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Diffusion-weighted imaging of the sellar region: A comparison study of BLADE and single-shot echo planar imaging sequences

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ABSTRACT

Purpose: The purpose of this study is to compare BLADE diffusion-weighted imaging (DWI) with single-shot echo planar imaging (EPI) DWI on the aspects of feasibility of imaging the sellar region and image quality.

Methods: A total of 3 healthy volunteers and 52 patients with suspected lesions in the sellar region were included in this prospective intra-individual study. All exams were performed at 3.0 T with a BLADE DWI sequence and a standard single-shot EP-DWI sequence. Phantom measurements were performed to measure the objective signal-to-noise ratio (SNR). Two radiologists rated the image quality according to the visualisation of the internal carotid arteries, optic chiasm, pituitary stalk, pituitary gland and lesion, and the overall image quality. One radiologist measured lesion sizes for detecting their relationship with the image score.

Results: The SNR in BLADE DWI sequence showed no significant difference from the single-shot EPI sequence ($P > 0.05$). All of the assessed regions received higher scores in BLADE DWI images than single-shot EP-DWI.

1. Introduction

Diffusion-weighted imaging (DWI) has emerged to measure aberrancies in the expected Brownian motion of free water [1,2]. The sequence has shown utility in the diagnosis of acute cerebral infarction [3–5] multiple sclerosis [6,7], brain injury [5], cerebral abscess [8], etc. Recent studies [9–12] have indicated that DWI can also predict the consistency of tumours within the sellar region, which has allowed neurologists to select an appropriate operation plan before surgery.

Although the clinical value of DWI is apparent, susceptibility artefacts arising from the commonly used single-shot EP-DWI have limited the clinical value of DWI, especially in the sellar region [13].

BLADE DWI is a turbo spin echo-based diffusion weighted imaging technique, which is inherently insensitive to B0 related artefacts [14]. BLADE DWI can oversample the region in the centre of the k-space to correct for heterogeneities prior to combing the data [11,15]. Depending on the merit of Turbo Spin Echo (TSE) techniques, B0-related artefacts from sinuses and eddy currents, for instance, can theoretically be dramatically reduced. Therefore, we hypothesise that BLADE DWI will outperform single-shot EP-DWI in skull base imaging, which contains ethmoid sinuses, sphenoid sinuses, frontal sinuses, mandibular sinuses, etc. Recent articles have paid little attention to the ability of BLADE DWI to increase imaging quality [11]. Further, to the best of our knowledge, there are no reports addressing its value in reducing asymmetric magnetic artefacts in the sellar region.

The purpose of this study is to determine whether BLADE DWI is more suitable for assessing sellar lesions than single-shot EP-DWI, and if so, to what extent it can increase the image quality.

2. Materials and methods

2.1. Patient population

This study was designed as a prospective, comparative investigation with intra-individual comparison. Our institutional review board approved the research protocol in this study, and written informed consent for the MR study was obtained from every patient

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before participation. Patient recruitment and imaging were performed between June and September of 2013.

The final study group consisted of 52 consecutive patients and 3 normal volunteers (21 male, 34 female; age range, 18–74; mean age of 43 years). Patients who had clinically suspected sellar lesions on the basis of conventional radiologic findings with or without laboratory results were enrolled in this prospective study prior to surgical treatment. None of the included patients had neurologic disorders other than sellar lesions.

In all participants, MR examination was performed at 3.0 T. 18 of the included patients had surgery. According to the pathology results, the final diagnoses were as follows: pituitary adenoma, $n = 13$, including macroadenoma ($n = 10$) and giant adenoma ($n = 3$); craniopharyngioma, $n = 1$; chordoma, $n = 1$; glioma, $n = 2$; and aneurysm, $n = 1$. The remaining 34 patients had clinical preferred diagnosis as follows: pituitary adenoma, $n = 24$, including microadenoma ($n = 9$), macroadenoma ($n = 11$) and giant adenoma ($n = 4$); Rathkes cyst, $n = 3$; meningioma, $n = 1$; hypophysitis, $n = 1$; pituitary abscess, $n = 1$; meningioma, $n = 1$; craniopharyngioma, $n = 1$; and uncertain $n = 1$.

2.2. Imaging technique

All MR images were acquired on a Siemens Verio 3.0 T system equipped with an 8-channel head coil. MR imaging of the sellar region was performed using the following routine sequences: sagittal and coronal pre-contrast T1-weighted images (TR/TE 2000/18 ms, matrix 358 × 512, one excitation, FOV 18 cm, bandwidth 122 Hz/pixel, slice thickness 3 mm without intersection gap); coronal T2-weighted images (TR/TE4000/94 ms, matrix 314 × 512, two excitations, FOV 24 cm, bandwidth 122 Hz/pixel, slice thickness 3 mm without intersection gap); coronal pre-contrast BLADE DWI images (TR/TE 3210/125 ms, matrix 256 × 256, one excitation, FOV 25.6 cm, bandwidth 260 Hz/pixel, slice thickness 3 mm without intersection gap); coronal pre-contrast echo-planar imaging DWI (TR/TE 5000/104 ms, matrix 192 × 192, one excitation, FOV 22.9 cm, bandwidth 1022 Hz/pixel, slice thickness 3 mm without intersection gap).

Contrast-enhanced T1-weighted images were then obtained in the sagittal and coronal plane using the same parameters as those for the pre-contrast images. All coronal DWI scans were performed on the same slices to make consistent comparisons. The spatial resolution of BLADE DWI was 1 mm; single-shot DWI used the highest clinically achievable spatial resolution.

The scan time of BLADE sequences is 5′51 min, which is acceptable for clinical use. Contrast-enhanced T1-weighted images were obtained during bolus injection of Gd-DTPA 20 ml (Bayer). The dose of gadolinium contrast material was 0.1 mmol/kg (0.2 mL/kg).

2.3. Data analysis

To calculate SNR, regions of interest (ROIs) were manually drawn around the solid part of lesions or normal pituitary glands (in both BLADE and single-shot EP-DWI images) and the air region as well. SNR was calculated with the following formula: $SNR = 0.665 \times S/SD_{air}$.

Two experienced neuroradiologists reviewed the coronal pre-enhanced DWI images obtained by BLADE and EPI sequences, and independently evaluated the following 6 points compared with coronal contrast-enhanced T1-weighted images: (1) the visualisation of internal carotid; (2) the visualisation of optic chiasm; (3) the visualisation of pituitary gland; (4) the visualisation of pituitary stalk; (5) the border between the lesion and its normal surroundings; (6) total image quality. We evaluated points 1–6 according to a five-point scale under the following criteria: the visualisation of DWI images are as clear as the one in enhanced T1-weighted images (excellent, 4); the visualisation of DWI images approaches enhanced T1-weighted images (good, 3); structures can be observed but are obviously vague compared with enhanced T1-weighted images (fair, 2); structures can be barely recognised in DWI images (poor, 1); structures cannot be recognised in DWI images (non-diagnostic, 0).

We did not evaluate point 5 (the border between the lesion and normal surroundings) in volunteers and omitted those points concerning structures which cannot be observed in contrast-enhanced T1-weighted images.

For qualitative assessments where 2 radiologists gave the same score, the data were collected by the analyst without intervention. In cases of disagreement, the radiologists would negotiate a score for the analyst to report.

Another research radiologist measured the minimal length of sellar lesions to determine the visual capability of BLADE DWI.

2.4. Statistical analysis

Statistical analysis was performed by using statistical software (SPSS, release 19.0, IBM, China). In qualitative assessment, the mean scores of the two readers were used for analysis.

Results of SNR values and visual assessments were compared using the Wilcoxon t-test for statistical analysis. A P-value of <0.05 was considered to indicate a statistically significant difference.

Logistic regression was used to determine whether a relationship existed between lesion size and its assessment score; if so, a fitted curve or straight line would be used to describe it.

3. Results

The SNR value (mean ± SD) is 23.67 ± 13.16 in BLADE DWI and 21.4 ± 18.94 in single-shot EP-DWI images ($P = 32.27\% > 5\%$).

DWI images obtained by BLADE DWI were significantly superior to those obtained by single-shot EP-DWI sequence for all 6 points: the visualisation of internal carotid artery, optic nerve, pituitary gland and pituitary stalk; the border between the lesion and normal surroundings ($P < 0.001$) and the total image quality ($P < 0.001$).

The scores in each point are listed in Fig. 1, and we categorised all DWI images into 2 groups: “visible” and “fair” (Table 1). “Visible” means that at least one radiologist saw the specified structure; therefore, the score in this item is over 0. “Fair” means that the average judgment of this item from 2 radiologists exceeds the “fair” level (a score over 2). In the category analysis shown in Table 1, it is clear that BLADE DWI significantly outperformed single-shot DWI.

There is no significant relationship between minimal lesion diameter and score concerning the internal carotid, optic nerve, pituitary gland or pituitary stalk. However, a weak relationship exists between the minimal length, lesion score and total image score. The fitted formulation is as follows: $y = 1.9985\ln(x) - 2.9159$ (BLADE DWI imaging, $P < 0.001$, $R^2 = 0.6295$); $y = 1.2638\ln(x) - 2.3329$ (EP-DWI imaging, $P < 0.001$, $R^2 = 0.5676$), which suggests that the minimal diameter of lesion would need to reach 12 mm before BLADE DWI image quality could be judged fair, while using EP-DWI would require a minimal diameter of 31 mm. R^2 of fitted curve for total image score is less than 0.5 in BLADE and EPI diffusion-weighted images while $P < 0.001$, suggesting a much weaker relationship (Fig. 2).

Representative cases are shown in Figs. 3 and 4.

Our results indicated the BLADE DWI sequence was significantly superior to the traditional EP-DWI sequence in image quality.