Original Article

Role of susceptibility-weighted imaging in characterisation of solitary intra-axial-enhancing lesions of brain

Karthik Gupta[1], Bodagala Vijayalakshmi Devi[1], A. Y. Lakshmi[1], V. V. Ramesh Chandra[2], Amit Kumar Chowhan[3]

Departments of [1]Radiodiagnosis, [2]Neurosurgery and [3]Pathology, Sri Venkateshwara Institute of Medical Sciences, Tirupati, Andhra Pradesh, India

Abstract

Background: To evaluate the role of susceptibility-weighted imaging (SWI) using intratumoural susceptibility signals (ITSSs) in characterising and grading intra-axial lesions of the brain.

Methods: We prospectively studied 37 consecutive patients with solitary enhancing intra-axial brain lesions on contrast-enhanced magnetic resonance imaging (MRI) who underwent surgery followed by histopathological examination of the specimen at our tertiary care teaching hospital during the period January 2015–August 2016.

Results: The mean age was 43.3 ± 15.7 years; there were 21 female. ITSS was detected in glioblastoma multiforme (GBM) (16/16), metastasis (2/6), high-grade glioma (2/2) and low-grade glioma (4/6). ITSS was not detected in granulomas. In semi-quantitative analysis, Grade 3 ITSS was able to differentiate GBM from other lesions (sensitivity = 87.5%; specificity = 86.4%; $P < 0.0001$). Grade 3 ITSS was able to differentiate GBM and metastasis (sensitivity = 87.5; specificity = 100; $P < 0.0001$).

Conclusion: SWI using ITSSs is useful MRI sequence in characteristing and grading intra-axial bram lessions.

Keywords: Glioblastoma multiforme, Metastasis, Solitary-enhancing lesion, Susceptibility-weighted imaging

Address for correspondence: Dr B. Vijayalakshmi Devi, Associate Professor, Department of Radiodiagnosis, Sri Venkateswara Institute of Medical Sciences, Tirupati, Andhra Pradesh, India.
E-mail: bvl1972@yahoo.co.in

INTRODUCTION

The aetiology of a solitary-enhancing brain lesion varies from benign lesions, such as tumefactive demyelination, inflammatory granulomas and malignant lesions such as gliomas and lymphomas. They exhibit similar features and often difficult to characterise on conventional magnetic resonance imaging (MRI). Newer variety of advanced MRI techniques have found their place in clinical practice providing more than anatomic information, particularly in solitary-enhancing lesions (SEL).[1] The susceptibility-weighted imaging (SWI) sequence is a useful recent MRI sequence which utilise the susceptibility difference between the deoxygenated blood in veins and the surrounding brain parenchyma.[2] The diagnostic aim of advanced neuroimaging of the central nervous system neoplasm is to optimise tumour characterisation and grading. SWI could detect vasculature and microhaemorrhages within brain tumours more effectively than conventional MRI techniques.[1,3,4] SWI was reported as being able to demonstrate the magnetic susceptibility differences of various tissues, and the susceptibility effect of microvenous structures and blood products using both magnitude and phase

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images.[5-9] Therefore, SWI can be used for non-invasive visualisation of normal or pathologic vascular structures; these observations from SWI could be useful in tumour characterisation, tumour grading or diagnosis of specific tumour type.[10-12] With this knowledge in background, we planned this study to determine the benefit of using SWI for characterising SEL by assessing intratumoural susceptibility signals (ITSSs).

MATERIAL AND METHODS

This study was conducted in the Department of Radiodiagnosis, Sri Venkateswara Institute of Medical Sciences, Tirupati, during the period of February 2015 to August 2016 after obtaining institutional Ethics Committee. This is a hospital-based prospective study which included 37 Patients who underwent contrast-enhanced MRI (CE-MRI) and SWI sequence. Written informed consent was obtained before the study from all participents. Patients presenting to the Department of Neurosurgery with a clinical presentation suggesting of space-occupying lesion were studied. Clinical and laboratory evaluation including imaging and management was done as per institutional protocol. Patients with SE intra-axial brain lesions on CEMRI who underwent surgery followed by histopathological examination of the surgical specimen were included. Patients who did not undergo surgery, patients with absolute contraindications for MRI, patients not willing to be part of the study and pregnant women were excluded from the study. The data were recorded on a pre-designed proforma.

MRI was done using 1.5 Tesla (Siemens Magnetom Aera 1.5T, Germany) machine. Following imaging sequences: T1WSE axial, T1WSE sagittal (500/8.9), T2WFS coronal, T2WFS axial (4500/89) and FLAIR axial (9000/86), followed by SWI and post-contrast T1 was acquired. The patients were kept in the head first supine position during image acquisition. Gadobenate dimeglumine is given as contrast at a dose of 0.1 ml/kg body weight. The images were visually assessed by the radiologist and judge for the differentiation of SEL.

Imaging analysis

For qualitative imaging analysis of SELs on SWI, an ITSS is defined with the following criteria: (i) low-signal-intensity fine linear or dot-like structures, which are not obvious on conventional magnetic resonance (MR) images, with or without conglomeration within a tumour as depicted on SWIs; (ii) attenuated or granular susceptibility low signals, which can be easily detected on conventional MRI, were excluded because these findings were not additional information on HR-SWI; (iii) fuzzy or diffuse low signals were excluded because the quantification of these findings could be subjective.[1] For semi-quantitative analysis, the degree of ITSS was divided into three grades: Grade 1 was defined as no ITSS; Grade 2 was defined as 1–10 dot-like or fine linear ITSSs; and Grade 3 was defined as >11 dot-like or fine linear ITSSs within a tumour.[1]

The surgically-resected lesions were sent in formalin solution and were subjected to processing and staining techniques and studied to arrive at a histopathological diagnosis by the pathologist. These details were recorded in the study proforma.

Statistical analysis

Pre-operative MRI findings were reviewed and compared with the final pathological diagnosis as the standard of reference. Receiver-operator characteristic (ROC) curve analyses were performed to determine optimum thresholds and diagnostic accuracy of ITSS for differentiating SELs. The parameters for the validity include sensitivity, specificity, predictive values of positive and negative tests and accuracy are used for determining the grade of agreement. Data analysis was done using software SPSS, version 20 for Windows.

RESULTS

The study was conducted in our tertiary care hospital during the period of January 2015–August 2016. Our study included 37 cases (females=21). Their mean age was 43.3±15.7 (range 14-71) years. The histopathological types of intra-axial lesions are shown in Table 1.

Table 1: Types of pathological lesions

Type of lesion	Number (%)
GBM	16 (42.24)
METS	6 (16.21)
HGG	2 (5.4)
LGG	6 (16.2)
Abscess	1 (2.7)
NTG	6 (16.2)

GBM=Glioblastoma multiforme; METS=Metastasis; HGG=High-grade glioma; LGG=Low-grade glioma; NTG=Non-tumorous granuloma

In our study, ITSS was detected in all the 16 cases of glioblastoma multiforme (GBM) (100%), and in 2 out of 6 metastasis (33.3%), in 2 out of 2 high-grade glioma (HGG), in 4 out of 6 low-grade glioma (LGG) (67%) and in one case of abcess. No ITSS was detected in all cases of NTGs; 4 out of 6 metastasis and 2 out of 6 LGG. SWI sequence with conventional sequence was able to make histopathological diagnosis in 37 cases accurately. Table 2 shows the incidence of ITSS along with grades in various pathologies among the study sample. Figure 1a-c shows

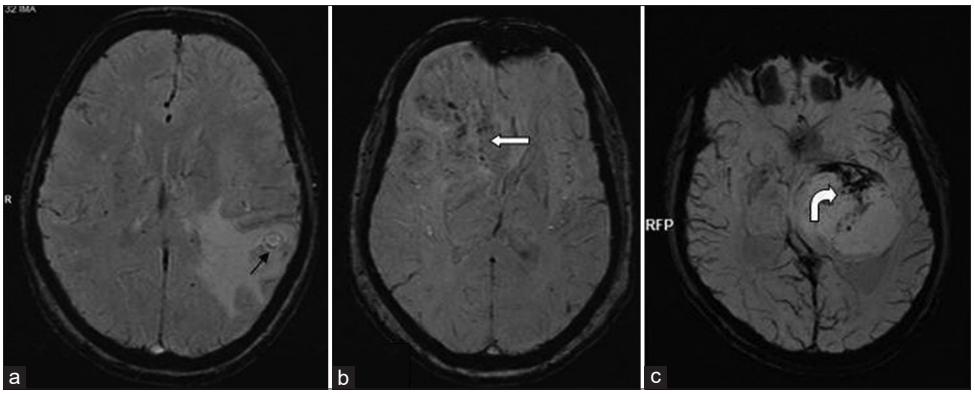

Figure 1: MRI brain showing Grade 1 (arrow (a)), Grade 2 (arrow (b)), Grade 3 (arrow (c)) intratumoural susceptibility signal in histologically diagnosed cases of NTG, low-grade glioma, glioblastoma multiforme, respectively. MRI=Magnetic resonance imaging

Grade 1, 2 and 3 ITSS in histologically proven cases of NTG, LGG, GBM, respectively.

Table 2: Incidence of intratumoural susceptibility signal along with grades in various pathologies of the study sample

Grade 1 ITSS (12 of 37 cases [32.43%])	Grade 2 ITSS (8 of 37 cases [21.6%])	Grade 3 ITSS (17 of 37 cases [45%])
4/6 METS	4/6 LGGs	14/16 GBMs
2/6 LGG	2/6 metastatic lesions	2/2 HGGs
6/6 of NTGs	2/6 GBMs	1/1 abscess

ITSS=Intratumoural susceptibility signal; METS=Metastasis; LGGs=Low-grade gliomas; NTGs=Non-tumorous granulomas; GBMs=Glioblastoma multiformes; HGGs=High-grade gliomas

In our study with high-grade ITSS differentiation between GBMs and metastatic tumours was significant with a sensitivity of 87.5% and specificity of 100% [Figure 2].

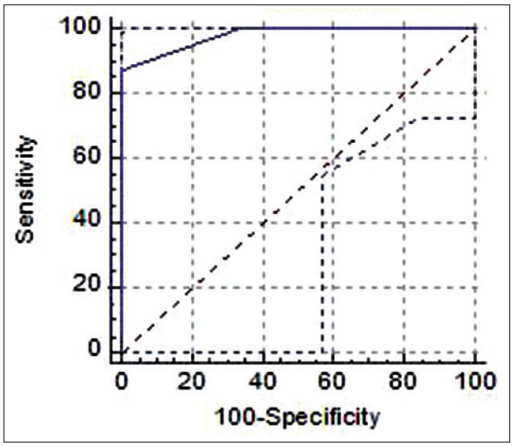

Figure 2: Receiver-operator characteristic curve analysis representing case distribution based on intratumoural susceptibility signal grade

Grade 3 (>2) ITSS was detected in 16 cases and absence of Grade 3 was noted in 6 cases. For detection of GBM Grade 3 (>2), ITSS showed statistically significant $P < 0.0001$ with sensitivity and specificity of 87.5% and 100%, respectively, with 95% confidence interval.

In our study, Grade 3 ITSS was able to differentiate between GBMs and rest all other SOLs with a sensitivity and specificity of 87.5% and 86.4%, respectively [Figure 3].

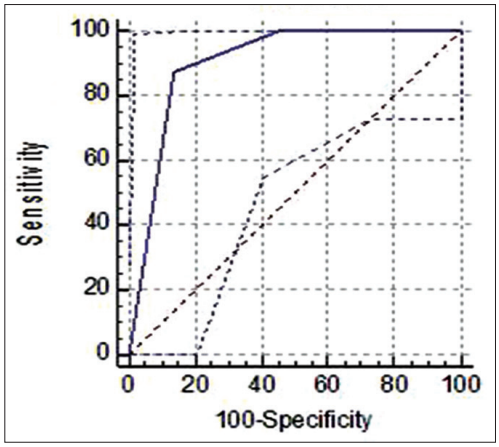

Figure 3: Receiver-operator characteristic curve analysis showing intratumoural susceptibility signal in glioblastoma multiformes versus other lesions

Grade 2 ITSS was unable to differentiate between METS and NTG (P =0.5351). Further Grade 1 ITSS was noted in all 6 out of 6 NTGs (100%). Hence, the lack of ITSS can be used as a marker to diagnose NTGs.

DISCUSSION

SE brain lesion range from benign lesions, such as tumefactive demyelination, inflammatory granulomas and malignant lesions such as gliomas, lymphomas. They exhibit similar features and often difficult to characterise on conventional MRI. Gliomas are the most common brain tumours and account for 70% of primary adult

malignant brain tumours.[13] There have been reports that the incidence of gliomas has been increasing in recent years and some studies have inconclusively linked this to increased cell phone usage.[14] The accurate grading of astrocytomas has important therapeutic and prognostic implications, because patients with high-grade astrocytomas must receive either radiochemotherapy or radiation therapy.

MRI features are related to the histological grade of the gliomas. MRI is the initial investigation of choice in patients with suspected glioma and plays a major role in the initial differential, but currently, no imaging features are considered in the confirmatory diagnosis or grading of gliomas.

Many imaging characteristics have been suggested to predict glioma grade which include contrast material enhancement, border definition, mass effect, signal-intensity heterogeneity, haemorrhage, necrosis, degree of oedema and involvement of the corpus callosum or crossing the midline.[15,16]

Some astrocytomas have characteristic imaging features that are correlated with tumour grade, whereas others do not. Majority of them are difficult to characterise solely on conventional MRI. High-grade astrocytomas are usually vascular and contain areas of haemorrhage.

In our study, the most common histopathological type of ICSOLs included were gliomas of which majority include GBMs representing 48% of sample. Our study included 37 cases, (21 females) with the mean age (43.3 ± 15.7) years. Similar observation were reported in another short (n= 64 patients with ICSOLs). GBMs were reported as the most common type of histopathological lesion to be encountered, accounting for 39% of total cases.

Lack of ITSS helped to arrive at a diagnosis regarding four metastases. The results are similar to that observed earlier[1,8,9] who showed that lack of ITSS on SWI was noted in metastasis and SWI sequence provides better information for characterising ICSOLs.

In our study, we found that the ITSS seen on SWI sequence in 22 out of 24 cases gliomas accounting for 91.6% cases and 3 out of 13 other lesions accounting for 8.1% cases. These observation are similar to that reported earlier[17] who reported that SWI was more sensitive than conventional MRI sequences in visualising tumour blood products and areas of microhaemorrhages which detected on an average, 35.50 ± 3.97 small vessels in high-grade astrocytomas and 6.40 ± 4.25 in low-grade astrocytomas ($P < 0.05$).

It was proposed that SWI was superior to conventional imaging techniques in visualising small vessels and microhaemorrhage in brain astrocytoma. In our study, ITSS was constantly associated with GBMs and HGGs than LGGs. This observation is similar to that reported in earlier studies[18,19] which showed that the ITSSs were seen in 22 (100%) of 22 GBMs (WHO Grade 4) and in 3 (43%) of 7 anaplastic astrocytomas (WHO Grade 3). There was no evidence of ITSS in low-grade astrocytomas (WHO Grade 2) concluding that ITSSs were most frequent in glioblastomas.

In our study, the presence of ITSS was noted 25 cases out of a total 37 cases (67.5%), which included Grade 3 ITSS in 14/16 GBMs and 2/2 cases of HGGs. Grade 2 ITSS was noted in 4/6 LGG. There were no ITSS (Grade 1) detected in 2 LGG. These results are in agreement another study[20] which showed the Grade 3 ITSSs were seen in 22/22 GBMs (WHO Grade 4) and Grade 2 in 3/7 anaplastic astrocytomas (WHO Grade 3). There was no evidence of ITSS in low-grade astrocytomas (WHO Grade 2).

In our study, Grade 3 ITSS was able to differentiate GBMs from other lesions with a sensitivity and specificity of 87.5 and 86.5% with a $P = 0.0001$. This is in agreement with Kim *et al*.[1] and Hori *et al*.[18] who reported that high ITSS is used to differentiate GBMs from other ICSOLs.

In our study, the incidence of Grade 3 ITSS was noted in 14 out of 16 GBMs (87%) and 2 out of 2 (100%) of HGGs. Presence of high-grade ITSS in the WHO Grade 4 lesions was in accordance with another study[4] who showed that high incidence of susceptibility effects in high-grade gliomas. Our results are similar to another report[21] where imaging features and tumour microvascularity correlated with tumour grade and the detection of the ITSS intensity in high-grade gliomas not only reflects tumour vascularity but also indicates macro- and microhaemorrhage in high-grade gliomas.

Differentiating predominantly necrotic GBMs from abscesses is a frequent clinical dilemma encountered in routine practice. Both these lesions are seen as hyperintense space-occupying lesions with an enhancing hypointense rim on T2-weighted images. The rim of brain abscesses is thought to represent the abscess capsule. When evaluated on SWI, it was found to have a negative phase value with certain characteristic features. The rims of brain abscesses compared with GBMs were found to be smoother and more complete. In pyogenic brain abscess, haemorrhage in the wall is considered exceptional and its presence is considered to support a diagnosis of haemorrhagic

tumour.[22-26] Recently, haemorrhagic changes in the walls of pyogenic abscess have been demonstrated on SWI with 3T MRI. In our study, we reported a case of pyogenic brain abscess showing ITSS in the peripheral portion of lesion on SWI with 1.5T MRI. Correlation with histopathology was achieved. This is similar to another study where it was reported that susceptibility sequence demonstrated haemorrhage in the wall of brain abscess.

In our study, the semi-quantitative analysis shows that Grade 3 ITSS was not found in any of the 6 patients with METS, Grade 2 ITSS was encountered in two cases, and rest of the four metastatic lesions were lacking of ITSS (Grade 1). Presence of Grade 3 ITSS was noted in 14 out of 16 GBMs, hence Grade 3 ITSS showed differentiation between GBM and METS with a sensitivity of 87.5% and specificity of 100% with a $P < 0.0001$. These results were in agreement with Park *et al*.[20] who found that the lack of ITSS can be a specific sign in the imaging diagnosis of lymphomas and metastasis lesions. However, in our study sample, lymphomas were not encountered during the study period.

In our study, ITSS was not detected in 6 cases of NTGs, hence lack of ITSS can diagnose NTGs from other ICSOLs with sensitivity of 100% with $P < 0.0001$. The obtained results are consistent with documented in another study.[20]

SWI sequence has advantage to arrive at a best possible diagnosis. Presence of Grade 3 ITSS can be used as a marker to diagnose HGGs and GBMs. The lack of ITSS can be used as marker to diagnose NTGs. Grade 2 ITSS only cannot be used to differentiate LGGs from METS.

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Conflicts of interest

There are no conflicts of interest.

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