

4. Gold MR, Birgersdotter-Green U, Singh JP, Ellenbogen KA, Yu Y, Meyer TE, et al. The relationship between ventricular electrical delay and left ventricular remodeling with cardiac resynchronization therapy. *Eur Heart J*. 2011;32:2516–24.
5. Kristiansen HM, Hovstad T, Vøllan G, Keilegavlen H, Faerestrånd S. Clinical implication of right ventricular to left ventricular interlead sensed electrical delay in cardiac resynchronization therapy. *Europace*. 2012;14:986–93.
6. Miranda RI, Nault M, Johri A, Simpson CS, Michael KA, Abdollah H, et al. Maximal electric separation-guided placement of right ventricular lead improves responders in cardiac resynchronization defibrillator therapy. *Circ Arrhythm Electrophysiol*. 2012;5:927–32.

<http://dx.doi.org/10.1016/j.rec.2014.05.010>

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 cardíaca

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%.¹ Its genetic bases are heterogeneous,^{1–3} with only two reported mutations in the alpha-cardiac actin gene (*ACTC1*): *ACTC1*^{M271V} and *ACTC1*^{E101K} 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 *ACTC1*^{I289T} 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).¹

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

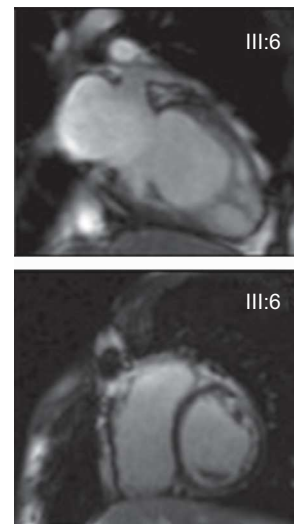
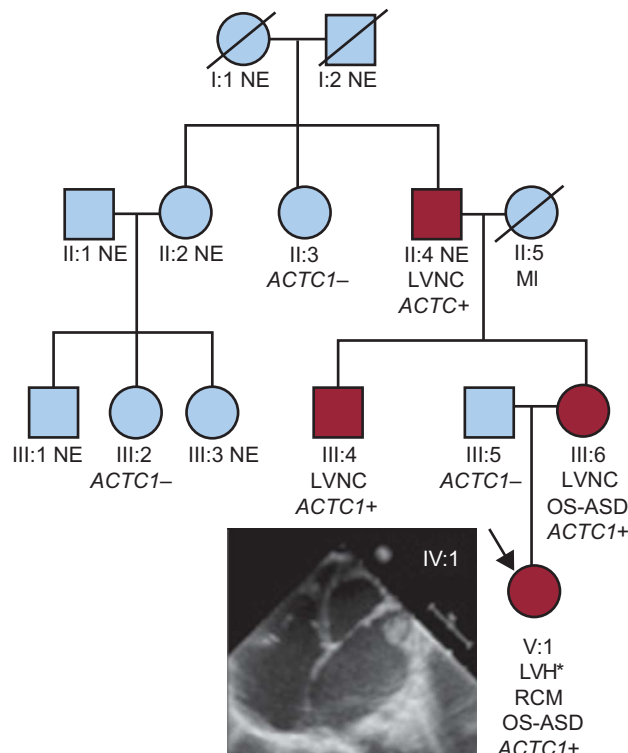


Figure. Familial pedigree. *ACTC1*, alpha-cardiac actin gene; LVNC, left ventricular noncompaction; LVH, left ventricular hypertrabeculation; MI, myocardial infarction; NE, not evaluated; OS-ASD, ostium secundum atrioseptal defect; RCM, restrictive cardiomyopathy. Circles denote females, squares males. Red symbols represent affected individuals. *Macroscopic evaluation at heart transplantation.

Table
Results From the Clinical Family Evaluation

Pedigree position	Sex/ Age, y	Clinical history	ECG	Echocardiography	CMRI	Holter	Exercise testing	Genetics: heterozygous ACTC1 ^{L289T} mutation
II:3	F/59	Asymptomatic	Normal	Normal	—	—	—	Non carrier
II:4	M/66	Dyspnea, NYHA class I-II/IV	SR, first degree AV block, QS in the inferior leads	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	LVNC; LVEF, 48%; intra-myocardial LGE at the inferior wall and posterior septum	SR, unremarkable isolated ventricular ectopies, unremarkable atrial ectopies in isolation, couplets and salvoes	Normal	Carrier
III:2	F/33	Asymptomatic	Normal	Normal	—	—	—	Non carrier
III:4	F/32	Previous clinical history: OS-ASD repaired at 10 years of age; one miscarriage (hydrops) At follow-up: Dyspnea class I-II/IV NYHA	Normal	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 hypertension. upper limit RV diameters with mildly impaired RVEF At 2-year follow-up: improvement of LVEF and RVEF	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	SR, isolated rare atrial and ventricular ectopies	Normal	Carrier
III:5	M/37	Asymptomatic	Normal	Normal	—	—	—	Non carrier
III:6	M/31	Dysnea, NYHA class II/IV	SR, nonspecific ventricular activation delay	LVNC; spheric-shaped dilated LV (65/52 mm); LVEF, 25%; restrictive filling pattern; severe mitral regurgitation; normal-sized RV with preserved RVEF	LVNC; dilated LV; LVEF, 27%; prolapse of posterior mitral left with severe mitral regurgitation.	SR; scarce atrial ectopies in couplets and salvoes; ventricular ectopies in isolation (1908); couplets (43), and one salvoe (5 beats)	Ventricular ectopies and 1 nonsustained ventricular tachycardia (3 beats) at peak exercise	Carrier
III:5	F/33	Asymptomatic	Normal	Normal	—	—	—	Non carrier
IV:1	F/3	Heart transplantation at 9 months of age because of refractory heart failure; no further clinical events	SR at 150 bpm; left atrial and LV hypertrophy and inespecific alteration in the ventricular repolarization	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	—	—	—	Carrier

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*^{I289T} 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*^{I289T} 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) amino acid, thus causing moderate modifications in the physico-chemical properties related to the hydrophobicity, charge, polarity, and mass of the protein (Grantham 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 filaments⁶ and next to the myosin binding site, possibly disrupted by the presence of the *ACTC1*^{I289T} mutation. Furthermore, our *ACTC1*^{I289T} 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* mutation⁴; 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*^{I289T} mutation.

In summary, we offer the phenotypical description of a family with LVNC caused by the highly penetrant, novel, heterozygous *ACTC1*^{I289T} mutation. Remarkably, in the literature this is the third *ACTC1* mutation causing LVNC, and associated ostium secundum atrioseptal defect in some affected family members.

Acknowledgements

We thank the patients for taking part in the study and Biobanco La Fe for its technical support (PT13/0010/0026).

FUNDING

This work was supported by the *Instituto de Salud Carlos III* (PI11/00019, CP09/00065 and RD12/0042/0029), the *Generalitat Valenciana* (PROMETEO 2011/027), and the *Agence Nationale de la Recherche* (ANR-13-BSV1-0023-03).

María Rodríguez-Serrano,^{a,b} Diana Domingo,^{a,b,c} Begoña Igual,^d Ana Cano,^e Pilar Medina,^c and Esther Zorio^{a,c,*}

^aServicio de Cardiología, Hospital Universitario y Politécnico La Fe, Valencia, Spain

^bDepartamento de Medicina, Universidad de Valencia, Valencia, Spain

^cGrupo Acreditado en Hemostasia, Trombosis, Arteriosclerosis y Biología Vascular, Instituto de Investigación Sanitaria La Fe, Valencia, Spain

^dUnidad de Imagen Cardíaca, ERESA, Valencia, Spain

^eSección de Cardiología Pediátrica, Servicio de Pediatría, Hospital Universitario y Politécnico La Fe, Valencia, Spain

* Corresponding author:

E-mail address: zorio_est@gva.es (E. Zorio).

Available online 5 September 2014

REFERENCES

- Oechslin E, Jenni R. Left ventricular non-compaction revisited: a distinct phenotype with genetic heterogeneity? *Eur Heart J*. 2011;32:1446–56.
- Monserrat Iglesias L. Miocardiopatía no compactada: una enfermedad en busca de criterios. *Rev Esp Cardiol*. 2008;61:112–5.
- Hoedemaekers YM, Caliskan K, Michels M, Frohn-Mulder I, Van der Smagt JJ, Pfefferkorn JE, et al. The importance of genetic counseling, DNA diagnostics, and cardiologic family screening in left ventricular noncompaction cardiomyopathy. *Circ Cardiovasc Genet*. 2010;3:232–9.
- Monserrat L, Hermida-Prieto M, Fernandez X, Rodríguez I, Dumont C, Cazón L, et al. Mutation in the alpha-cardiac actin gene associated with apical hypertrophic cardiomyopathy, left ventricular non-compaction, and septal defects. *Eur Heart J*. 2007;28:1953–61.
- Ackerman MJ, Marcou CA, Tester DJ. Medicina personalizada: diagnóstico genético de cardiopatías/canalopatías hereditarias. *Rev Esp Cardiol*. 2013;66:298–307.
- Mundia MM, Demers RW, Chow ML, Perieteanu AA, Dawson JF. Subdomain location of mutations in cardiac actin correlate with type of functional change. *PLoS One*. 2012;7:e36821.

<http://dx.doi.org/10.1016/j.rec.2014.05.015>

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 dyssynchronous basal LV contraction.⁵ 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