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Cross-sectional investigation of correlation between hepatic steatosis and IVIM perfusion on MR imaging

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Abstract

The purpose of this study was to investigate the relationship between liver fat fraction (FF) and diffusion parameters derived from the intravoxel incoherent motion (IVIM) model. Thirty-six subjects with suspected nonalcoholic fatty liver disease underwent diffusion-weighted magnetic resonance imaging with 10 *b*-values and spoiled gradient recalled echo imaging with six echoes for fat quantification. Correlations were measured between FF, transverse relaxivity (R2*), diffusivity (*D*) and perfusion fraction (*f*). The primary finding was that no significant correlation was obtained for *D* vs. FF or *f* vs. FF. Significant correlations were obtained for *D* vs. R2* (r=−0.490, P=.002) and *f* vs. *D* (r=−0.458, P=.005). The conclusion is that hepatic steatosis does not affect measurement of perfusion or diffusion and therefore is unlikely to confound the use of apparent diffusivity to evaluate hepatic fibrosis.

Keywords: DW; Perfusion; IVIM; Diffusion; Liver

1. Introduction

Magnetic resonance (MR) imaging is increasingly used in noninvasive assessment of liver disorders [1]. Diffusion-weighted (DW) imaging — in particular, the intravoxel incoherent motion (IVIM) model — has frequently been used to explain reduced apparent diffusion coefficient (*D*) measurements in cirrhotic livers [2–4]. The IVIM model attributes DW imaging signal changes in the low *b*-value range to microcirculatory perfusion that, on the scale of an imaging voxel, mimics random molecular motion, while signal changes in the high *b*-value range reflect ordinary diffusion [5–7].

The perfusion parameters derived from IVIM modeling have been proposed as potential biomarkers of liver fibrosis as the microcirculatory environment is altered by deposition of collagen and other macromolecules in perisinusoidal space (space of Disse) as well as closure of fenestrations along the endothelium separating the sinusoidal and perisinusoidal space. Together, these alterations have the consequences of expanding the perisinusoidal space and compressing the sinusoids, causing resistance to sinusoidal blood flow and thus reduced microcirculatory perfusion. The passage of water molecules from sinusoidal to perisinusoidal space, within perisinusoidal space and from perisinusoidal space into hepatocytes is also restricted, hence the reduced diffusion.

In some respects, hepatic steatosis has a similar effect to fibrosis on diffusion/perfusion. Fat accumulates as droplets in the hepatocytes which cause hepatocyte swelling, distortion of the microcirculatory anatomy and compression of sinusoids [8]. Thus, fat in the liver may have a similar effect on diffusion/perfusion, mimicking the changes associated with fibrosis. Another difficulty due to fat is imperfect suppression of the fat signal; since fat diffuses very slowly (low *D*), any residual fat signal would tend to lower the measured diffusivity. Fat frequently coexists

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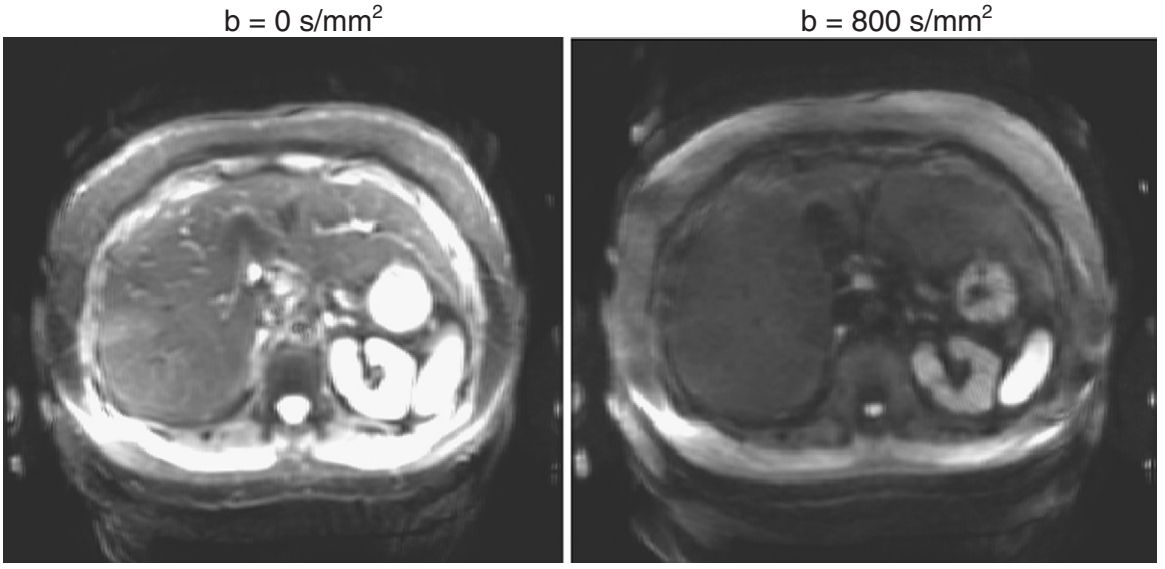

Fig. 1. Typical images for the DW EPI acquisitions (note that window/level is identical). Signal amplitude was recorded at 10 *b*-values between 0 and 800 and modeled using biexponential analysis [Eq. (1)].

with fibrosis; however, the relationship between IVIM parameters and liver fat has not been well studied in human subjects.

The relationship between diffusion/perfusion and liver fat needs to be understood if IVIM measurements are to be developed further for fibrosis assessment, as fat may confound the relationship between IVIM parameters and liver fibrosis. The main purpose of this study is to address this gap in knowledge by prospectively assessing the cross-sectional relationship between liver fat fraction (FF) and IVIM parameters. Based on these introductory remarks, we anticipate a negative correlation for *D* versus FF and perfusion fraction (*f*) versus FF.

2. Material and methods

2.1. MR imaging

This prospective, cross-sectional, single-site study was approved by an institutional review board and was compliant with the Health Insurance Portability and Accountability Act. Subjects with suspected nonalcoholic fatty liver disease were recruited consecutively between January and August 2010 (36 total, 14 male, 22 female, ages 11–62). None of the subjects had a known diagnosis of liver fibrosis at the time of study. Additionally, none of the subjects had morphological changes of advanced fibrosis, as interpreted by a radiology body imaging fellow. Informed consent was obtained from

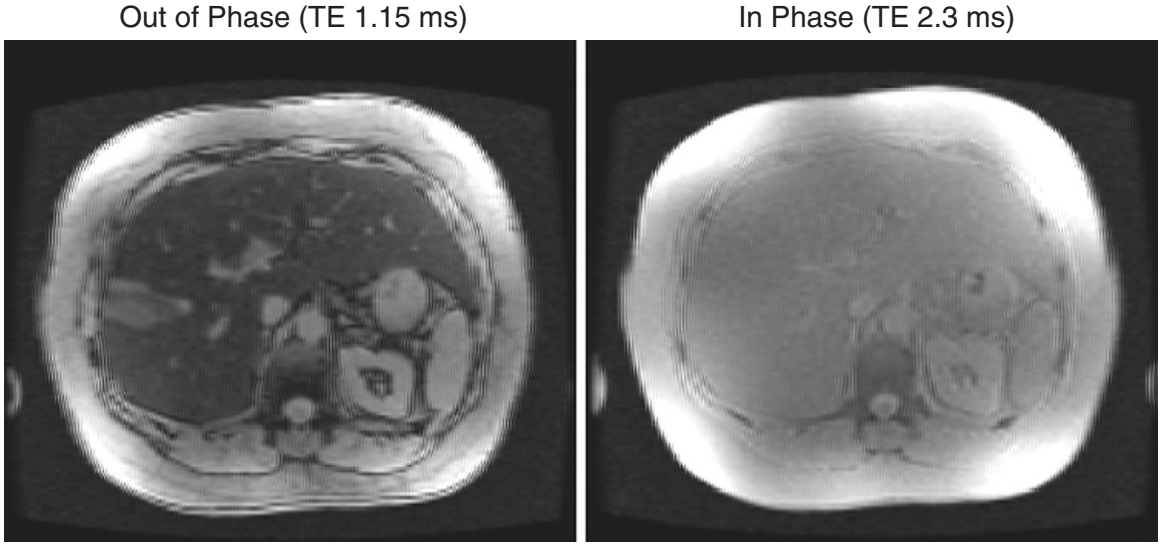

Fig. 2. Typical images for the spoiled gradient echo acquisitions for fat quantification (note that window/level is identical). Signal amplitude was recorded at six echo times and modeled using an oscillating exponential decay.