexes were included, adults only (From 18 to 75 year old). ***Exclusion criteria:*** patients known to have contraindications for MRI, e.g. an implanted magnetic device, pacemakers or claustrophobia, patients potentially eligible for receiving RTP or thrombectomy (those presenting within 6 hours of symptom onset), patients with bad general condition needing life support, patients with hemorrhagic transformation of the infarction, ***Histopathological Analysis:*** the histology was reviewed by an experienced pathologist. ***MRI imaging:*** Selected patients were imaged by MRI stroke protocol which includes the following sequences: T1WI (Tr =120, Te = 21), T2WI (Tr = 5288, Te = 120), FLAIR (Tr = 1100/2800, Te = 130). DWI and ADC maps (Tr = 3580, Te = 112), MRA(Tr = 17, Te = 6.9). High resolution SWI sequence will be then be added with the following parameters: TR/TE 24/34, flip angle 10, Post-processing will be performed and MIP images will be generated during the exam. Follow-up MR fluid-attenuated inversion recovery (FLAIR) and T2 weighted images will be obtained at least 7 days later if the patient's condition is stable or earlier if the clinical condition worsens for assessment of final infarct (FI) size. ***MRI data analysis:*** A 10-point semi-quantitative CT scoring system, Alberta Stroke Program Early CT Score (ASPECTS) will be used to assess the extent of abnormal signal intensities on individual DWI, SWI, and follow up FLAIR images, for calculating ASPECTS values, 1 point is subtracted from 10 for each area of abnormal signal as follows, on DWI, 1 point will be subtracted from 10 for each area of infarction (which is defined as an area of high signal intensity on DWI with dark signal intensity on ADC), on SWI, 1 point will be subtracted from 10 for each area displaying asymmetric prominent vessels on SWI, defined as a local prominence of hypo intense vessels with either increased vessel number or diameter in the target area (MCA territory), when compared with the contralateral normal side. On follow up FLAIR images, 1 point will be subtracted from 10 for each area of hyperintensity. ***Statistical analysis:*** According to the relationship between ASPECTS values on initial DWI and FI studies, patients will be classified as infarct growth (IG) group (DWI > FI), non-infarct growth (NIG) group (DWI = FI), or DWI reversal group (DWI < FI). SWI-DWI Mismatches will be determined if DWI ASPECTS values is greater than SWI ASPECTS values, aspects values of different sequences will be compared to one another in each group and across different groups, aspect scores of different sequences will be compared to aspects scores of final infarct on follow up images as well as infarct growth, SWI-DWI mismatches will be compared to infarct growth, Statistical tests were used to determine statistically significant correlations and differences, results were displayed in form of tables and graphs.

RESULTS

Twenty-adult patients (11 females) were included in our study. The median age of patients was 57 years (range, 45 t0 74years), The average PSI (prediagnostic symptomatic interval) was 10 hours (range, 3 to 24 hour). None of the patients had acute thrombolytic therapy.

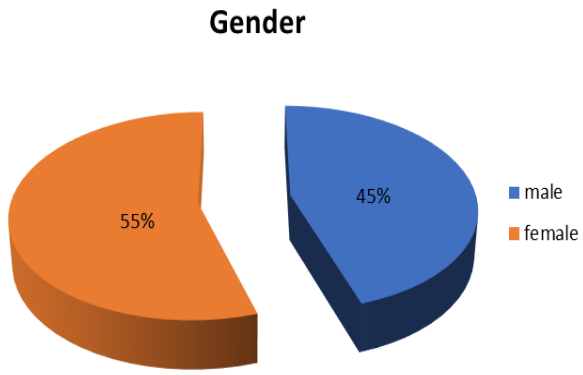

Figure (1): The results of the semiquantitative evaluation of acute DTI, SWI, and T2 data are shown.

Follow-up neuroimaging studies WITH T2 and FLAIR were available and were performed, on average 7 days after acute neuroimaging (range, 5 day to 14 days). In the acute neuroimaging studies, a mismatch between SWI and DWI was found in 12 patients (60%). The number of vascular territories with SWI-hypointense venous signal was greater than the number of vascular territories with restricted diffusion in 12 patients (60%) and equal in 8 patients (40%). In 8 patient (40%), the vascular territories with SWI-hypointense venous signal and restricted diffusion matched. A mismatch between SWI and ASL was found in 11patients (55%). In 1 patient, the vascular territories with SWI-hypointense venous signal and reduced perfusion matched perfectly. The results of the semiquantitative evaluation of acute DTI, SWI, and T2 /FLAIR data of 20 patients with a stroke

within at least 1 of the 10 regions of the right MCA territory was found in17 patient (85%).

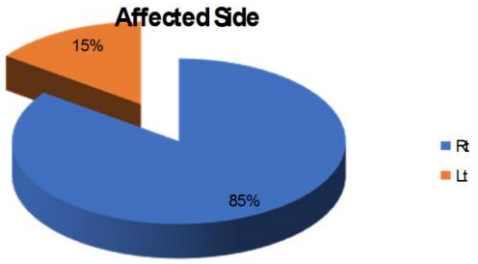

Figure (2): Follow-up images were available for all patients included in the statistical analysis. A mismatch between SWI hypointense veins with vascular territories greater than those on DTI was found in12 patient, of which 11 patient showed infarct progression. A match between SWI hypointense veins with vascular territories was found in 8 patients.

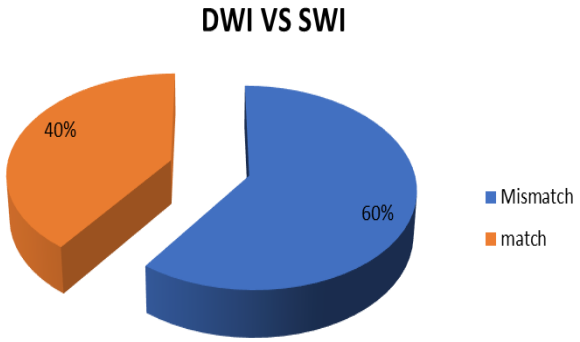

Figure (3): This mismatch between SWI and DTI was significantly associated with stroke progression on follow-up imaging (*P* _0.00188).

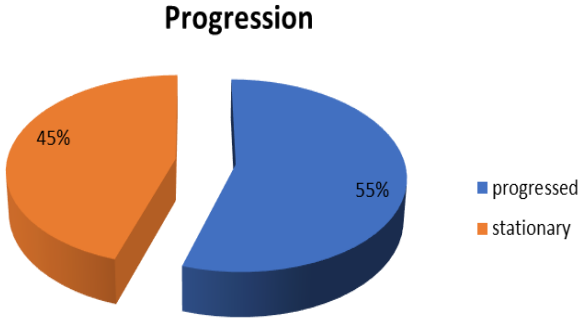

Figure (4): Progression.

Table (1): Wilcoxon Signed-Rank Test

Wilcoxon Signed-Rank Test			
	Z Value	**P Value**	**Significance**
DWI VS SWI	-3.1074	0.00188	S
DWI VS T2	-2.9341	0.00338	S
SWI VS T2 *	-1.1558	0.24604	NS
SWI VS T2	-0.7645	0.44726	NS

DISCUSSION

SWI has been increasingly shown to be a useful non-contrast enhanced imaging sequence in the evaluation of acute stroke [5]. ***SWI may do the following:*** Detect hemorrhagic components within infarcted tissue with higher sensitivity than other MR imaging sequences or imaging modalities [6]. 1) Demonstrate hypointense signals in the veins draining hypoperfused areas and evaluate the ischemic penumbra by focusing on the venous drainage [7]. 2) Show hyperintense signal in the veins draining regions of hyperperfusion or luxury perfusion indicating an increased risk of developing postischemic malignant edema [8]. 3) Detect acute occlusive arterial thromboemboli [9]. 4) Quantify microhemorrhages and predict hemorrhagic transformation before thrombolytic [10]. Ischemic penumbra is characterized by hypoperfused brain tissue with the potential for functional recovery without morphologic damage [11]. This is possible if local blood flow can be reestablished at a sufficient level within a certain time interval. The identification of the ischemic penumbra is important because it represents tissue that could potentially be salvaged with the use of thrombolytic therapy. Although the benefit of thrombolytic therapy in acute stroke has yet to be demonstrated in prospective clinical trials, retrospective studies show that at least a subset of patients with AIS may potentially benefit from it [12]. Thrombolysis in Stroke trial. Ischemic penumbra can be depicted as a mismatch between reduced perfusion and normal diffusion by combining PWI and DWI/DTI.23. However, the routine application of PWI outside research protocols and tertiary care centers is still limited. DSC-PWI requires a rapid bolus injection of intravenous paramagnetic contrast agents that may delay acute antithrombotic therapy. ASL is a non-contrast-enhanced PWI method capable of measuring tissue perfusion by using blood as an endogenous “contrast” agent. ASL is not routinely performed in the acute setting because of the low SNR and limited spatial resolution. In addition, changes in signal intensity on ASL may be determined by factors other than reduced flow or ischemia, and knowledge of ASL-related artifacts is crucial for accurate interpretation [12]. The relationship between CBF and the oxygen extraction fraction (OEF) has been shown in both animal stroke models and humans by using PET,

and 4 patterns have been observed in focal brain ischemia. In the first pattern, an increase in CBV was observed to maintain CBF in response to physiologic conditions or demands (autoregulation). The second pattern is an increase of OEF to maintain a stable cerebral metabolic rate of oxygen (CMRO2) in response to a reduction of CBF. The third pattern is characterized by an increase of OEF in brain regions with reduction of both CBF andCMRO2 and represents ischemic penumbra [(13)]. The fourth pattern represents the infarct core and is characterized by very low CBF andCMRO2 with poor OEF. SWI accentuates the magnetic susceptibility differences between deoxygenated hemoglobin in the vessels and adjacent oxygenated tissues and is an ideal MR imaging sequence to depict changes in OEF noninvasively. In a retrospective study including 15 adult patients with Non lacunar ischemic stroke, ***Kao et al.*** [(14)] showed that both SWIDWI and PWI (MTT)-DWI mismatches were significantly associated with a higher incidence of infarct progression and had a similar ability to predict stroke evolution. In addition, they showed that semiquantitative evaluation of SWI patterns and MTT values correlated best in the MCA territories. The authors concluded that SWI is an alternative to PWI to assess ischemic penumbra and predict stroke evolution. In children, the role of SWI in depicting the ischemic penumbra was previously shown only in a small case series and a few case reports [(15)]. Also in aretro spective study including 24 children with acute non lacunar infarcts, ***Polan et al.*** [(16)] showed that SWI/DWI mismatch was significantly assosciated with higher incidence of infarcts progression. In our present study, we found a mismatch between vascular territories with SWI-hypointense venous signal and restricted diffusion in 12 patients. In 11 of them, stroke progression was observed at follow up. By contrast, no stroke progression on follow-up was found in Patients without SWI-DTI mismatch. Our results show that a mismatch between vascular territories with SWI-hypointense venous signal and restricted diffusion is significantly associated with infarct progression in acute stroke. ***Our present study had several limitations;*** The number of patients was still small, also, the study was retrospective; images were evaluated using a semi-quantitative approach (approximate measurements may be difficult to reproduce), the difference in slice thickness between DWI and minIP SWI images may have caused partial misregistration, some patients with a serious acute ischemic stroke were uncooperative during the examination, and this led to some mobile false images and deviations in judgment, the scan time of SWI was long (5to 8 min), that some patients with serious clinical symptoms cannot remain stationary in the whole examination, it may produce some motion artifacts and then affected the image interpretation.

CONCLUSION

Susceptibility-weighted imaging (SWI) which is a high-resolution, three-dimensional, gradient-echo T2* MR technique with enhanced sensitivity for paramagnetic substances is a potential alternative for detecting ischemic penumbra and thus predicting infarct growth. In the ischemic brain, the increased oxygen extraction fraction and slow flow contribute to a higher level of deoxyhemoglobin and vein dilatation, which increases the conspicuity of vessels on SWI. As a result, SWI can show asymmetric prominent hypointense vessels potentially from different concentrations of deoxyhemoglobin between ischemic and normal brain areas. This potential metabolic information on SWI may help to delineate penumbra without contrast agent administration.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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