CASE REPORT

Contrast-Enhanced Cardiac Magnetic Resonance in a Patient with Familial Isolated Ventricular Non-compaction

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ABSTRACT

Isolated ventricular non-compaction (IVNC) is an idiopathic form of cardiomyopathy. Recent clinical reports have suggested that this form of cardiomyopathy is more frequently associated with complications of congestive heart failure, thromboembolism and malignant ventricular arrhythmias. Contrast enhanced cardiac magnetic resonance imaging with its excellent spatial resolution, its large field of view and its ability to demonstrate thrombus and myocardial scar is an excellent modality to non-invasively assess patients with this form of cardiomyopathy. This paper presents a case of familial isolated ventricular non-compaction. We describe the echocardiographic, X-ray angiographic and cardiac MRI findings. Cine imaging using a steady-state free precession sequence (BFFE) was performed in axial and short axis planes. Left ventricular (LV) mass was estimated both with and without the incorporation of trabeculations from a contiguous stack of short axis images. Trabecular mass was expressed as a percentage of total left ventricular mass. We compared trabecular mass: total LV mass in 10 patients with dilated cardiomyopathy. The mean percentage trabecular mass: LV mass in dilated cardiomyopathy was 11.3% (range 1.5%–19%), and this differed significantly from the trabecular mass of the noncompaction patient (two-tailed Mann–Whitney test, p=0.028). Trabecular mass of greater than 20% of total myocardial mass may be a useful index to suggest the diagnosis of IVNC. Gadolinium was administered (0.1 mmol/kg). Qualitative analysis of first pass perfusion suggested reduced trabecular perfusion. Early imaging with an inversion

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recovery sequence and a fixed long inversion time did not demonstrate LV thrombus. Late imaging with the same sequence (TI=280-300 msec) did not demonstrate myocardial fibrosis.

Key Words: Contrast enhanced cardiac MRI; Familial isolated ventricular non-compaction.

INTRODUCTION

Isolated noncompaction of the myocardium is an idiopathic form of cardiomyopathy due to intrauterine arrest of myocardial compaction. It was originally described in infants but more recently in adult patients (Agmon et al., 1999; Maltagliati and Pepi, 2000; Oechslin et al., 2000). Both sporadic and familial forms are recognized. An X-linked familial form with six males affected in a single family has been described (Bleyl et al., 1997). It is characterized echocardiographically by extremely thickened hypo-kinetic segments consisting of a thin, compacted epicardial layer over which there is a much thicker trabeculated endocardial layer with deep intertrabecular recesses (Jenni et al., 2001; Oechslin et al., 2000). Patients initially have near normal ventricular function, however, in time there is a decline in left ventricle (LV) function and systolic heart failure may be the most common presentation in older patients.

Histologically, the large endocardial trabeculations are scarred, most likely due to inadequate blood supply (Oechslin et al., 2000).

There is a spectrum of clinical presentation, and recent clinical reports have suggested that isolated ventricular noncompaction (IVNC) is associated with the important complications of thromboembolism, congestive heart failure, and malignant ventricular arrhythmias (Agmon et al., 1999; Maltagliati and Pepi, 2000; Oechslin et al., 2000).

Cardiac magnetic resonance (CMR) is an ideal imaging modality for assessing patients with IVNC (McCrohon et al.). Its high spatial resolution enables visualization and quantification of the extent of ventricular trabeculations. Left ventricular size and function can be accurately and reproducibly measured (Grothues et al., 2002). Cardiac magnetic resonance is also able to assess potential complications in these patients. Furthermore, using contrast (gadolinium-DTPA) qualitative estimation of first-pass perfusion of the myocardium and trabeculations is possible (Schwitter et al., 2001). On later imaging, evidence of myocardial scarring and fibrosis could potentially be seen (Moon et al., 2003). Thromboembolic complications have also been reported in these patients. Presumably, thrombus forms in the deep crypts between the trabeculations. Immediate imaging after contrast injection with an inversion recovery sequence has been shown to be a very sensitive way of diagnosing ventricular thrombus by CMR (Barkhausen et al., 2002).

In this report we describe the clinical, electrocardiographic, histological, echocardiographic, angiographic, and CMR features of a patient with familial isolated ventricular noncompaction.

CASE REPORT

A 26-year-old man was hospitalized with new onset congestive heart failure. He gave a 2-week

Figure 1.   Echocardiography—Apical two chamber (left) and four chamber (right) echocardiographic images demonstrating extensive trabeculations of the mid and distal anterior, antero-lateral, inferior, and apical segments.
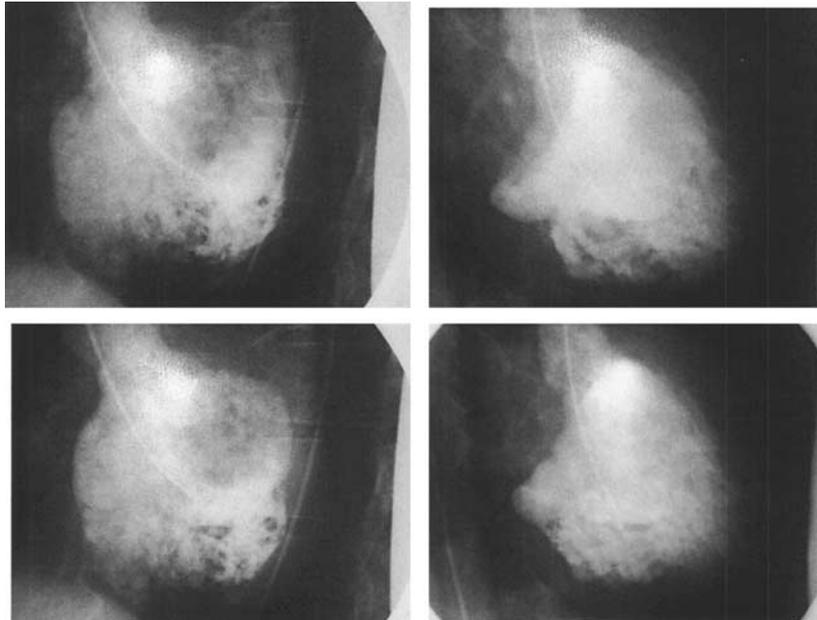
Figure 2. Left ventriculogram—Images on the left are right anterior oblique and those on the right are left anterior oblique with diastole at the top and systole at the bottom.

history of a flu-like illness with progressive breathlessness. He had no prior cardiac history and besides mild asthma had no other relevant medical or surgical conditions.

He took regular inhaled steroids for asthma and there was no history of excess alcohol consumption.

Of importance is that his father died of heart failure at age 50 years. An echocardiogram performed on his father just prior to his demise in the early 1990s commented on very striking left ventricular trabeculations.

On initial clinical examination the patient appeared anxious and tachypnoeic. His pulse rate was 135 beats per minute and his blood pressure was BP 130/100 millimeters of mercury. The jugulo-venous pulse was 10 centimeters elevated and the oxygen saturation was 95% on room air.
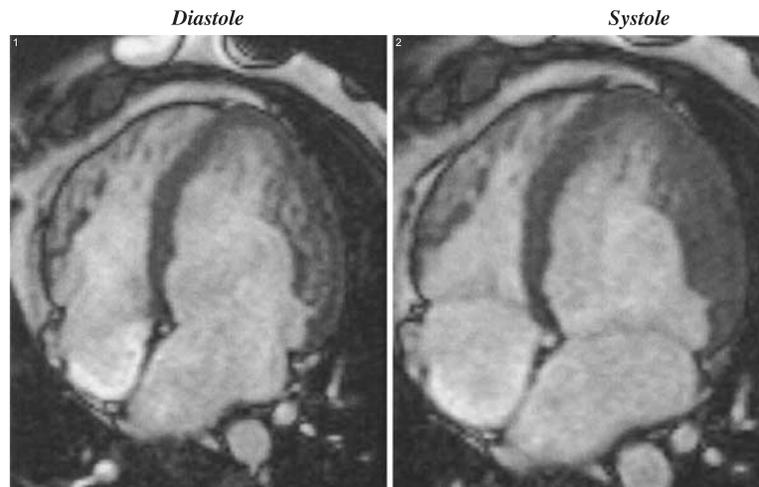

Figure 3. Extensive meshwork of ventricular trabeculations involving lateral and apical segments of the left and right ventricle. LV is significantly dilated.

Table 1. Left ventricular volumes and mass.

Left ventricular end diastolic volume (mls)	Left ventricular end systolic volume (mls)	Stroke volume (mls)	LV diastolic mass (g)	LV mass (excluding trabeculations) (g)	Trabecular mass (g)	Trabecular mass/total mass (%)	Ejection fraction
227	149	79	192	149	43	22	34

The *electrocardiogram* showed sinus tachycardia with deep anterior S waves and low anterior voltages. There was inferolateral T wave inversion.

The *chest x-ray* demonstrated an enlarged cardiothoracic ratio (15.5/29.5) with interstitial pulmonary edema, which subsequently cleared.

Transthoracic 2-D echocardiography (Fig. 1) demonstrated an enlarged left atrium (transverse diameter 5.5 cm) and severely dilated left ventricle (LV end-diastolic diameter 7.7 cm, LV end-systolic diameter 7.5 cm). Left ventricle systolic function was severely impaired. The right ventricle was mildly dilated and systolic function was severely impaired.

The left ventricle had prominent trabeculations of the inferior, lateral, and apical segments with deep intertrabecular clefts, which, on color doppler demonstrated flow. There was evidence of restrictive LV filling. All valves were normal and there was a mild degree of functional mitral and tricuspid regurgitation. Pulmonary pressure estimated using the tricuspid jet was moderately elevated at 50 millimeters of mercury.

Once euvolumic *cardiac catheterization* and myocardial biopsy were performed. The pulmonary capillary wedge pressure measured 16 mmHg, the mean pulmonary artery pressure was 26 mmHg, the transpulmonary gradient measured 10 mmHg, and the cardiac output by thermodilution measured 3.4 l/min. The pulmonary vascular resistance was 2.9 Wood units.

Coronary angiography was normal. Left ventriculography (Fig. 2) demonstrated severe left ventricular dilatation and systolic impairment of a very trabeculated left ventricle. Left ventricular pressures were 105/15 mmHg.

Myocardial Biopsy

Fragments of endomyocardial tissue showed no significant inflammation or any infiltrative process. There was little variability in myofiber size and no fibrosis. Special stains for amyloid, glycogen, and hemosiderin were negative.

Cardiac MRI

The patient was studied using a Philips Intera 1.5 Tesla machine. Studies were performed with prospective gating using a vectorcardiographic system. We used a four-element synergy body coil.
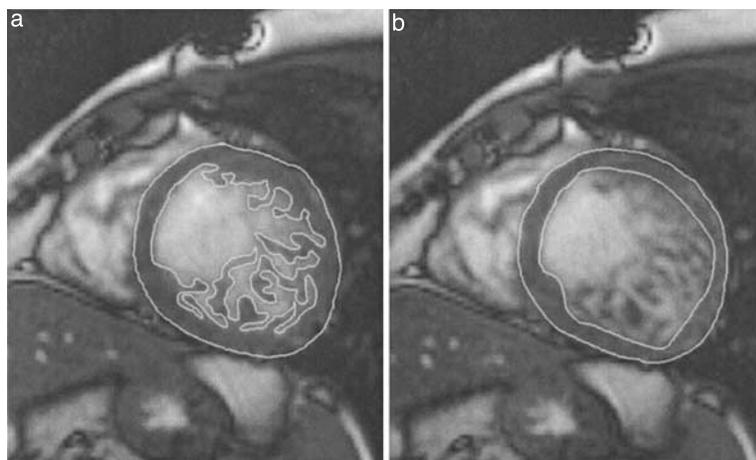

Figure 4. (a) Single-slice LV mass incorporating trabecular mass (Software; CMR tools, Imperial College, London, UK); (b) Single-slice LV mass excluding trabecular mass.

Figure 5. First-pass perfusion demonstrating relatively reduced uptake of gadolinium by a relatively larger trabeculation compared to neighboring myocardium.

Cine images were performed using a Balanced Fast Field sequence with an echo time (TE) of 1.5 ms and repetition time (TR) of 3 ms, allowing imaging in steady state. Cines were obtained in vertical long-axis, four-chamber, left ventricular outflow tract, and short-axis views.

Assessment of left ventricular mass and volumes was achieved using a stack of short-axis images 8 mm thick with an intersection gap of 2 mm.

Hereafter gadolinium was administered at a dose of 0.1 mmol/kg. First-pass perfusion was performed using turbo field echo with the following parameters: TE 0.93 ms, TR 2.8 ms, flip angle 20°, matrix 112×128, sense 2.

Early imaging was done with an inversion recovery sequence [TE 1.25 ms, TR 4.2 ms, flip 15°, inversion time (TI) 400 ms, matrix 256×256, sense factor 2] to detect ventricular and atrial thrombus.

Approximately 10 minutes after gadolinium administration, imaging with the same sequence was performed (TI 280–300 ms) to detect myocardial and trabecular fibrosis or scarring. Cardiac magnetic resonance imaging took approximately 45 minutes.

RESULTS

Ventricular Size and Function

There was significant left ventricular dilatation and systolic dysfunction (Fig. 3).

The ejection fraction was calculated as 34% by short-axis multislice cine acquisition (Simpson's rule) (Pennell, 2002).

Ventricular mass was estimated including the trabeculations and then repeated excluding the trabeculations (Fig. 4). The endocardial border on the latter measurements was traced over the compacted myocardial layer. Diastolic trabecular mass was calculated by

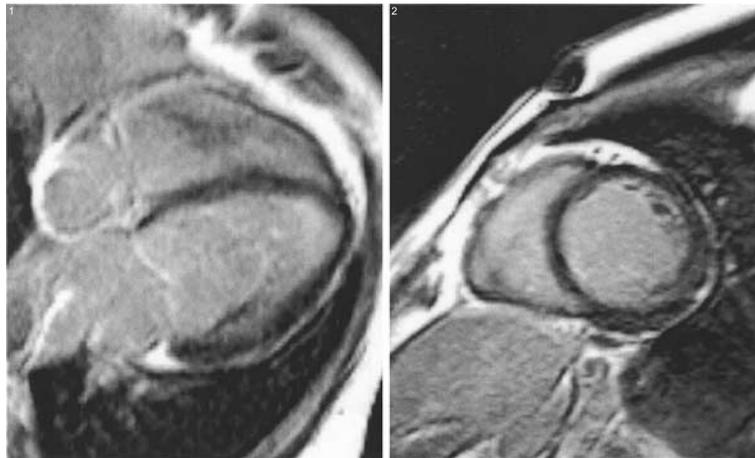**Figure 6.** No ventricular or atrial thrombus on immediate imaging after intravenous gadolinium.

Figure 7. No hyperenhancement of either myocardium or trabeculations using an inversion recovery sequence 10 minutes after intravenous gadolinium.

simple subtraction and comprised 22% of the total diastolic myocardial mass (Table 1).

Myocardial perfusion was assessed qualitatively from a midventricular slice. Perfusion of the trabeculations was reduced (Fig. 5).

This confirms former suspicions that there is poor perfusion of trabeculations in patients with IVNC (Borges et al., 2003; Oechslin et al., 2000).

Immediate imaging after gadolinium did not reveal evidence of either ventricular or atrial thrombus (Fig. 6).

To date this patient has not suffered a thromboembolic complication. Imaging 10 minutes after gadolinium with an inversion recovery sequence did not reveal evidence of hyperenhancement, suggesting the absence of significant myocardial fibrosis (Fig. 7).

DISCUSSION

A rare form of cardiomyopathy, isolated ventricular non-compaction (IVNC) is a rare form of cardiomyopathy and remains unclassified by the WHO classification system (WHO/ISFC, 1980). It has a relatively low prevalence and is thought to be a hereditary condition. In a recent series of 34 patients with IVNC there was a high incidence of ventricular arrhythmias and thromboembolic complications (Oechslin et al., 2000). It is therefore important that this diagnosis is not missed in newly diagnosed patients with heart failure.

Given the young age of the patient and the likely natural history of ventricular noncompaction, an early assessment for cardiac transplantation was considered appropriate. Coronary angiography, left ventriculography, and right heart catherization were performed. During this study a right ventricular biopsy was performed, as there was clinical suspicion of a superimposed acute viral myocarditis. However, myocardial biopsy carries significant risk in the nontransplanted patient, and contrast-enhanced CMR is a potentially useful noninvasive diagnostic tool in acute myocarditis (Friedrich et al., 1998). Earlier performance of contrast-enhanced CMR in our patient would have obviated the need for this procedure.

Harmonic echocardiography is able to make the diagnosis of IVNC in patients with adequate echo windows (Agmon et al., 1999; Maltagliati and Pepi, 2000). Cardiac magnetic resonance with contrast offers additional information in the management and risk
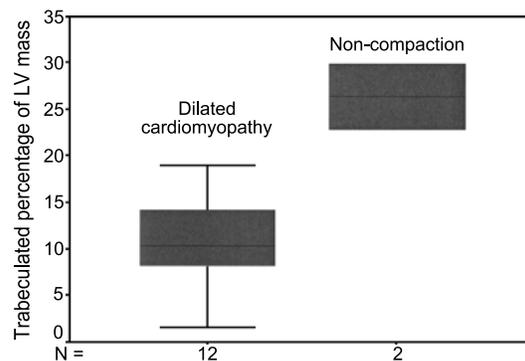

Figure 8. Proportion of LV mass that is trabeculated. Boxplots show median, quartile, and extreme values.

stratification of these patients. Serial measures of LV size and mass are highly reproducible, which is important in monitoring the effects of treatment and planning future therapies such as possible cardiac transplantation (Grothues et al., 2002). These patients seem more prone to thromboembolic complications than are those with other forms of cardiomyopathy (Oechslin et al., 2000). This is possibly due to blood stasis in the deep crypts between the noncompacted trabeculations. Some authors feel that all patients with IVNC should receive empiric anticoagulation (Oechslin et al., 2000). Cardiac magnetic resonance has been shown to be a sensitive investigation in diagnosing ventricular thrombus in certain clinical situations (Barkhausen et al., 2002). Whether the spatial resolution of CMR is good enough to demonstrate intertrabecular thrombus is uncertain. Our patient had no obvious LV thrombus.

Gadolinium-DTPA is an extracellular tracer. The concentration of gadolinium in the myocardium during the washout phase has been shown to increase in conditions of myocardial interstitial expansion (Moon et al., 2003). Previous histological studies of patients with IVNC have demonstrated necrosis and fibrosis (interstitial expansion) in patients with IVNC (Oechslin et al., 2000). These areas of fibrosis may potentially create a substrate for future lethal ventricular arrhythmias. Our patient did not have evidence of myocardial hyperenhancement and neither does he have clinical suspicion of ventricular arrhythmias.

Echocardiographic criteria have been established for the diagnosis of IVNC (Agmon et al., 1999; Maltagliati and Pepi, 2000). These could easily be adopted by CMR. However, IVNC often manifests predominantly at the apex, an area that can be difficult to visualize with echocardiography. Cardiac magnetic resonance images the apex with great clarity and in multiple planes.

We suggest that CMR could add an additional criterion for the diagnosis of IVNC viz. the ratio of LV trabecular mass:total LV mass. To date we have studied two patients with IVNC. The index patient had a diastolic trabecular mass that comprised 22% of the total diastolic myocardial mass. A second patient had a trabecular mass of 30% of total diastolic myocardial mass.

We compared diastolic trabecular mass in 10 patients with dilated cardiomyopathy (Fig. 8). The mean percentage trabecular mass to total myocardial mass was 11.3% (range 1.5%–19%), and this differed significantly from the trabecular mass of the noncompaction patients (two-tailed Mann–Whitney test, p=0.028). Trabecular mass of greater than 20% of total myocardial mass may be a useful index to suggest the diagnosis of IVNC. More patients need to be studied to validate our proposed index for the diagnosis of IVNC.

Limitations

The accuracy of exact trabecular mass estimation with CMR is limited due to problems of partial voluming (8 mm slice thickness with 2 mm gap) and spatial resolution. These limitations apply to both the IVNC and cardiomyopathy patients, thus still making the ratio of diastolic trabecular mass to total myocardial mass a potentially useful one.

CONCLUSION

We describe the utility of cardiac MR in the evaluation of a case of severely dilated cardiomyopathy due to isolated ventricular noncompaction. It is proposed that the ratio of diastolic trabecular mass to total myocardial mass may differentiate this condition from other causes of dilated cardiomyopathy.

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