Familial Left Ventricular Noncompaction
Associated With a Novel Mutation in the Alpha-cardiac Actin Gene

Miocardiopatía no compactada familiar asociada con una mutación nueva en el gen de la alfa-actina cardiaca

To the Editor,

Left ventricular noncompaction (LVNC) is characterized by multiple prominent ventricular trabeculations and deep intertrabecular recesses.1 A familial background is found in 18% to 50% of adults and the estimated prevalence in echocardiographic studies is 0.014% to 1.300%.3 Its genetic bases are heterogeneous,1–3 with only two reported mutations in the alpha-cardiac actin gene (ACTC1)4: ACTC1M227V and ACTC1E101K with additional apical hypertrophic cardiomyopathy, restrictive filling, and septal defects.4 As in other inherited familial conditions, the finding of a pathogenic mutation can be very valuable when screening at-risk relatives.5

Herein we present a family with LVNC caused by the novel heterozygous ACTC1I289T mutation, which exhibited different clinical features and courses in the affected family members, namely isolated LVNC, LVNC associated with atrioseptal defect, and restrictive cardiomyopathy associated with atrioseptal defect.

A 9-month-old girl underwent heart transplantation in another hospital because of a restrictive cardiomyopathy with dilated atria, depressed left ventricular ejection fraction, and an associated small ostium secundum atrioseptal defect (proband, Figure, IV:1). At hospital discharge, the presence of a previously unsuspected LVNC was reported in the macroscopic evaluation of the heart. No histologic evaluation was carried out and no samples from the explanted heart were kept for further examination. A comprehensive workup, approved by the local research ethics committee, was offered to her first-degree relatives and the family tree was accordingly expanded. This evaluation included electrocardiogram, echocardiography, and blood sampling for genetic studies. Cardiac magnetic resonance imaging, exercise testing, and Holter-electrocardiogram were performed at cardiologist discretion. LVNC was defined following Jenni’s (telesystolic noncompacted/compacted myocardium > 2 by echocardiography) and/or Petersen’s criteria (telediastolic noncompacted/compacted > 2.3 by cardiac magnetic resonance imaging).6

Sanger sequencing (MYH7, myosin binding protein C3, Nkx2.5, and ACTC1 genes) was performed in genomic DNA of the maternal

Figure. Familial pedigree. ACTC1, alpha-cardiac actin gene; LVNC, left ventricular noncompaction; LVH, left ventricular hypertrabeculation; MI, myocardial infarction; NE, not evaluated; OS-ASD, ostium secundum atrioseptal defect; RCM, restrictive cardiomyopathy. Circles denote females, squares males. Red symbols represent affected individuals. *Macroscopic evaluation at heart transplantation.
<table>
<thead>
<tr>
<th>Pedigree position</th>
<th>Sex/ Age, y</th>
<th>Clinical history</th>
<th>ECG</th>
<th>Echocardiography</th>
<th>CMRI</th>
<th>Holter</th>
<th>Exercise testing</th>
<th>Genetics: heterozygous ACTC1289T mutation</th>
</tr>
</thead>
<tbody>
<tr>
<td>II:3</td>
<td>F/59</td>
<td>Asymptomatic</td>
<td>Normal</td>
<td>Normal</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Non carrier</td>
</tr>
<tr>
<td>II:4</td>
<td>M/66</td>
<td>Dyspnea, NYHA class I-II/IV</td>
<td>SR, first degree AV block, QS in the inferior leads</td>
<td>One year before this study, in another center: echocardiography within normal limits At the beginning of this study: LVNC, normal LV size; LVEF, 36%; moderately impaired RVEF At follow-up: upper limit LV diameters with hypertrabeculation; LVEF, 25%; normal RVEF</td>
<td>LVNC; LVEF, 48%; intramyocardial LGE at the inferior wall and posterior septum</td>
<td>SR, unremarkable isolated ventricular ectopies, unremarkable atrial ectopies in isolation, couplets and salvos</td>
<td>Normal</td>
<td>Carrier</td>
</tr>
<tr>
<td>III:2</td>
<td>F/33</td>
<td>Asymptomatic</td>
<td>Normal</td>
<td>Normal</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Non carrier</td>
</tr>
<tr>
<td>III:4</td>
<td>F/32</td>
<td>Previous clinical history: OS-ASD repaired at 10 years of age; one miscarriage (hydrops) At follow-up: Dyspnea class I-II/IV NYHA</td>
<td>Normal</td>
<td>Three years before this study, in another center: echocardiography within normal limits At the beginning of this study: normal LV size; LVEF, 53%; apical and septal hypertrabeculation, restrictive filling pattern normal sized RV with mildly impaired RVEF At 1-year follow-up: upper limit LV diameters (51/43 mm); LVEF, 36%; restrictive filling pattern; apical hypertrabeculation not full-filling criteria for LVNC; moderate tricuspid regurgitation without pulmonary hypertens. upper limit RV diameters with mildly impaired RVEF At 2-year follow-up: improvement of LVEF and RVEF</td>
<td>Three years before this study, in another center: hypertrabeculation in lateral and inferolateral regions; normal sized LV; LVEF, 51% At the beginning of this study: LVNC more prominent at the anterolateral and inferolateral wall; dilated LV; LVEF, 55%; RVEF, 46%; subepicardial LGE at the inferior and lateral walls; akinetic biventricular apical segments</td>
<td>SR, isolated rare atrial and ventricular ectopies</td>
<td>Normal</td>
<td>Carrier</td>
</tr>
<tr>
<td>III:5</td>
<td>M/37</td>
<td>Asymptomatic</td>
<td>Normal</td>
<td>Normal</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Non carrier</td>
</tr>
<tr>
<td>III:6</td>
<td>M/31</td>
<td>Dyspnea, NYHA class II/IV</td>
<td>SR, nonspecific ventricular activation delay</td>
<td>LVNC: spheric-shaped dilated LV (65/52 mm); LVEF, 25%; restrictive filling pattern; severe mitral regurgitation; normal-sized RV with preserved RVEF</td>
<td>LVNC: dilated LV; LVEF, 27%; prolapse of posterior mitral left with severe mitral regurgitation.</td>
<td>SR: scarce atrial ectopies in couplets and salvos; ventricular ectopies in isolation (1908); couplets (42), and one salvoe (5 beats)</td>
<td>Ventricular ectopies and 1 nonsustained ventricular tachycardia (3 beats) at peak exercise</td>
<td>Carrier</td>
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<tr>
<td>III:5</td>
<td>F/33</td>
<td>Asymptomatic</td>
<td>Normal</td>
<td>Normal</td>
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<td>Non carrier</td>
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<tr>
<td>IV:1</td>
<td>F/3</td>
<td>Heart transplantation at 9 months of age because of refractory heart failure: no further clinical events</td>
<td>SR at 150 bpm; left atrial and LV hypertrophy and inespecific alteration in the ventricular repolarization</td>
<td>Before heart transplantation: dilated LV (36/27 mm) and LVEF, 46%; restrictive filling pattern; severe-moderate mitral and tricuspid regurgitation; moderate pulmonary hypertension; OS-ASD, 5 mm At heart transplantation: LV hypertrabeculation</td>
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ACTC1, alpha-cardiac actin gene; AVB: atrioventricular block; CMRI, cardiac magnetic resonance imaging; ECG, electrocardiogram; F, female; LGE, late gadolinium enhancement; LV, left ventricle; LVEF, left ventricular ejection fraction; LVNC, left ventricular noncompaction; M, male; MI, myocardial infarction; NE, not evaluated; NYHA, New York Heart Association; OS-ASD, ostium secundum atrioseptal defect; RV, right ventricle; RVEF, right ventricular ejection fraction; SR: sinus rhythm.
proband’s uncle since the proband was initially not available for mutation screening. The heterozygous ACTC1\(^{1289T}\) mutation was identified and cascade genetic studies were undertaken in the remaining relatives. No additional mutation was found in any of the other screened genes. The Table shows the results of the family study in affected (II:4, III:4, III:6 and IV:1) and nonaffected individuals (no additional family members were available for the study).

Gene sequencing yielded the presence of the heterozygous ACTC1\(^{1289T}\) mutation, not present in the National Center for Biotechnology list of single nucleotide polymorphisms in the ACTC1 gene. Although hundreds of variants have been identified in sarcomeric and desmosomal genes, only a few polymorphisms and \(< 30\) mutations causing any kind of cardiomyopathy have been described in the ACTC1 gene, suggesting that changes in the ACTC1 gene are poorly tolerated. Actin is essential for cell morphology, adhesion, and migration. This novel variant alters a preserved amino acid residue (I289) in the protein, replacing a nonpolar (isoleucine) with another polar and noncharged (threonine) aminoacid, thus causing moderate modifications in the physicochemical properties related to the hydrophobicity, charge, polarity, and mass of the protein (Graneth distance 89 [0-215]). The prediction of in silico (SIFT [Sorting Intolerant from Tolerant], Polyphen-2, and Pmut) analyses neither confirmed nor ruled out its pathogenicity (inconclusive results with low confidence). The preserved I289 amino acid residue maps to subdomain 3, important for the stability and polymerization of the actin filaments\(^6\) and next to the myosin binding site, possibly disrupted by the presence of the ACTC1\(^{1289T}\) mutation. Furthermore, our ACTC1\(^{1289T}\) mutation cosegregated perfectly with the LVNC phenotype, with a 100% penetrance in the individuals available for the study.

We acknowledge that a more thorough genetic study could have included many other genes. Nonetheless, we considered it finished in terms of cost-effectiveness for three reasons: a) our results were consistent with a previous study linking LVNC and septal defects due to ACTC1 mutation\(^3\); b) the variant strongly cosegregated with the phenotype, and c) the molecular consequences of the variant were considered probably pathogenic. Further functional information obtained from animal models may be valuable to confirm the causal role of the ACTC1\(^{1289T}\) mutation.

In summary, we offer the phenotypical description of a family with LVNC caused by the highly penetrant, novel, heterozygous ACTC1\(^{1289T}\) mutation. Remarkably, in the literature this is the third ACTC1 mutation causing LVNC, and associated ostium secundum atrioseptal defect in some affected family members.

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**Improvement in Hemodynamics and Contractility With Multipoint Left Ventricular Pacing in Cardiac Resynchronization Therapy**

**Mejoría hemodinámica y de la contractilidad con la estimulación multipunto del ventrículo izquierdo en la terapia de resincronización cardíaca**

**To the Editor,**

Heart failure is a leading cause of morbidity and mortality in Western countries. Biventricular pacemakers have been used to treat heart failure since the 1990s.\(^1\) Over the last decade, randomized studies\(^2\)\(^3\) have demonstrated the benefit of cardiac resynchronization therapy (CRT) and helped to establish its indications. This therapy has been shown to increase survival and decrease hospitalizations in patients with heart failure, left ventricular (LV) dysfunction, and prolonged QRS, in particular in those with complete left bundle branch block.\(^4\) Unfortunately, a significant number of patients (30%-40%) have no response to CRT.\(^5\) This lack of response could be explained by inappropriate pacing site selection, suboptimal device programming, or absence of dysynchronous basal LV contraction.\(^6\) Another limitation could be that pacing from a single LV point is incapable of generating a coordinated mechanical activation. Quadripolar electrodes would allow LV pacing from 2 points far