IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 16, Issue 8 Ver. IX (Aug. 2017), PP 61-67
www.iosrjournals.org

The Role of GRE Imaging And SWI in Detection Acute ICH

*Vahed Changizi[1,] *Ayoob Dinar[2],Hedayatolah Sorosh[3]

[1]Professor, Department of Technology of Radiology and Radiotherapy, Allie Medical Sciences School, Tehran University of Medical Sciences, Tehran, Iran.
[2]Msc student, Department of Technology of Radiology and Radiotherapy, Allie Medical Sciences School, TehranUniversity of Medical Sciences, International Campus, Tehran, Iran.
[3]Msc senior lecturer, Department of Technology of Radiology and Radiotherapy, Allie Medical Sciences School, Tehran University of Medical Sciences, Tehran, Iran.
*Corresponding author: *Vahed Changizi*

Abstract :
Objective *: this review was aimed to assess the role of gradient recalled echo (GRE) and susceptibility-weighted imaging (SWI) sequences in detection of acute intracranial hemorrhage.*
Method: *we were searched Embase, the Cochrane library, PubMed, Elsevier, Springer, free journals and Google scholar using the search terms: acute intracranial hemorrhage, ICH, stroke, detection, Magnetic resonance imaging, MRI, Gradient recall echo, GRE, susceptibility weighted imaging, SWI.*
Results: *After systematic search in scientific search engine, we retrieved a total of 382 articles. By assessing the titles and abstracts, we found 130 articles to be potentially relevant. 16 published article met the inclusion criteria of having information on the clinical role of GRE and SWI MRI sequences in detecting acute ICH. Of the 16 included studies in this review, 12 were prospective and 4 retrospective. A total of 1308 patients were involved in these studies.*
Conclusion: *This review briefly outlines the usefulness of GRE and SWI MRI sequences in clinical evaluation of patients with acute and chronic stroke and provide overview of the indications and diagnostic information in the setting of acute stroke, highlighting the advantages of each technique.*
Keywords*: Magnetic Resonance Imaging (MRI), Gradient Recall Echo (GRE), Intracranial Hemorrhage (ICH), susceptibility weighted imaging (SWI).*

Date of Submission: 12 -07-2017 Date of acceptance: 23-08-2017

I. Introduction

Intracranial hemorrhage (ICH) is a dangerous situation and may be caused by trauma, or related to therapeutic anticoagulation, hens the early diagnosis will help in choosing a suitable treatment.[1] Computed tomography (CT) are an important technique for diagnosing acute cerebral hemorrhage, However, MRI is used frequently because it is more accurate than the CT and using a specific sequences like GRE and SWI which detects and evaluate the hemorrhage in the brain.(2) MRI appeared as an extremely sensible device for diagnosis of acute hemorrhage.[3] MRI display advantages for the assessment of acute stroke[4]. A gradient echo (GRE) is simply a smart manipulation of the free induction decay (FID) signal that begins by applying an external dephasing gradient field across the tissue[5]. GRE sequences seems appropriate in assessment of suspected hemorrhagic stroke [6]. Susceptibility weighted imaging (SWI) is an MRI sequence which is particularly sensitive to compounds which distort the local magnetic field and so make it useful in detecting blood products[7]. SWI has shown increased depiction of hemorrhages compared to conventional MRI techniques, including two-dimensional (2D)-GRE T2*-weighted imaging[8]. This review aimed to assess the role of gradient recalled echo (GRE) and susceptibility- weighted imaging (SWI) sequences in detection of acute intracranial hemorrhage.

II. Methods

For this review, we searched Embase, the Cochrane library, PubMed, Elsevier, Springer, free journals and Google scholar using the search terms: acute intracranial hemorrhage, ICH, stroke, detection, Magnetic resonance imaging, MRI, Gradient recall echo, GRE, susceptibility weighted imaging, SWI. Only original articles that performed during the years 1990 to 2016 presented in English language that relevant to our objectives were considered for inclusion. References of all retrieved articles were manually searched for additional relevant manuscripts. Studies found through these search terms were assessed for potential eligibility by reading the abstracts first and then applying inclusion and exclusion criteria.

Included articles were only those in which intracranial hemorrhage imaging was performed by using GRE and SWI. To be eligible for this review, we decided that a study should consist patients with any type of ICH by any cause who were imaged using GRE or SWI technique. Studies were not excluded if other imaging techniques were performed in parallel with studied methods in order to evaluate diagnostic value. After this initial assessment, the publications were summarized using a standard extraction form. Extracted data included: first author, year of publication, study design (retrospective or prospective), population size, mean patient age and range, ICH type and imaging result assessment.

Some studies were excluded if the study outcome proved not to contain information on diagnostic evaluation by MRI. All reported P-values ≤0.05 were considered statistically significant. The large heterogeneity observed in the included studies precluded us from pooling data, which is why we chose to use descriptive statistics in this review. To answer research questions that we start with, we chose some variables in the referenced articles to be reviewed. These variables are:

1. Article study type: like clinical trial, systematic review, meta-analysis, RCT (Randomization control trial), case control, cross sectional studies and case reports. Each of study type has its own level of evidence.
2. Image analysis and raters' agreement according their previous neuroradiological experience will be considered in this review when available.

We compared ICH detection rates among various studies used different MRI techniques and discussed sensitivity of each technique, besides describing main relevant characteristics of studied patients.

III. Results

Study Selection

After systematic search in scientific search engine, we retrieved a total of 382 articles. By assessing the titles and abstracts, we found 130 articles to be potentially relevant. After the full text assessment, 16 published article (table 2) met the inclusion criteria of having information on the clinical role of GRE and SWI MRI sequences in detecting acute ICH. Furthermore, we submitted the eligible articles to further in depth reading, abstracting and comparison in this systematic review.

Study and Patients Description Of the 16 included studies in this systematic review, 12 were prospective and 4 retrospective. A total of 1308 patients were involved in these studies. Among those patients, acute, hyperacute, subacute, chronic ICH were identified besides CMBs and HT. Studied ICH were either primary or secondary. The characteristics of included studies are illustrated in table 2.

Table 2. Main characteristics of included studies

Author	Year	Study type	Patients No.
Lin et al.	2001	R	125
Alemany et al.	2004	P	75
Arnould et al.	2004	P	25
Kidwell et al	2004	P	200
Mitchell et al	2001	P	41
Chalela et al.	2007	P	365
Schellinger et al.	1999	P	9
Nighoghossian et al.	2002	P	100
Gupta et al.	2014	P	5
Kidwell et al.	2002	R	41
Liang et al	1999	P	50
Nandigam et al	2009	P	14
Greer et al.	2004	R	15
Vernooij et al.	2008	P	200
Wycliffe et al.	2004	R	38
Linfante et al.	1999	P	5

P = prospective; R= retrospective;

Role of GRE and SWI sequences in detecting ICH

We reviewed illegible 16 studies conducted in past 27 years where data on investigating the role of GRE and SWI is available in diagnosing, detecting or evaluating patients with hemorrhagic stroke. Table 3 shows main results and conclusions derived from these studies and MRI imaging systems and protocols used.

Author	Imaging system	Sequence parameters	field strength	Results	Conclusion
Lin et al.	NA	Axial plane, 425/15/1, 20 flip angle, 256	1.5 T	GRE detected 13 hemorrhagic acute	GRE scans were more sensitive than b0

		×160 matrix, 1:45-minute acquisition time		infarcts; 22 acute hematomas; 17 chronic hematomas. 37 Punctate hemorrhages	images in the detection of all subtle hemorrhagic lesions. Less sensitive for subarachnoid hemorrhage
Alemany et al.	NA	Axial plane, 500/14, 30 flip angle	1.5 T	GRE detected 82 intraparenchymal haematoma, 15 hemorrhagic infarcts	T2*-weighted GE sequence detected all hematomas (100%).
Arnould et al.	Signa Echospeed system (General Electric Medical Systems, Milwaukee, WI)	TR 4200, ms; TE, 50 ms; NEX, 3; matrix, 128 × 128	1.5 T	EPI-GRE T2*-weighted depicted all positive cases of HT (n = 12)	Confirmed the higher sensitivity of EPI-GRE T2*-weighted imaging in detecting HT. potentially overestimates true blood extravasation
Kidwell et al	Siemens Medical System, Iselin, NJ and General Electric Medical Systems, Milwaukee, Wis.	Slice thickness 7mm, repetition time (TR), 800 ms; flip angle 30°; acquisition matrix, 256×192	1.5 T	Acute hemorrhage in 25 patients on GRE and CT, 4 patients with HT on MRI but not on the CT, In 3 patients, and acute hemorrhage on CT were as chronic on MRI. In 1 patient SAH on CT but not on MRI. In 49 patients MBs seen on MRI but not on CT	GRE MRI may be as accurate as CT for the detection of acute ICH and is more accurate for the detection of chronic ICH
Mitchell et al	1.5T system with 27 mT/m gradients (Eclipse, Picker Medical Systems, Cleveland, Ohio, USA).	Transverse field of view 250 mm. Matrix = 256×256 or 192×256. Thickness=7 mm continuous, TR 588 ms, TE 30 ms, BW 15.6 kHz	1.5 T	The sensitivities of GRE T2* to detect acute SAH 94% (CT 95%). For subacute SAH 100% (CT 75%). For any SAH = 97% (CT 90%)	The most sensitive sequence was the gradient echo T2* to detect SAH, particularly subacute.
Chalela et al.	(GE Signa, General Electric, Milwaukee, WI, USA).	field of view 24 cm, (TR) 800 ms, (TE) 20 ms, flip angle 30°, and acquisition matrix 256×192.	1.5 T	For diagnosis of acute ICH, MRI had a sensitivity of 81% (and a specificity of 100%, accuracy of 89% compared with 89%, 100% and 54%, for CT. respectively	MRI might be as accurate as CT for diagnosis of ICH
Schellinger et al.	whole-body MR imager (EDGE, Picker) equipped with enhanced gradient hardware for echo planar imaging	NA	1.5 T	MRI identified all ICHs detected by CT. GRE is the best to depict ICH and its evolution over time in the acute period. T2*-WI substantially overestimated the hematoma size	GRE are suited best for the diagnosis of ICH particularly in hyperacute phase
Nighoghossian et al.	1.5 T (Siemens AG, Medical Group) that used a circular polarized head Coil equipped with enhanced gradient hardware for echo-planar	TR of 800 ms, TE of 26 ms, flip angle of 20°, thickness of 5 mm, 20 axial slices, distance factor of 0.20, asymmetric matrix of n×256, 2 excitations, acquisition time of 6 minutes, and a field of view of	1.5 T	MBs were seen in 20 patients exclusively on T2*-weighted imaging. 10 of them have CB. CB was diagnosed in 18 patients by GRE and in 8 patients within the first week with CT	Confirm the usefulness of T2*-weighted GRE sequence in detecting early hemorrhage transformation as part of a multimodal stroke MRI protocol.

	imaging.	250 mm.			
Gupta et al.	18-channel, 1.5 Tesla scanner (Avanto, Siemens, Erlangen, Germany)	(TR)-760 ms, (TE)-26 ms, flip angle-20°, slice thickness-3 mm, bandwidth-80 kHz, (FOV) read-230 mm, FOV phase-87.5%, base resolution-256, phase resolution75%,	1.5 T	GRE successfully diagnosed acute and chronic hemorrhages and MBs beside providing clue to the etiology of hemorrhage	GRE sequence is the most sensitive for the detection of ICH as compared with other sequences.
Kidwell et al.	Siemens Visions scanner (Siemens Medical Solutions).	GRE sequence:7-mm slice thickness, no gap, field of view 220 mm, TR 800 ms, TE 15 ms, and flip angle 30°. EPI-SWI sequences :5- to 7-mm slice thickness, no gap, field of view 240 mm, TR 2000 ms, and TE 60 ms	1.5 T	Pretreatment GRE and SWI MRIs revealed evidence of old silent microbleeds in 5 cases (12%). While no one by CT. no difference in MBs detection rate between GRE and SWI sequences	GRE and SWI sequences are better than CT in detection of MBs
Liang et al	NA	TR/TE/excitations 500/15/2 Flip angle 15, Matrix 192 × 256 FOV (mm) 265 × 199 Section thickness (mm) 5 Gap (mm) 1 Bandwidth (Hz/pixel) 78 Acquisition time 3 min, 27 s	1.5T	GRE and GRE-EPI sequences detected 36/50 patients with ICH detected more hemorrhagic lesions than other sequences (P< .0001)	GRE and GRE-EPI sequences were the most sensitive to detect chronic ICH
Nandigam et al	Avanto versus 3T Trio by using a 12-channel Total Imaging Matrix head coil; both Siemens Medical Systems, Erlangan, Germany)	Section thickness (mm) 1.2-5 Gap (mm) 0-1 In-plane resolution (mm) 0.5-0.9× 0.7 1.15. Acquisition time (min) 2.5-11,TR (ms) 27-48, TE (ms) 21-40, Flip angle 15-20, Number of averages 1-2 Acquisition matrix 192-448 ×144-299, FOV (mm)221-230× 130-151	1.5 T	SWI, smaller section thickness, and higher magnetic field each yielded substantially increased lesion contrast for CMB	SWI detected more CMBs than GRE do
Greer et al.	(Signa, GE Medical Systems) with echo-planar capabilities (Advanced NMR Systems).	Multiplanar gradient recalled; TR, 750 ms; TE, 25 ms; skip, 5 mm; slice thickness, 1 mm; number of excitations, 2.	1.5 T	Nine patients had areas of hypointensity suggestive of acute hemorrhage. matched the areas of hypointensity on DWI and confirmed on follow-up CT	SWI is clinically useful tool for detecting hemorrhage in the immediate post–IA thrombolysis period in patients with a hyperdense lesion on CT
Vernooij et al.	GE Healthcare, Milwaukee, Wis.	TR 45-775, TE 20-31, flip angle 13-25, bandwidth 11.9-14.7, FOV 26*19.5, 25*17.5, matrix size 256*256, 320*224, thickness 5, 1.6, aquestion time 2min 29sec, 5 min 55 sec	1.5 T	CMBs were detected in significantly more participants on 3D SWI (35.5%) than on 2D T2*-weighted GRE images (21.0%; P < .001)	3D SW images depict more CMBs than do conventional 2D T2*-weighted GRE images.
Wycliffe et al.	1.5-Tesla Siemens Magnetom Vision MRI scanner	SWI: bandwidth (78 Hz/pixel) 3D-fast low angle shot (FLASH) sequence (TR/TE = 57/40 msec, FA =20°) GRE:(TR/ TE =500/18 msec, (FA) = 15°, 4 mm thick, matrix = 192 * 256, FOV varying	1.5 T	42% showed the presence of hemorrhage in the MR SW sequence, as opposed to 13.2% by CT. SWI detected seven cases were undetected in the other conventional MRI	The detection rate of hemorrhage by SWI was higher than that of in CT and the sequences of MRI, including GRE T2*-weighted imaging

Linfante et al.	Siemens Vision 1.5 scanner (Siemens Medical System).	TR, 0.8 ms; TE, 60 ms; flip angle, 60°; 20 slices; slice thickness, 7 mm; matrix size, 96?128; FOV, 240;acquisition time, 2 seconds;	1.5 T	SWI detected all hematomas as iso-hyper tense center and hypotense periphery in 5 patients within first 2 hrs.	SWI is the most useful image modality to detect hyperacute ICH

ICH= intracranial hemorrhage, SAH= subarachnoid hemorrhage, MBs=microbleeds, CMBs=cerebral microbleeds, CB=cerebral bleeding. HT= hemorrhagic transformation.

IV. Discussion

A growing part of researches have suggested that GRE pulse sequences sensitive to static magnetic field inhomogeneity are accurately detected hyperacute parenchymal blood[9-11]. Typically on GRE/ T2*, the hyperacute lesion consists of a core of heterogeneous signal intensity, reflecting the most recently bleeding containing of diamagnetic oxyhemoglobin, surrounded by a hypointensity rim, reflecting parenchymal blood that contains deoxygenated blood and becomes paramagnetic[10, 12]. The high sensitivity of T2*-GRE MR sequences having the susceptibility effects of paramagnetic and super-paramagnetic substances increases the number of hemorrhagic lesions that can be identified. A major limitation of the T2*-GRE sequence is that this sequence cannot help in estimating the age of the hematomas[2, 6]. GRE may be an important technique in emergency MR studies for acute stroke, just adding 2 to 3 minutes to the overall examination time, especially when thrombolytic therapy is suggested[6].

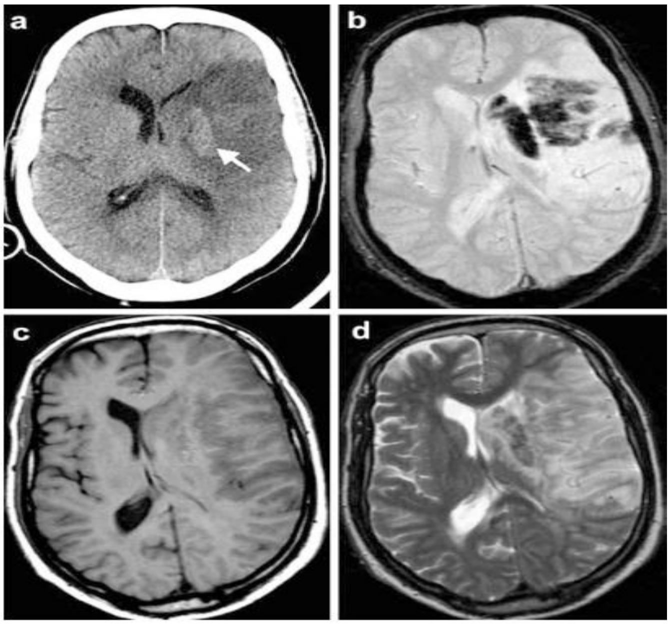

Figure 1. a–d Patient with an extensive infarct in the territory of the middle cerebral artery. The oval increased density in the left basal ganglia depicted on CT (arrow in a) could represent a spared lent form nucleus. The MR images were obtained 3 days later. Haemorrhagic transformation is best depicted on T2*-weighted GE (dark areas in b). The haemorrhagic changes are underestimated on T1- (c) and T2-weighted (d) sequences.

Greater contrast resolution achieved and no pulse is used in the GRE sequence beside high spatial resolution (GRE matrix of 2562) and high signal-to-noise ratio allowing GRE for the detection of subtle hemorrhagic lesions and increasing its level of diagnostic certainty, hence smaller lesions cannot be missed[13]. Previous MBs may increase the risk of hemorrhage after thrombolysis or antithrombotic drugs. Small deposits of hemosiderin are found on MRI in 12% to 20% of stroke patients. GRE and SWI sequences are sensitive to susceptibility effects and characterized by short acquisition times resulting in fewer movement artifacts and shorter therapeutic delay [14, 15].

Microbleedings MBs) are often occult on head CT but readily appreciated on GRE or SWI MRI sequences as areas of hypointense susceptibility blooming[16, 17]. Using a high sensitive MRI sequence to susceptibility signal-intensity loss with a higher field strength, which make susceptibility effects scale increasing, would increase their detection for CMBs. In addition, at higher resolution, partial voluming effects are smaller. Thus, it is expected to predict that CMB would be better detected with higher resolution MRI parameters[18]. The major challenge for SWI and higher resolution GRE is longer scanning-acquisition time,

which should be considered in unstable patients[16]. SWI sequence with smaller section thickness, and higher magnetic fields strength are associated with significantly increase in detection rates of CMB[14, 19].
3D SWI, with its higher sensitivity, identifies many CMBs that not seen on routine GRE images [14, 20-22]. SWI is highly sensitive to even traces of hemorrhage and has a potential role to monitor the complications of revascularization therapy [14, 23, 24].

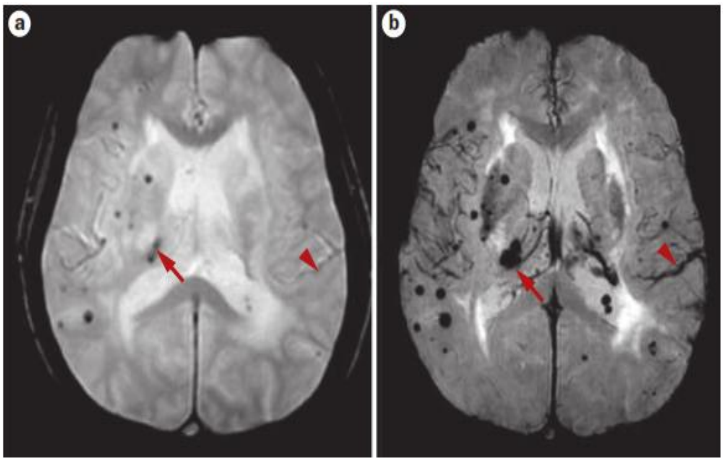

Figure 2. Susceptibility-weighted imaging. Multiple microbleeds (arrows) and enlarged veins (arrowheads) seen on a | gradient-recalled echo and b | susceptibility- weighted imaging maps. Susceptibility-weighted imaging is more sensitive than gradient-recalled echo to venous structures.

SWI is not only sensitive in detecting bleeds in the brain parenchyma but also shows intraventricular and SAH even better than CT[20]. Also in traumatic brain injury, it have demonstrated that SWI is more sensitive than GRE imaging for detecting hemorrhage in diffuse axonal injury which reflects poor prognosis[21, 25]. 3D T2*-weighted GRE images depict more MBs than do conventional 2D T2*- weighted GRE images [26-29]. Using SWI showed increased sensitivity for detection of hemorrhage in acute stroke when compared to CT, conventional MRI sequences and 2D-GRE T2*-weighted imaging[8, 30]

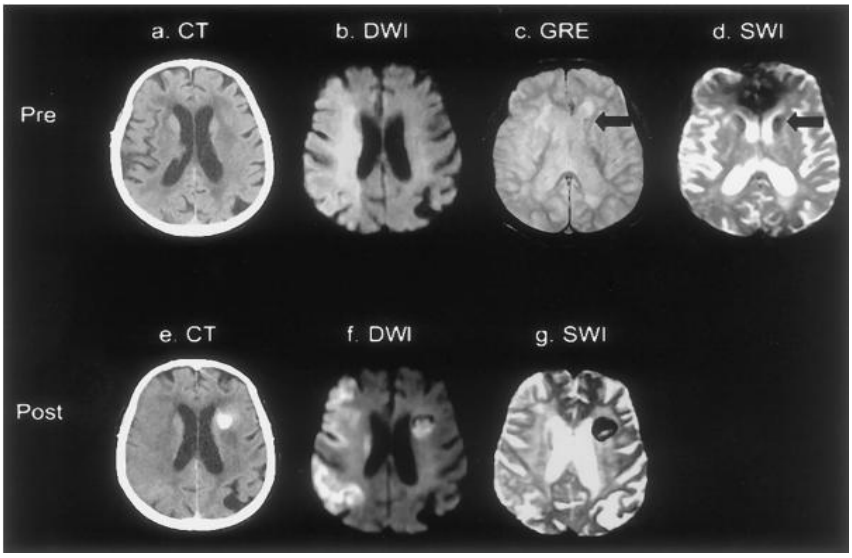

Figure 3. Pretreatment (top row) and post treatment (bottom row) imaging studies in a 96-year-old woman receiving intra-arterial thrombolysis for an acute right MCA occlusion. a, Pretreatment CT shows no evidence of acute or chronic hemorrhage and no hypodensity in right MCA territory. b, Pretreatment DWI study shows increased signal consistent with acute ischemia in right MCA territory. c, Pre- treatment SWI sequence shows hypointensity in left anterior periventricular region consistent with a previous silent microbleeds (arrow). d, Corresponding hypointense region on GRE sequence (arrow). e, Post treatment head CT shows hyperdensity consistent with acute blood in left anterior periventricular region occurring at site of old microbleeds. f, Post-treatment DWI shows evolution of infarction in right MCA territory. g, Post-treatment SWI shows hypointensity in right periventricular region corresponding to region of acute hemorrhage visualized on CT.

Acknowledgments:

We thank Dr. Changizi for proofing and other contributions to this article.

References

[1]. Krishnamoorthy T, Fiorelli M. MR detection of intracranial hemorrhage. Magnetic Resonance Imaging in Ischemic Stroke: Springer; 2006. p. 159-69.
[2]. Alemany Ripoll M, Stenborg A, Sonninen P, Terent A, Raininko R. Detection and appearance of intraparenchymal haematomas of the brain at 1.5 T with spin-echo, FLAIR and GE sequences: poor relationship to the age of the haematoma. Neuroradiology. 2004;46(6):435-43.
[3]. Greer DM, Koroshetz WJ, Cullen S, Gonzalez RG, Lev MH. Magnetic resonance imaging improves detection of intracerebral hemorrhage over computed tomography after intra-arterial thrombolysis. Stroke. 2004;35(2):491-5.
[4]. Chalela JA, Kidwell CS, Nentwich LM, Luby M, Butman JA, Demchuk AM, et al. Magnetic resonance imaging and computed tomography in emergency assessment of patients with suspected acute stroke: a prospective comparison. The Lancet. 2007;369(9558):293-8.
[5]. Bernstein MA, King KF, Zhou XJ. Handbook of MRI pulse sequences: Elsevier; 2004.
[6]. Willinek WA, Gieseke Jr, von Falkenhausen M, Neuen B, Schild HH, Kuhl CK. Sensitivity encoding for fast MR imaging of the brain in patients with stroke. Radiology. 2003;228(3):669-75.
[7]. Schweser F, Deistung A, Lehr BW, Reichenbach JR. Differentiation between diamagnetic and paramagnetic cerebral lesions based on magnetic susceptibility mapping. Medical physics. 2010;37(10):5165-78.
[8]. Wycliffe ND, Choe J, Holshouser B, Oyoyo UE, Haacke EM, Kido DK. Reliability in detection of hemorrhage in acute stroke by a new three-dimensional gradient recalled echo susceptibility-weighted imaging technique compared to computed tomography: A retrospective study. Journal of Magnetic Resonance Imaging. 2004;20(3):372-7.
[9]. Schellinger PD, Jansen O, Fiebach JB, Hacke W, Sartor K. A standardized MRI stroke protocol. Stroke. 1999;30(4):765-8.
[10]. Linfante I, Llinas RH, Caplan LR, Warach S. MRI features of intracerebral hemorrhage within 2 hours from symptom onset. Stroke. 1999;30(11):2263-7.
[11]. Patel MR, Edelman RR, Warach S. Detection of hyperacute primary intraparenchymal hemorrhage by magnetic resonance imaging. Stroke. 1996;27(12):2321-4.
[12]. Atlas SW, Thulborn KR. MR detection of hyperacute parenchymal hemorrhage of the brain. American journal of neuroradiology. 1998;19(8):1471-7.
[13]. Kidwell CS, Wintermark M. The role of CT and MRI in the emergency evaluation of persons with suspected stroke. Current neurology and neuroscience reports. 2010;10(1):21-8.
[14]. Gasparotti R, Pinelli L, Liserre R. New MR sequences in daily practice: susceptibility weighted imaging. A pictorial essay. Insights into imaging. 2011;2(3):335-47.
[15]. Hermier M, Nighoghossian N. Contribution of susceptibility-weighted imaging to acute stroke assessment. Stroke. 2004;35(8):1989-94.
[16]. Nandigam R, Viswanathan A, Delgado P, Skehan M, Smith E, Rosand J, et al. MR imaging detection of cerebral microbleeds: effect of susceptibility-weighted imaging, section thickness, and field strength. American Journal of Neuroradiology. 2009;30(2):338-43.
[17]. Greenberg SM, Vernooij MW, Cordonnier C, Viswanathan A, Salman RA-S, Warach S, et al. Cerebral microbleeds: a guide to detection and interpretation. The Lancet Neurology. 2009;8(2):165-74.
[18]. Tang MY, Chen TW, Zhang XM, Huang XH. GRE T2-weighted MRI: principles and clinical applications. BioMed research international. 2014;2014.
[19]. Haacke EM, Ye Y. The role of susceptibility weighted imaging in functional MRI. Neuroimage. 2012;62(2):923-9.
[20]. Mittal S, Wu Z, Neelavalli J, Haacke EM. Susceptibility-weighted imaging: technical aspects and clinical applications, part 2. American Journal of neuroradiology. 2009;30(2):232-52.
[21]. Thomas B, Somasundaram S, Thamburaj K, Kesavadas C, Gupta AK, Bodhey NK, et al. Clinical applications of susceptibility weighted MR imaging of the brain–a pictorial review. Neuroradiology. 2008;50(2):105-16.
[22]. Robinson RJ, Bhuta S. Susceptibility-Weighted Imaging of the Brain: Current Utility and Potential Applications. Journal of Neuroimaging. 2011;21(4).
[23]. Santhosh K, Kesavadas C, Thomas B, Gupta A, Thamburaj K, Kapilamoorthy TR. Susceptibility weighted imaging: a new tool in magnetic resonance imaging of stroke. Clinical radiology. 2009;64(1):74-83.
[24]. Liu S, Buch S, Chen Y, Choi HS, Dai Y, Habib C, et al. Susceptibility-weighted imaging: current status and future directions. NMR in Biomedicine. 2017;30(4).
[25]. Tong KA, Ashwal S, Holshouser BA, Shutter LA, Herigault G, Haacke EM, et al. Hemorrhagic shearing lesions in children and adolescents with posttraumatic diffuse axonal injury: improved detection and initial results. Radiology. 2003;227(2):332-9.
[26]. Vernooij MW, Ikram MA, Wielopolski PA, Krestin GP, Breteler MM, van der Lugt A. Cerebral microbleeds: accelerated 3D T2*-weighted GRE MR imaging versus conventional 2D T2*-weighted GRE MR imaging for detection. Radiology. 2008;248(1):272-7.
[27]. Charidimou A, Jäger HR, Werring DJ. Cerebral microbleed detection and mapping: principles, methodological aspects and rationale in vascular dementia. Experimental gerontology. 2012;47(11):843-52.
[28]. Charidimou A, Krishnan A, Werring DJ, Jäger HR. Cerebral microbleeds: a guide to detection and clinical relevance in different disease settings. Neuroradiologie Scan. 2014;4(02):123-47.
[29]. Cheng A-L, Batool S, McCreary CR, Lauzon M, Frayne R, Goyal M, et al. Susceptibility-weighted imaging is more reliable than T2*-weighted gradient-recalled echo MRI for detecting microbleeds. Stroke. 2013;44(10):2782-6.
[30]. El-Serougy LG, El-Rakhawy MM, Ashamallah GA, Mustafa WF. Reliability of magnetic susceptibility weighted imaging in detection of cerebral microbleeds in stroke patients. The Egyptian Journal of Radiology and Nuclear Medicine. 2017;48(1):225-9.

*Vahed Changizi. " The Role of GRE Imaging And SWI in Detection Acute ICH." IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) 16.8 (2017): 61-67