DEVELOPMENT OF DIFFUSION-WEIGHTED IMAGE USING A 0.3T OPEN MRI


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SUMMARY

The purpose of this study was to develop a new technique for diffusion-weighted MRI (DWI) with a low-field scanner. DWI is becoming important for assessment of acute stroke. Until recently DWI required expensive technology. We developed multishot-DWI sequence for 0.3T open type MR imager. We prospectively studied forty patients on this 0.3T MRI and compared this DWI to single-shot-DWI by 1.5T-MRI. Group A: Twenty-four patients with acute cerebral infarctions detected by 1.5T-DWI were re-examined using 0.3T-DWI within 24 hours. Sixteen patients with acute cerebral infarctions detected by 0.3T-DWI were re-examined using 1.5T-DWI within 24 hours. In 22 (92%) of 24 cases, 0.3T-DWI showed high signal. In the other two patients, motion artifact distorted 0.3T-DWI. Group B: In all 16 patients, all infarctions detected by 0.3T-DWI showed high signal on 1.5T-DWI. These preliminary data show that, as long as the patient is able to keep still, multishot-DWI can be acquired successfully on a 0.3T open type MRI system.

Key words: DWI, Infarction, 0.3tesla MRI, Open type MRI.

RÉSUMÉ

Imagerie de diffusion en champ ouvert de 0.3 T

Le but de cette étude est de développer une nouvelle technique de diffusion sur un appareil d’IRM à bas champ. L’imagerie de diffusion, très utile en cas d’accident vasculaire cérébral ischémique (AVCI) à la phase aiguë, nécessite une technologie chère. Nous avons mis au point une séquence multishot en champ ouvert de 0.3 T. Celle-ci a été comparée de façon prospective à une séquence de diffusion single-shot effectuée avec une machine 1.5 T. Vingt-quatre patients atteint d’AVCI détecté en imagerie de diffusion à 1.5 T ont été ré-examinés à 0.3 T dans les 24 heures (groupe A). Seize patients atteint d’AVCI détecté en imagerie de diffusion à 0.3 T ont été ré-examinés à 1.5 T dans les 24 heures (groupe B). Dans 22 (92%) des 24 cas, l’imagerie à 0.3 T a montré un hypersignal; dans les deux autres cas, des artefacts de mouvement ont gênés l’interprétation. Tous les 16 infarctus du groupe B détectés à 0.3 T ont été vus à 1.5 T. Ces résultats préliminaires que, si le patient reste calme, la séquence multishot est utile à champ ouvert de 0.3 T.

Mots-clés : infarctus, bas champ, 0.3 T, champ ouvert.

INTRODUCTION

Diffusion-weighted MR imaging (DWI) is now a routine component of the brain MR imaging examination and is critical in the evaluation of the stroke patient. The use of DWI resides in the ability to detect and provide image contrast dependent on the translational motion of water through brain tissue [1, 5, 7, 12, 13]. Until recently, DWI was performed with echo-planar technology using scanners at high field strength with relatively strong and fast gradients. However echo-planar technology is not readily available at all institutions. DWI does not necessarily require high magnetic field strengths. It has been shown to be performable at lower field strengths using a variety of technologies, such as line-scan imaging [9, 10], fast spin-echo imaging [6, 11, 15] or even echo-planar imaging [8]. In developing countries, low- and medium-magnetic field MRI units still comprise the majority in clinical hospitals. The purpose of this study was to assess the efficacy of DWI using an open 0.3T MRI unit in detecting acute cerebral infarction.

MATERIALS AND METHODS

Patients

Patients were referred with a high degree of suspicion of having an acute stroke, after examination by a neurologist or neurosurgeon. In order to exclude hematoma, CT had been performed in all cases. There was no hemorrhage visible in any case. The final diagnosis was based on findings at clinical follow-up and late imaging. Forty patients with acute infarctions were included in this prospective study. They were divided into two groups at random. Group A: Twenty-four (15 male, 9 female)
patients with acute cerebral infarctions detected by 1.5T-DWI were re-examined using 0.3T-DWI within 24 hours. The mean age was 72 years with a range of 53 to 89 years. Group B: Sixteen (6 male, 10 female) patients with acute cerebral infarctions detected by 0.3T-DWI were re-examined using 1.5T-DWI within 24 hours. The mean age was 72 years with a range of 58 to 86 years.

**Time to MRI**

Mean time after onset of symptoms was 4 days with a range of 5 hours to 7 days in group A. Mean time between scanning on both systems was 67 min with a range of 10 min to 240 min. Mean time after onset of symptoms was 5 days (range 1-10 days) in group B. Mean time between scanning on both systems was 6.5 hours (range 30 min-23 hours).

**MR imaging**

Patients were examined on a 1.5T echo-planar system (Gyroscan ACS-NT, Philips Medical Systems) and on an open 0.3T scanner (AIRIS II, Hitachi Medical Co.). The technique used was a single-shot spin-echo echo-planar sequence at 1.5T MRI and a multi-shot spin-echo echo-planar sequence at 0.3T MRI.

The whole brain was imaged using a multi-slice technique: on the 1.5T system a total of nineteen 6.5mm thick axial slices were acquired with b values of 0 and 1,000 s/mm\(^2\), field of view: 230mm, 256 x 151 matrix, TR: 3895ms, TE: 130ms, NEX: 1. The diffusion gradients were applied in the x, y, and z directions and trace images were generated. ADC values were not available using console software. Acquisition time was 23.4 sec.

On the 0.3T system the parameters were: a total of sixteen 7.5mm thick axial slices acquired with b values of 0 and 604-998 (mean 798) s/mm\(^2\), field of view: 220mm, 124 x 110 matrix, TR: 3900ms, TE: 114ms, NEX: 1. The diffusion gradients were applied in the x and y directions. ADC values were not available using console software. Acquisition time was 169-274 (mean 210) sec.

**Image interpretation**

Two radiologists interpreted the 0.3T-DWI while blind to the interpretation of 1.5T-DWI, results of the follow-up examination and clinical information. Then they interpreted the 1.5T-DWI while blind to the result of the follow-up examination and clinical information. They interpreted the presence, conspicuousness and size of high signal intensity lesions by visual inspection.

**RESULTS**

**Concordance study with both radiologists**

Both observers obtained the same results for the presence, conspicuousness and size of high signal intensity lesions on both systems.

**Lesions**

In 22 (92%) of 24 cases in group A, 0.3T-DWI showed high signal. In 16 (67%) of these 22 cases, the size and extension of the high signal on 0.3T-DWI were the same as those of the high signal on 1.5T-DWI (figure 1). In six other cases (25%), the high signal on 0.3T was smaller than that on 1.5T (figure 2). In all of these 22 cases, the high signal on 0.3T-DWI was less conspicuous than that on 1.5T-DWI. In two (8%) of 24 cases, 0.3T-DWI showed no high signal. In one of these two cases, patient motion...
was so marked that motion-induced artifacts masked the diffusion-high signal on 0.3T-DWI obtained 30 min after 1.5T-DWI. In the other case, vigorous patient motion resulted in complete signal loss on 0.3T-DWI (figure 4).

In all 16 cases of group B, all infarctions detected by 0.3T-DWI showed high signal on 1.5T-DWI.

**Localization**

In Group A, 17 (71%) of the lesions were perforator infarctions, 5 (21%) cortical infarctions and 2 (8%) of mixed type. In Group B, 7 (44%) were perforator infarctions, 6 (37%) cortical infarctions and 3 (19%) of mixed type.

**DISCUSSION**

Diffusion-weighted MR imaging is particularly sensitive for the detection of acute stroke [1, 5, 7, 12, 13]. After 24 hours, however, infarction usually can be detected as hypoattenuated lesions on CT scans and hyperintense lesions on T2- and fluid-attenuated inversion-recovery (FLAIR)-weighted images. Diffusion imaging also is useful in this setting. Older
patients commonly have T2-hyperintense abnormalities that may be indistinguishable from acute lesions on T2- and FLAIR-weighted images. The acute infarctions are hyperintense on DWI and hypointense on ADC maps because of elevated diffusion [2]. In one study in which there were indistinguishable acute and chronic white-matter lesions on T2-weighted images in 62% of patients, the sensitivity and specificity of DWI for detecting acute subcortical infarction were 94.9% and 94.1%, respectively [15].

Low-field open MRI system usually allows only a moderate slew rate and amplitudes of the field gradients. One disadvantage of the low-field system is the significantly longer scan time, which is problematic because of the increased possibility of patient motion-induced artifacts. While multishot-DWI is very motion sensitive, DWI itself is independent of the field strength being used. Development of single-shot DWI using 0.3T scanner could be a solution.

In this study, 0.3T-DWI detected 92% of infarcts detected by 1.5T-DWI. Motion-induced artifacts masked the DWI signal in the other 8%. By eliminating patients who move and enrolling only cooperative patients, 0.3T-DWI detected all infarcts detected by 1.5T-DWI. On the other hand 0.3T-DWI showed no false positive finding. We clarified that DWI performed on a 0.3T open scanner can demonstrate acute and subacute ischemia equally well as a conventional 1.5T scanner.

Fig. 4. – Homme de 89 ans, examiné 4 jours après le début des symptômes. Les séquences de diffusion (b) et T2 EPI à 1.5T (c) montrent un hypersignal thalamique gauche. Les artefacts de mouvement importants sont responsables d'une perte de l'hypersignal sur la séquence de diffusion à 0.3T (a) fait 20 minutes après.

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High signal on 0.3T-DWI was smaller than that on 1.5T-DWI in 25%. All high signals on 0.3T-DWI were less conspicuous than those on 1.5T-DWI. Lower b value may account for these results [4]. Even if the image quality obtained with the low-field system was not the same as the one observed on the high-field system, this did not diminish its ability to serve as a screening tool for patients with suspected stroke. This is extremely important since on the one hand low-field systems are quite widely available due to their lower cost compared to high-field systems, especially in developing countries. Moreover since stroke patients are often unstable it is important to be able to monitor them. The open type MRI allows easier access to the patients.

We only acquired 0.3T-DWI images with the gradients in two directions. This has however been proven to provide DWI images of sufficient diagnostic accuracy for the acute evaluation of stroke patients. This is in agreement with a previous report indicating that the theoretical concerns about the pitfalls of orthogonal-axis DWI may be unfounded in the clinical setting of diagnosing early stroke [3].

This study has many limitations. First, as the groups are poorly paired, no statistical comparison is available. Second, stroke was defined on clinical examination and DWI hyperintensities without ADC calculation. Then, the nature of these hyperintensities remains questionable. Third, group A (1.5T DWI first) may give an evaluation of 0.3 DWI sensitivity (92%) but no evaluation of specificity could be performed. Group B (0.3T DWI first) may give an evaluation of 0.3 DWI positive predictive value (100%) but no evaluation of negative predictive value could be performed. Except for the sensitivity and positive predictive value, very little information is available for the other variables. However it is important to state that 0.3T DWI has high sensitivity and high positive predictive value in the clinical setting. Data from the World Health Organization (WHO) (http://www.who.int/eht/en/DiagnosticImaging.pdf) show that two-thirds of the world’s population have no access to medical imaging at all, let alone MRI. The cost savings associated with low-field MR imaging are clear. Current data suggest that the cost of a 1.5T scanner is about 2 times higher than that of a 0.3T scanner [16]. In develop-
ing countries, DWI for cheaper low-field MR imag-
ers could be helpful especially for abscess detection.

In conclusion, although higher field MRI is still
desirable, 0.3T open type MRI system represents an
acceptable clinical compromise for obtaining DWI if
no other alternative is readily available. Further
quantitative rigorous assessment of the clinical effect
of low-field scanner in larger case series or well-
controlled comparison trials is mandatory.

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