Diagnosing Left Ventricular Noncompaction by Echocardiography and Cardiac Magnetic Resonance Imaging and Its Dependency on Neuromuscular Disorders

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ABSTRACT

Background: Left ventricular hypertrabeculation (LVHT), also termed noncompaction LVHT, is diagnosed by echocardiography or cardiac magnetic resonance imaging (CMRI), and associated with neuromuscular disorders (NMD). The aim of this study was to assess if LVHT can be diagnosed by CMRI applying echocardiographic definitions.

Methods and Results: The CMRI images of 19 echocardiographically diagnosed LVHT patients were re-evaluated (10 female, 14-67 y of age). Left ventricular hypertrabeculation was diagnosed by CMRI in 9 cases. Patients with CMRI-diagnosed LVHT were more often females (67% versus 40%), experienced heart failure more often (100% versus 50%), had an LV end diastolic diameter >57 mm (67% versus 40%), had an LV fractional shortening <25% (89% versus 40%), and had a larger extension of LVHT than patients without CMRI-diagnosed LVHT. The prevalence of NMD (87%) did not differ between both groups.

Conclusions: Echocardiographic definition for CMRI yielded the diagnosis of LVHT in only 47%. When looking for LVHT by CMRI, LV size, function, and extension of LVHT have to be considered.

Key words: cardiac magnetic resonance imaging, cardiomyopathy, echocardiography, neuromuscular disorders, noncompaction

Introduction

Left ventricular hypertrabeculation (LVHT), also termed noncompaction LVHT, is a rare cardiac abnormality characterized by prominent trabeculations and deep intertrabecular recesses of the left ventricle, and is associated with neuromuscular disorders (NMD) in up to 82% of cases.[1] Left ventricular hypertrabeculation is mainly diagnosed by echocardiography,[2] and different echocardiographic diagnostic criteria for LVHT are applied.[1,3] Left ventricular hypertrabeculation can also be visualized by cardiac magnetic resonance imaging (CMRI),[4] computed tomography,[5] or ventriculography.[6] For CMRI, no specific diagnostic criteria are available. It is generally assumed that echocardiographic criteria also applies to CMRI.[7–10] There are only small series comparing echocardiography and CMRI in the diagnosis of LVHT.[11,12] No systematic investigation on the applicability of echocardiographic criteria to CMRI has been carried out so far. Echocardiographically, only slight differences are found between LVHT patients with and without NMD.[13] It is unknown, however, if LVHT visualized by CMRI is different in patients with and without NMD.

This study was carried out to assess if an echocardiographic definition of LVHT is useful for CMRI.

Methods and Material

Included in the study were all patients in whom LVHT had been diagnosed in the echocardiographic laboratory of the Second Medical Department of the Rudolfstiftung Hospital (Vienna, Austria) between June 1995 and May 2004, and who underwent CMRI from 2001 to 2004. During this period, LVHT was diagnosed echocardiographically in 81 patients. The findings of 77 of these patients have been previously published.[13] The echocardiographic examinations were performed from 1995 to 1997 by an Aloka 870 (Aloka Co. Ltd., Tokyo, Japan), and from 1998 to 2004 by a Vingmed System FiVe (GE, Vingmed, Horten, Norway) and 2.5–3.6 MHz transducers. At transthoracic 2-Dimensional (2-D), M-mode, and Doppler echocardiography the following parameters were evaluated: LV end diastolic diameter, left ventricular wall thickness, LV fractional shortening, and valvular abnormalities. Additionally, it checked for LVHT. In order to differentiate between trabeculations, false tendons, and aberrant bands, the transducer had to be angulated and pictures in atypical views best delineated LVHT. Left ventricular hypertrabeculation was echocardiographically defined as more than 3, prominent trabeculations protruding from the LV wall, apically to the papillary muscles, visible in 1 imaging plane, and intertrabecular spaces perfused from the ventricular cavity, as visualized on color Doppler imaging. Trabeculations were defined as structures with the same echogenicity, like the myocardium, and moving synchronously with the ventricular contractions.[1] In addition, all the patients fulfilled the criterion of >2 noncompacted/compacted layers in the most hypertrabeculated segment at end systole.[3]

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Of the 81 patients in whom LVHT was diagnosed by echocardiography, 19 (10 females, aged 14–67 y) underwent CMRI. Indications for CMRI in these 19 patients were confirmation of the diagnosis (n = 11), differentiation of LVHT from thrombi (n = 5), from apical type of hypertrophic cardiomyopathy (n = 2), and from cardiac metastases (n = 1). The radiologist performing the investigation was not blinded to the echocardiographic diagnosis. Cardiac magnetic resonance imaging was performed by using a Siemens Magnetom Sypmpony 1.5 T high-field system (Siemens, Erlangen, Germany) using quantum high-speed gradients. No dedicated cardiac imaging coils were used. The protocol included T1 and T2 weighted turbo spin-echo (TSE), dark blood in the axial axis, true fast imaging with steady-state precession (TrueFISP) gradient echos T1, bright blood in the 4-chamber view and the short and long axis, and a cine sequence (FLASH 2D T1 bright blood) in the short axis. Initially, the CMRI diagnosis of LVHT was based on the morphologic impression of a hypertrabeculated left ventricle, and no distinct diagnostic criteria were applied. Applying this procedure, CMRI confirmed LVHT in all 19 cases in whom it was echocardiographically diagnosed.

In May 2004, the CMRI images were collected for re-evaluation. For re-evaluation of the CMRI images, the following echocardiographic diagnostic criteria of LVHT were applied: more than 3 prominent trabeculations with the same signal intensity like the myocardium, protruding from the LV wall, apically to the papillary muscles, visible in one imaging plane, and communication of the intertrabecular spaces with the LV cavity.[1] Re-evaluation was done by 2 radiologists who, again, were not blinded to the echocardiographic diagnosis. The TrueFISP images were used (single frame as well as cine mode images) were used for re-evaluation. In cases where the radiologists failed to diagnose LVHT according to the diagnostic criteria, the video recordings of the echocardiographic investigation were reviewed with a cardiologist.

All patients underwent a baseline cardiological examination during which medical history and cardiovascular symptoms were assessed. A 12-lead electrocardiogram was registered.

All patients were invited for a neurological investigation comprising history and clinical neurological examination. If there were indications for neuropathy, an established screening program for neuropathy including blood, cerebrospinal fluid investigation, and, if indicated, nerve biopsy was carried out. If a myopathy was suspected, a screening program for myopathy was initiated including muscle enzymes, electromyography, and muscle biopsy.

Results

Applying the diagnostic criteria, LVHT was diagnosed by CMRI in 9 of the 19 cases (47%) (Table 1, Figures 1 and 2). Patients in whom LVHT was CMRI-diagnosed were more often females (67% versus 40%), had experienced heart failure more often (100% versus 50%), had an LV end diastolic diameter >57 mm (67% versus 40%), and had an LV fractional shortening <25% (89% versus 40%) than patients in whom CMRI did not diagnose LVHT. In patients with heart failure, CMRI diagnosed LVHT in 64% of patients, whereas CMRI diagnosed LVHT in 0% of patients without heart failure. In left ventricles with an end diastolic diameter >57 mm, CMRI diagnosed LVHT in 60% of patients, whereas CMRI diagnosed LVHT in only 33% of those patients. In cases with an LV fractional shortening <25%, CMRI diagnosed LVHT in 62% patients, whereas CMRI diagnosed patients in cases with an LV fractional shortening >25% in only 17% of patients. In patients whom CMRI diagnosed LVHT, LVHT extended over more parts of the left ventricle compared with patients in whom LVHT was not diagnosed by CMRI. Furthermore, re-evaluation of the echocardiographic recordings of the 10 cases in whom LVHT could not be diagnosed by CMRI revealed that LVHT in these patients was of localized spongiform character, and consisted of a fine trabecular meshwork rather than of coarse trabeculations.

Fifteen of the 19 patients underwent a neurological investigation. Neuromuscular disorders were diagnosed in 13 of these 15 patients (87%). Nine patients were diagnosed as suffering from nonspecific NMD, 2 from myotonic dystrophy, 1 from mitochondriopathy, and 1 from polyneuropathy. The prevalence of NMD did not differ between patients with and without CMRI-diagnosed LVHT.

Discussion

This study showed that LVHT, according to an echocardiographic definition, could be diagnosed by CMRI in only 47% of the cases. Left ventricular hypertrabeculation by CMRI was diagnosed more often in females than in males, more often in patients with heart failure, and more often in patients with LV dilatation, and systolic dysfunction than in patients without these abnormalities, and was dependent on the extension and morphology of LVHT.

Left ventricular hypertrabeculation is a cardiac abnormality of unknown etiology. At present, it is unknown if LVHT is distinct cardiomyopathy or a morphologic abnormality caused by different disorders. Left ventricular hypertrabeculation is found in children as well as in adults.[1,2,10,11] It can be detected in dilated left ventricles with decreased systolic function, as well as in well contracting normally sized left ventricles.[1–3,6,7,10] The prognosis of patients with LVHT is dependent on cardiac comorbidity and systolic function.[2,10]

The low diagnostic yield of the applied definition to diagnose LVHT by CMRI may be explained by the following considerations:

(1) CMRI is not capable of visualizing LVHT in all cases due to a lower image resolution of the applied system than echocardiography. This is illustrated in Figures 1 and 2 by the less impressing CMRI images compared with echocardiographic images (the true number of trabeculations may have been reduced to ≤3 by CMRI.

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TABLE 1: Clinical, echocardiographic, and neurologic findings of 19 patients with echocardiographically-diagnosed LVHT who underwent CMRI

No.	Age (y)/sex	NYHA[a]	LVEDD[b] (mm)	LVFS[c] (%)	Location of LVHT[d]	Neurologic diagnosis
LVHT confirmed by CMRI						
1	55/m	IV	62	19	Lateral	ns NMD[e]
2	43/f	IV	48	17	Apex, lateral	ns NMD
3	48/f	I	52	23	Apex, lateral	ns NMD
4	62/f	II	72	15	Apex, lateral, anterior, posterior	Polyneuropathy
5	63/f	IV	72	14	Apex, lateral	Normal
6	47/f	IV	66	13	Apex, lateral	Investigation denied
7	55/m	II	76	19	Apex, lateral, posterior	ns NMD
8	43/m	II	56	29	Apex, lateral	Myotonic dystrophy
9	67/f	IV	88	6	Apex, lateral	ns NMD
LVHT not confirmed by CMRI						
10	43/f	0	48	46	Apex	ns NMD
11	42/m	III	65	22	Lateral	Mitochondriopathy
12	28/m	0	53	22	Apex	ns NMD
13	55/m	III	70	18	Apex	Investigation denied
14	52/m	II	68	20	Apex	Investigation denied
15	56/m	0	50	26	Apex, lateral	Investigation denied
16	24/f	0	49	35	Lateral, inferior	Normal
17	14/f	0	40	36	Lateral	Myotonic dystrophy
18	55/m	IV	80	15	Apex, lateral	ns NMD
19	60/f	II	44	31	Apex, lateral, anterior	ns NMD

[a]NYHA class of heart failure. [b]LVEDD measured by echocardiography. [c]LVFS measured by echocardiography. *Abbreviations*: CMRI = cardiac magnetic resonance imaging; f = female; LVEDD = left ventricular end diastolic diameter; LVFS = left ventricular fractional shortening; LVHT = left ventricular hypertrabeculation; m = male; NMD = neuromuscular disorder; ns = nonspecific; NYHA = New York Heart Association.

(2) Visualization of LVHT by CMRI may be dependent on the systolic function and size of the left ventricle, as suggested by our findings that CMRI visualizes LVHT better in a dilated or poorly contracting left ventricle than in a normally sized well contracting left ventricle, possibly because the intertrabecular spaces are wider and thus better vizualized.

(3) Echocardiography, as a real-time imaging technique, can provide multiple images of the left ventricle just by slightly moving the transducer. When performing CMRI, standard imaging planes are used but not in real-time. Thus, the insertion and course of the trabeculations and the recesses can be visualized better by echocardiography than by CMRI, and false tendons or aberrant bands can be better differentiated from trabeculations. Possibly, this technical limitation can be overcome by new CMRI real-time sequences.

(4) Left ventricular hypertrabeculation might be overlooked by CMRI in patients with LVHT involving only small areas of the left ventricle.

A currently used echocardiographic definition for LVHT was not applied for the actual CMRI study,[3] since it has

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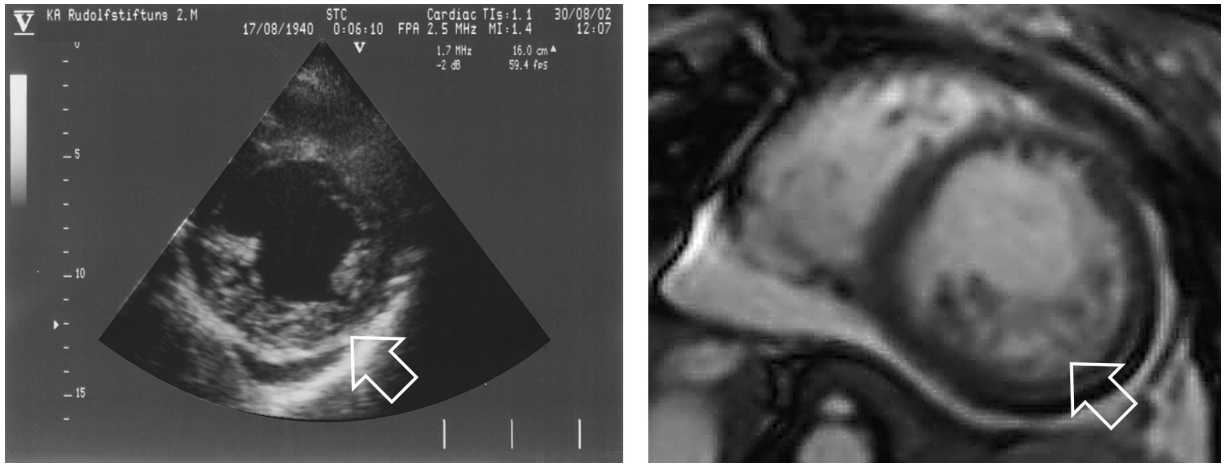

Figure 1: Echocardiographic (left panel) and magnetic resonance (right panel) short-axis view of patient 3 visualizing LVHT of the LV posterior (arrow) and lateral wall.

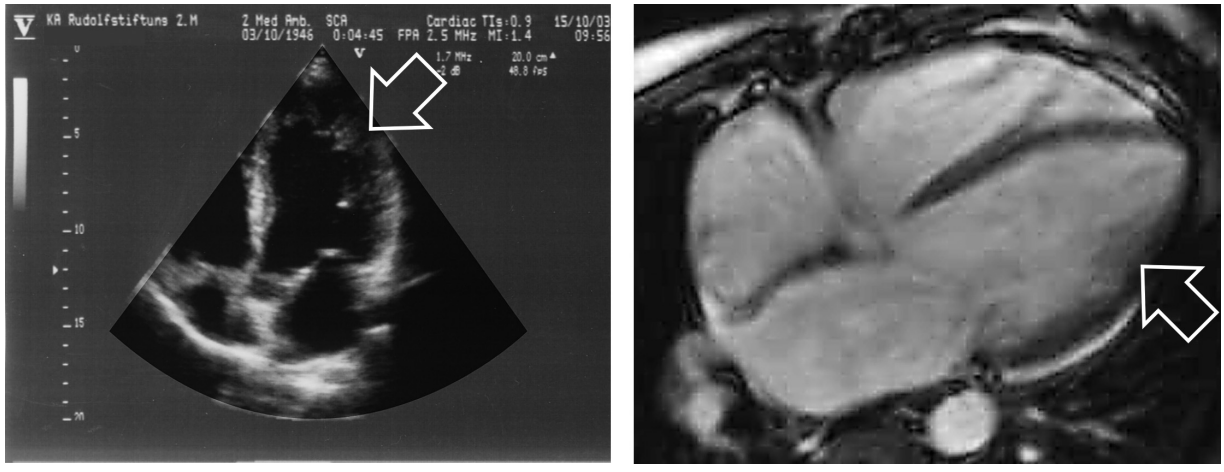

Figure 2: Echocardiographic (left panel) and magnetic resonance (right panel) 4-chamber view of patient 1 visualizing LVHT of the LV lateral wall (arrow), which was only diagnosed by CMRI after reviewing the echocardiographic recording.

already been found by another CMRI study, that the ratio of noncompacted to compacted myocardium cannot be accurately assessed at end systole. This is because the intertrabecular recesses are not visible during this part of the cardiac cycle.[12] Also, echocardiographically, the differentiation between noncompacted and compacted layers of the myocardium at end systole is not always possible, especially in small well contracting left ventricles.[12,14] A further difficulty in applying this definition for LVHT, either by echocardiography or by CMRI, is that the ratio of noncompacted to compacted myocardium should be assessed in the short-axis view. In the short-axis view, however, the differentiation between trabeculations on the one side and papillary muscles, false tendons, and aberrant bands on the other side is sometimes problematic. The definition for LVHT applied in our laboratory, on the contrary, uses anatomical landmarks, excludes explicitely the papillary muscle, and is applicable for the short axis, long axis, and 4-chamber views. Overall, there is a need to unify the different currently applied echocardiographic definitions by comparing them with the gold standard of pathoanatomic findings.

A further problem of all definitions of LVHT is that at present the pathologic significance of LVHT is unknown. It is uncertain if LVHT is only a normal variant, if it is a distinct entity, or if it is the common morphologic endpoint of different disorders and pathologic processes. The imaging quality of the echocardiographic machine has improved considerably within the last years, and the same is taking place with the CMRI technology. Therefore, today we see much more within the cardiac cavity than in previous years, and it is unknown whether these findings are just innocent variants from normal or have pathologic

significance. Only the correlation with clinical findings, pathoanathomic studies, and follow-up studies of patients with LVHT will clarify these issues.

Left ventricular hypertrabeculation has been shown to be associated with NMD in 82% of the cases:[1] Becker muscular dystrophy, metabolic myopathy, myotonic dystrophy 1, myoadenylatedeaminase deficiency, dystrobrevinopathy, Cypher gene mutations, Barth syndrome, and other rare genetic disorders.[15,16] The visualization of LVHT on CMRI was independent of the presence or absence, and the type of NMD may be due to the high rate of NMD in LVHT or the heterogenous aetiology of NMD.

Limitations of the study are that echocardiography was considered the golden standard, and that no pathoanatomical confirmation of the echocardiographic diagnosis was available. Cases in which echocardiography had overlooked LVHT are not included in this study. Interestingly, there are reports in the literature, that in patients who were echocardiography-diagnosed, only LV hypertrophy and CMRI detected LVHT.[17,18] Further limitations are that the study was retrospective and included only a small number of patients. There was no control group without echocardiographically-diagnosed LVHT due to the retrospective design of the study. We did not use the most recent CMRI technologies, and the radiologists were not blinded to the echocardiographic diagnosis when performing CMRI and re-evaluating the images. Furthermore, we restricted the comparison of echocardiography and CMRI to morphologic findings. It has been shown that CMRI is also capable of visualizing perfusion abnormalities in LVHT.[19–21] It has to be assessed by future studies whether or not these applications for CMRI will be helpful for diagnosis and therapy of LVHT patients. Additionally, neurological investigations were not carried out in 21% of the patients, and a definite neurologic diagnosis was achieved in only a few patients. Furthermore, we cannot give any explanation why CMRI-diagnosed LVHT is found more often in females than in males. Cardiac magnetic resonance phase-contrast imaging was not performed, since the software for the application was not available in our institution at that time.

This study shows that the applicability of an echocardiographic definition for LVHT by CMRI is not useful. When looking for LVHT by CMRI, especially in normally sized and well contracting left ventricles, the echocardiographically assessed appearance and location of LVHT has to be considered for the protocol of the CMRI investigation. There is a need to improve definitions for LVHT by CMRI, and to correlate CMRI findings with the gold standard of pathoanatomic findings. As long as there are no clear definitions for LVHT by CMRI, echocardiography should be the preferred investigation for this disorder. Cardiac magnetic resonance imaging should be performed in suspected LVHT patients when the image quality at echocardiography is poor and, especially, when the LV apex cannot be adequately visualized.

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