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ORIGINAL ARTICLE

The value of b0 images obtained from diffusion-weighted echo planar sequences for the detection of intracranial hemorrhage compared with GRE sequence

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Abstract *Purpose:* Our aim was to evaluate the clinical utility of b0EPI images obtained from diffusion sequence for the detection of the intracranial hemorrhagic lesions, especially acute intracerebral bleeds thereby shorten the scan time particularly in the critical acute cases of stroke.
Materials and methods: Among all consecutive MR brain studies performed in our department last year, we retrospectively selected those who followed the following criteria: (1) clinically suspected or radiographically confirmed acute infarction or hemorrhage. (2) MRI imaging including DWI and T2* images. Sensitivity of hemorrhage detection, conspicuity of lesions, and diagnostic certainty were compared between the b0EPI and GRE sequences.

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Results: There were 77 hemorrhagic lesions with a variety of pathogeneses in various locations. 76/77 (98.7%) of these lesions were hemorrhagic (hypointense) on the GRE sequences, whereas 61 (79.2%) were characterized as hemorrhagic on b0EPI images, and 16 (20.8%) were not detected. The overall difference in hemorrhage conspicuity/diagnostic certainty between GRE and b0EPI sequences was statistically significant ($P < .05$).

Conclusion: b0EPI sequence, although shorter in acquisition time, was inferior to GRE imaging in the detection of acute and chronic intracerebral hemorrhage.

1. Introduction

MR imaging is increasingly used for the initial emergent examination of patients presenting with sudden neurologic symptoms owing to the high sensitivity of diffusion-weighted (DW) imaging for the detection of ischemic brain damage (1). Previous studies (2–4) supported the use of MR imaging as the only technique for imaging patients with acute stroke. In this setting, identification of the intracranial hemorrhage by using MR imaging is critical to the determination of appropriate stroke management (1).

The accuracy of conventional MR sequences in the assessment of acute intracranial blood has been questioned in the past, but some studies have indicated that gradient-echo (GRE) and fluid-attenuated inversion-recovery (FLAIR) sequences markedly increase the sensitivity of MR imaging as compared with other MR sequences and CT (5).

In routine clinical DWI, four sets of spin-echo EPI images are acquired. Three DWI sets (obtained with orthogonally applied diffusion gradients) are combined to produce an isotropic DWI scan, and a b0 set is acquired without diffusion gradients (6). Since EPI is intrinsically sensitive to magnetic field heterogeneity, paramagnetic blood breakdown products produce signal loss similar to that in T2* weighted GRE sequence (6).

If DWI is sensitive to the detection of blood products, an additional computed tomography (CT) examination of the brain or a gradient echo (GRE) sequence for the exclusion of intracerebral bleeds will not be necessary (7).

The aim of this work was to evaluate the clinical utility of b0 image from EPI DWI for the detection of the hemorrhagic lesions, particularly acute intracerebral bleeds thereby shorten the scan time especially in the cases of acute stroke.

2. Materials and methods

Among all consecutive MR brain studies performed in our department last year, we retrospectively selected those who followed the following criteria: (1) clinically suspected or radiographically confirmed acute infarction or hemorrhage. (2) MRI imaging including DWI and T2* GRE images. Patients with underlying brain tumors, vascular anomaly, trauma, and acute, subacute or chronic hemorrhage were included in the study. The institutional review board allowed retrospective review of patient data sets.

Seventy-seven patients (46 females and 31 males) fulfilled these criteria and constituted our study group. They range in age from 5 to 83 years (mean 52.9 ± 16 years). The clinical manifestations of the patients include: symptoms due to cerebral vascular disease ($n = 11$), hypertension ($n = 9$), blood disease ($n = 16$), complication of treatment ($n = 5$), trauma ($n = 1$), primary brain tumor ($n = 6$), metastatic brain tumor ($n = 11$), extra-cranial tumor ($n = 5$), fungal infection ($n = 1$).

2.1. MRI technique

The MR imaging was done on a 1.0T magnet panorama open high field MR unit with echo-planar capability (1.0T Gyroscan Intera, Philips Medical Systems, Netherlands) using standard head coil. All MRI examinations included (a) axial and sagittal T1WI (256 × 192 matrix, 548/15 ms [TR/TE], NSA;2), (b) axial FLAIR (256 × 192 matrix, 6000/90 ms [TR/TE], NSA;2), (c) axial T2WI (256 × 192 matrix, 4000/102 ms [TR/TE]), and (d) axial GRE (256 × 192 matrix, 630/21 ms [TR/TE], NSA;2, flip angle 18°). Single-shot echo-planar spin-echo (SE) planar imaging DWI sequences were obtained by applying diffusion gradients in three orthogonal directions at each slice with two diffusion weighting (b value = 0 and 1000 s/mm^2), the parameters of DWI were 192 × 68 matrix, 2517/94 ms [TR/TE], NSA;6. The scan time was about 51 s for the DWI sequence, 135 s minutes for GRE, 180 s for T1W, 120 s for FLAIR and 90 s for T2W images.

2.2. Image analysis

These studies were analyzed retrospectively and independently by two experienced radiologists blinded to the clinical data.

In each case, b0EPI and GRE images were reviewed for the presence or absence of hemorrhage at separate sessions in a random order. No other MR or CT images were provided for the initial review. Subsequently, the b0EPI and GRE images were analyzed side-by-side, in conjunction with the DWI scans, for conspicuity of hemorrhage and diagnostic certainty. If one patient showed multiple lesions, each lesion was reviewed separately.

The presence or absence of hemorrhages in each sequence was recorded, and the images were classified as either negative or positive. Hemorrhages were diagnosed as present when there were areas of abnormally low signal intensity. When a hemorrhagic lesion was identified, it was further characterized by its age, anatomic location and pathogenesis. We rated the degree of visualization of hemorrhage with b0EPI and GRE as easily identified, hardly identified and unidentified.

The accuracy of detection of hemorrhage by b0EPI was assessed. The results were compared to the presence of low signal intensity on GRE sequences and/or the presence of high-attenuation lesion on CT scan performed within 2 days.

Computer software package SPSS 15 was used in the analysis. Chi-square and Fisher-exact tests were used to determine whether the difference in hemorrhage detection using b0EPI

Table 1 Number and types of hemorrhagic lesions.

	Hyperacute	Acute	Subacute	Chronic	Total
Intra-axial hemorrhage (59)					
Microbleeds	–	12	1	6	19
Parenchymal hematoma	–	8	1	3	12
Hemorrhagic infract	1	11	1	-	13
Hemorrhage in neoplastic lesion	–	4	5	4	13
Hemorrhage in cavernous angioma				1	1
Hemorrhage in a fungal mass				1	1
Extra-axial hemorrhage (19)					
Subarachnoid hemorrhage (SAH)	–	6	–	–	6
Intraventricular hemorrhage (IVH)	–	3	–	–	3
Subdural hematoma	1	7	2	–	10
Total	2	50	10	15	77

Table 2 Lesion conspicuity and diagnostic certainty with EPI versus GRE according to the age of blood.

Type of blood	EPI			T2*			Total
	Unidentified	Hardly identified	Easily identified	Unidentified	Hardly identified	Easily identified	
Hyperacute	1	0	1	0	0	2	2
Acute	11	15	24	1	9	40	50
Subacute	2	2	6	0	1	9	10
Chronic	2	4	9	0	0	15	15
Total	16 (20.8%)	21 (27.3%)	40 (51.9%)	1 (1.3%)	10 (13%)	66 (85.7%)	77

and GRE was statistically significant. A P value less than .05 was considered statistically significant.

3. Results

There were 77 hemorrhagic lesions with a variety of pathogeneses in various locations, including cerebral microbleeds, parenchymal hematomas, hemorrhagic infarct, hemorrhage in a cavernous angioma, hemorrhage in a fungal mass, hemorrhagic tumors, subarachnoid hemorrhage, subdural or intraventricular hematomas (Table 1).

Side-by-side analysis of GRE and b0 images revealed that hemorrhages were invariably more conspicuous on the GRE sequences (Table 2). 76/77 (98.7%) of these lesions were hypointense on the GRE sequences, whereas 61 (79.2%) were characterized as hemorrhagic (hypointense) on b0 images, and 16 (20.8%) were not detected (Figs. 1–3). The overall difference in lesion conspicuity/diagnostic certainty between GRE and EPI scans was statistically significant ($P < .05$).

Hyperacute bleeds were detected in two cases. These lesions were easily recognized on the T2*-GRE images. One case was only detected as hypointense lesion on b0 images.

There were 50 cases of acute hematomas in all locations. Forty-nine were identified on GRE sequence. Thirty-nine were characterized as hemorrhage on b0 images whereas 11 lesions were not detected. With regard to subacute bleeds, GRE image detected all 10 lesions, whereas eight lesions were identified on b0 images.

Among the cases included in our study, 15 were incidental chronic hematomas (microbleeds, intraparenchymal, hemorrhage in a neoplastic lesion, fungal mass or cavernous angi-

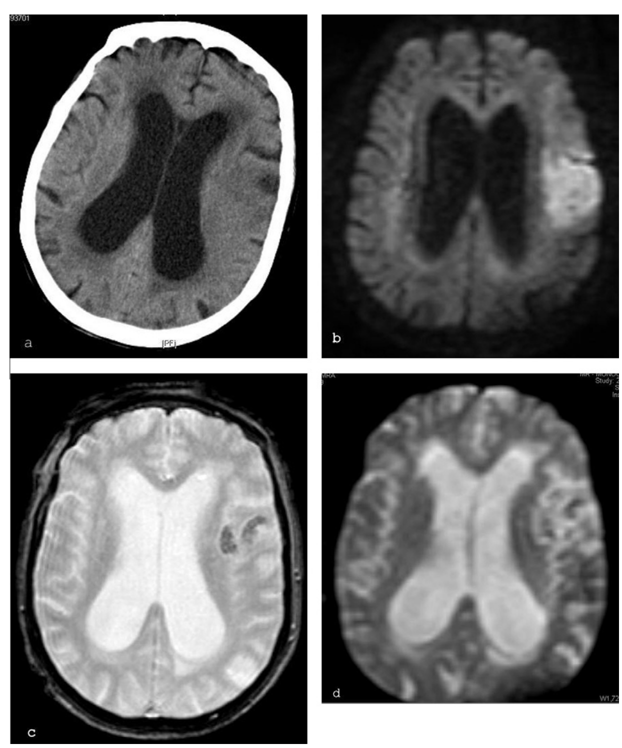

Fig. 1 Sixty year old female patient presented with right hemiparesis. (a) CT examination shows no abnormalities. (b) DWI (b = 1000), (c) GRE and (d) b0EPI images showing left parietal acute hemorrhagic infarct. The infarct is hyperintense on DWI, with central hypointensity reflecting hemorrhage is detected on GRE (c) better than b0EPI (d).

oma) all depicted as areas of hypointensity on GRE sequence. Thirteen of these hemorrhages were detected on b0 scans.

Hemorrhagic infarctions were detected in 13 patients. Blood products were recognized on the GRE sequences on all cases and were more pronounced compared with b0 sequences. b0 images missed the diagnosis of hemorrhage in one case, and hardly detected hemorrhage in three cases. The difference in sensitivity for detecting hemorrhagic infarction was statistically significant ($P < .05$).

The GRE sequence was superior to the b0 sequence in 19 cases of small punctate hemorrhages <10 mm in diameter (microbleeds). They were seen on 19 GRE studies, but only on 14 of the b0 images. This difference in sensitivity was statistically significant ($P < .05$).

b0EPI sequence detected all cases of hemorrhage in neoplastic lesions ($n = 13$), hemorrhage in a fungal mass ($n = 1$), hemorrhage in cavernous angioma ($n = 1$).

SAH was detected in 5/6 cases on GRE scans, compared to 3/6 on b0 scans. In all six cases the presence of SAH was evident on the FLAIR sequence and CT scan.

b0EPI images detected five out of 10 patients with subdural hematomas, and one out of three patients with intraventricular hemorrhage. None of them were missed by GRE images.

4. Discussion

MR imaging has been increasingly used as the primary imaging tool for patients with suspicion of acute stroke. Although CT is still the usual mean for detecting early hemorrhage, several studies support the use of early MRI imaging for this purpose owing to high sensitivity to identify early blood degradation products (8). In addition to that MRI is more accurate than CT in revealing chronic bleeding in the brain, particularly microbleeds (9).

After a series of studies, GRE sequences are now considered the most sensitive of the MR sequences for detecting intracranial hemorrhage, even superior to CT (2,3,10). However, GRE is time consuming, and intracranial hemorrhage cases are critical, requiring quick therapeutic decision making (11).

DWI with an echo planar imaging (EPI) technique is a fast sequence and is desirable for the assessment of confused and uncooperative patients presenting with acute strokes (7). On top of its superiority in detecting ischemia, it might also be used to detect the inhomogeneity of the magnetic field due to the presence of blood products (7).

In this study we evaluated the clinical utility of b0 images obtained from diffusion in the detection of intracerebral hemorrhage. The findings in this series showed that b0 images from DWI were less sensitive than GRE sequences in the detection of hemorrhages. Blood products were more conspicuous and readily detected by GRE sequences compared to b0EPI sequences. The overall difference in lesion conspicuity/diagnostic certainty between GRE and b0EPI scans was statistically significant ($P < .05$). Due to lower spatial resolution of b0EPI compared to GRE sequence (EPI matrix is 192×68, GRE matrix is 265×192) some cases of hemorrhage were not clearly depicted on b0EPI due to small size of the lesions and difficult characterization of their internal structure.

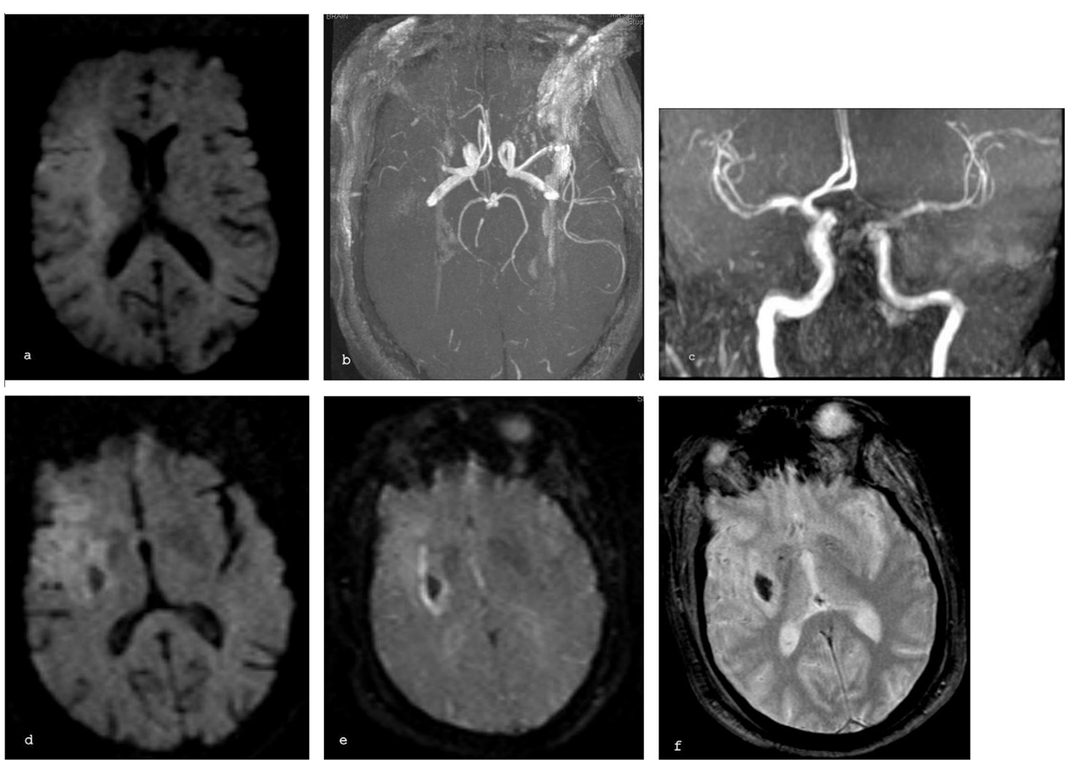

Fig. 2 Forty-three year old man presented with left sided hemiparesis (a) DWI ($b = 1000$), (b) MRA image showing acute infraction and attenuated Right MCA, thrombolysis is indicated. (c) MRA image 24 h after thrombolysis showing recanalization of the Right MCA. (d) DWI ($b = 1000$), (e) b0EPI, (f) GRE images showing small area of restricted diffusion with central hypointensity coincided with the hemorrhagic complication of the antithrombolysis therapy.

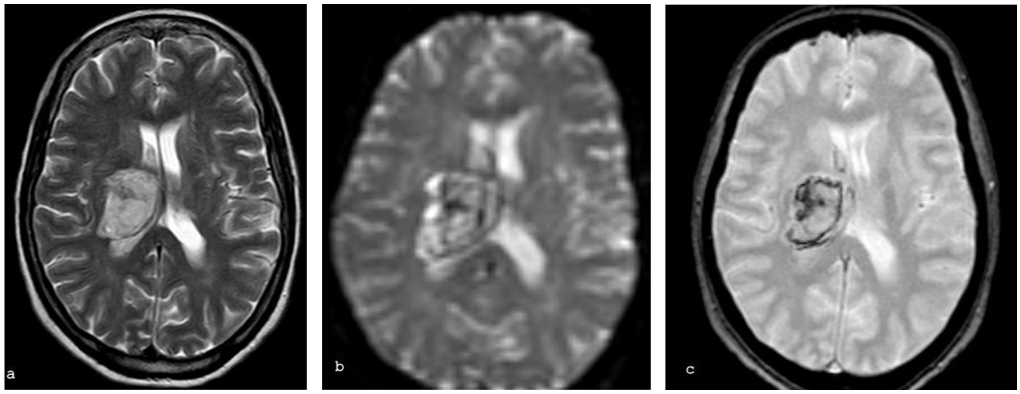

Fig. 3 (a) Axial T2WI, (b) b0EPI and (c) GRE images showing hypertensive parenchymal hematoma in the right basal ganglia. The hypointense foci suggestive of blood products are more conspicuous on GRE image.

In our study, GRE sequence yielded better results in revealing acute hemorrhage, especially in cases of acute infarction. Our results were in agreement with Lin et al. who reported that GRE sequence was more sensitive than b0 EPI for identifying acute hemorrhage at 1.5 T. They stated that GRE is a crucial sequence in MR protocol for acute stroke particularly when thrombolytic therapy is contemplated (6).

However Lu and his colleagues found that, there was no significant difference in the sensitivity between GRE and b0EPI for acute hemorrhage detection at 3T. They documented that b0 images can fast detect as many hemorrhagic lesions as GRE. Therefore, evaluation of acute stroke patients with a 3.0T scanner should not routinely include GRE; GRE can be reserved for equivocal lesion on b0EPI (11). The reason for better results of b0EPI images in their study might be due to increased magnetic susceptibility at higher magnetic field (12), therefore it becomes more sensitive to deoxyhemoglobin. However one of the limitations of their study is that they compared the EPI images with fast GRE and not conventional GRE, which should have longer TE and thus, a stronger susceptibility effect.

In depicting microbleeds, b0EPI was also less sensitive than GRE sequence. These small lesions were less conspicuous on b0EPI images, most likely as a result of limited spatial resolution. These findings were in agreement with the study by Lam et al. (7). Microbleeds are found in 12–20% of MRI-examined stroke patients (13,14). Although these microbleeds are unrelated to patient's acute clinical presentation, they suggest the presence of vascular fragility and a risk factor for subsequent intracranial hemorrhage (15). Therefore its detection is of clinical significance and could raise the clinicians for intracerebral hemorrhage when administering thrombolysis or anticoagulant therapy (7).

The usefulness of FLAIR in the diagnosis of IVH and SAH is well known (16,17) and relates to the hyperintense appearance of these hemorrhage, caused by a higher protein concentration, against a dark CSF background allowing blood to be seen in ventricles and sulci (8). In this study, GRE sequences were more sensitive than b0EPI for detecting SAH, and missed only one case which was depicted on FLAIR images. However Lin et al. reported that both b0EPI and GRE sequences were insensitive for the detection of SAH (6).

Our results agree with Hernalsteen and his colleagues' findings that b0 images could not replace GRE for the detection of acute IVH. They evaluated the diagnostic accuracy of MRI for detecting early IVH using five different MRI sequences (T1WI, FLAIR, EPI-GRE-T2* and DWI images including b0I and b1000). The sensitivity of b0EPI images for detection of IVH was 88% (8).

The low sensitivity of the b0 images for the detection of SAH and IVH might be explained by the fact that CSF dilutes blood and therefore lowers the concentration of deoxyhemoglobin necessary to cause hypointensity on this sequence (18).

The limitations of this study include its retrospective design, relatively small number of patients together with too small sample size in some types of hemorrhage for useful statistical evaluation.

In conclusion the b0EPI sequence, although shorter in acquisition time, was inferior to GRE imaging in the detection of acute and chronic intracerebral hemorrhage. We suggest that when there is time limit, or in case of clinically unstable, or uncooperative patients, an ultrafast b0EPI sequence may be useful in reducing scan time and may give sufficient information for a management decision.

Conflict of interest

The Authors declare no conflict of interest.

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