Myocardial blood flow estimates depend on the location of the arterial input function within the cardiac cycle in first-pass DCE-MRI studies of myocardial perfusion

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Introduction Dynamic contrast-enhanced MRI (DCE-MRI) acquired during first-pass of intravenously administered contrast agent can provide a measure of myocardial blood flow (MBF). For quantitative estimates of MBF, adequate representation of DCE-MRI signal changes in the blood pool is required. The arterial input function (AIF) for quantitative assessment of MBF in the left ventricular (LV) myocardium is derived from a region of interest placed within the LV cavity. Significant differences in temporal characteristics of AIFs sampled in systolic and diastolic part of the cardiac cycle have been reported [1]. In this work we examined the impact of these AIF differences on the estimates of MBF.

Methods Seventeen healthy volunteers (eight women, nine men; mean age, 34 years; age range, 24–48 years) were included in the study. The study protocol was approved by the local ethics committee, and written informed consent was obtained from all volunteers. DCE-MRI acquisition was performed using a dual phase sequence, with one systolic and one diastolic short axis frame acquired in each heartbeat during the first pass of Gd-DTPA at rest and during adenosine induced stress. The details of the acquisition protocol and adenosine infusion were described earlier [1]. Briefly, DCE-MRI data were collected using a saturation recovery prepared single-shot gradient echo sequence with 2-fold SENSE, TR/TE/a 2.7/1.0/15°, image matrix 160 × 160, preparation delay TP = 150 msec, and acquisition duration 135 msec. The timing of the DCE-MRI readout was selected so that one slice was placed in end-systole, followed by the second slice, acquired mid-diastole. MBF was estimated with a Fermi-constrained deconvolution method [2] using an AIF derived from the diastolic slice, and compared to the values obtained using systolic AIF [1]. The detection of the onset of enhancement in AIF and myocardium was performed using identical automated computer algorithms with no user input, but the search for the optimal offset delays was constrained over a different time interval depending on the choice of AIF.

Results Analysis of AIF curves (time to peak (TTP), and amplitude (AIFmax)) was carried out by performing a paired-samples t-test between the measurements obtained at systole and diastole. MBF estimates obtained using systolic AIF [1], were compared to the estimates acquired using diastolic AIF using a paired-samples t-test (Table 1). All tests were performed at α= 0.05 significance level.

![Figure 1](image1.png)

**Figure 1.** An example of DCE-MRI curves and differences between systolic and diastolic AIF at stress (left) and rest (right). In this healthy volunteer, resting MBF (in ml/g/min) of 1.59 (systole) and 1.57 (diastole) was estimated using systolic AIF. With diastolic AIF, resting MBF estimates were 1.42 (systole) and 1.41 (diastole). At stress, systolic AIF yielded MBF of 5.62 (systole) and 7.23 (diastole). These estimates were reduced to 3.02 (systole) and 3.35 (diastole), when diastolic AIF was used. Dashed lines labelled “myo” represent transmural myocardial DCE-MRI curves sampled in systole and diastole.

<table>
<thead>
<tr>
<th>AIF</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>rest MBF systole</td>
<td>1.6 ± 0.4</td>
<td>1.4 ± 0.4</td>
</tr>
<tr>
<td>MBF diastole</td>
<td>1.7 ± 0.5</td>
<td>1.4 ± 0.4</td>
</tr>
<tr>
<td>stress MBF systole</td>
<td>4.3 ± 0.9</td>
<td>3.2 ± 0.7</td>
</tr>
<tr>
<td>MBF diastole</td>
<td>5.7 ± 1.7</td>
<td>3.5 ± 0.7</td>
</tr>
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**Table 1.** MBF estimated using systolic and diastolic AIF (in ml/g/min). All pairwise differences were statistically significant (n = 17). *MBF estimates obtained using systolic AIF, as reported in [1].

The trends illustrated in Figure 1 were consistently replicated within our study population. At stress, diastolic AIF preceded systolic AIF by 0.97 ± 0.37 seconds (mean ± SD) with 95%CI (0.78, 1.1). At rest, the interval between diastolic and systolic AIF increased to 1.2 ± 0.40 seconds, with 95%CI (0.97, 1.4). Diastolic AIF tended to be more compact (shorter TTP at rest as well as stress, p<0.05, Figure 2), with higher amplitudes (higher AIFmax at stress and rest, p<0.05).

![Figure 2](image2.png)

**Figure 2.** Diastolic TTP was reduced at stress and rest (means ± SD)

The impact of these systematic differences in AIF on MBF estimates was assessed by comparing the results obtained using systolic and diastolic AIF as a representation of epicardial blood supply to the myocardium (Table 1).

Discussion The left ventricular cavity provides an easily accessible site for positioning ROIs for the measurement of AIF in first-pass DCE-MRI studies of myocardial perfusion. This surrogate measure of epicardial arterial input, however, is not cardiac phase independent [1]. In this study, we found that it is not only the shape of AIF that varies systematically between the cardiac phases: we found that the diastolic AIF consistently precedes the systolic one. Our findings contradict a commonly held assumption that the systolic AIF is more compact than the diastolic one (Figure 2).

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