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Original contribution

Brain imaging: Comparison of T1W FLAIR BLADE with conventional T1W SE

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ABSTRACT

Introduction: Although T1 weighted spin echo (T1W SE) images are widely used to study anatomical details and pathologic abnormalities of the brain, its role in delineation of lesions and reduction of artifacts has not been thoroughly investigated. BLADE is a fairly new technique that has been reported to reduce motion artifacts and improve image quality.
Objective: The primary objective of this study is to compare the quality of T1-weighted fluid attenuated inversion recovery (FLAIR) images with BLADE technique (T1W FLAIR BLADE) and the quality of T1W SE images in the MR imaging of the brain. The goal is to highlight the advantages of the two sequences as well as which one can better reduce flow and motion artifacts so that the imaging of the lesions will not be impaired.
Materials and methods: Brain examinations with T1W FLAIR BLADE and T1W SE sequences were performed on 48 patients using a 1.5 T scanner. These techniques were evaluated by two radiologists based on: a) a qualitative analysis i.e. overall image quality, presence of artifacts, CSF nulling; and b) a quantitative analysis of signal-to-noise ratios (SNR), contrast-to-noise ratios (CNR) and Relative Contrast. The statistical analysis was performed using the Kruskal-Wallis non-parametric system.
Results: In the qualitative analysis, BLADE sequences had a higher scoring than the conventional sequences in all the cases. The overall image quality was better on T1W FLAIR BLADE. Motion and flow-related artifacts were lower in T1W FLAIR BLADE. Regarding the SNR measurements, T1W SE appeared to have higher values in the majority of cases, whilst T1W-FLAIR BLADE had higher values in the CNR and Relative Contrast measurements.
Conclusion: T1W FLAIR BLADE sequence appears to be superior to T1W SE in overall image quality and reduction of motion and flow-pulsation artifacts as well as in nulling CSF and has been preferred by the clinicians. T1W FLAIR BLADE may be an alternative approach in brain MRI imaging.

1. Introduction

T1 weighted spin-echo (SE) images are widely used to study anatomical details and pathologic abnormalities of brain. Artifacts can degrade the quality of these images; sometimes they may obscure or mimic pathology. Patient motion, blood flow in major vessels, and metallic clips placed during surgery can induce significant artifacts in magnetic resonance images. The most common source of artifacts is patient motion [1]. Studies have shown that MR imaging with BLADE, which is a PROPELLER equivalent implementation of the Siemens Medical System (Erlagen, Germany), effectively reduces motion and pulsatile flow artifacts in healthy and adult patients as well as in children [2–8], and therefore it has the potential of reducing the frequency of anesthesia in uncooperative adults and children [1,9].

The term BLADE is the commercial name of a SE sequence that uses the PROPELLER (periodically rotated overlapping parallel lines with enhanced reconstruction) k-space trajectory. This method employs N number of blades, which rotate around the center of the k space [10]. Each blade consists of L lowest phase encoding lines (i.e., echo train length [ETL]) of a conventional rectilinear k-space trajectory that are

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Table 1
Summary of the parameters of the sequences that were applied for brain MR examination.

Parameters/sequences	T1W SE	T1W FLAIR BLADE
Number of slices	22	22
Slice thickness (mm)	5.0	5.0
TR (ms)	550	2000
TE (ms)	8.7	59
Distance factor (%)	30	30
FOV (mm)	230	230
Base resolution	256	256
Echo spacing (ms)	–	5.9
ETL	–	49
Bandwidth (Hz/pixel)	150	362

acquired after a single radiofrequency excitation. The BLADE technique has the advantage of central k-space oversampling, so that image artifacts are greatly reduced. The BLADE technique has been applied in many different anatomical sites and clinical contexts. More specifically, in brain imaging, BLADE technique has been reported to reduce motion artifacts and improve image quality [2,3,8,11–13]. Similar findings have been reported in examinations of the upper abdomen [12] and knee [14]. Another sequence with great importance in brain imaging is fluid attenuation inversion recovery (FLAIR). FLAIR is a special inversion recovery sequence with long T1 to remove the effects of fluid from the resulting images. T1 time in FLAIR pulse sequence is adjusted to the relaxation time of the component that should be suppressed [14–16]. For fluid suppression, the inversion time (long T1) is set to the zero crossing point of fluid, resulting in the 'erase' of the signal [17]. FLAIR is used in brain imaging to more clearly see periventricular and cord lesions because it nulls the high signal from CSF. Additionally, it is very useful in visualizing multiple sclerosis plaques and acute sub-arachnoid hemorrhage [18]. A study has shown that image contrast is superior in T1-weighted FLAIR images, which also provide improved lesion-to-background and grey to white matter contrast-to-noise ratios. These indicate an important role for T1-weighted FLAIR sequence in intracranial imaging [2] and highlight its advantage over the more widely practiced T1-weighted FSE sequence (T1W SE) [19].

A comparison between T1W FLAIR BLADE technique and T1W SE has shown that the first one is superior for delineation of lesions and reduction of flow-related artifacts, especially within the posterior fossa, and is preferred by observers [1]. BLADE images showed significantly less pulsation and motion artifacts than the standard T1-weighted spin-echo sequence scan. They also showed statistically significant lower signal-to-noise ratio but higher contrast-to-noise ratios with superior grey-white matter contrast. BLADE MR imaging at 1.5 T is applicable for central nervous system imaging of unsedated pediatric patients, reduces motion and pulsation artifacts, and minimizes the need for sedation or general anesthesia without loss of relevant diagnostic information [2].

The aim of this study is to compare the quality of T1-weighted FLAIR BLADE sequence with T1 conventional SE sequence in the MR imaging of the brain. The goal is to highlight the advantages of the two sequences as well as to indicate which one can better reduce flow and motion artifacts so that the imaging of the lesions will not be impaired.

2. Materials and methods

2.1. Patients

Forty eight patients (25 females, 23 males; age range 21–90 years (apart from two patients, who were 3 months old), who routinely underwent brain MRI examination during the period between February 2012 to March 2014, participated in the study.

2.2. MR imaging techniques

On all the patients, brain examination was performed using a 1.5-T scanner (Magneton Avanto, Siemens Healthcare Sector, Erlangen, Germany) with the Siemens 12-channel head matrix coil. The parameters of the different sequences are presented in Table 1. The sequences of this study were applied in the way that was recommended by Siemens Healthcare Sector.

The spin echo pulse sequence commonly uses a 90° excitation pulse to flip the net magnetization vector (NMV) into the transverse plane. When the 90° radiofrequency pulse is removed, a free induction decay signal (FID) is produced. T2* dephasing occurs almost immediately, and the signal decays. A 180° radiofrequency pulse is then used to compensate for this dephasing [18]. The signal that is received after the application of the 180° radiofrequency pulse is called a spin echo. Spin echo pulse sequences are the gold standard for most imaging. They may be used for almost every examination. T1 weighted images are useful for demonstrating anatomy because they have a high SNR. Moreover, in conjunction with contrast enhancement, they can also show pathology.

The BLADE sequences have a longer acquisition time (4 min and 20 s) than the conventional sequences (2 min and 25 s) as well as larger echo training length (ETL) and bandwidth (BW) values, which are important factors for eliminating motion artifacts. The PROPELLER MR technique was proposed by Pipe [3], and it is a variant of radial scanning techniques. This technique uses an alternative way of sampling in order to reduce artifacts that are induced by in-plane rotation and translational motion. It acquires multiple echo trains of a turbo spin echo (TSE) acquisition in a rotating and partially overlapping fashion, which are known as "blades". Phase correction is performed on each blade dataset to remove phase inconsistency resulting from motion during each acquisition [3]. The BLADE technique, which is a PROPELLER-equivalent implementation of the Siemens Medical System (Erlagen, Germany), acquires a number of blades that are rotated around the center of the k-space [7]. Each blade consists of L lowest phase encoding lines (i.e., echo train length [ETL]) of a conventional rectilinear k-space trajectory that are acquired after a single radiofrequency excitation. The BLADE technique has the advantage of central k-space oversampling, which leads to a great reduction of image artifacts [3,7,20].

2.3. Quantitative analysis

A quantitative analysis was performed on all the patients for both of the sequences. In the quantitative analysis the following items were analyzed: (a) the signal-to-noise ratio (SNR) of the CSF, white matter, grey matter, fat, optical nerve, (b) the contrast-to-noise ratio (CNR) and (c) the Relative Contrast between white matter and grey matter, CSF and white matter, CSF and grey matter, optical nerve and fat. For calculating these values, the signal intensity (SI) was measured with small elliptical

Table 2
Summary of the results of the quantitative comparison between T1W SE and T1W FLAIR BLADE sequences.

Parameters/sequences	T1W SE	T1W FLAIR BLADE	*p*-Value
SNR			
White matter	101.4 ± 34.0	87.6 ± 30.0	0.300
Grey matter	82.7 ± 30.6	61.2 ± 22.1	0.008
Fat	230.0 ± 72.5	255.1 ± 104.2	0.490
CSF	35.1 ± 13.2	9.0 ± 14.7	<0.001
Optical nerve	99.3 ± 42.7	94.5 ± 52.5	0.490
CNR			
White matter/grey matter	18.8 ± 9.0	26.4 ± 12.2	0.042
CSF/white matter	66.3 ± 29.4	78.6 ± 32.3	0.019
CSF/grey matter	47.6 ± 26.8	52.9 ± 23.6	0.300
Optical nerve/fat	130.7 ± 50.3	164.3 ± 62.3	0.003
ReCON			
White matter/grey matter	10.8 ± 5.1	18.0 ± 8.1	<0.001
CSF/white matter	47.9 ± 11.3	83.8 ± 19.5	<0.001
CSF/grey matter	39.1 ± 14.0	78.6 ± 21.6	<0.001
Optical nerve/fat	40.7 ± 12.6	49.2 ± 14.5	0.042

Table 3
Summary of the results of the qualitative comparison between the conventional and BLADE sequences.

Parameters/sequences	T1W SE	T1W FLAIR BLADE	*p*-Value
Overall image quality	3.4 ± 0.6	4.6 ± 0.6	<0.001
Contrast at the white matter and grey matter interface	2.8 ± 0.6	4.1 ± 0.7	<0.001
Contrast at the CSF and white matter interface	3.6 ± 0.6	4.6 ± 0.6	<0.001
Contrast at the CSF and grey matter interface	3.3 ± 0.6	4.3 ± 0.7	<0.001
Contrast fat and muscle	4.0 ± 0.6	4.8 ± 0.5	<0.001
Nulling CSF	4.0 ± 0.4	5.0 ± 0.2	<0.001
Motion	1.6 ± 0.8	1.3 ± 0.7	0.050
Flow pulsation artifacts	2.4 ± 0.8	1.1 ± 0.3	<0.001
Aliasing or foldover	2.8 ± 0.5	1.1 ± 0.3	<0.001

The values in bold indicate statistical significance. In all the cases T1 FLAIR BLADE shows a better result than T1 SE. The scale used for the last three cases (motion, flow pulsation artifacts and aliasing or foldover) was from 1 to 5, with 1 being the best. In the rest of the cases, a scale from 1 to 5 was used with 5 being the best.

regions of interest (ROI), which were placed at five regions (CSF, white matter, grey matter, fat, optical nerve). These ROIs were placed for measurement in the most homogeneous area of those regions in one sequence and then they were copied to measure the corresponding region in the other sequence as well, by using Eqs. (1), (2), and (3). The background noise was defined as a standard deviation of a measurement made by placing an elliptical ROI anterior to the frontal bone (air). The size of the ROIs used for the grey matter and fat was 0.1 cm^2, for the CSF and white matter was 0.1 cm^2, whereas for the optical nerve was 0.2 cm^2. These ROIs for each patient were basically placed at an identical position and size on the comparisons sequences. When the positions of ROIs were moved in some cases because of patient motion, ROIs were selected from the relative position to adjacent tissues. The SNR was calculated by the following mathematical expression:

$$SNR_A = \frac{SI_A}{N} \tag{1}$$

where A represents the tissue of interest, the SI_A is the signal intensity of A measured by an elliptical region-of-interest (ROI) on the system console, N is the background noise, which was defined as the standard deviation of a measurement made by placing an elliptical 2 cm ROI anterior of frontal lobe (air). The CNR was calculated based on the

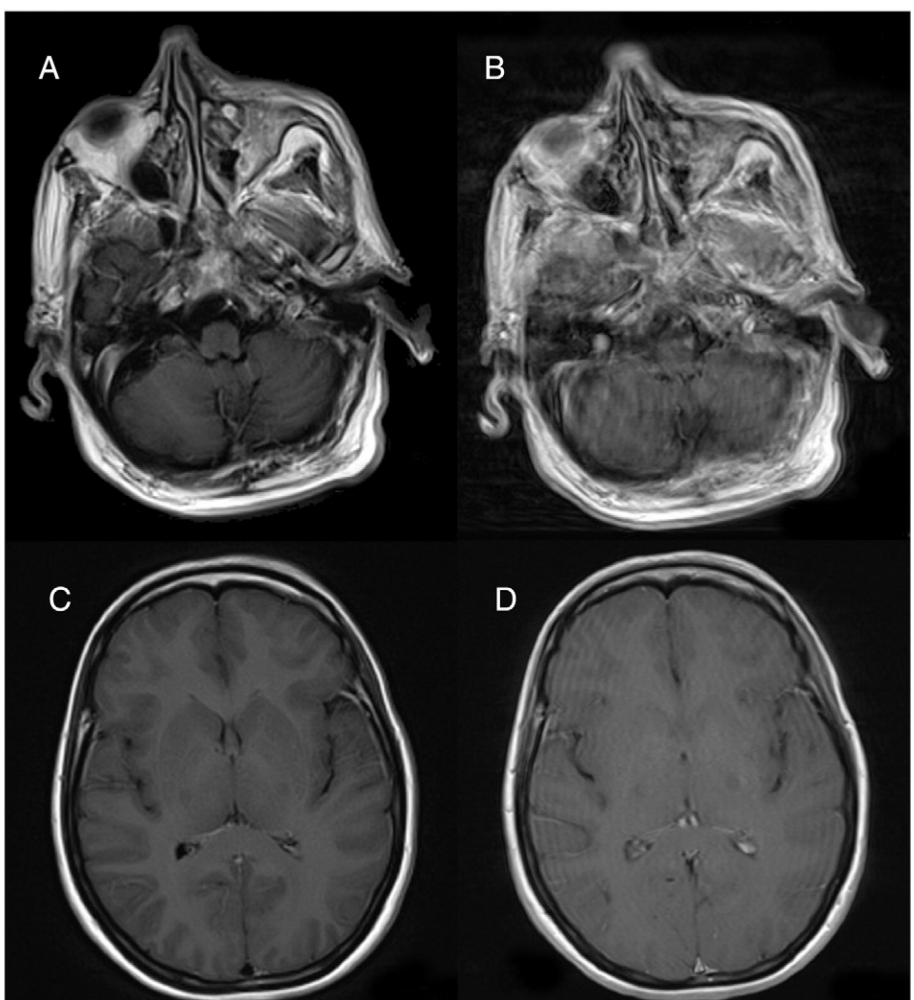

Fig. 1. Sequences: T1W FLAIR BLADE (A, C), T1W SE (B, D). T1W FLAIR BLADE eliminates motion artifacts.

following formula:

$$CNR_{AB} = \frac{SI_A - SI_B}{N} \quad (2)$$

where SI_A and SI_B define the SI of the tissues A and B, respectively. The Relative Contrast was also calculated as follows:

$$ReCon_{AB} = \frac{SI_A - SI_B}{SI_A + SI_B} \times 100\%. \quad (3)$$

Furthermore, we compared the standard deviation of the T1-W SE sequence against the corresponding T1-W FLAIR BLADE sequence. A fundamental requirement for any comparison of SNR or CNR between two different sequences is that the resolution should be made equivalent between the two methods. In this case the FOV, the matrix and the slice thickness were the same in the two sequences, so no normalization was required to compare the respective SNR and CNR values. Quantitative evaluation was performed by means of the Kolmogorov–Smirnov nonparametric test.

2.4. Qualitative analysis

All the MR images of the T1W FLAIR BLADE and the T1W SE sequences were evaluated independently at two separate sittings with 3 weeks interval by two radiologists who reached a consensus. The images of the two sequences were filmed at optimal window and level settings. The radiologists graded five image characteristics on a five-point scale (1, non-visualization; 2, poor; 3, average; 4, good; 5, excellent). The examined image characteristics are: (1) overall image quality, (2) contrast at the white matter and grey matter interface, (3) contrast at the CSF and white matter interface, (4) contrast between CSF and grey matter, (5) contrast between fat and rectus extraocular muscle, (6) CSF nulling. The image evaluators also evaluated the presence of image motion artifacts, other (e.g., Gibbs, susceptibility artifacts, foldover artifact, phase encoding from vessels) artifacts and pulsatile flow artifacts (in the subarachnoid space and periventricular artifacts "shine through effects") by using a separate score scale (5: maximum; 4: severe; 3: moderate; 2: slight; 1: minimum). The statistical significance of the qualitative data was determined by the Kruskal–Wallis non-parametric test.

3. Results

3.1. Quantitative analysis

The results of the quantitative analysis from all the patients are presented in Table 2. The evaluation was performed using the Kolmogorov-Smirnov non parametric test. Regarding the SNR measurements, the conventional sequence appear to have higher values than the corresponding BLADE sequence in white matter, grey matter, fat and optical nerve. However, with the T1W FLAIR BLADE sequence CSF nulling with $p < 0.001$ could be achieved and a statistically significant difference for grey matter (p-value $= 0.008$) in favor of the BLADE sequence was observed.

Regarding the CNR results, the values of the BLADE sequence are higher than those of the corresponding conventional sequence in all the cases. Similarly, the BLADE sequence had higher values than the corresponding conventional sequence for all the cases regarding Relative Contrast measurements. The results showed significant statistical

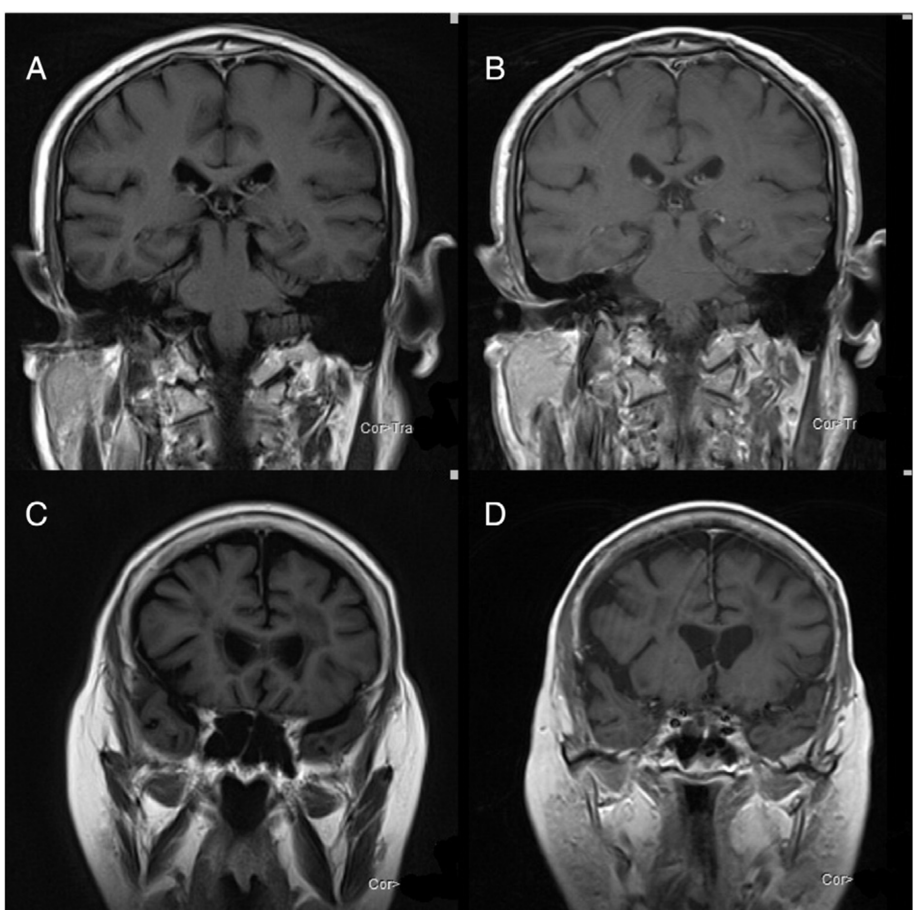

Fig. 2. Sequences: T1W FLAIR BLADE coronal (A, C), T1W SE coronal (B, D). T1W FLAIR BLADE can better eliminate foldover artifacts and motion artifacts.

difference between white matter/grey matter ($p < 0.001$), CSF/white matter ($p < 0.001$), CSF/grey matter ($p < 0.001$) and optical nerve/fat ($p = 0.0420$).

The above analysis showed that T1W FLAIR BLADE sequence was better in the imaging of grey matter as far as the SNR measurements are concerned and superior to the conventional sequence regarding contrast between white matter, grey matter, CSF, optical nerve and fat.

3.2. Qualitative analysis

The results of the qualitative analysis from all the patients are presented in Table 3. The statistical significance of the differences was determined by the Kruskal-Wallis non-parametric test. In all the comparisons, the BLADE sequence had a higher scoring than the conventional sequence with the differences being statistically significant in most of the cases.

More specifically, T1W FLAIR BLADE was superior to T1W SE in the overall image quality ($p = 1.4E-6$), where motion artifacts, other artifacts (e.g. Gibbs, susceptibility artifacts, phase encoding from vessels) and pulsatile flow artifacts had been eliminated. BLADE sequence had also a higher score in nulling CSF ($p = 5.7E-11$), which led to a result of having higher scores in contrast between the white matter and grey matter interface ($p = 1.9E-7$), between CSF and white matter interface ($p = 2.0E-6$) as well as between CSF and grey matter ($p = 6.2E-5$). Additionally, a higher score in contrast was observed between muscles of the eyes/retrobulbar and fat tissue ($p = 7.3E-5$) in the BLADE sequence. According to the study by Alkan et al. [1], observers identified a star-like artifact in 35% of BLADE images, while this artifact was not present in any of the SE images. The present analysis also showed that motion ($p = 0.05$) and flow pulsation artifacts ($p = 2.4E-7$), as well as aliasing or foldover errors ($p = 2.2E-12$) were lower in BLADE sequences. BLADE sequence eliminated all the motion artifacts in five non-cooperative patients and reduced pulsatile flow artifacts in the posterior fossa in all the patients (see Fig. 1). In Fig. 2, it can be seen that T1W FLAIR BLADE eliminated foldover artifacts.

In four cases, where the patients had arteriovenous malformations, these were better visualized in T1W FLAIR BLADE than with T1W SE sequence (see Fig. 3). BLADE sequence could also achieve a better

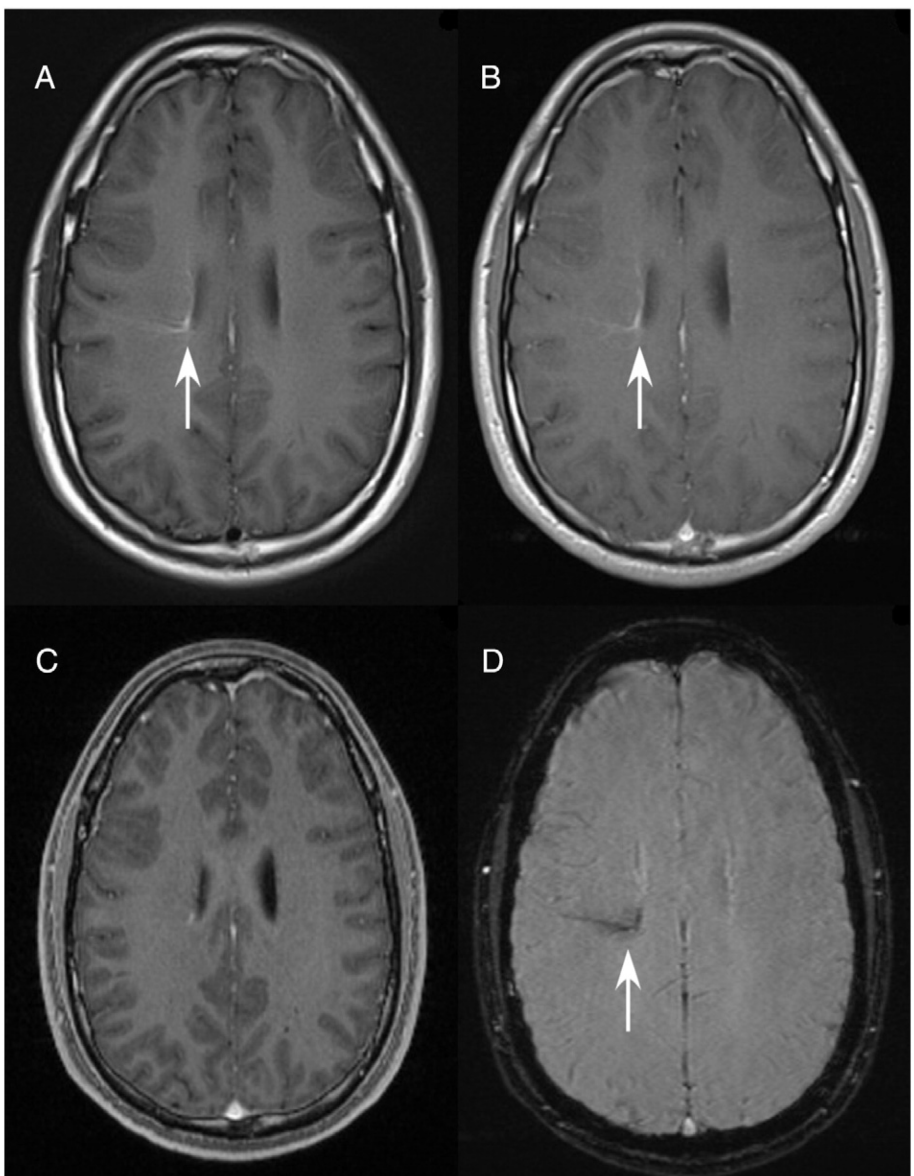

Fig. 3. Sequences: T1W FLAIR BLADE (A), T1W SE (B), T1-MPR (C) and T2* (D). Compared to T1W SE conventional and T1-MPR, T1W FLAIR BLADE depicts better the arteriovenous malformations but equally well with the T2* sequence. The arrows show the AVM's.

visualization of the vessels. In two cases, where metallic objects were present (one patient had undergone craniotomy and another one had metallic nasal diaphragm), the BLADE sequence reduced the susceptibility errors. Fig. 4 shows that T1W FLAIR BLADE offers a better imaging of the facial bones and the orbit. In two other cases, T1 FLAIR BLADE better depicted lesions with low signal. The one case was an ischemic stroke and the other one multiple sclerosis (see Fig. 5). In another case with intracerebral hemorrhage, T1W FLAIR BLADE depicted hemorrhage as well as T2* without the presence of magnetic susceptibility error due to high signal intensity lesions, which were present in the conventional T1 SE sequence (see Fig. 6). In two cases with brain metastases, T1W FLAIR BLADE visualized them better than the conventional T1W SE (see Fig. 7). Finally, in a case that the patient had a meningioma in contact with the sagittal sinus, T1W FLAIR BLADE depicted better the meningioma as well as its anatomical correlation with the sagittal sinus.

4. Discussion

FLAIR is another variation of the inversion recovery sequence. In FLAIR, selecting a TI corresponding to the time of recovery of CSF from 180° to the transverse plane, nulls the signal from CSF. There is no longitudinal magnetization present in CSF. When the 90° excitation pulse is applied, because there is no longitudinal component of CSF there is no transverse component after excitation and the signal from CSF is nulled [18]. FLAIR is used in brain imaging to more clearly see periventricular and cord lesions, because the high signal from the adjacent CSF is nulled. It is especially useful in visualizing multiple sclerosis plaques, acute subarachnoid hemorrhage and meningitis [18]. T1-weighted FLAIR imaging provides improved lesion-to-background and grey to white matter contrast-to-noise ratios. Superior conspicuity of lesions and overall image contrast is obtained in comparable acquisition times. These indicate an important role for T1-weighted FLAIR in intracranial imaging and highlight its advantage over the more widely practiced T1-weighted FSE sequence [19].

Shapiro has reported that T1-weighted FLAIR is better than T1-weighted FSE sequence in delineating normal tissue interfaces between soft tissue/CSF, bone or disc/CSF as well as abnormal/normal tissue [15]. A study of twenty patients with brain lesions that underwent T1-weighted fast spin-echo (FSE) and T1-weighted FLAIR during the same imaging session showed that both sequences were effective in imaging those lesions. Image contrast was superior in T1-weighted FLAIR images with significantly improved grey to white matter CNRs and CSF to WM CNRs. The overall image contrast was considered to be superior on T1-weighted FLAIR images compared with T1-weighted FSE images by all neuroradiologists. Two out of three reviewers considered that the FLAIR images had slightly increased imaging artifacts that, however, did not interfere with image interpretation [19].

Fast T1-weighted FLAIR imaging when nulling CSF causes improved conspicuity of syrinxes, spinal cord cysts, intraspinal tumors, multiple sclerosis and detection of edema and metastatic lesions in the fatty

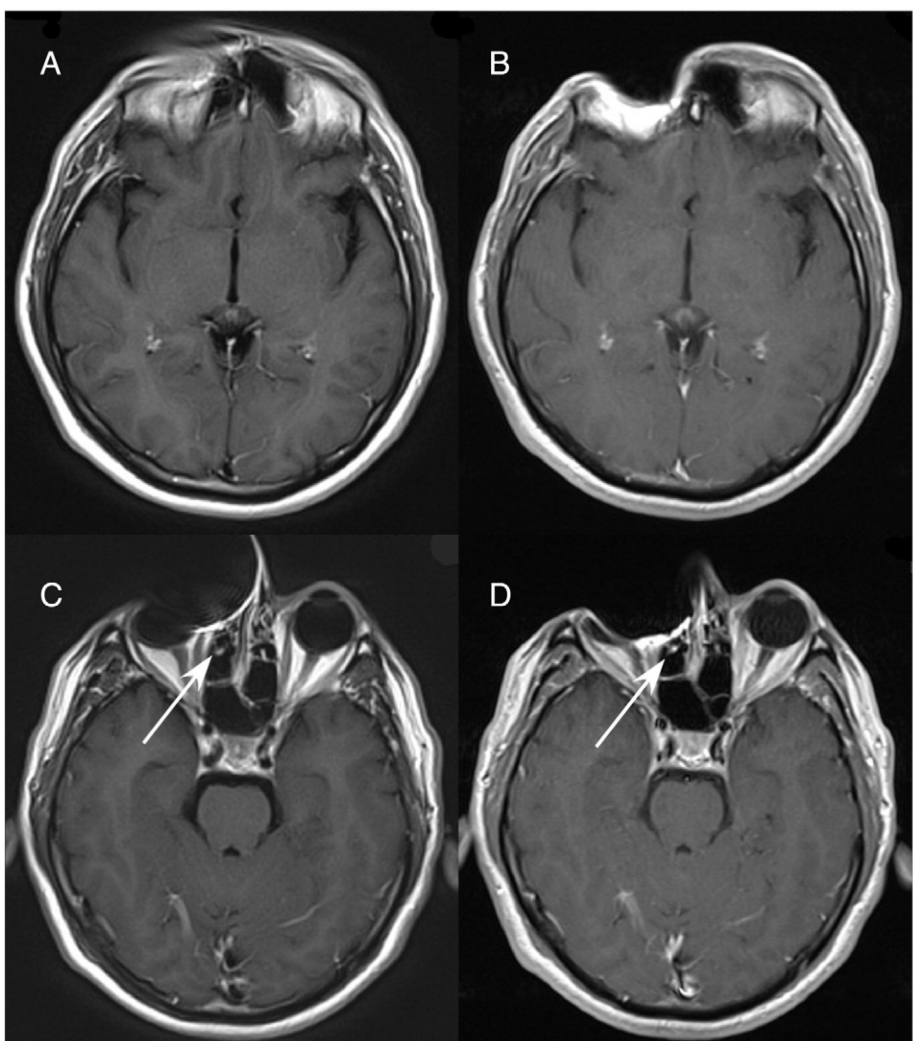

Fig. 4. Sequences: T1W FLAIR BLADE (A, C), T1W SE (B, D). T1W FLAIR BLADE reduces susceptibility artifacts and offers a better imaging of the facial bones and the orbit.

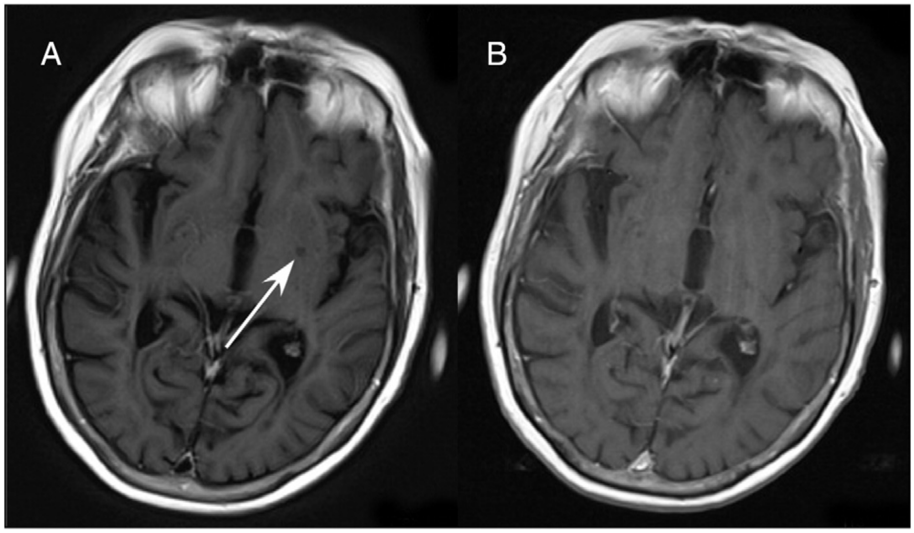

Fig. 5. Sequences: T1W FLAIR BLADE with contrast medium (A), T1W SE with contrast medium (B). T1W FLAIR BLADE achieves CSF nulling, thus lesions with low signal can be better visualized. The arrow shows the ischemic stroke which is not depicted in the conventional T1 sequence.

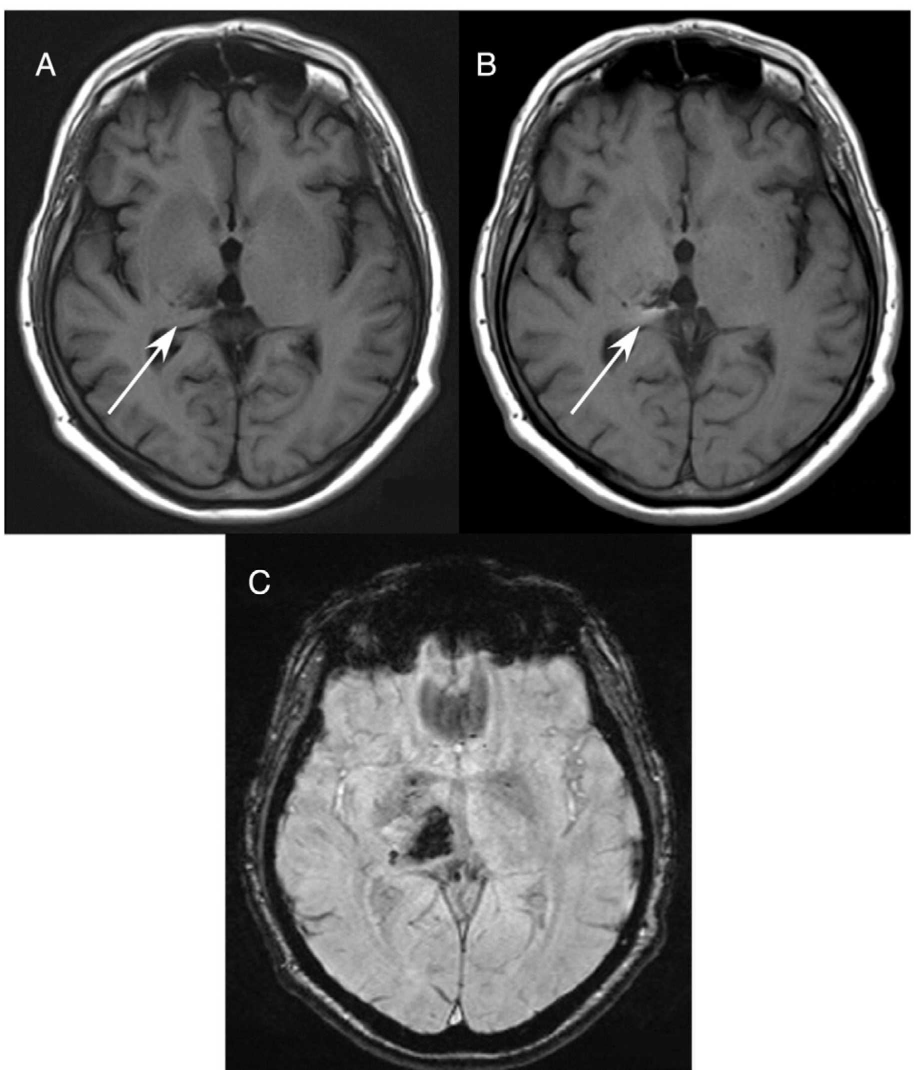

Fig. 6. Sequences: T1W FLAIR BLADE (A), T1W SE (B), T2* (C). T1W FLAIR BLADE depicts hemorrhage equally well as T2*. The advantage is that the first one can better eliminate magnetic susceptibility artifacts caused by high signal intensity lesions. T1W SE cannot eliminate these artifacts.

bone marrow and increased contrast at the CSF/cord and CSF/disc herniation interfaces. However, inversion pulses are prone to field inhomogeneity, increase scan time and may lower the image SNR altering image contrast [21].

BLADE uses periodically rotated overlapping parallel lines with enhanced reconstruction (PROPELLER, BLADE), which is a MR technique with spin echo (SE) sequence for evaluation of artifacts, and detection and delineation of brain lesions. Few studies have been performed regarding the comparison of BLADE and conventional sequences in different anatomical sites and MRI systems (1.5 and 3.0 T). Most of them propose the use of BLADE sequences especially in pediatric MR examinations and uncooperative patients [9,10,14]. Nyberg et al. [8] compared brain MR images of moving patients obtained at 1.5 T by using partially radial and rectilinear acquisition techniques. Based on a semi-quantitative method to compare the different sequences, they concluded that BLADE sequences reduce the extent of motion artifacts in brain images of moving patients, improving image quality and lesion characterization. Similar to this and other studies [8,9], the present study performed both a qualitative evaluation and a quantitative analysis. In cooperative patients, we propose the use of BLADE sequences because they provided better image quality and minimized or even eliminated all the motion artifacts as well as the foldover error without increasing the face oversampling parameter. Both in the quantitative and qualitative analyses, contrast between fatty tissue/muscle was higher in the BLADE sequence. A different study that compared the conventional and the BLADE techniques in intracranial MRI, showed that all the lesions that were depicted with the CE T1W-SE sequence were also detected with the CE T1W-FLAIR BLADE technique [1]. Delineation of lesions was better on CE T1W-FLAIR BLADE in the majority of the patients. Flow-related artifacts were considerably reduced in CE T1W-FLAIR BLADE. A star-like artifact at the level of the 4(th) ventricle was noted in CE T1W-FLAIR BLADE but not in CE T1W-SE. The lesion-to-background CNR and lesion-to-CSF CNR did not show a statistically significant difference between the two techniques. CE T1W-FLAIR BLADE images were preferred by the observers over the CE T1W-SE images, indicating good interobserver agreement ($k = 0.70$). In the study, they concluded that CE T1W-FLAIR BLADE technique is superior to CE T1W-SE regarding delineation of lesions and reduction of flow-related artifacts, especially within the posterior fossa, and it was the sequence of preference by the evaluators. CE T1W-FLAIR BLADE may be an alternative imaging approach, especially for posterior fossa lesions [1].

In the present study, we found similar results in the quantitative analysis. Although the T1W SE sequence had higher values in the SNR measurements, the T1W FLAIR BLADE sequence had better results in CNR and Relative Contrast measurements in all the cases. With T1W FLAIR BLADE we could achieve CSF nulling and better imaging of grey matter, white matter, optical nerve and fat. The results in Relative Contrast measurements were also statistically significant between white matter/grey matter, CSF/white matter, CSF/grey matter, optical nerve/fat.

In the qualitative analysis, the results in most of the cases favored T1W FLAIR BLADE sequence, in which, motion artifacts, as well as flow pulsation artifacts and foldover errors (see Figs. 1 and 2) were significantly lower than in the conventional T1W SE sequence. More

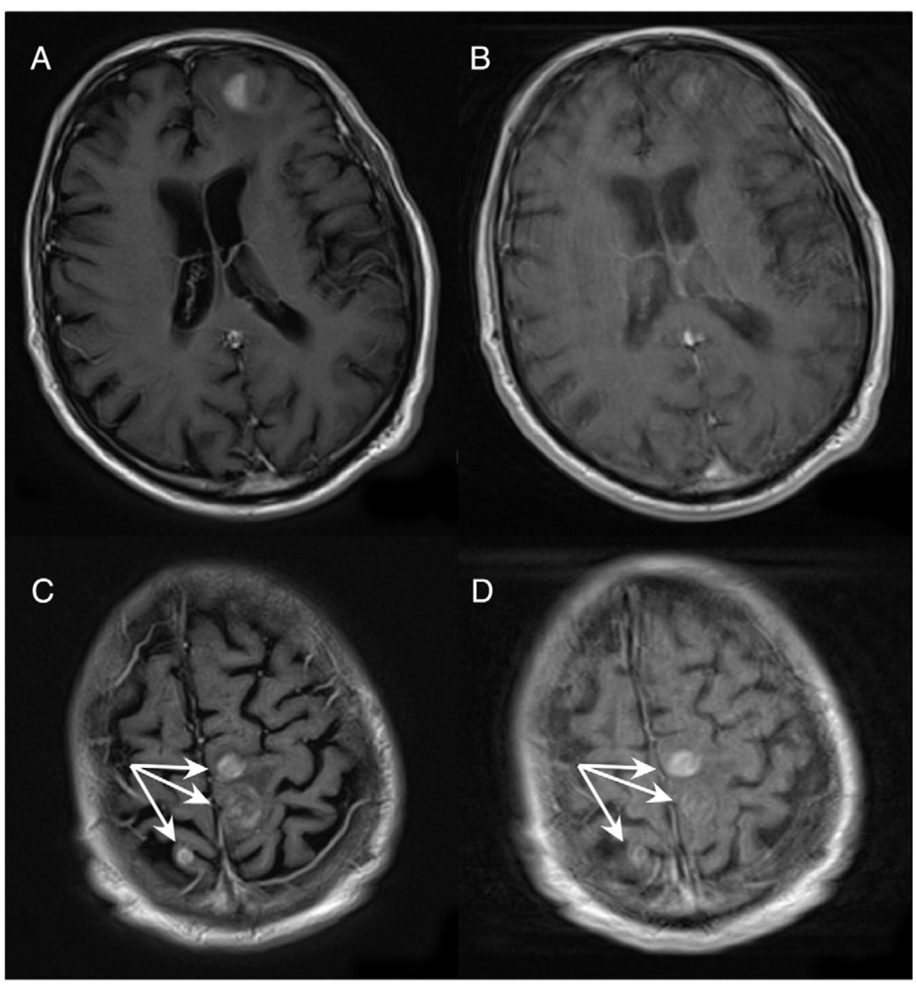

Fig. 7. Sequences: T1W FLAIR BLADE with contrast medium (A, C), T1W SE with contrast medium (B, D). The arrow shows the cerebellar metastasis which is better enhanced in the BLADE sequence than in the conventional SE.

specifically, the BLADE sequence reduced motion and flow pulsation artifacts in the posterior fossa in five non-cooperative patients (see Fig. 1). Artifacts in magnetic resonance imaging and foreign bodies within the patient's body may be confused with a pathology or may reduce the quality of examinations. Radiologists are frequently not informed about the medical history of patients and face postoperative/other images they are not familiar with. A truncation artifact in the spinal cord could be misinterpreted as a syrinx. Motion artifacts caused by breathing, cardiac movement, CSF pulsation/blood flow create a ghost artifact which can be reduced by patient immobilization, or cardiac/respiratory gating. Aliasing artifacts occur when the anatomical structures located outside the field of view are mapped at the opposite end of the image. In the study by Alkan et al. [1], as well as in this present study, it has been found that BLADE sequences reduce significantly most types of artifacts during an MRI scan.

In four different cases, the T1W FLAIR BLADE depicted better the arteriovenous malformations and showed the vessels with higher perspicuity (see Fig. 3). In two other cases with the presence of metallic objects, the BLADE sequence notably reduced the susceptibility errors and offered a better imaging of the facial bones and orbit (see Fig. 4). The BLADE sequence also reduced the susceptibility errors in a intracerebral hemorrhage case. During this case, the most important finding was that BLADE depicted hemorrhage equally well as T2* while simultaneously eliminating any errors due to high signal intensity lesions, which were not eliminated in T1W SE sequence (see Fig. 6). Furthermore, the BLADE sequence was highly sensitive regarding lesions that had low signal (ischemic stroke, multiple sclerosis – Fig. 5). In two different cases of brain metastases (see Fig. 7), T1W FLAIR BLADE offered a better imaging and in a case of a patient with meningioma BLADE better visualized the lesion and its correlation with the sagittal sinus.

Based on the studies mentioned above, FLAIR sequence itself offers many advantages such as improved lesion to background ratio, grey to white matter CNR, superior conspicuity of lesions and overall image contrast as well as delineation of tissue. The studies also show that BLADE sequence itself has also many benefits like reducing most types of artifacts in brain images, improving image quality and image characterization and also depicting brain lesion with high overall image contrast. In this present study, the combination of FLAIR and BLADE features into one sequence (T1W FLAIR BLADE) demonstrates better results against T1W SE for most of the metrics examined but worse results in some metrics too.

We suggest the use of T1W FLAIR BLADE sequence in examinations of patients with metallic objects, in examinations of AVM, hemorrhages, brain metastases, ischemic stroke, multiple sclerosis, meningioma and other neoplasms to visualize better the relation with the vessels. BLADE sequences offers the ability of reducing motion artifacts, flow pulsation artifacts and foldover errors without compromising the quality of the image, which can benefit the examination of non-cooperative patients and orbital examination. However, to propose the replacement of T1 SE by T1 FLAIR BLADE further studies should be conducted.

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