Diagnostic and Interventional Imaging (2018) xxx, xxx—xxx

ORIGINAL ARTICLE /*Head and neck imaging*

Diffusion-weighted magnetic resonance imaging of extraocular muscles in patients with Grave's ophthalmopathy using turbo field echo with diffusion-sensitized driven-equilibrium preparation

A. Hiwatashi*, O. Togao, K. Yamashita, K. Kikuchi, D. Momosaka, H. Honda

Department of Clinical Radiology, Graduate School of Medical Sciences, Kyushu University, 3-1-1 Maidashi, Higashi-ku, Fukuoka 812-8582, Japan

KEYWORDS
Diffusion-weighted imaging;
Apparent diffusion coefficient;
Orbit;
Thyroid associated ophthalmopathy;
Graves' disease

Abstract
Purpose: The purpose of this study was to correlate diffusivity of extraocular muscles, measured by three-dimensional turbo field echo (3DTFE) magnetic resonance (MR) imaging using diffusion-sensitized driven-equilibrium preparation, with their size and activity in patients with Grave's ophthalmopathy.
Materials and methods: Twenty-three patients with Grave's ophthalmopathy were included. There were 17 women and 6 men with a mean age of 55.8 ± 12.6 (SD) years (range: 26—83 years). 3DTFE with diffusion-sensitized driven-equilibrium MR images were obtained with b-values of 0 and 500 s/mm^2. The apparent diffusion coefficient (ADC) of extraocular muscles was measured on coronal reformatted MR images. Signal intensities of extraocular muscles on conventional MR images were compared to those of normal-appearing white matter, and cross-sectional areas of the muscles were also measured. The clinical activity score was also evaluated. Statistical analyses were performed with Pearson correlation and Mann-Whitney *U* tests.
Results: On 3DTFE with diffusion-sensitized driven-equilibrium preparation, the mean ADC of the extraocular muscles was 2.23 ± 0.37 (SD) $\times 10^{-3}$ mm2/s (range: 1.70×10^{-3}—3.11×10^{-3} mm^2/s). There was a statistically significant moderate correlation

* Corresponding author.
E-mail address: hiwatasi@radiol.med.kyushu-u.ac.jp (A. Hiwatashi).

https://doi.org/10.1016/j.diii.2018.02.007

Please cite this article in press as: Hiwatashi A, et al. Diffusion-weighted magnetic resonance imaging of extraocular muscles in patients with Grave's ophthalmopathy using turbo field echo with diffusion-sensitized driven-equilibrium preparation. Diagnostic and Interventional Imaging (2018), https://doi.org/10.1016/j.diii.2018.02.007

between ADC and the size of the muscles ($r = 0.61$). There were no statistically significant correlations between ADC and signal intensity on conventional MR and the clinical activity score.

Conclusion: 3DTFE with diffusion-sensitized driven-equilibrium preparation technique allows quantifying diffusivity of extraocular muscles in patients with Grave's ophthalmopathy. The diffusivity of the extraocular muscles on 3DTFE with diffusion-sensitized driven-equilibrium preparation MR images moderately correlates with their size.

Introduction

Grave's ophthalmopathy is an autoimmune disorder of the orbit that is clinically symptomatic in 25—50% of patients with Graves' disease [1—4]. Patients with Grave's ophthalmopathy often experience highly incapacitating symptoms such as severe ocular pain and diplopia [5]. Previous studies have shown that computed tomography of the orbit could provide information on fat and muscle enlargement, which can be useful for diagnosing Grave's ophthalmopathy [5—11]. Other studies using magnetic resonance (MR) imaging revealed that the extraocular muscles of patients with active disease had a higher signal intensity ratio on T2-weighted and postcontrast T1-weighted MR images than those with inactive disease [6—12].

Diffusion-weighted (DW) MR imaging is widely used to diagnose tumors, inflammation, and vascular disease in both intracranial and extracranial lesions [5,13—22]. Previous studies also revealed the efficacy of DW MR imaging to evaluate orbital lesions including orbital tumors [16,18,20,21,23], IgG4-related disease [16], endophthalmitis [13], and optic nerve lesions [14]. However, it is sometimes difficult to evaluate intraorbital structures with echo planar imaging, which is the most common imaging technique for DW MR imaging. A previous study with echo planar DW MR imaging revealed its efficacy in assessing the activity of Grave's ophthalmopathy but found unsatisfactory image quality [5].

Compared to echo planar DW imaging, three-dimensional turbo field echo (3DTFE) with diffusion-sensitized driven-equilibrium preparation can produce images with higher spatial resolution and fewer susceptibility artifacts [15—20]. 3DTFE with diffusion-sensitized driven-equilibrium preparation minimizes image distortion while reducing B0 and B1 inhomogeneity and eddy current effects [24]. It was used to assess cholesteatoma [15], pituitary gland [17,19], and orbital tumors [16,18,20]. However, to date no studies have evaluated 3DTFE with diffusion-sensitized driven-equilibrium preparation in Grave's ophthalmopathy.

The purpose of this study was to compare diffusivity of extraocular muscles, measured by 3DTFE MR imaging with diffusion-sensitized driven-equilibrium preparation, with their size and activity in patients with Grave's ophthalmopathy.

Methods

This retrospective study was approved by our institutional review boards, and written informed consent was waived.

Patients

Twenty-three consecutive patients with Grave's ophthalmopathy who underwent 3DTFE with diffusion-sensitized driven-equilibrium preparation MR imaging examination between January 2011 and February 2014 at our institution were studied. There were 17 women and 6 men with a mean age of 55.8 ± 12.6 (SD) years (range: 26—83 years). All patients were diagnosed with Graves' disease. The previous treatments before MR imaging for hyperthyroidism in these 23 patients were as follows: none ($n = 12$; 12/23; 52.2%), potassium iodine ($n = 6$; 6/23; 26.1%), 1-methyl-2-mercaptoimidazole ($n = 6$; 6/23; 26.1%), radiation ($n = 2$; 2/23; 8.7%) and surgery ($n = 1$; 1/23; 4.3%). Two patients (2/23 = 8.7%) had previously received steroid for Grave's ophthalmopathy. The clinical activity score, which includes spontaneous retrobulbar pain, pain on attempted up- or down gaze, redness of the eyelids, redness of the conjunctiva, swelling of the eyelids, inflammation of the caruncle and/or plica, and conjunctival edema, were assessed by the referring clinicians [3]. A clinical activity score more than 3 indicated active Grave's ophthalmopathy [3].

Imaging technique

All patients underwent MR imaging with a 3.0-T system (Achieva TX®, Philips, Best, The Netherlands) with an 8-channel head coil. The details of the 3DTFE with diffusion-sensitized driven-equilibrium preparation are described elsewhere [15—20]. Briefly, it has two distinct components: the diffusion-sensitized driven-equilibrium preparation, and the segmented 3DTFE data acquisition [24]. Adiabatic refocusing pulses and additional gradients inserted in front of the sequence were used to reduce the sensitivity to B0 and B1 inhomogeneity as well as eddy current effects [24]. Data acquisition using 3DTFE was performed immediately after the diffusion-sensitized driven-equilibrium preparation.

To eliminate T1 effects in the acquired signal by 3DTFE, we used a phase-cycling scheme. For the 3DTFE with

Please cite this article in press as: Hiwatashi A, et al. Diffusion-weighted magnetic resonance imaging of extraocular muscles in patients with Grave's ophthalmopathy using turbo field echo with diffusion-sensitized driven-equilibrium preparation. Diagnostic and Interventional Imaging (2018), https://doi.org/10.1016/j.diii.2018.02.007