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RESEARCH

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Contrast enhanced FLAIR versus contrast enhanced T1W images in evaluation of intraparenchymal brain lesions

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Abstract

Background: Patients with suspected brain lesions are usually evaluated by means of intravenous contrast materials. These lesions may demonstrate enhancement through different mechanisms. At most institutions, CE-T1WI is the preferred sequence. FLAIR is a sort of inversion recovery pulse sequence with a long TR, TE and T1 and hence effectually nulls signals from CSF**.** The long T1 causes mild T effect and this result in lesion enhancement on post-contrast study. Therefore, lesions demonstrating enhancement on CE-T1WI will also demonstrate enhancement on CE-FLAIR images. The purpose of this work was to assess the role of CE-FLAIR versus CE-T1WI in evaluation of different intraparenchymal brain lesions.

Results: Comparing CE-T1WI to CE-FLAIR in various brain pathologies, both observers found higher sensitivity and specificity for lesion to background contrast ratio on CE-FLAIR comparing to CE-T1WI. Observer 1 found that lesion to background contrast ratio on CE-FLAIR had sensitivity of 71.4%, specificity of 66.7% and AUC of 0.661 versus 63.3% sensitivity, 58.3% specificity and 0.634 AUC for CE-T1WI. Observer 2 found that lesion to background contrast ratio on CE-FLAIR had sensitivity of 77.6%, specificity of 66.7% and AUC of 0.719 versus 61.2% sensitivity, 50% specificity and 0.628 AUC for CE-T1WI.

Conclusion: On comparing CE-FLAIR to CE-T1WI, CE-FLAIR display better lesion detection and enhancement also better soft tissue contrast resolution.

Keywords: CE-T1WI, CE-FLAIR, MRI, Intraparenchymal, Brain lesions

Background

The term brain lesion is commonly applied to define any lesion within the cranial cavity, which usually raises the volume of intracranial contents and causes a rise in the intracranial pressure. It includes any neoplasm (benign or malignant, primary or secondary), also any acute or chronic inflammatory lesion, any hematomas, various types of cysts, vascular malformations, traumatic and meningeal pathologies [1].

MRI used to assess these lesions through different sequences, the most important used sequences are non-enhanced T1-weighted image (T1WI), T2-weighted image (T2WI), FLAIR (Fluid attenuated inversion recovery), susceptibility-weighted image (SWI) and diffusion weighted image (DWI). Patients with suspected brain lesions are usually evaluated by means of intravenous contrast materials. These lesions may demonstrate enhancement through different mechanisms. At most institutions, CE-T1WI is the preferred sequence [2].

FLAIR is a sort of inversion recovery pulse sequence with a long TR (repetition time), TE (echo time) and TI (inversion time) and hence effectually nulls signals from

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cerebrospinal fluid (CSF) [3]. The long T1 causes mild T effect and this result in lesion enhancement on post-contrast study. Therefore, lesions demostrating enhancement on contrast enhanced T1WI (CE-T1WI) will also demonstrate enhancement on contrast enhanced FLAIR (CE-FLAIR) images. Previous studies showed that CE-FLAIR provide extra information comparing to CE-T1WI [3, 4].

CE-FLAIR has a substantial role in meningeal pathologies. It is very useful in the early diagnosis of leptomeningitis resulting in reduction in the mortality rate due to early initiation of an effective treatment [5, 6]. Also it has an important role in evaluating arterial pathologies, acute stroke, subacute cortical infarct and also in assessment of post-operative changes [7–10]. In addition to that it has a substantial role in assessment of facial neuritis in which CE-T1WI has a confined role due to the normal enhancement of the facial nerve. It was found that CE-FLAIR can improve the specificity and accuracy of MRI in patients with idiopathic facial palsy [11]. To the best of our knowledge, only few studies concentrated on the role of CE-FLAIR versus CE-T1WI in evaluation of intraparenchymal brain lesions [2, 12, 13].

Aim of the work

The aim of this study was to evaluate the role of CE-FLAIR versus CE-T1WI in evaluation of different intraparenchymal brain lesions.

Methods

Patient's demographic data

This prospective study included 61 patients (30 male and 31 female) with an age range from 5 to 72 years (mean ± SD = 41.35 ± 15.62). MRI studies for all cases were performed in the period from June 2020 to November 2021. This study was approved by our institution ethics committee and informed written consent was obtained from each patient.

Inclusion criteria

Patients presented by variable neurological conditions including:

- Suspected infection (Fever, disturbed conscious level, neck stiffness).
- Patients with clinical suspicion of multiple sclerosis (numbness, limb weakness, fatigue, gait disturbance and visual symptoms) or on follow-up to assess activity of disease.
- Patients with suspected primary brain tumor or on post-operative / post radiotherapy follow-up.
- Patients with known elsewhere primary brain tumor with underlying metastatic work up to detect metastatic brain lesions.

Exclusion criteria

1. General contra-indications for MRI scan, for example:
   (a) Patients who have a cardiac pacemaker.
   (b) Patients with cochlear implants.
   (c) Patients having an intracranial aneurysmal clip.
   (d) Un-cooperative and claustrophobic patients.
   (e) Bad general condition.
2. Patients who have contraindications to contrast media as in severely impaired renal function for the fear of nephrogenic systemic sclerosis and other complications of IV Gadolinium contrast media.

MRI technique

MRI examinations were performed for all patients using 1.5 T. MRI unit (Philips Interna) with standard head coil and with the patient in supine position. The following sequences were obtained for all patients: fast spin echo (FSE) T1WI (TR/TE: 581/15 ms, slice thickness: 5 mm, interslice gap: 1 mm, flip angle: 69, FOV: 230 mm and matrix: 256), T2WI (TR/TE: 4000/100 ms, slice thickness: 5 mm, interslice gap: 1 mm, flip angle: 90, FOV: 230 mm and matrix: 256), FLAIR (TR/TE: 11,000/110 ms, TI: 2800 ms, slice thickness: 5 mm, interslice gap: 1 mm, flip angle: 90, FOV: 230 mm and matrix: 256) and DWI (TR/TE: 3614/160 ms, TI: 2800 ms, slice thickness: 5 mm, interslice gap: 1 mm, flip angle: 90, FOV: 230 mm and matrix: 256).

Contrast enhanced images were acquired after intravenous injection of Gadolinium (Magnevist) in the dose of 0.1 mmol/kg body weight. One minute after the injection of contrast agent, the acquisition of axial, sagittal and coronal conventional CE-T1WI were immediately done, the axial or coronal CE-FLAIR images were acquired successively with a delay time of approximately 3–4 min (the scan parameters were the same as the pre-contrast images).

Image analysis

MR images were analyzed independently by two experienced radiologists with about 14 and 10 years' experience in neuroimaging.

At first the radiologists interpret the conventional MRI sequences to detect any brain lesion (e.g., tumor, infection, multiple sclerosis (MS), etc.). Then CE-T1WI and CE-FLAIR images were assessed and compared with each other's. Images were assessed both qualitatively and quantitatively.

If CE-FLAIR images were unable to differentiate enhancing lesion from surrounding edema (as in tumors) or unable to detect lesion enhancement as in lesions with initially high signal intensity (SI) in pre contrast FLAIR images especially in cases of MS, we use subtraction MRI technique by performing a subtraction between the post-contrast and the corresponding pre-contrast FLAIR images to evaluate and confirm the presence of enhancement. Subtraction technique was added in most of the cases of our study (39 cases).

Qualitative evaluation by visual assessment includes the following:

- Existence of lesion contrast enhancement.
- Defining the site and pattern of lesion enhancement.
- Estimation of the lesion rate of enhancement in both CE-T1WI and CE-FLAIR and classing it in CE-FLAIR images as: superior, equivocal or inferior comparing to CE-T1WI.
- Assessment of lesion conspicuity which was defined as delineation of the border of the enhanced lesion in CE-FLAIR images and differentiating the lesion from the surrounding edema or from the normal appearing brain parenchyma, it was classified into: no, fair or good delineation.
- Linking the images findings with the provided clinical data.

Quantitative evaluation includes the following items:

- **Calculating contrast enhancement index (CEI):**

It was done by measuring the SI of the lesion in both pre and post contrast FLAIR images by using region of interest (ROI). It was calculated by using the following equation: $I\hat{} = I - I0$ ($I\hat{}$ is CEI, I is the lesion SI on CE-FLAIR images and I0 is the lesion SI on pre-contrast FLAIR images).

- **Calculating lesion to background contrast ratio:**

It was done by measuring the lesion SI as well as the background SI in normal appearing brain parenchyma by using ROI and applied to pre and post contrast T1W images as well as pre and post contrast FLAIR images. The lesion to background contrast ratio was calculated by using the following equation: Lesion to background contrast ratio = Lesion SI − Background SI/Background SI.

Standard of reference

In our study histopathology was used as a standard of reference in all included cases of space occupying lesions. In cases of MS we used clinical findings and CSF analysis as our standard of reference, while in cases of infection, we used the clinical and laboratory findings as a standard of reference.

Statistical analysis and data interpretation

Data were fed to the computer and analyzed using IBM SPSS Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Qualitative data were described using number and percent. Quantitative data were described using median (minimum and

(See figure on next page.)

Fig. 1 Male patient aged 52 years old, presented by long standing headache and signs of increased intracranial pressure with history of prior excision of glioblastoma multiformis. **A**, **B** Axial pre and post contrast T1W images show: an intra-axial SOL occupying left parietal lobe showing mixed solid and cystic components with surrounding mild perifocal edema and exerting mass effect in the form of effacement of cortical sulci. The lesion display mixed heterogeneous SI on T1WI and showing faint enhancement on CE-T1WI. **C**, **D** Axial pre and post contrast FLAIR images show: The lesion appear of mixed heterogenous SI on precontrast FLAIR images and showing more evident and intense enhancement on CE-FLAIR image in comparison with post contrast T1W image denoting superiority of CE-FLAIR in assessment of lesion activity. **E**, **F** Pre and post contrast FLAIR at same level: measurements of the SI, denoting the difference between pre and post contrast and confirms the presence of enhancement (CEI = 739, Lesion to background contrast ratio = 1.8). **G**, **H** Pre and post contrast T1WI: measurements of the SI in pre and post contrast images (CEI = 328, Lesion to background contrast ratio = 0.65). Final diagnosis: Residual/Recurrent Glioblastoma Multiformis

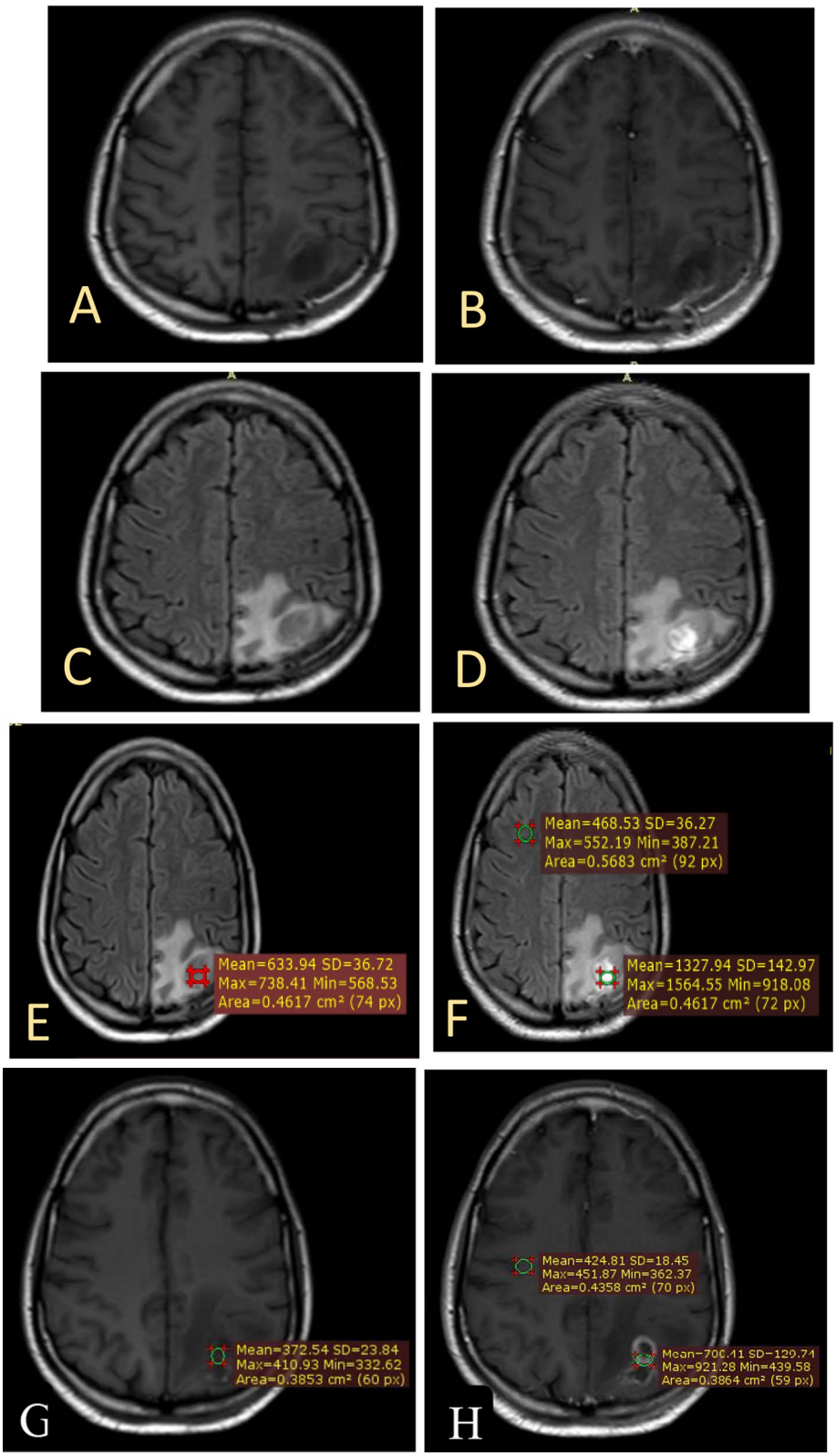

Fig. 1 (See legend on previous page.)

maximum) for non-parametric data and mean, standard deviation for parametric data after testing normality using Kolmogorov–Smirnov test. Significance of the obtained results was judged at the (0.05) level. The diagnostic performance of a test was evaluated using Receiver Operating Characteristic (ROC) curve analysis. Sensitivity and Specificity were detected from the curve and PPV, NPV and accuracy were calculated through cross tabulation. Inter-class correlation was used to detect agreement between continuous variables with correlation coefficient more than 0.7 was considered excellent agreement. Kappa agreement was calculated by cross tabulation for categorical variables with Kappa of 0.81–0.99 was considered Perfect agreement.

Results

This prospective study included 61 patients, 31 females (50.8) and 30 males (49.2%). Their age ranged from 5 to 72 years (mean age was 41.35 ± 15.62). According to final diagnosis in accordance with standard of reference, most of our cases were tumors (80.3%), followed by MS (8.2%) then ischemic (4.9%), infection (3.3%) and the least were traumatic and metabolic (1.6% each). As regard space occupying lesions we divided our studied cases in primary (38 cases; 62.3%) and secondary tumors (11 cases; 18%), in primary tumors we included 11 cases (18%) of Glioma (Fig. 1), 6 cases (10%) of Astrocytomas, 8 cases (13.1%) of meningiomas (Fig. 2), 8 cases (13.1%) of medulloblastomas, 3 cases (4.9%) of oligodendroglioma, one case (1.6%) of ependymoma and one case (1.6%) of central neurocytoma (Fig. 3). In secondary tumors we included 5 cases (8.3%) metastatic from breast cancer, 3 cases (4.9%) from lung cancer, one case (1.6%) from urinary bladder cancer, one case (1.6%) from rectal cancer and one case (1.6%) from high grade mucoepidermoid carcinoma.

A qualitative comparison of CE-T1WI and CE-FLAIR images was carried out, revealing the following: The first observer found that CE-FLAIR was superior to CE-T1WI in 67.2% of cases, equivocal in 24.6% of cases and inferior in 8.2% of cases. The second observer found that CE-FLAIR was superior to CE-T1WI in 70.5% of cases, equivocal in 21.3% of cases and inferior in 8.2% of cases. There was excellent agreement between both observers (Kappa = 0.930) (Table 1).

Regarding lesion conspicuity, first observer found that In CE-FLAIR images: The majority of cases (68.9%) had good delineation, 24.6% had fair delineation, and 6.6% had no delineation, while the second observer found that 75.4% of cases had good delineation, 18% had fair delineation and 6.6% had no delineation. There was excellent agreement between both observers regarding lesion conspicuity on CE-FLAIR (Kappa = 0.848) (Table 2).

Regarding the number of enhanced lesions in CE-FLAIR in comparison with CE-T1WI, the results revealed higher number of enhanced lesions detected in CE-FLAIR images comparing to CE-T1WI (Table 3; Fig. 4).

Regarding quantitative measurements, there was excellent agreement between both observers regarding the CEI which represent the difference between SI of lesions in pre and post contrast FLAIR images with the mean CEI detected by observer 1 was 88 (0.5–651) and the mean CEI detected by observer 2 was 83.0 (0.5–651.0) (ICC = 0.959, 95% CI 0.933–0.975). Comparing lesion to background contrast ratio on CE-FLAIR and CE-T1WI, both observers found higher lesion to background contrast ratio on CE-FLAIR images. Observer 1 found the mean lesion to background contrast ratio on CE-FLAIR images was 0.40 (0.02–1.89) versus 0.168 (0.01–0.81) on CE-T1WI. Observer 2 found the mean lesion to background contrast ration on CE-FLAIR images was 0.428 (0.03–1.89) versus 0.177(0.02–0.81) on CE-T1WI (ICC = 0.917, 95% CI 0.865–0.949) (Table 4).

Comparing CE-T1WI to CE-FLAIR in various brain pathologies, both observers found higher sensitivity and specificity for lesion to background contrast ratio on CE-FLAIR comparing to CE-T1WI. Observer 1 found that lesion to background contrast ratio on CE-FLAIR had sensitivity of 71.4%, specificity of 66.7% and AUC of 0.661 versus 63.3% sensitivity, 58.3% specificity and

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Fig. 2 Female patient aged 30 years old, complaining of headache. **A**, **B** Axial pre and post contrast T1WI show: well-defined isointense extraxial dural based SOL in right frontal lobe with intense homogenous enhancement on CE-T1WI. **C**, **D** Axial pre and post contrast FLAIR images show: the lesion appear isointense on precontrast FLAIR images with surrounding mild perifocal edema and showing peripheral rim of enhancement on CE-FLAIR image. **E** CE-FLAIR subtraction image show: more delineation of the lesion from the surrounding edema with more evident enhancement. **F**, **G** Pre and post contrast FLAIR at same level: measurements of the SI, denoting the difference between pre and post contrast and confirms the presence of enhancement (CEI = 73, Lesion to background contrast ratio = 0.55). **H**, **I** Pre and post contrast T1WI: measurements of the SI in pre and post contrast images (CEI = 271, Lesion to background contrast ratio = 0.81). Final diagnosis: Meningioma

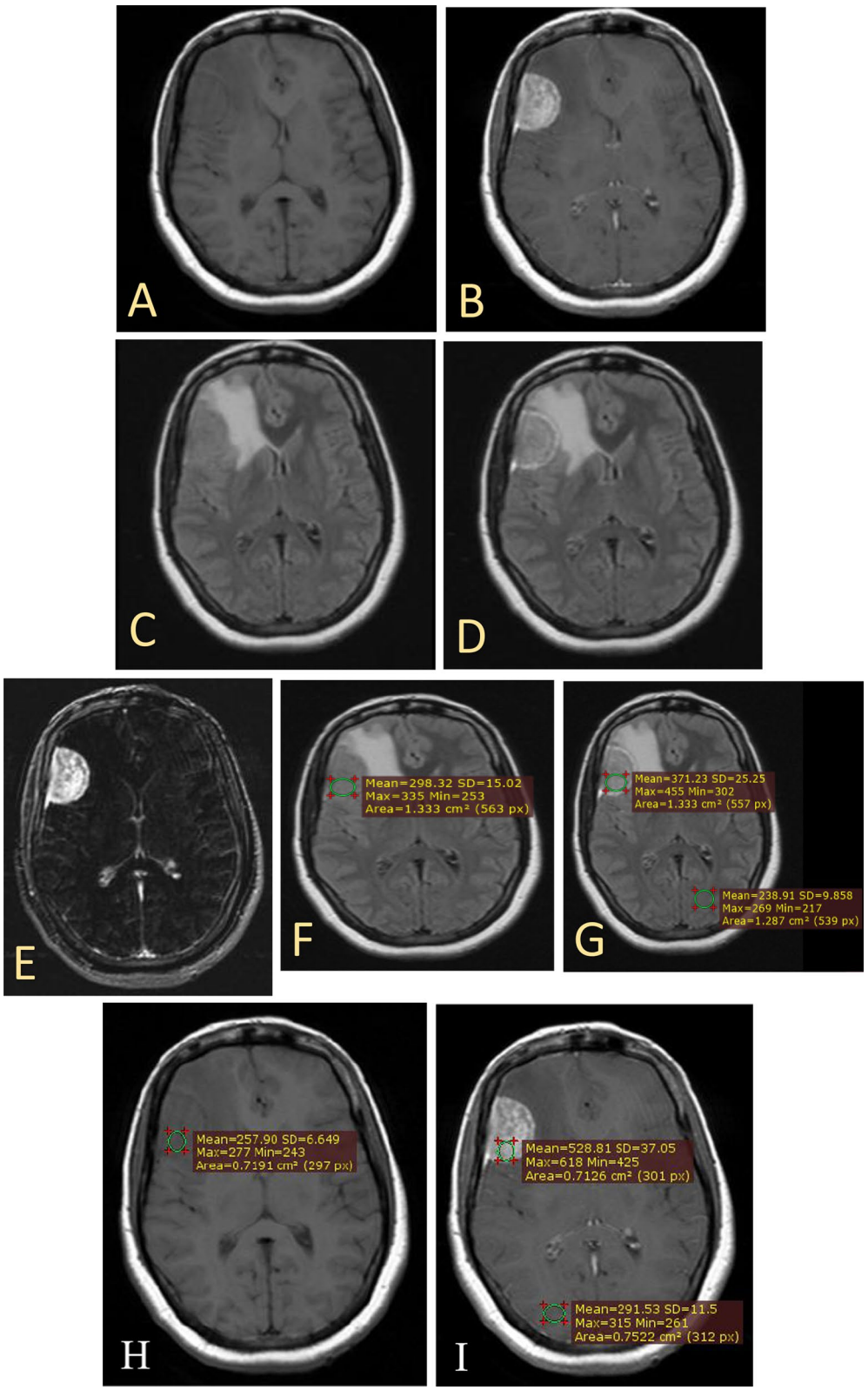

Fig. 2 (See legend on previous page.)

0.634 AUC for CE-T1WI. Observer 2 found that lesion to background contrast ratio on CE-FLAIR had sensitivity of 77.6%, specificity of 66.7% and AUC of 0.719 versus 61.2% sensitivity, 50% specificity and 0.628 AUC for CE-T1WI (Table 5) (Fig. 5).

Discussion

The detection and characterization of brain lesions were improved by using intravenous magnetic resonance contrast materials. Gadolinium (the commonly used contrast agent), cause shortening of both T1 and T2 relaxation times of tissues in which it has accumulated. However, at clinical doses the T1-shortening effect is responsible for the lesion contrast enhancement [12]. The shortening of the MR relaxation times caused by the injection of contrast agents causes enhanced tissue to appear hyper intense on CE-T1WI. FLAIR images are equivocal to T2WI except for dark CSF caused by the T1 effect which is due to the long TI. After contrast injection, the resultant T1 shortening will cause hyper intensity on CE-FLAIR images; therefore, lesions demonstrating enhancement on CE-T1WI will also demonstrate enhancement on CE-FLAIR images [2].

In this study, there was excellent agreement between both observers regarding the superiority of CE-FLAIR over CE-T1WI in lesion detection (Kappa = 0.930). This is in line with Mahale et al. [13] who reported that CE-FLAIR was superior over CE-T1WI in detection of lesions in 72% of the studied cases. It was also in line with Azuma et al. [14] who reported that there was excellent interobserver agreement regarding the superiority of CE-FLAIR over CE-T1WI in lesion detection with Kappa agreement above 0.824. Our results also were in support with the research conducted by Rastogi et al. [15] who found that CE-FLAIR images exhibited superior enhancement in 63.2% of the studied cases.

Regarding lesion conspicuity which refers to the ability to define the margin of the enhanced lesion in CE-FLAIR images, we found that CE-FLAIR images revealed better lesion conspicuity over CE-T1WI in 68.9% of the cases. High interobserver agreement was noted (Kappa = 0.848). Another study [16] stated that CE-FLAIR images revealed better lesion conspicuity only in 39.4% of the studied cases. These different ratios may be due to the additional application of subtraction imaging between post and pre contrast FLAIR in our study, which had a very important role in detection of tiny and faintly enhancing lesions. Also it had an important role in detection of lesion enhancement in lesions with initially high SI in pre contrast FLAIR images also in lesions where there is inadequate delineation of the enhancing border from the surrounding hyperintense perilesional edema. We also found that subtraction images helped to reduce false-positive cases, reduce the reading time, and raised the accuracy of detection of contrast enhancement in CE-FLAIR images, this was supported by the study done by Gao et al. [17] who estimated the added value and superiority of pre and post contrast FLAIR subtraction images in diagnosis of brain gliomas and distinguishing its recurrence from post-treatment changes.

Based on our observations higher number of enhanced lesions were detected in CE-FLAIR images comparing to CE-T1WI, for example in patients with multiple sclerosis (MS) included in our study, we noticed that CE-FLAIR was superior to CE-T1WI in 90% of the studied cases of MS. CE-FLAIR offered better lesion detection and detected larger number of active MS plaques. This was determined by describing active plaques as ultra-bright in comparison with pre-contrast FLAIR images and using subtraction images to confirm the presence of enhancement. Our findings were in line with another study [18] which concluded that CE-FLAIR had the highest sensitivity comparing to CE-T1WI, DWI & ADC in detection of active MS plaques due to the CSF signal suppression in FLAIR, thus offering enough TR time recovery in active enhanced plaques. In their study higher number of active MS plaques in supratentorial region was found on CE-FLAIR comparing to CE-T1WI.

Regarding quantitative analysis, CEI was calculated for all cases. Our results showed significantly higher lesion

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Fig. 3 Male patient aged 36 years old, presented by headache and seizures. **A** Pre-contrast T1WI: shows large heterogeneous isointense intraventricular soft tissue mass. **B** CE-T1WI: shows mild to moderate enhancement of the lesion. **C** Pre-contrast FLAIR shows iso to hyperintense intraventricular mass with numerous cystic areas (bubbly appearance) and flow voids inside. **D** CE-FLAIR: revealed thicker and more extensive enhancement in comparison with CE-T1WI. **E**, **F** Pre and post contrast FLAIR at same level: measurements of the SI, denoting the difference between pre and post contrast and confirms the presence of enhancement (CEI = 137, Lesion to background contrast ratio = 1.07). **G**, **H** Pre and post contrast T1WI: measurements of the SI in pre and post contrast images (CEI = 51, Lesion to background contrast ratio = 0.04). Final diagnosis: Central neurocytoma

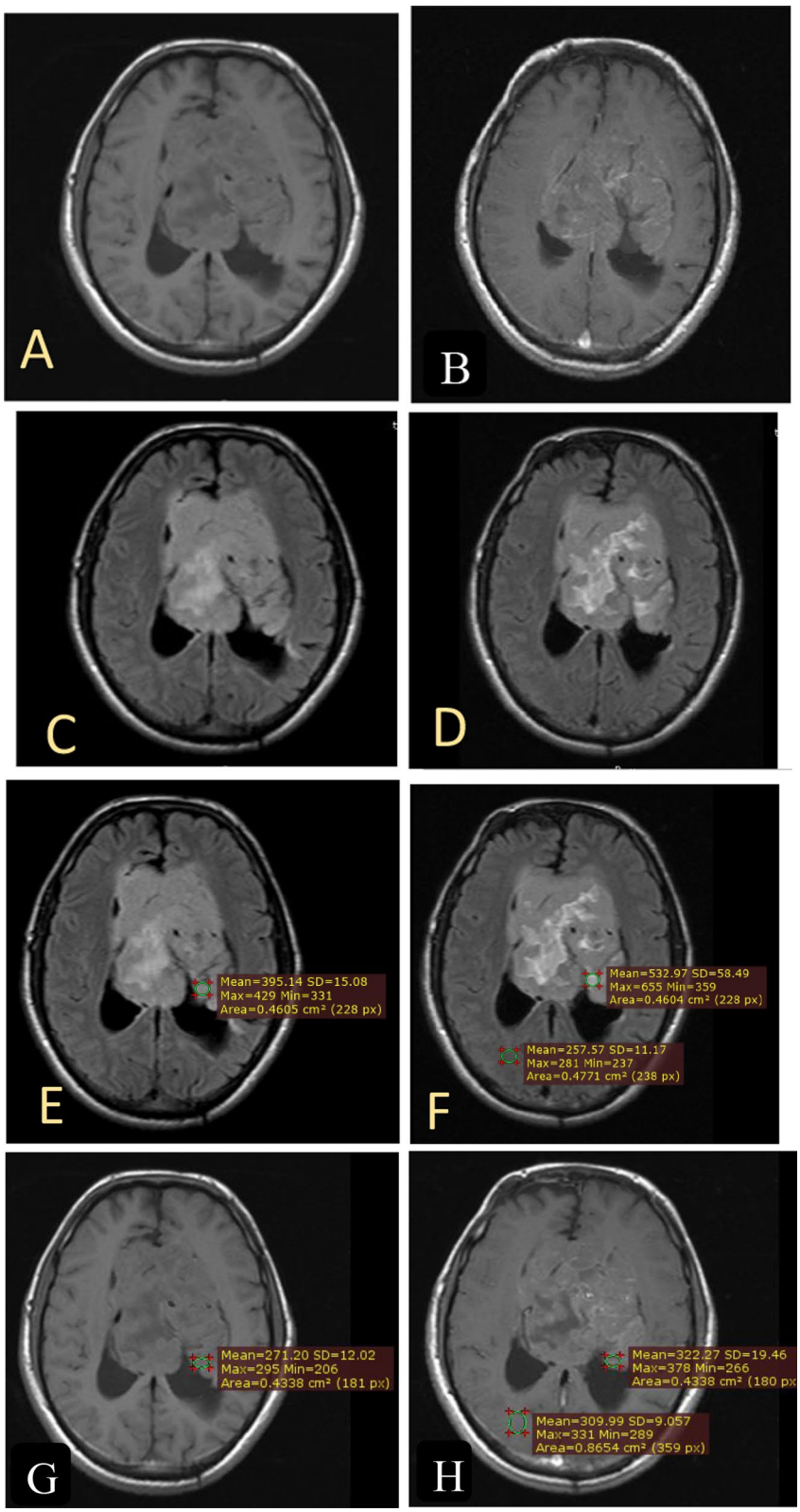

Fig. 3 (See legend on previous page.)

Table 1 Demonstrates comparison between CE-FLAIR and CE-T1WI regarding enhancement rate of lesions among studied cases

Comparison with post-contrast T1WI	1st observer *N* = 61	Percentage %	2nd observer *N* = 61	Percentage%	Kappa agreement
Equal	15	24.6	13	21.3	0.930
Superior	41	67.2	43	70.5	
Inferior	5	8.2	5	8.2	

Table 2 Demonstrates lesion conspicuity in CE-FLAIR among studied cases

Comparison with post-contrast T1WI	1st observer *N* = 61	Percentage %	2nd observer *N* = 61	Percentage %	Kappa agreement
No	4	6.6	4	6.6	0.848
Fair	15	24.6	11	18	
Good	42	68.9	46	75.4	

Table 3 Demonstrates comparison between CE-FLAIR and CE-T1WI regarding number of enhanced lesions among studied cases

	1st observer *n* = 61	2nd observer *n* = 61	Kappa agreement
Number of enhanced lesions in CE-T1WI			0.974
0	29	28	
1	23	24	
2	6	6	
3	1	1	
4	1	1	
5	1	1	
Number of enhanced lesions in CE-FLAIR			0.952
0	17	18	
1	28	28	
2	10	9	
3	3	3	
5	2	2	
9	1	1	

SI on CE-FLAIR images compared to pre contrast ones and this proved the presence of lesion enhancement on CE-FLAIR images, for observer one, the mean CEI was 88 ranging from 0.5 to 651, for observer two, the mean CEI was 83 ranging from 0.5 to 651 (ICC = 0.959, 95% CI 0.933–0.975). These results were in line with another study [19] which found higher CEI in CE-FLAIR in comparison with pre-contrast FLAIR images with CEI ~ 262 ranging from 40 up to 1708.

In addition to that, our study included contrast to background ratio which was objectively calculated with a view to avert creating delusive data by visual assessment of contrast enhnacement, which may be influenced by windows and levels, magnification and monitor brightness. In our study both observers found significantly higher contrast to background ratio in CE-FLAIR in comparison with CE-T1WI (ICC = 0.917 & 95% CI 0.865–0.949) which allowed better delineation of lesions by CE-FLAIR. The higher contrast to background ratio on CE-FLAIR can be explained by higher inherent soft tissue contrast resolution in FLAIR compared to T1W sequence. These results were supported by the results of study conducted by Mustafa et al. [19] who found higher contrast to background ratio in CE-FLAIR than in CE-T1WI. They found the contrast to background enhancement ratio ranging from 0.2 to 3 in CE-FLAIR compared to 0.05 to 1.2 in CE-T1WI. Our study also agreed with the results of Kim et al. [20] who found that CE-FLAIR images had higher tumor to background contrast ratio in comparison with CE-T1WI. On their study the contrast to background ratio on CE-FLAIR was about 97.7 in comparison with 29.3 in CE-T1WI.

The limitations of this study was the limited number of patients especially those with brain infections and metabolic disorders.

Conclusions

On comparing CE-FLAIR to CE-T1WI, CE-FLAIR display better lesion detection and enhancement also better soft tissue contrast resolution. It can provide additional information that affect disease management and progression. So we recommend CE-FLAIR to be integrated as a routine pulse sequence in MRI examination of different intraparenchymal brain lesions.

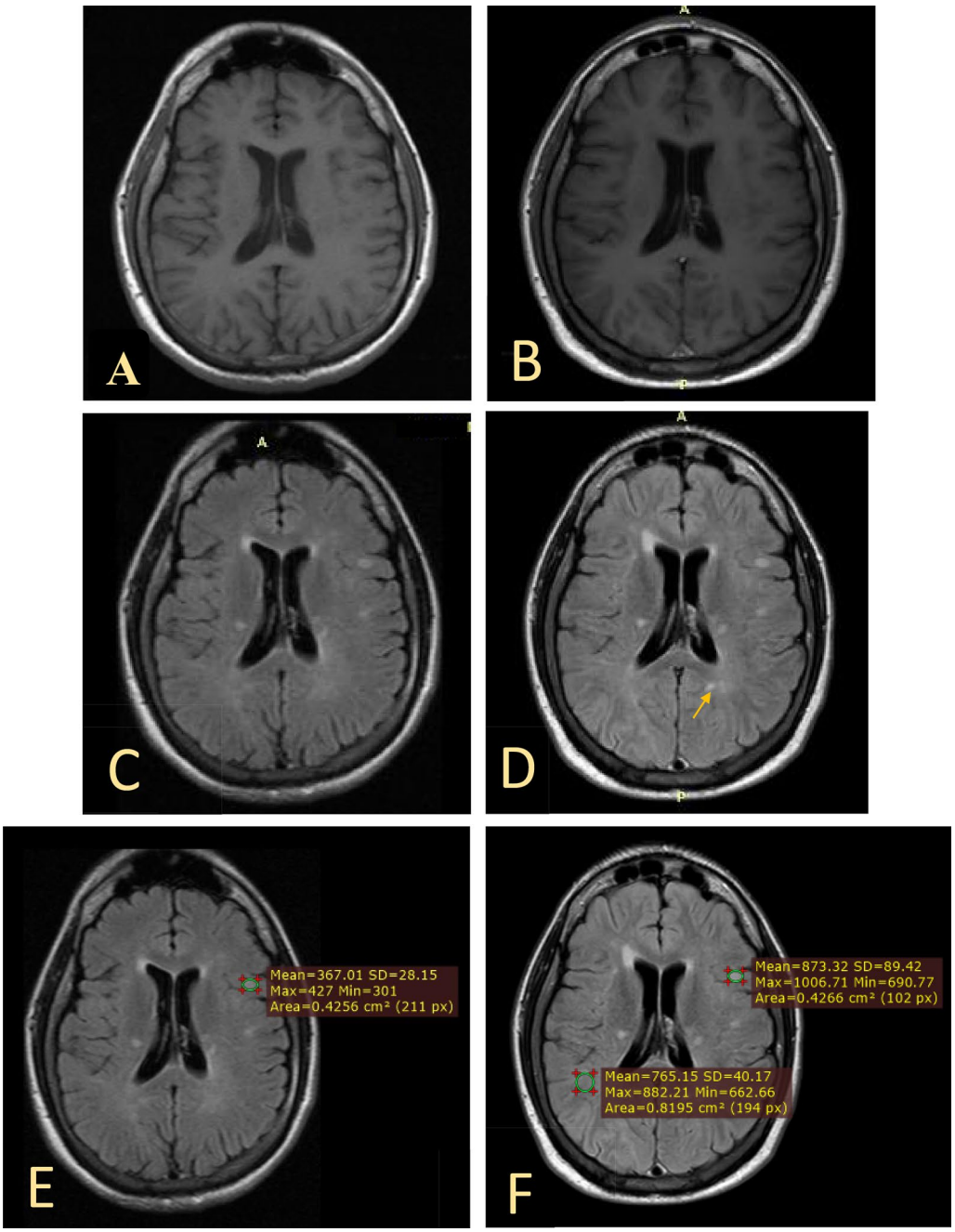

Fig. 4 Male patient aged 27 years old, known case of MS on follow-up presented by clinical signs of activity. **A**, **B** Axial pre and post contrast T1WI: show multiple hypointense lesions in the periventricular white matter with no definite enhancing lesions on post contrast study. **C** Axial pre-contrast FLAIR shows multiple foci of high signal intensity at periventricular white matter. **D** Axial CE-FLAIR: shows nodular enhancement of MS plaques (arrows) which were not detected in pre contrast FLAIR (denoting more number of enhancing lesions shown in CE-FLAIR sequence without corresponding enhancement in post contrast T1W image. **E**, **F** Axial pre and post contrast FLAIR at same level: measurements of the SI, denoting the difference between pre and post contrast and confirms the presence of enhancement (CEI = 506, Lesion to background contrast ration = 0.12). Final Diagnosis: A case of MS with signs of activity

Table 4 Demonstrates interobserver agreement regarding the CEI and lesion to background contrast ratio on CE-FLAIR and CE-T1WI among studied cases

	1st observer *n* = 61	2nd observer *n* = 61	ICC	95% CI
Contrast enhancement index (CEI)	88 (0.5–651)	83.0 (0.5–651.0)	0.959	0.933–0.975
Lesion to background contrast ratio on CE-FLAIR images	0.40 (0.02–1.89)	0.428 (0.03–1.89)	0.917	0.865–0.949
Lesion to background contrast ratio on CE-T1WI	0.168 (0.01–0.81)	0.177 (0.02–0.81)	0.890	0.823–0.932

ICC Interclass correlation, *CI* Confidence interval

Table 5 Demonstrate sensitivity and specificity of lesion to background contrast ratio on CE-FLAIR and CE-T1WI by both observers

	AUC (95% CI)	*P* value	Cut off point	Sensitivity%	Specificity %
Lesion to background contrast ratio on CE-T1WI (First observer)	0.634 (0.485–0.784)	0.152	0.122	63.3	58.3
Lesion to background contrast ratio on CE-T1WI (second observer)	0.628 (0.478–0.777)	0.174	0.113	61.2	50.0
Lesion to background contrast ratio on CE-FLAIR (First observer)	0.661 (0.499–0.823)	0.086	0.2341	71.4	66.7
Lesion to background contrast ratio on CE-FLAIR (second observer)	0.719 (0.555–0.882)	0.02*	0.2341	77.6	66.7

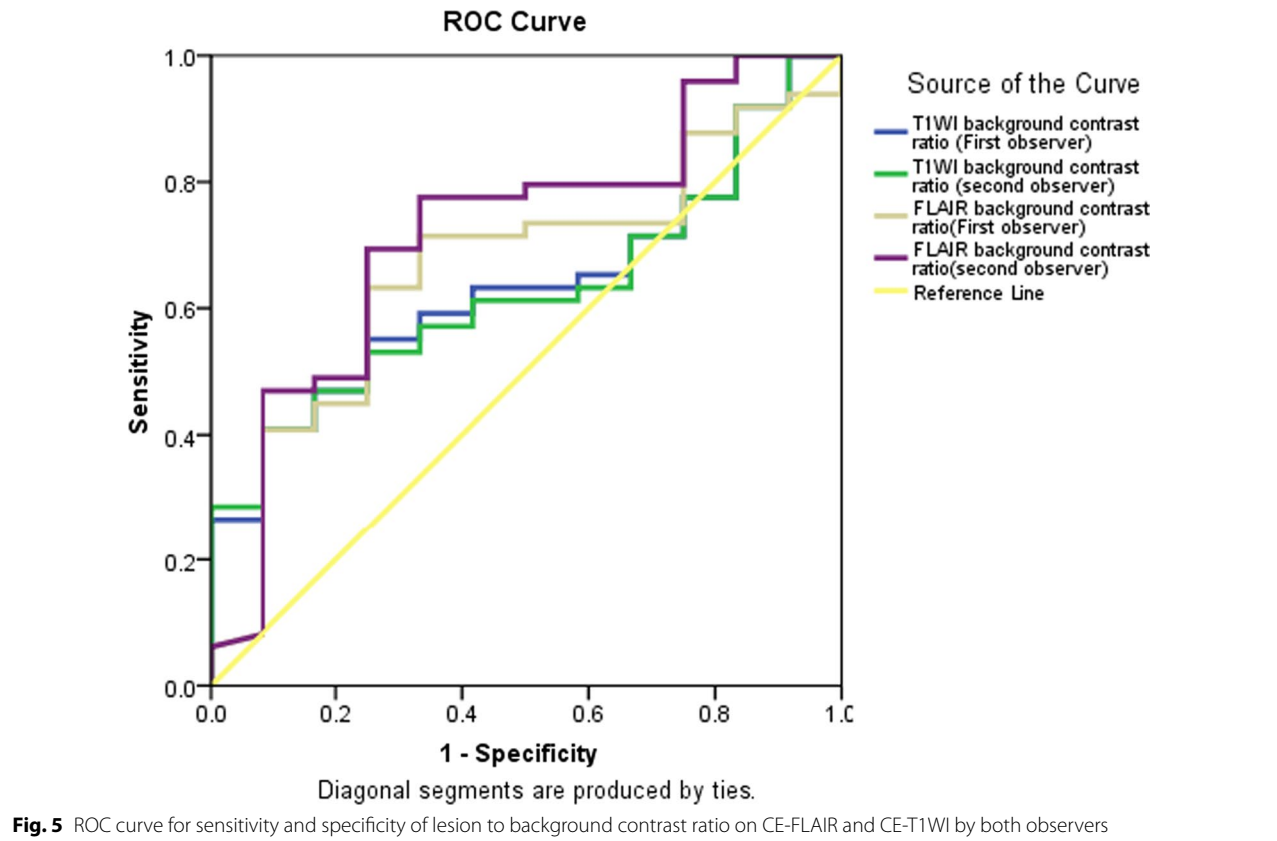

Fig. 5 ROC curve for sensitivity and specificity of lesion to background contrast ratio on CE-FLAIR and CE-T1WI by both observers

Abbreviations
MRI: Magnetic resonance imaging; T1WI: T1 weighted image; T2WI: T2 weighted image; FLAIR: Fluid attenuated inversion recovery; SWI: Susceptibility-weighted image; DWI: Diffusion weighted image; TR: Repetition time; TE: Echo time; TI: Inversion time; CSF: Cerebrospinal fluid; CE-T1WI: Contrast enhanced T1WI; CE-FLAIR: Contrast enhanced FLAIR; SD: Standard deviation; ms: Millisecond; FOV: Field of view; FSE: Fast spin echo; ROI: Region of interest; CEI: Contrast enhancement index; SI: Signal intensity; MS: Multiple sclerosis; SOL: Space occupying lesion; ICC: Interclass correlation coefficient; CI: Confidence interval; AUC: Area under curve.

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Author contributions
MB revised the collected data and the manuscript. YR, DM and ME analyzed the MRI images of all patients. ME & DM wrote the manuscript and performed the statistical analysis. All authors read and approved the final manuscript.

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Availability of data and material
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by our institution's ethics committee (Mansoura Faculty of Medicine Institutional Research Board) (ethics committee reference number is MS/19.09.819) and all patients gave their written informed consent before inclusion in the study.

Consent for publication
Written informed consent for the publication of this data was taken all patients involved in this study.

Competing interests
The authors declare that they have no competing interests.

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