Cine Viability Cardiac MRI using Contrast-enhanced 3D Balanced Steady-state Free Precession Imaging

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INTRODUCTION

Cardiac MRI is a powerful tool for assessing both morphology and function of the heart. Cine cardiac MRI estimates the regional wall thickness and motion, volume of the left ventricular (LV) cavity, LV ejection fraction, and LV myocardial mass, while contrast-enhanced MRI defines the nonviable myocardium associated with myocardial infarction (MI) and the fibrosis associated with hypertrophic cardiomyopathy (HCM). However, a number of repeated breath-holds are usually requested for cardiac MRI. Even when using 3D imaging sequences, cine and delayed contrast-enhanced MRI are obtained separately, and thus misregistration of imaging section and cardiac phase between the two cardiac MRI can occur. Three-dimensional balanced steady-state free precession (SSFP) imaging has several possible advantages: complete data acquisition during a single breath-hold, myocardial and soft tissue suppression owing to short TR and inherent T2/T1 contrast, high SNR, and persistent high signal of the enhancing structures after gadolinium injection. The purpose of this study is to demonstrate the potential of contrast-enhanced 3D cine balanced SSFP imaging as cine viability cardiac MRI that can simultaneously demonstrate myocardial wall motion and viability in the same imaging section.

METHODS

Eight patients with acquired cardiac diseases were enrolled. They were classified into two groups: those with delayed myocardial hyperenhancement, including three patients with MI and one patient with HCM after transluminal alcohol ablation, and those without myocardial hyperenhancement, including two patients with HCM, one with right ventricular failure, and one with ventricular premature beats. The presence of delayed myocardial hyperenhancement was determined using delayed contrast-enhanced images acquired using 2D inversion-recovery gradient-echo MRI.

MRI examinations were performed using a 1.5T unit with high performance gradient (Intera, Philips). A five-element phased-array coil and vector electrocardiography were used for signal reception and cardiac gating, respectively. Two-dimensional cine balanced SSFP, e.g., balanced turbo field-echo (TFE) imaging was acquired in the short axis plane for the standardized evaluation of LV ejection fraction and myocardial mass. Three-dimensional cine balanced TFE in the short axis plane was performed before and 5-10 minutes after gadolinium injection at a dose of 0.15mmol/kg. Thereafter, 2D inversion-recovery gradient-echo imaging was performed to assess delayed hyperenhancement in the LV myocardium.

The agreements of LV ejection fraction and myocardial mass between these images were assessed using correlation analyses. The SNRs of normal myocardium, damaged myocardium including MI and ablated region, and LV cavity were estimated. The CNRs were assessed between LV cavity and normal myocardium, LV cavity and damaged myocardium, and damaged and normal myocardia. Contrast-enhancement ratio (CER) of damaged or normal myocardium was defined as (postcontrast signal – precontrast signal) / precontrast signal. The differences in the SNRs of each tissue and the CNRs were evaluated between pre- and postcontrast 3D cine MRI. The difference in the CER between normal and damaged myocardia was also assessed in 3D cine MRI.

RESULTS

Contrast-enhanced 3D cine MRI provided cine images comparable to 2D cine MRI. The LV ejection fraction and myocardial mass acquired using contrast-enhanced 3D cine MRI was highly concordant with those acquired using 2D cine MRI ($r > 0.95$).

The SNRs of the normal myocardium ($P = 0.004$), damaged myocardium ($P = 0.008$), and LV cavity ($P = 0.018$) significantly increased after contrast enhancement in the 3D cine MRI. Although there was no difference in SNR between damaged and normal myocardia ($P = 0.38$) before contrast enhancement, a significant difference was observed with the higher SNRs of damaged myocardium in the contrast-enhanced 3D cine MRI ($P = 0.009$). The CNRs between LV cavity and normal myocardium ($P = 0.046$) and between damaged and normal myocardia ($P = 0.006$) significantly increased after contrast enhancement, but no significant difference in the CNR between damaged myocardium and LV cavity was obtained between pre- and postcontrast 3D cine MRI ($P = 0.15$). The CER of damaged myocardium was significantly higher than that of normal myocardium ($P = 0.023$).

DISCUSSION

Contrast-enhanced 3D cine balanced SSFP imaging demonstrated hyperenhancing damaged myocardium as well as cine images with 16 cardiac phases. Because of the inherent high SNR and the persistent sensitivity to gadolinium in the tissues, this imaging technique may provide cine viability imaging of the heart. The advantages of this imaging technique are the simultaneous acquisition of cine and viability images during a single breath-hold and in the same imaging section, and the potential for several postprocessing procedures as well as the accurate assessment of LV ejection fraction and myocardial mass.

In conclusion, contrast-enhanced 3D cine balanced SSFP imaging may allow the simultaneous assessment of myocardial wall motion and hyperenhancement in the same imaging sections.

REFERENCES 1. Miller S, et al. Radiology 2002; 223: 263-269. 2. Kim RJ, et al. N Engl J Med 2000; 343: 1445-1453.