Susceptibility weighted imaging in acute stroke with co-morbids: Magnetic resonance imaging protocol revisited

Abstract

Introduction:

We aim to investigate ischemic penumbra using Diffusion weighted imaging- Susceptibility weighted imaging mismatch using DWI Alberta Stroke Program Early Computed tomography Stroke Score scoring in patients with multiple co morbid.

Methods:

From January 2011 to December, 2017; 70 consecutive patients (50 men, 20 women; mean age 64.5; range 45-82 years) with acute infarct on Diffusion weighted imaging (DWI) were selected for the study. Stroke protocol performed including DWI and susceptibility weighted imaging (SWI) on first day and repeat within three days. All initial MR images were interpreted by one Neuroradiologist with more than ten years blind to the clinical findings of each patient. The definition of an acute infarct area was high signal intensity on DWI with dark signal intensity on Apparent diffusion weighted imaging (ADC). The infarct extent was scored using the Alberta Stroke Program Early CT Score (ASPECTS) system. Infarct growth was defined as any new or larger lesion on the second DWI.

For correlation with infarct growth, the same topographic system was used to record the extent of the Prominent vessel sign(PVS) on SWI.

Spearman's rank correlation test was used to examine the correlations between PVS score and infarct growth score. Regression was computed, with $P<0.05$ considered significant.

Results:

The study included 12 women and 10 men, (mean age 67.1 years).

MRI images were initially acquired as stroke protocol (mean 12 hours) in acute stage and the next MRI was done within 3 days after the acute stage.

9 patients had right sided and 13 patients had left sided MCA territory infarct, the mean DWI-ASPECTS score was 4.3 (range 0–9). PVS was detected in 15 patients (mean score 4.1, range 0–10).

Out of 22 patients 9 patients showed no evolution in infarct however in 13 patients evolution was from (ASPECTS mean score 3.95, range 0–9; mean infarct growth score 7.4, range 0–10).

7 patients devoid of PVS in initial MRI, did not exhibited evolution of infarction. Of 15 patients with PVS on initial MRI, 13 (87%) had infarct growth. Correlation between the evolution in infarct size and PVS score was observed ($r = 0.86, P<0.001$).

Conclusion:

PVS seen in infarcted territory is related to poor prognosis and this can be reliably used as a surrogate marker of oxygen extraction in penumbra.

SWI can predict tissue at risk and can be a replacement for perfusion scan in clinical scenerio of acute ischaemic infarct.

Keywords stroke, magnetic resonance imaging, diffusion magnetic resonance imaging

Introduction

The estimated annual incidence of stroke in Pakistan is 250/100,000 population which is projected to an estimate of 350,000 new cases each year [1].

In another developing neighbor country like India stroke prevalence is (479.86–617.05) per 100,000 population with deaths occurring within 30 days ranging between (30.66–53.80)[31].

The role of imaging in triage for of acute stroke is to rule out haemorrhage or ischemic infarction and selection of ischaemic stroke patients for available reperfusion therapies [2].

Choice of imaging modality for a stroke should allow patients to be selected for thrombolytic therapy for safety and efficacy.

3 hour window for IV-TPA (tissue plasminogen activator) administration in non-hemorrhagic stroke is the protocol described by 1995 National Institute of Neurological Disorders and Stroke (NINDS) trial, for non-hemorrhagic strokes [3].

However, infarct core and penumbra is desired for selection of reperfusion options as well as to prognosticate [4].Options for penumbra detection currently used and have several controversies are CT or MR with perfusion. These were particularly advised when mechanical thrombectomy is the plan [5].

Response to thrombolysis after early reperfusion is favorably predicted by PWI and DWI mismatch, and can be used as a substitute for ischemic penumbra [6] but estimation of infarct growth or clinical outcome is debatable and has been questioned [7].

Additionally, there are limitations to the use of perfusion studies in patients with renal insufficiency because contrast is used.

Potential alternative for prediction of growth in infarct is Susceptibility-weighted imaging (SWI). In brain ischemia, the augmented oxygen extraction fraction and limited flow contribute to higher levels of deoxyhemoglobin and vein dilatation, causing greater vascular conspicuity on SWI [8].

Kaya et al. [8] recognized multiple hypointense vessels noticeably during hyperacute phase of stroke in the ischemic territory on gradient T2* [9] but Haacke et al [10] worked on high resolution 1.5 T system for SWI, it enriched the susceptibility effect more than the T2*. The area was bigger than depicted on DWI and related well with the absolute infarct after 72 hours.

Divergence between SWI/DWI has also been suggested as a prospective indicator of infarct growth in some reports [11]

Using a similar approach, we aim to investigate pneumbra mainly DWI- SWI mismatch using ASPECT scoring. To our knowledge no such study has been conducted so far on national level.

Materials & Methods

Study Location: Department of imaging, Aga Khan University hospital, Karachi, Pakistan.

Study Design:

Our institutional data base was used retrospectively to collect the cases and then those cases were prospectively evaluated as a *hypothesis-driven scientific study.* Study design was Cross-sectional analytical from January 2011 to December, 2017. The assessment was directed in accordance with guidelines of the research committee of our institution.

Inclusion criteria: Imaging with stroke protocol on first day including DWI and SWI sequences. Acute infarct on DWI in MCA territory and repeat DWI within three days. *Exclusion criteria*: Tissue plasminogen activator (TPA) given, Hemorrhagic infarction on initial presentation or Watershed infarcts/Posterior circulation infarcts.

Patient: 70 consecutive patients were extracted from the hospital data base (50 men, 20 women; mean age 64.5; range 45-82 years) 22 patient met the inclusion criteria, 12 women and 10 men, (mean age 67.1 years).

Inclusion criteria:

Acute infarct on DWI in MCA territory.

Stroke protocol performed including DWI and SWI on first day.

Repeat DWI with in three days.

Exclusion criteria:

Tissue plasminogen activator (TPA) given.

Haemorrhagic infarction on initial presentation.

Watershed infarcts/Posterior circulation infarcts

Sampling technique: Non-probability purposive

Imaging techniqueScanners: 1.5 T scanner (Magnetom Avanto; Siemens Medical Solutions, Erlangen, Germany) and 3T (Titan,Toshiba)with a standard 12-channel head coil. [7]

Stroke protocol: After routine axial T2W Only DWI and SWI sequences were performed in first encounter after triage.

For the DWI sequences, (with TR/TE = 3700/109 ms, b = 1000 s/mm2, slice thickness = 5 mm, slice number = 28, and matrix = 128x128) and generated ADC maps. [7]

For the transverse 3-dimensional (3D) SWI sequences, TR/TE = 49/ 40 ms, flip angle = 15°, slice thickness = 2 mm with 60 sections per slab, matrix = 224×256, 64 slices, and (integrated parallel acquisition technique (iPAT) acceleration factor = 2. The phase, magnitude (mag), minIP, and SWI images were uploaded and made available on a picture archiving and communication (PACS) system (Rogan). [7]

The total scan time for stroke protocol was 5-6 mins. Follow up scan was performed within 3 days with axial T1W, T2W, Coronal FLAIR, DWI, SWI AND Time Of flight MR angiogram of the circle of Willis.

Image interpretation: Neuroradiologist with more than ten years of expertise and Neuroimaging fellow, read the MRI scans. These scans were blinded with the clinical findings.

MRI Image analysis;

Acute stroke is defined as high signal intensity on DWI sequence and low signals on corresponding ADC sequence. [24]

A semi quantitative 10 points scoring system, the Alberta Stroke Program Early CT Score (ASPECTS) was used to score the infarct, it is a well-established and investigated assessment system to quantify the extent of ischemic changes and to foretell the functional outcome in patients with acute ischemic stroke.[12]

It is a 10 point scoring system, and each point is allocated to the MCA territory zones. A normal brain scores 10 while 0 score is given to brain with diffuse infarction [13]

The integration of ASPECT score to DWI imaging in stroke extended and it adds to predict outcome and rapid risk assessment before thrombolytic therapy.[14]

Growth in infarct was defined as any new or bigger lesion on follow-up DWI.

PVS on SWI was defined as the local prominence of hypo-intense vessels with either an increased number of vascular vessels or an increased diameter in the target area relative to the non-target area.

MCA territory in the infarction side was the target area, in the study.

The PVS of the lower MCA-territory (cortical or medullary vessels) were logged as (M1, M2, or M3), (higher MCA-territory) as M4, M5, or M6), insular as (I), thalamostriate as (C, L or IC) as they drain via caudate nucleus, lentiform nucleus, and internal capsule. [7]

A PVS score of 0 to 10 was given once both the readers reached a consensus.

Statistical Analysis: SPSS, version 19.0 was used. (SPSS, Chicago, IL, USA). Mean and standard deviation of PVS scores, DWI-ASPECTS scores, and infarct growth scores were calculated.

Spearman's rank correlation test was used to examine the correlations between PVS score and infarct growth score. Regression was computed, with $P<0.05$ considered significant.

Results

The study included 12 women and 10 men, (mean age 67.1 years).

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Similar results were observed in recently published studies on pediatric arterial ischemic stroke by Polan,RM, .et al [13] and SWI/DWI mismatch as predicting ischemic stroke studied by Chia,Yuen ,.et al. [7].

Discussion

Our study revealed that PVC on SWI is an indicator for ischemic tissue salvation that will transform to infarction if timely blood perfusion id not established. Our results were comparable eith previous studies by,s KesavadasC, et al.Jneurol [15].KaoHW et al. Euro Radiol [16], HuangP, et al. Neurol [17], Baik et al. CerebrovascDis [18], YamashitaE, et al Acta Radiol [19].

Similar results were observed in recently published studies on pediatric arterial ischemic stroke by Polan,RM, .et al [13] and SWI/DWI mismatch as predicting ischemic stroke studied by Chia,Yuen ,.et al. [7].

The PVS had a positive predictive rate of 87% and a negative predictive rate of 100%.

Not only veins but PVS can reflect small arteries with deoxyhemoglobin blood in the Penumbra area. Consistent with previous SWI studies [13, 16, 17], our study of 22 patients showed PVS in 15, microbleed in 6, and intra-arterial thrombus in 9. A lower microbleed rate would be expected, with parenchymal hemorrhage used as an exclusion criterion.

Only two patients (25%) with infarct growth in the lentiform nucleus, internal capsule, or caudate nucleus had PVS, which can be explained by the admixed venous flow in the thalamostriate vein, which drains not only these structures, but also the thalamus. Notable association between extent of PVS and growth of infarction was also observed.

The affected zones (M1-M6) of the MCA territory correlated with the PVS extent constantly, showing DWI/SWI mismatch a predictor of evolution in stroke [7].

In Baik's study[18], recanalization improved the outcome clinically ostensible normalization of PVS in veins. A case report [22] suggesting hyperperfusion, described by SWI intensity change of the draining veins as a contributor to development of post ischemic malignant edema [23-25].

In our study, the magnitude of penumbra can be recognized by the range of PVS, Therefore a greater volume of tissue can be salvaged if it is correlated with the PVS.

Limitations:

– Small patient number.

– PWI or arterial spin labeling was not performed.

– Patient with poor outcome or who died.

– Interpretation bias, PVS were observed and compared rather than objectively measured.

_ Use of ASPECTS for PVS semiquantification is questionable [26].

– Quantitative mapping of susceptibility is an advancement of SWI that require phase data to acquire information on susceptibility [27-30]

Quantifiable data may be gathered in future for oxygen metabolism using noninvasive techniques such as imaging.

Conclusions

Venous congestion seen in infarcted territory is related to poor prognosis and this can be reliably used as a surrogate marker of oxygen extraction in pneumbra.

SWI can predict tissue at risk and can be a replacement for perfusion scan in clinical scenerio of acute ischaemic infarct.

MRI stroke protocol can be a one stop shop with initial first day DWI-SWI sequences to detect core and pneumbra with multiple co-morbids and in settings were reperfusion is planned.

Disclaimer regarding Consent/Ethical Approval:

As per university standard guideline participant consent and ethical approval has been collected and preserved by the authors.

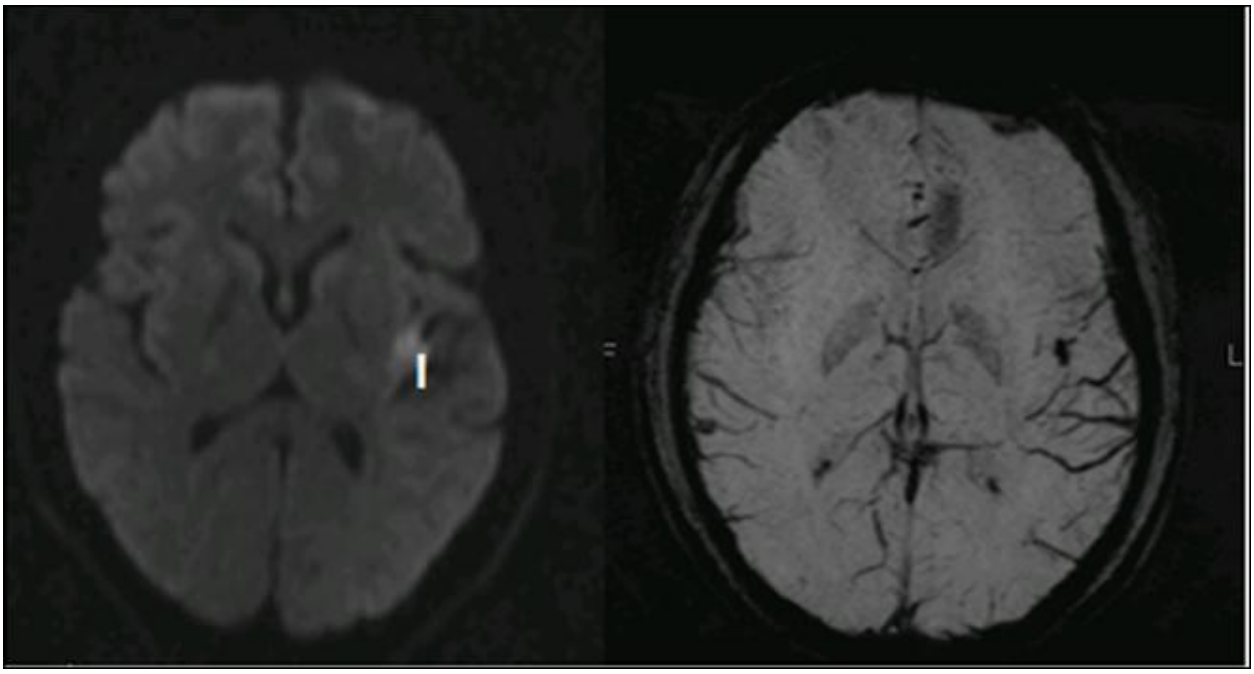
References

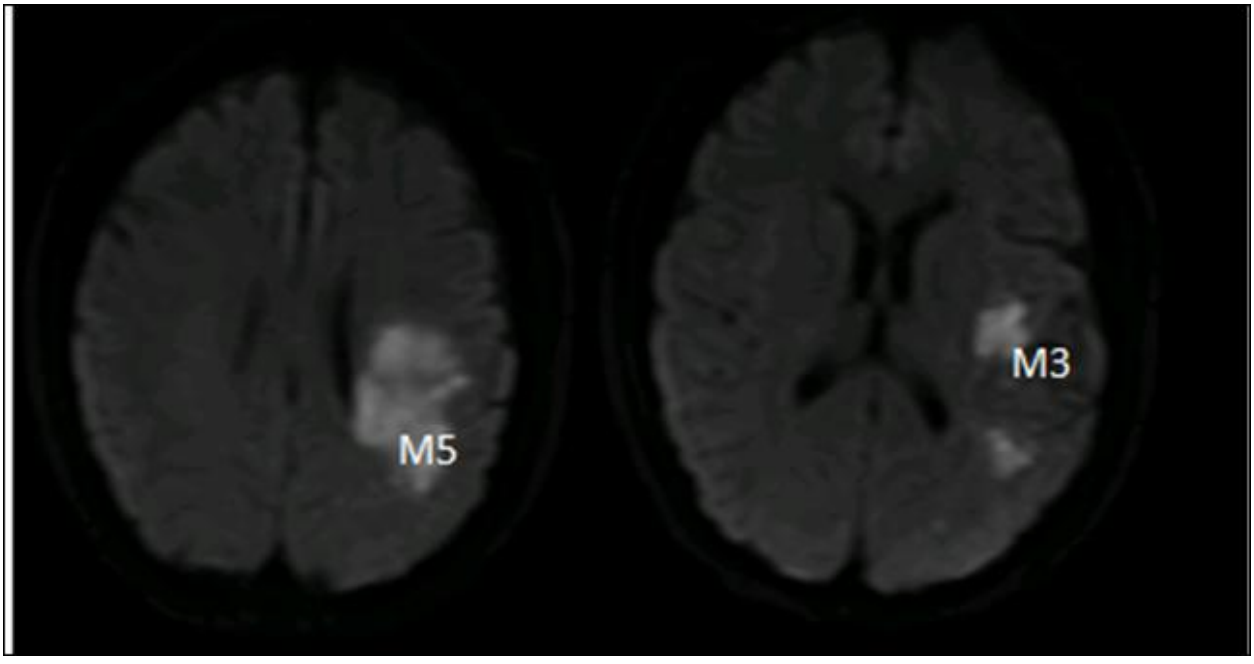
1. Bhojo A. Khealani1, Bilal Hameed2, Uzma U. Mapari3 Department of Medicine1, Aga Khan University Hospital, Karachi, Department of Medicine2,3, University of Alberta, Edmonton, Alberta, Canada. : Stroke in Pakistan. J Pak Med Assoc . 2008, 58:400-403.
2. Max Wintermark, MD MAS, Associate Professor,1 Pina Sanelli, MD MPH, Associate Professor,2 Gregory W. Albers, MD, Professor,3 Jacqueline Bello, MD, FACR, Professor,4 Colin Derdeyn, MD, FACR, Professor,5 Steven W. Hetts, MD, Associate Professor,6 Michele H. Johnson, MD, Associate Professor,7 Chelsea Kidwell, MD, Professor,8 Michael H. Lev, MD FAHA FACR, Associate Professor,9 David S. Liebeskind, MD FAHA FAAN, Neurology Director,10 Howard Rowley, MD, Professor,11 Pamela W. Schaefer, MD, Associate Director,12 Jeffrey L. Sunshine, MD, PhD, Professor,13 Greg Zaharchuk, MD, PhD, Associate Professor,14 and Carolyn C. Meltzer, MD, Professor15: Imaging Recommendations for Acute Stroke and Transient Ischemic Attack Patients: A Joint Statement by the American Society of Neuroradiology, the American College of Radiology and the Society of NeuroInterventional Surgery. AJNR Am J Neuroradiol. 2013, 34:117-127. 10.3174/ajnr.A3690
3. Monitoring Editor: Bart M. Demaerschalk Natalie T. Cheng, MD1 and Anthony S. Kim, MD, MAScorresponding author1: Intravenous Thrombolysis for Acute Ischemic Stroke Within 3 Hours Versus Between 3 and 4.5 Hours of Symptom Onset. Neurohospitalist. 2015, 5:101-109. 10.1177/1941874415583116
4. Yannan Yu,1 Quan Han,1 Xinfa Ding,2 Qingmeng Chen,1 Keqi Ye,1 Sheng Zhang,1 Shenqiang Yan,1 Bruce C. V. Campbell,3 Mark W. Parsons,4 Shaoshi Wang,5 and Min Loua,1 : Defining Core and Penumbra in Ischemic Stroke: A Voxel- and Volume-Based Analysis of Whole Brain CT Perfusion. Sci Rep. 2016, 6:10.1038/srep20932
5. Campbell BCV, Donnan GA, Mitchell PJ, et al : Endovascular thrombectomy for stroke: current best practice and future goals . Stroke and Vascular Neurology. 2016, 6:Accessed: 10.1038/srep20932: 10.1136/svn-2015-000004
6. Feng Chen and Yi-Cheng Ni : Magnetic resonance diffusion-perfusion mismatch in acute ischemic stroke: An update. World J Radiol. 2012, 4:63-74. 10.4329/wjr.v4.i3.63
7. Chia-Yuen Chen, Chin-I Chen, Fong Y. Tsai, Ping-Huei Tsai, Wing P. Chan : Prominent Vessel Sign on Susceptibility-Weighted Imaging in Acute Stroke:

Prediction of Infarct Growth and Clinical Outcome. PLOS. 2015, 1-12. 10.1371/journal.pone.0131118

8. Atay Vural Rahsan Gocmen Kader Karli Oguz Mehmet Akif Topcuoglu Ethem Murat Arsava: Bright and dark vessels on stroke imaging: different sides of the same coin?. Diagn Interv Radio. 2016, 22:284-290. 10.5152/dir.2015.15271
9. Kaya D, Dinçer A, Yildiz ME, Cizmeli MO, Erzen C. : Acute ischemic infarction defined by a region of multiple hypointense vessels on gradient-echo T2* MR imaging at 3T.. Am J Neuroradiol. 2009, 30:1227-32. 10.3174/ajnr.A1537
10. Haacke EM, Xu Y, Cheng YC, Reichenbach JR. : Susceptibility-weighted imaging (SWI). Magn Reson Med. 2004, 52:612-18. 10.1002/mrm.20198
11. Tsui YK, Tsai FY, Hasso AN, Greensite F, Nguyen BV. : Susceptibility-weighted imaging for differential diagnosis of cerebral vascular pathology: a pictorial review. . J Neurol Sci . 2009, 287:7-16.
12. Barber PA1, Hill MD, Eliasziw M, Demchuk AM, Pexman JH, Hudon ME, Tomanek A, Frayne R, Buchan AM : Imaging of the brain in acute ischaemic stroke: comparison of computed tomography and magnetic resonance diffusion-weighted imaging.. J Neurol Neurosurg Psychiatry.. 2005, 76:1528-33. 10.1136/jnnp.2004.059261
13. Polan RM1, Poretti A1, Huisman TA1, Bosemani T2.: Susceptibility-weighted imaging in pediatric arterial ischemic stroke: a valuable alternative for the noninvasive evaluation of altered cerebral hemodynamics.. AJNR Am J Neuroradiol. . 2015, 36:783-8. 10.3174/ajnr.A4187
14. Haacke EM, Tang J, Neelavalli J, Cheng YC. : Susceptibility mapping as a means to visualize veins and quantify oxygen saturation.. J Magn Reson Imaging. 2010, 32:663-76. 2081506510.3174/ajnr.A4187
15. Viratsinh Vaghela, Chandrasekharan Kesavadas, Bejoy Thomas: Year : 2010 | Volume : 58 | Issue : 6 | Page : 879-885 Functional magnetic resonance imaging of the brain: A quick review. Neurology India. 2010, 58:879-885. 10.4103/0028-3886.73735
16. Kao HW, Tsai FY, Hasso AN. 2012;22:1397–1430: Predicting stroke evolution: comparison of susceptibility-weighted MR imaging with MR perfusion.. Euro Radiol. 2012, 22:1397-1430.. 10.1007/s00330-012-2387-4
17. Huang P, Chen CH, Lin WC, Lin RT, Khor GT, Liu CK. 2012;259:1426–32 pmid:22186853: Clinical applications of susceptibility weighted imaging in patients with major stroke. . J Neurol. 2012, 259:1426-32.. 10.1007/s00415-011-6369-2.
18. Baik SK, Choi W, Oh SJ, Park KP, Park MG, Yang TI, et al. : Change in cortical vessel signs on susceptibility-weighted images after full recanalization in hyperacute ischemic stroke.. J Neurol. 2012, 34:206-12. 23006622
19. Yamashita E, Kanasaki Y, Fujii S, Tanaka T, Hirata Y, Ogawa T: Comparison of increased venous contrast in ischemic stroke using phase-sensitive MR imaging with perfusion changes on flow-sensitive alternating inversion recovery at 3 Tesla.. Acta Radiol. 2011, 52:905-10. 2184411

20. Haacke EM, Tang J, Neelavalli J, Cheng YC. : Susceptibility mapping as a means to visualize veins and quantify oxygen saturation. . J Magn Reson Imaging. 2010, 32:663-76. 20815065
21. Hermier M, Nighoghossian N, Derex L, Adeleine P, Wiart M, Berthezène Y, et al. : Hypointense transcerebral veins at T2*-weighted MRI: a marker of hemorrhagic transformation risk in patients treated with intravenous tissue plasminogen activator.. J Cereb Blood Flow Metab . 2003, 23:1362-70. 14600444
22. Sobesky J, Zaro Weber O, Lehnhardt FG, Hesselmann V, Neveling M, Jacobs A, et al. : Does the mismatch match the penumbra? MRI and PET in early ischemic stroke.. Stroke. 2005, 36:980–5 . 15790950
23. Rosso C, Hevia-Montiel N, Deltour S, Bardinet E, Dormont D, Crozier S, et al. : Prediction of Infarct growth based on apparent diffusion coefficients: penumbral assessment without intravenous contrast material.. Radiology. 2009, 250:184–92. 19017923
24. Wechsler LR.: Imaging evaluation of acute ischemic stroke.. Stroke . 2011, 42:12–15. 21164129
25. Rivers CS, Wardlaw JM, Armitage PA, Bastin ME, Carpenter TK, Cvoro V, et al. : Do acute diffusion- and perfusion-weighted MRI lesions identify final infarct volume in ischemic stroke?. Stroke . 2006, 37:98–104. 16322499
26. Tsui YK, Tsai FY, Hasso AN, Greensite F, Nguyen BV. : Susceptibility-weighted imaging for differential diagnosis of cerebral vascular pathology: a pictorial review.. J Neurol Sci. 2009, 287:7–16. 19772973
27. Hermier H, Nighoghossian N. : Contribution of susceptibility-weighted imaging to acute stroke assessement.. Stroke. 2004, 35:1989–94 . 15192245
28. Mittal S, Wu Z, Neelavalli J, Haacke EM. : Susceptibility-weighted imaging: technical aspects and clinical applications. Part 2. . Am J Neuroradiol . 2009, 30:232–52 . 19131406
29. Tong KA, Ashwal S, Obenaus A, Nickerson JP, Kido D, Haacke EM.: Susceptibility-weighted MR imaging: a review of clinical applications in children. Am J Neuroradiol . 2008, 29:9–17 . 7925363
30. Rovira A, Orellana P, Alvarez-Sabín J, Arenillas JF, Aymerich X, Grivé E, et al. : Hyperacute ischemic stroke: middle cerebral artery susceptibility sign at echo-planar gradient-echo MR imaging.. Radiology. 2004, 232:466–73. 15215546
31. Verma R. Stroke: A neglected epidemic in India. J Neurosci Rural Pract [serial online] 2018 [cited 2019 Apr 30];9:453-4. Available from: http://www.ruralneuropractice.com/text.asp?2018/9/4/453/239829





A 63-year-old woman had a diagnosis of LEFT middle cerebral artery territory infarct.

Susceptibility-weighted imaging revealsprominent hypointense cortical and medullary vessels diffusely seen in the insula and M1to M6 zones of the left

Middle cerebral artery territory. Engorged deep veins and thalamostriate artery over the lesions compared with the healthy side were also noted. Involved

M1to M6 zones and insula lost7 points and an engorged thalamostriate vein lost3 points. The prominent vessel sign score was 0 (10–7–3= 0).

Susceptibility-weighted imaging(C,D) at the basalganglia and suprabasal ganglion levels reveal prominent vessel signs in the cortical veins(arrows),
medullary veins(arrows)and thalamostriatevein (arrowhead).