Cardiac diffusion MRI of acute and chronic myocardial infarction: preliminary results

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Abstract

Purpose. To use diffusion weighted MR imaging (DWI), a technique routinely used in patients with stroke, for diagnosis of myocardial infarction (MI).

Materials and methods. A breath hold ECG gated DWI sequence (b=300 sec/mm²) was developed and applied to 7 patients with recent MI (3-15 days), 3 patients with chronic MI (> 6 months) and 4 patients with valvular heart disease without MI (control cases). DWI data were correlated to T2W, first pass perfusion and delayed enhancement data.

Results. In all patients with recent MI, DWI showed an area of increased signal with reduction of ADC relative to normal myocardium. Hyperintense lesion on DWI corresponded to areas of delayed enhancement. The diffusion images were normal in patients with chronic MI or no MI.

Conclusion. Even though no animal model or other reference method is available, these preliminary results indicate that DWI could assist clinicians in detecting recent MI.

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Discussion

Our preliminary data indicate that DWI MR imaging is able to detect areas of infarction in MI, irrespective of reperfusion procedures, and to differentiate necrotic from viable myocardium, whereas it normalizes in chronic infarcts. DWI is one of the main MR imaging sequences for diagnosis of acute stroke syndromes (1). Due to its sensitivity in detecting ischemia, it allows detection of infarcts within a few hours of clinical onset. ADC maps improve the diagnostic accuracy by providing a map of cytotoxic edema (supposed to correspond to irreversible ischemia), characteristic of peripheral vasogenic edema at risk. The potential advantage of cardiac DWI is that the heart possesses a larger blood volume than the brain (3). Since DWI of the heart was first described, several studies have been published, including one on animals. These publications demonstrated changes in diffusion in isolated perfused rabbit hearts following ligation of the left anterior descending coronary artery.

Table I

<table>
<thead>
<tr>
<th>Number of patients</th>
<th>Diffusion</th>
<th>T2W</th>
<th>FPE</th>
<th>DE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Homogeneous hyperintensity (reduced ADC)</td>
<td>Hyperintensity (edema)</td>
<td>Transient perfusion defect (low-reflow)</td>
<td>Transmural hyperintensity</td>
</tr>
<tr>
<td>3</td>
<td>Subendocardial and subepicardial hyperintensity with increased ADC around a central hypointense region with low ADC</td>
<td>Hyperintensity (edema)</td>
<td>Persistent perfusion defect (no-reflow)</td>
<td>Subendocardial and subepicardial hyperintensity around a central hypointense region (necrosis)</td>
</tr>
<tr>
<td>2</td>
<td>Homogeneous subendocardial or transmural hyperintensity (reduced ADC)</td>
<td>Normal</td>
<td>Normal</td>
<td>Homogeneous subendocardial or transmural hyperintensity</td>
</tr>
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Results

In all patients with recent MI (with ST elevation or STEMI, or without ST elevation or NSTEMI), DWI showed increased signal at the infarct site with corresponding reduced ADC signal compared to normal appearing myocardium on 3 separate modes of myocardial diffusion (table I), irrespective of urgent coronary reperfusion procedures (n=5) or not (n=2), perfectly correlating to areas of signal abnormality on T2W, FPE and especially DE images (fig. 1 to 3). The average number of involved parts was 2.57±0.1. DWI, FPE and DE imaging showed no area of abnormal signal, and normal ADC values. FPE imaging showed no enhancement, and DE imaging showed increased transmural enhancement in the non-viable portion of the infarct. DWI, ADC maps, T2W, FPE and DE imaging were normal in patients with valvular disease.

Criteria for image review

Qualitative interpretation was performed by 3 reviewers by consensus. Diffusion data were obtained by using isotropic diffusion in all 3 planes. DWI images were compared to T2W, FPE and DE images. MI was defined as an area of increased signal with or without thickening on T2W images, a perfusion defect on FPE images and an area of increased signal sometimes associated with an area of lower signal or no-reflow on DE images. Because the purpose was simply to evaluate MI detectability on DWI, post-processing consisted of co-registration of DWI and DE images using the AW software (GE Healthcare, Milwaukee, Wis). The latter was performed by orthogonal reformatting of DWI data along the double obliquity of DE images. The left ventricular myocardium was thus divided into 8 parts as opposed to 17 segments due to the differences in acquisition planes: base and anterior apical, septal, inferior and lateral left ventricular portions. Co-registration was achieved with the help of fiducial markers. Apparent diffusion coefficient (ADC) maps were calculated with the Functool software using regions of interest (ROI) centered over areas of hyperintensity detected on b=300 sec/mm² images as well as distant regions of normal appearing myocardium on b=0 sec/mm² images. A statistical analysis of these preliminary data was not performed.

Table I

Imaging characteristics of infarcted myocardium in patients with recent MI.

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Fig. 1: Inferior MI.

a Sagittal diffusion-weighted image of the heart showing hyperintense signal along the inferior wall (arrows) compared to the normal anterior wall (arrows).

b Color-coded ADC map showing a 50% reduction in ADC values (green, arrows) compared to the normal anterior wall (red, arrows).

c-d T2W image (c) showing edema of the inferior wall, whereas transmural enhancement of the inferior wall (arrows) is demonstrated on long axis DE images (d) in the same region.

Fig. 2: Lateral MI.

a Axial diffusion-weighted image showing two areas of hyperintensity, subendocardial and subepicardial, surrounding an area of hypointensity at the lateral wall (arrow). ADC values in the hypointense zone are decreased by 50% compared to the normal septum, whereas they are increased by a factor of 2 in the hypointense subendocardial zone (not illustrated). Short axis FFE images confirmed the absence of subendocardial enhancement at the lateral wall (not illustrated).

b-c Four-chamber (b) and short axis (c) DE images showing subendocardial and subepicardial hyperintense signal with hypointense area corresponding to the image in (a).
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Our study confirms that recent MI can be assessed using ECG-gated breath hold DWI, usually acquired in less than one minute in clinical practice. This technique is simpler and much faster than other pulse sequences routinely used for cardiac MR. The different DWI characteristics of recent STEMI, NSTEMI and chronic MI could allow differentiation between necrotic, viable and scarred myocardium. This first clinical trial suggests that DWI MR imaging could be useful for rapid evaluation of patients with recent MI. The acquisition of diffusion imaging software would then become valuable if not essential should the results from this study be confirmed. Additional studies are required to establish its role in patients with acute coronary syndromes, especially NSTEMI, where it could potentially become the most valuable imaging modality, and to establish its value in myocardial viability assessment compared to other imaging modalities. Additional studies are needed to confirm these preliminary data.

The authors disclose no conflict of interest.

References

6. Okayama S, Uemura S, Saito Y. Detection of infarct-related myocardial edema using cardiac diffusion-weighted magnetic resonance imaging. Int J Cardiol 2007 Dec 17; (Epub ahead of print)