Quantitative evaluation of trabeculated mass in diagnosis of left ventricular non-compaction cardiomyopathy using cardiac magnetic resonance imaging.

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Aims and objectives

Left ventricular (LV) non-compaction (LVNC) is recognized as a primary, genetic cardiomyopathy by the American Heart Association. It is a cardiomyopathy characterized by a thin, compacted epicardial layer and an extremely thick endocardial layer with prominent trabeculation and deep recesses that communicate with the LV cavity but not with the coronary circulation (Fig.1), which can lead to heart failure, thrombo-embolism, malignant arrhythmia, and can occur as an isolated anomaly or associated with other congenital heart diseases.

Despite several efforts using echocardiography and cardiac magnetic resonance in the diagnosis of left ventricular non-compaction (LVNC), there are no universally accepted gold standard diagnostic criteria. All of these criteria have been developed on the basis of relatively small numbers of patients with limited subsequent validation studies and no independent means of verification.

Echocardiography is currently the most commonly used imaging tool for the diagnosis of LVNC, applying the criteria established by Jenni et al. This approach is highly investigator-dependent, diagnosis is based on two dimensional planes using semi-quantitative or qualitative criteria and specificity is low because of highly variable LV trabeculation. Therefore, absolute quantification of non compacted mass should be performed. Cardiovascular magnetic resonance (CMR) has been reported as a promising imaging modality to characterize patients with LVNC as it provides both a high spatial resolution and a good contrast between trabeculation and blood pool.

Petersen et al established a two-dimensional CMR diagnosis criteria for LVNC which is based on a ratio of the thickness of non-compacted to compacted myocardial layers of 2.3, measured in the diastolic phase and on an adapted version of the existing echocardiographic criteria; therefore have the same limitations. A three dimensional CMR approach allows for imaging of the entire volume of the heart and therefore absolute quantification of non compacted mass, with lower investigator dependency and without limitations caused by the patient’s constitution.

In 2010, Jacquier et al. based on a case-control study with 16 patients, reported that a value of non-compacted LV myocardial mass above 20 % of the global mass of the LV is highly sensitive and specific for LVNC.

Recently, Grothoff et al. based on a case-control study with 12 patients, suggested a cut off value of 25% for percentage of LV non-compacted mass/total LV mass and 15g/m2 for total LV non-compacted mass

The aim of this retrospective study was to determine the capacity of cardiac magnetic resonance (CMR) derived myocardial parameters, calculating LV non-compacted and total mass, to discriminate patients with left ventricular non-compaction cardiomyopathy.
For this purpose LV non-compacted mass and percentage of LV non compacted/total mass were studied in two different populations: patients for whom a diagnosis of LVNC was established on echocardiographic criteria of Jenni and/or Petersen CMR criteria (n=25), and control subjects (n=26).

Images for this section:

**Fig. 1:** short-axis end-diastolic cine image, in a patient with LVNC. Note two myocardial layers: thin, compacted epicardial layer and an extremely thick endocardial layer with prominent trabeculation and deep recesses.
Methods and materials

Patient population, control group and study design:

We retrospectively analyzed CMR of 25 patients (15 Males, 10 Females) with a mean age of 39.4 yo (range 17-80) for whom a diagnosis of left ventricular non-compaction cardiomyopathy (LVNC) was established on echocardiographic criteria of Jenni and/or CMR criteria of Petersen. We included retrospectively 26 control subjects (16 Males, 10 Females), mean age of 41.5yo (range17-79) with CMR without significant findings and similar demographic characteristics to the patients group. Patient and control group characteristics are presented in table 1.

Cardiac magnetic resonance imaging:

All patients and controls were examined at a 1.5T scanner, with a 6-element phased-array cardiac coil. A standard protocol was performed to assess LV structure and function, including cine steady-state free precession sequences and late gadolinium enhancement (LGE) imaging. Cine sequences were acquired on long-axis 2-chamber, 3-chamber, 4-chamber, and short-axis views to cover the whole LV (Fig 3, 4, 5, 6). We used cine sequences with retrospective cardiac gating adjusted as follows: TR/TE= 3.4/1.7 ms, slice thickness= 7 mm, 10% gap between slice, flip angle = 60, matrix = 192 × 256, field of view= 300 mm, and temporal resolution = 35 ms. LGE images in short-axis orientation were acquired for quantification of fibrosis 10-15 min after application of 0.1 mmol/kg/body weight gadobutrol(Gadovist) using a three-dimensional T1-weighted inversion recovery turbo gradient echo sequence.

Imaging analysis:

All examinations were transferred to a dedicated workstation and the total LV myocardial mass, LV myocardial compacted mass, ventricular volume and systolic function were measured in end-diastole in a complete stack of short axis view, based on Simpson´s rule, applying the MR cardiac analysis, post-processing software. Epicardial, endocardial and papillary muscle contours were outlined in a manually fashion. Papillary muscles were included in the myocardial mass. Compacted and total LV mass were measured only at the end-diastolic phase. To assess total LV mass, the endocardial border and papillary muscle contour were drawn to include compacted layer, on compacted layer and LV papillary muscles. (Fig9,11)

To evaluate compacted LV mass, the endocardial border and papillary muscle contour were drawn to include papillary muscle and compacted layer, and exclude LV non
compacted layer (Fig7,8,10,12). For calculation of the myocardial mass the specific density of 1.05 g/ml was used.

Non-compacted LV mass (trabeculated mass) was calculated as follows:

None compacted LV mass = Total LV mass - compacted LV mass.

Percentage of non-compacted = Non compacted mass/total mass x 100

Additionally, LV end-diastolic volumes, end-systolic volumes and ejection fractions were calculated.

The distribution of myocardial trabeculation was assessed by qualitative analysis of the segments for the presence or absence of any degree of trabeculation. A segment was considered as trabeculated if the visual appearance suggested the presence of two myocardial layers with different degrees of tissue compaction.

Statistics:

The statistical analysis was performed using SPSS for Windows 16.0. Categorical variables are expressed as number. Continuous variables are given as mean ± standard deviation.

Student t test was used for comparison of means between the LVNC group and control group.

The categorical data of the segmental analysis were analyzed using the chi-square test.

Images for this section:
<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Age</th>
<th>Sex(M/F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case(LVNC)</td>
<td>25</td>
<td>39.4 (17-80)</td>
<td>10/15</td>
</tr>
<tr>
<td>control</td>
<td>26</td>
<td>41.5 (17-80)</td>
<td>10/16</td>
</tr>
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</table>

**Fig. 2:** Table 1. Demographic data
Fig. 3: short-axis end-diastolic cine image in a patient with LVNC.
Fig. 4: 2-chamber view, end-diastolic cine image in a patient with LVNC.
Fig. 5: 3-chamber view, end-diastolic cine image in a patient with LVNC.
Fig. 6: 4-chamber view, end-diastolic cine images in a patient with LVNC.
Fig. 7: Basal short-axis end-diastolic cine image. Illustration of the described method for measuring the compacted LV mass in a patient with LVNC. (Yellow contour for epicardial border, green contour for endocardial border, blue contour for papillary muscles)
Fig. 8: Midventricular short-axis end-diastolic cine image. Illustration of the described method for measuring the compacted LV mass in a patient with LVNC. Shows the inclusion of papillary muscles and the exclusion of LV trabeculation for the measurements of the compacted LV mass.
**Fig. 9:** Apical short-axis end-diastolic cine image, measuring the global LV mass in a patient with LVNC.
Fig. 10: Basal short-axis end-diastolic cine image, measuring the compacted left ventricular mass in a control subject.
Fig. 11: Midventricular short-axis end-diastolic cine image, measuring the total LV in a control subject.
Fig. 12: Apical short-axis end-diastolic cine image, measuring the compacted LV mass in a control subject.
Results

The mean myocardial non-compacted mass in patients (72.12±25.48g) was significantly higher than those of control subjects (16.12±5.87g), (p<0.001). Differences of non-compacted myocardial percentage between patients (35.21±9.44%) and controls (10.89±3.57%) were also statistically significant (p<0.001).

The mean LV compacted mass was the same in LVNC group (129.56±43.4, p=NS) and controls (133.98±34.68, p=NS). (Table2)

All LVNC patients had an LV non-compacted myocardial mass percentage above 21% (Fig 15) No subjects included in the study showed LGE. Trabeculation was more common on the midventricular and apical segments. (Fig 16)

Images for this section:

<table>
<thead>
<tr>
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<th>Controls n=26</th>
<th>LVNC n=25</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mass(gr)</td>
<td>150.1±36.92</td>
<td>205.75±51.02</td>
<td>P=NS</td>
</tr>
<tr>
<td>Compacted mass(gr)</td>
<td>133.98±34.68</td>
<td>129.56±43.4</td>
<td>P=NS</td>
</tr>
<tr>
<td>Non-comp mass(gr)</td>
<td>16.12±5.87</td>
<td>72.12±25.48</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Non-comp/total mass(%)</td>
<td>10.89±3.57</td>
<td>35.21±9.44</td>
<td>P&lt;0.001</td>
</tr>
</tbody>
</table>

Fig. 13: Distribución of patients and control group, LV myocardial parameters
**Fig. 14:** Box plot diagram demonstrating the highly significant differences of percentage of LV non-compacted myocardial mass/total mass between patients with LVNC and controls. All LVNC patients had an LV non-compacted myocardial mass percentage above 21%.
Fig. 15: Midventricular and apical short-axis end-diastolic cine views, in a patient with LVNC
Conclusion

CMR is a robust imaging tool that enables to distinguish LVNC, as it provides high spatial resolution and a good contrast between trabeculation and blood pool, and because of its three-dimensional approach, which allows for imaging of the entire volume of the heart with lower investigator dependency and without limitations caused by the patient’s constitution.

This study showed that total LV-non-compacted mass and percentage of LV non-compacted were significantly increased in LVNC and could be good discriminators between patients with LVNC and healthy controls (P<0.001). All the patients had a non-compacted percentage above 21%, which is similar to the cut-off value recently published by Jacquier et al.

Further studies with larger patient population should be done to establish the diagnostic accuracy of these parameters.

Personal information

References


3. Jenni R, Oechslin E, Schneider J, Attenhofer Jost CH, Kaufmann PA

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