Universiteit Leiden
The Netherlands

Cardiovascular magnetic resonance of myocardial viability

Kaandorp, T.A.M.

Citation
Kaandorp, T. A. M. (2007, March 14). *Cardiovascular magnetic resonance of myocardial viability*. Department Radiology, Faculty of Medicine / Leiden University Medical Center (LUMC), Leiden University. Retrieved from https://hdl.handle.net/1887/11409

Version:	Corrected Publisher's Version
License:	Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden
Downloaded from:	https://hdl.handle.net/1887/11409

Note: To cite this publication please use the final published version (if applicable).

Chapter 4

Head-to-head comparison between delayed contrast-enhanced magnetic resonance imaging and dobutamine magnetic resonance imaging in male patients with ischemic cardiomyopathy

4 Head-to-head comparison between delayed contrast-enhanced magnetic resonance imaging and dobutamine magnetic resonance imaging in male patients with ischemic cardiomyopathy

TA Kaandorp, JJ Bax, JD Schuijf, EP Viergever, EE van der Wall, A de Roos, HJ Lamb

The American Journal of Cardiology 2004;93:1461-4

Abstract

Delayed contrast-enhanced magnetic resonance imaging (MRI) can predict functional recovery post-revascularization. Segments with small, subendocardial scars have a high likelihood of recovery, and segments with transmural infarction have a low likelihood of recovery. Segments with an intermediate extent of infarction have an intermediate likelihood of recovery, and therefore additional information is needed. Accordingly, the transmurality of infarction on delayed contrast-enhanced MRI was compared with low-dose dobutamine MRI to further define viability in 48 patients. Regional contractile dysfunction was determined by cine MRI at rest (17-segment model), and contractile reserve was determined using low-dose dobutamine infusion. Delayed contrast-enhanced MRI was performed to assess the extent of scar tissue. A total of 338 (41%) segments were dysfunctional with 61% having contractile reserve. Most (approximately 75%) segments with small, subendocardial scars (hyperenhancement scores 1 or 2) had contractile reserve, whereas contractile reserve was not frequently (17%) observed in segments with transmural infarction (hyperenhancement score 4) ($p<0.05$). Of segments with an intermediate infarct transmurality (hyperenhancement score 3), contractile reserve was observed in 42%, whereas 58% did not have contractile reserve. In conclusion, the agreement between delayed contrast-enhanced MRI and low-dose dobutamine MRI is high in the extremes (subendocardial scar and transmural scar), and delayed contrast-enhanced MRI may be sufficient to assess the

likelihood of recovery of function post-revascularization. However, segments with an intermediate extent of scar tissue on MRI have contractile reserve in 42%. In these segments, low-dose dobutamine MRI may be needed to optimally differentiate myocardium with high and low likelihood of functional recovery after revascularization.

Introduction

There are currently two issues that are not defined adequately regarding assessment of myocardial viability using magnetic resonance imaging (MRI). First, from a pathophysiological point-of-view, contractile reserve and delayed contrast-enhancement do not reflect the same entity. While low-dose dobutamine is used to demonstrate the presence of contractile reserve in dysfunctional myocardium and thus identifies viable myocardium, delayed contrast-enhanced imaging identifies scar tissue. The precise relation between these two techniques is not known, as is the exact clinical definition of 'viable' and 'non-viable', based on delayed contrast-enhanced MRI. Second, from a practical point-of-view, it is preferable to perform delayed contrast-enhanced MRI only. It is unknown whether or not contractile reserve and delayed contrast-enhancement are both needed for the clinical decision to perform revascularization. Accordingly, a head-to-head comparison between delayed contrast-enhanced MRI and low-dose dobutamine MRI was performed in consecutive patients with ischemic left ventricular (LV) dysfunction.

Materials and methods

Patient population, study protocol

Consecutive male patients with chronic coronary artery disease (CAD) were included. The inclusion criteria were: 1. Chronic CAD (angiographically documented); 2. Depressed LV function (LV ejection fraction <40%); 3. Sinus rhythm. Patients with severe valvular disease, unstable CAD, pacemakers and intracranial clips were excluded.

The study protocol consisted of a cine MRI at rest to evaluate regional and global LV function (and LV volumes), followed by delayed contrast-enhanced MRI to determine the extent and transmurality of infarcted tissue, and finally a cine MRI was

acquired during infusion of low-dose dobutamine. Each patient gave informed consent to the study protocol that was approved by the local ethics committee.

Data acquisition

A clinical 1.5-Tesla Gyroscan ACS-NT MRI scanner (Philips Medical Systems, The Netherlands) equipped with powertrack 6000 gradients, release 9.1 scanner software and 5-element cardiac synergy coil was used. Patients were positioned in the supine position. Images were acquired during breath-holds of approximately 15 seconds using vector electrocardiographic gating; blood pressure was monitored continuously. The heart was imaged from apex to base [1] with 10 to 12 imaging levels (dependent on the heart size) in short-axis view using a sensitivity encoding balanced fast field echo sequence. Typical parameters were field of view 400 x 400 mm, matrix size 256 x 256, slice thickness 10.00 mm, slice gap 0.00 mm, flip angle 50°, time to echo 1.82 ms and time to repeat 3.65 ms. Temporal resolution was 25 to 39 ms. Geometry settings of the baseline scans were stored and repeated for low-dose dobutamine stress and delayed contrast-enhanced images, to ensure matching of the same slices (and therefore myocardial segments). Delayed contrast-enhanced images were acquired approximately 15 minutes after bolus injection of Gadolinium-DTPA (Magnevist, Schering/Berlin, Germany, 0.15 mmol/kg) with an inversion-recovery gradient echo sequence; inversion time was determined using real time planscan. Typical parameters were the following: field of view 400 x 400 mm, matrix size 256 x 256, slice thickness 5.00 mm, flip angle 15°, time to echo 1.36 ms and time to repeat 4.53 ms.

Intravenous dobutamine infusion was started at a rate of 5 μg/kg/min and increased after 5 minutes to 10 μg/kg/min. Then, after 5 minutes, low-dose dobutamine magnetic resonance images were acquired in 2- and 4-chamber and short-axis view. The same parameters were applied as described for imaging at rest.

Data analysis

To determine regional wall motion at rest, cine MRI images were visually interpreted by two experienced observers (blinded to other MRI and clinical data) using a 17-segment model. Each segment was assigned a wall motion score using a 5-point scale with 0: normal wall motion, 1: mild hypokinesia, 2: severe hypokinesia, 3: akinesia, and 4: dyskinesia [2]. Summation of the individual segmental scores yielded the summed wall motion score (reflecting systolic (dys-) function per patient). In the dysfunctional segments at rest (score 1-4), the presence or absence of contractile reserve was based

on visual analysis of the difference in myocardial wall motion between MRI acquisitions at rest and during infusion of low-dose dobutamine. An improvement in segmental wall motion score by one grade or more was considered indicative of contractile reserve. Of note, dyskinetic segments becoming akinetic were not considered to exhibit contractile reserve [3]. Delayed contrast-enhanced images were scored visually by two experienced observers (blinded to other magnetic resonance and clinical data) using the same 17-segment model as used for functional analysis. Each segment was graded on a 5-point scale (segmental scar score) with 0: absence of hyperenhancement, 1: hyperenhancement of 1% to 25% of LV wall thickness, 2: hyperenhancement extending from 26% to 50%, 3: hyperenhancement extending from 51% to 75%, and 4: hyperenhancement extending from 76% to 100% of the LV wall thickness [4]. Summation of the individual segmental scores yielded the summed scar score (reflecting the damage per patient).

Statistical analysis

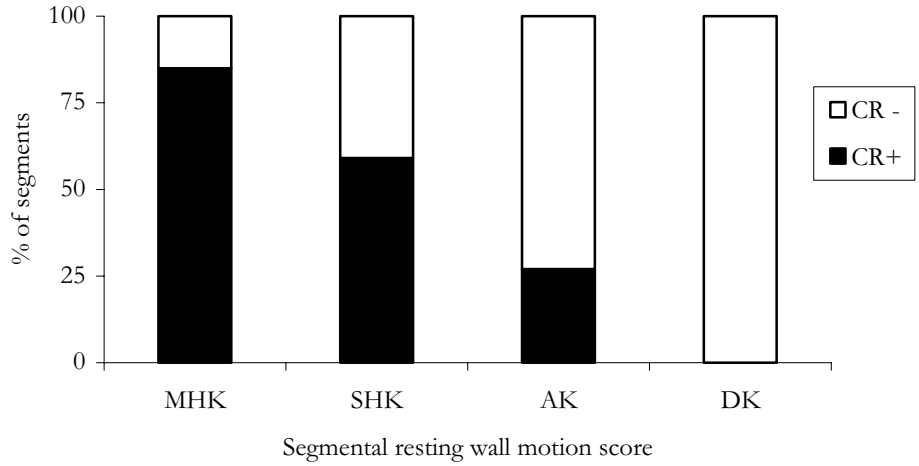
Continuous data were expressed as mean ± standard deviation and compared using the two-tailed Student's *t* test for paired and unpaired data when appropriate. Comparison of proportions was performed using chi-square analysis. Simultaneous comparison of >2 mean values was performed using one-way analysis of variance (ANOVA). Relations were determined by linear regression analysis. A p-value <0.05 was considered statistically significant.

Table 1. Clinical characteristics of the study population.

Age (years)	63 (36-84)
Previous myocardial infarction	34 (71%)
Q-wave on electrocardiogram	45 (94%)
Angina pectoris class	2.4 ± 0.8
Heart failure (NYHA class)	1.8 ± 0.1
Left ventricular end-diastolic volume (ml)	239 ± 65
Left ventricular end-systolic volume (ml)	149 ± 66
Left ventricular ejection fraction (%)	37 ± 10

NYHA: New York Heart Association.

Figure 1. Relation between segmental wall motion score at rest and the absence or presence of contractile reserve (CR) ($p<0.05$). An inverse relation can be appreciated between wall motion abnormalities and CR. AK: akinesia; DK: dyskinesia; MHK: mild hypokinesia; SHK: severe hypokinesia.



Results

The study population consisted of 48 male patients with chronic CAD and ischemic cardiomyopathy; 34 (71%) patients had a previous infarction (>3 months before the study), and 45 exhibited Q waves on the electrocardiogram. Baseline characteristics of the study population are summarized in Table 1. All patients had significant CAD on angiography (>70% reduction in luminal diameter of at least one major coronary artery). They had an average of 2.4 ± 0.8 stenosed vessels.

Regional wall motion and contractile reserve

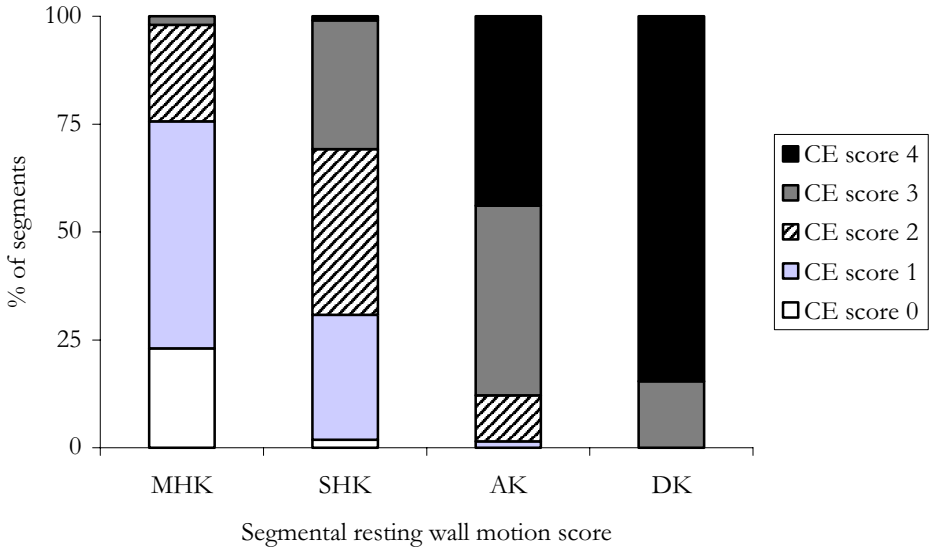
A total of 816 segments were evaluated, with normal wall motion in 59% of segments. Of 338 dysfunctional segments, 152 (45%) had mild hypokinesia, 107 (32%) were severely hypokinetic, 66 (19%) akinetic and 13 (4%) dyskinetic. Since low-dose dobutamine MRI was performed in 46 patients (not available in 2 patients for logistical reasons), the number of dysfunctional segments that were evaluated for

contractile reserve was limited to 323. Contractile reserve was present in 198 (61%) dysfunctional segments. The precise relation between segmental wall motion score at rest and the presence of contractile reserve is shown in Figure 1. The presence of contractile reserve decreased gradually when the severity of wall motion abnormalities at rest increased. In particular, 85% of the mildly hypokinetic segments demonstrated contractile reserve as compared to only 27% in akinetic segments, whereas none of the dyskinetic segments showed contractile reserve ($p<0.05$).

Assessment of scar tissue

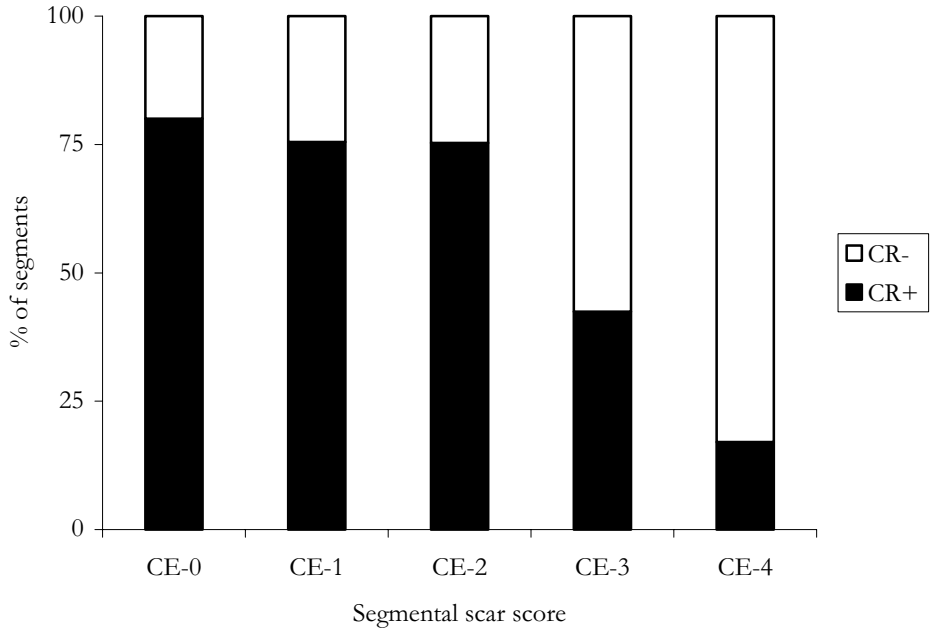
Of the 816 segments, 351 (43%) segments revealed hyperenhancement. In particular, 156 (44%) showed minor hyperenhancement (score 1, transmurality 1% to 25%), 88 (25%) had hyperenhancement score 2, 66 (19%) hyperenhancement score 3, and 41 (12%) segments score 4. The relation between segmental transmurality of infarction and segmental wall motion score at rest is displayed in Figure 2. The severity of segmental wall motion abnormality (reduction in systolic function) paralleled the

Figure 2. Segmental scar tissue score in relation to the segmental wall motion score at rest. AK: akinesia; CE: delayed contrast-enhancement; DK: dyskinesia; MHK: mild hypokinesia; SHK: severe hypokinesia.



extent of transmurality. The majority of segments with mild hypokinesia had minimal scar tissue, whereas segments with a- or dyskinesia had extensive, transmural scar tissue. Of interest, in segments with severe hypokinesia (one third of all dysfunctional segments), the transmurality of infarction varied substantially. The summed wall motion score was linearly related to the summed scar score (y=0.84x + 3.7, r=0.83, p<0.01).

Figure 3. Relation between delayed contrast-enhancement (CE) and contractile reserve in dysfunctional segments. An inverse relation can be seen between segmental scar score and contractile reserve (CR) (p< 0.05). 0: absence of hyperenhancement, 1: hyperenhancement of 1% to 25% of LV wall thickness, 2: hyperenhancement extending to 26% to 50%, 3: hyperenhancement extending to 51% to 75%, and 4: hyperenhancement extending to 76% to 100% of the LV wall thickness.



Contractile reserve versus scar tissue

The segments with contractile reserve had a significantly lesser extent of hyperenhancement: the summed scar score was 3.28 ± 2.27 in the segments with contractile reserve versus 8.0 ± 4.46 in the segments without contractile reserve ($p<0.001$). The relation between contractile reserve and scar tissue is shown in Figure 3. The percentage of segments with contractile reserve gradually decreased when the scar score increased. The majority (75%) of the segments with a minimal extent of scar tissue (scar score 1 and 2, hyperenhancement ≤50% of the LV wall) had contractile reserve, whereas only 17% of the segments with extensive, transmural scar tissue (scar score 4, 76% to 100% hyperenhancement) ($p<0.05$) had contractile reserve. Thus, agreement between the two MRI techniques was high in the extremes. Of interest, the segments with an intermediate extent of scar tissue (score 3) had contractile reserve in 42%, whereas 58% did not have contractile reserve.

Discussion

In the current study, two techniques were evaluated in patients with chronic ischemic LV dysfunction. The extent of scar tissue was related to the segmental wall motion at rest (Figure 2). The infarct transmurality was minimal in segments with mild hypokinesia, whereas segments with a- or dyskinesia had (near-) transmural infarct tissue. Similarly, the presence of contractile reserve was related to the severity of segmental wall motion abnormalities at rest. Segments with mild hypokinesia had a high likelihood of having contractile reserve, whereas segments with a- or dyskinesia had a low likelihood of contractile reserve (Figure 1). The agreement between the two techniques was good in segments with a minimal extent of scar tissue (≤50% of the LV wall): 77% of these segments exhibited contractile reserve. The agreement was also good in segments with extensive, transmural scar tissue (76% to 100% of the LV wall): 83% of these segments did not show contractile reserve. Of particular interest, the agreement was not good in the segments with an intermediate extent of scar tissue (50% to 75%), 42% had contractile reserve and 58% did not. These segments (the segments with an intermediate extent of scar tissue) were the segments that had an intermediate likelihood of recovery (42%) in the study by Kim et al [5]. The percentage of contractile reserve (42%) in the segments with an intermediate extent of scar tissue, may well explain why some segments with an intermediate extent of infarcted myocardium do recover in function after revascularization, whereas other segments

(without contractile reserve) will not improve in function. Therefore, in this 'intermediate viability' group, integration of assessment of extent and transmurality of scar tissue and assessment of contractile reserve, may allow optimal identification of segments with a high likelihood of recovery after revascularization. This hypothesis needs further study in patients undergoing revascularization.

Acknowledgements

This work was supported by The Netherlands Organization for Scientific Research (NWO), grant number 902-37-124 (H. J. Lamb, Leiden, The Netherlands), the Schering visiting research fellowship grant funded by Schering AG, as part of the ECR Research and Education Grant 2002 (H. J. Lamb, Leiden, The Netherlands). J. D. Schuijf is supported by The Netherlands Heart Foundation, grant number 2002B105 and ICIN, The Netherlands.

References

1. Lamb HJ, Doornbos J, van der Velde EA, Kruit MC, Reiber JH, de Roos A. Echo planar MRI of the heart on a standard system: validation of measurements of left ventricular function and mass. J.Comput.Assist.Tomogr. 1996;20:942-49.
2. Cerqueira MD, Weissman NJ, Dilsizian V, Jacobs AK, Kaul S, Laskey WK *et al.* Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart: a statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. Circulation 2002;105:539-42.
3. Arnese M, Fioretti PM, Cornel JH, Postma-Tjoa J, Reijs AE, Roelandt JR. Akinesis becoming dyskinesis during high-dose dobutamine stress echocardiography: a marker of myocardial ischemia or a mechanical phenomenon? Am.J.Cardiol. 1994;73:896-99.
4. Wu E, Judd RM, Vargas JD, Klocke FJ, Bonow RO, Kim RJ. Visualisation of presence, location, and transmural extent of healed Q-wave and non-Q-wave myocardial infarction. Lancet 2001;357:21-28.
5. Kim RJ, Wu E, Rafael A, Chen EL, Parker MA, Simonetti O *et al.* The use of contrast-enhanced magnetic resonance imaging to identify reversible myocardial dysfunction. N.Engl.J.Med. 2000;343:1445-53.