

# Non-Compaction Cardiomyopathy. Risk Stratification of Sudden Death for Automatic Cardioverter Defibrillator Implantation

NESTOR O. GALIZIO<sup>MTSAC</sup>, JOSEPH L. GONZÁLEZ<sup>MTSAC</sup>, LILIANA E. FAVALORO, MIRTA DIEZ<sup>MTSAC</sup>, ADRIAN FERNANDEZ, EDUARDO GUEVARA<sup>MTSAC</sup>, ALEJANDRO A. PALAZZO, FEDERICO ROBLES, JOSEPH H. CASABÉ<sup>MTSAC</sup>

Received: 10/13/2010

Accepted: 12/15/2010

## Address for reprints:

Dr. Nestor O. Galizio  
Rodríguez Peña 1034  
(1876) Bernal  
Province of Buenos Aires  
e-mail: ngalizio@gmail.com

## SUMMARY

### Background

Non-compaction cardiomyopathy is a rare disease. Its natural history includes heart failure, thromboembolic events, arrhythmias and sudden death (SD). In the absence of data from randomized studies or records, the ACC / AHA / HRS 2008 guidelines recommend the automatic implantable cardioverter defibrillator (AICD) in all patients with non-compaction cardiomyopathy to reduce the risk of sudden death.

### Objective

Describe the outcomes of patients with non-compaction cardiomyopathy according to selected criteria for risk stratification of sudden death to decide the implantation of an AICD.

### Material and Methods

A total of 80 patients were analyzed. The diagnosis was established by echocardiography and nuclear cardiac magnetic resonance imaging criteria.

The criteria for implantation of an AICD as a secondary prevention included sudden death and sustained ventricular tachycardia (SVT); as primary prevention included left ventricular ejection fraction (LVEF) < 30% or ≥ 2 risk factors (family history of sudden death [FHSD], syncope and non-sustained VT).

### Results

AICD group (n = 26) for secondary prevention (n = 3): 3 patients suffered sudden death (2 SVT). AICD group for primary prevention (n = 23): 10 patients had LVEF < 30%, 1 LVEF < 30% + FHSD, 1 LVEF < 30% + syncope, 5 LVEF < 30% + non-sustained VT, 3 non-sustained VT + syncope, 2 non-sustained VT + FHSD and 1 SVT in electrophysiological study. Follow up was a median of 16.61 months. Two patients underwent a heart transplant, 3 patients received appropriate shocks and 4 patients, inappropriate shocks. Group without AICD (n = 54): 4 patients had syncope and 4, non-sustained VT. Follow up was a median of 12.15 months. Two patients died due to heart failure and 3 underwent a heart transplant.

### Conclusions

32.5% of patients with non-compaction cardiomyopathy received an AICD, 88.5% for primary prevention; 11.5% received appropriate shocks.

There was no sudden death in patients without AICD, these patients died due to heart failure progression. This record suggests that patients with non-compaction cardiomyopathy could be stratified to select those at higher risk of sudden death and who could be benefited from an AICD implantation.

REV ARGENT CARDIOL 2011;79:14-20.

**Key words >** Abdominal Aortic Aneurysm - Vascular Prosthesis

## Abbreviations >

<b>FHSD</b>	Family History of Sudden Death	<b>SP</b>	Secondary prevention
<b>AICD</b>	Automatic Implantable Cardioverter Defibrillator	<b>NMRI</b>	Nuclear magnetic resonance imaging
<b>LVEF</b>	Left Ventricular Ejection Fraction	<b>CAT</b>	Computed Axial Tomography
<b>VF</b>	Ventricular fibrillation	<b>VT</b>	Ventricular tachycardia
<b>HF</b>	Heart failure	<b>SVT</b>	Sustained ventricular tachycardia
<b>SD</b>	Sudden death	<b>LV</b>	Left ventricle
<b>PP</b>	Electrocardiogram		

## BACKGROUND

In 1932 it was initially reported by Bellet et al. as “LV hypertrabeculation”, associated with congenital cardiac defects (1) and afterwards in 1984 it was reported by Engberding and Bender as “isolated persistence of myocardial sinusoids”, (2) non-compaction cardiomyopathy of left ventricular was officially described by Chin et al. in 1990 to be understood better the anomaly in the morphogenesis of myocardium. (3)

It is an uncommon pathology, classified as a primary genetic cardiomyopathy by the American Heart Association (4) and as an unclassified cardiomyopathy by the Working Group on Myocardial and Pericardial Diseases of the European Society of Cardiology. (5)

It is characterized by preseting a widened myocardium with two layers consisting of one compact myocardial and one non-compact myocardial, with prominent trabeculae and deep intertrabecular recesses, continuity between the left ventricular cavity and intertrabecular recesses, which receive blood from cavity, and decreased coronary flow reserve in most segments that show an abnormal movement of the wall.

The hypothesis of non-compaction is based on that hypertrabeculated myocardial compaction of the embryo is arrested or slowed by a primary genetic defect that occurs between the fifth and eighth weeks of embryonic development. (6)

At that time, the hypertrabeculated, “spongy myocardium” begins to compact in parallel with the development of the coronary vasculature: from trough to peak and from epicardium to endocardium.

The severity of the phenotype will depend on the moment in which the natural course of myocardium maturation stops or slows. Only 25-50% of patients have genetic disorders.

Genetic heterogeneity is evident from the manifold identified mutations, which in their pathogenesis involve sarcomeric, mitochondria, of cytoskeleton and, of Z line proteins. However, many isolated cases are related to novo mutations. (7)

Its natural history, still unresolved, includes left ventricular systolic dysfunction and heart failure (HF), thromboembolic events, arrhythmias and sudden death.

Due to the lack of data from randomized studies or records, ACC / AHA / HRS 2008 guidelines recommended the implantation of an automatic implantable cardioverter defibrillator (AICD) in all patients non-compaction cardiomyopathy to reduce the risk of sudden death (class IIb, C evidence level). (8)

However, there is no sufficient evidence yet for the detection of patients at higher risk of sudden death that they may be benefited most from the implantation of an AICD.

Records are useful to determine the impact of clinical studies and guideline recommendations in the everyday medical practice, since the conclusions that

can be extracted from them may improve the prevention and treatment strategies. COMPASS (Comparing Prevention Strategies Sustained Arrhythmia) is a prospective record of patients with implanted AICD for primary and secondary prevention of sudden death that takes place in our Hospital Universitario.

This study was carried out with the aim to describe, from the results obtained from a prospective record, the outcomes of patients with non-compaction cardiomyopathy in which risk of sudden death was stratified to decide an AICD implantation.

## MATERIAL AND METHODS

Between January 1997 and January 2010, 80 consecutive patients were analyzed with non-compaction cardiomyopathy. Age:  $41 \pm 17$  years (51 men). Follow up: Median 13.35 months (25-75 percentile between 5.85 to 25.09), range from 0.8 to 151 months. The follow up in the group without AICD began at the time of diagnosis, whereas in the group with AICD began the day of device implantation.

During follow up, the final events (death, appropriate and inappropriate shocks) were assessed by ambulatory controls and regular telephone consultations every 4 months. No patients were lost at follow up.

Thirty-four patients were in functional class II-IV (NYHA), 17 patients with left ventricular ejection fraction (LVEF)  $<30\%$ , 3 had suffered sudden death, 2 had sustained ventricular tachycardia (SVT), 15 had non-sustained VT, 10 had syncope and 3 patients had stroke.

The diagnosis was established on the basis of accepted criteria for cardiac echo-Doppler and nuclear magnetic resonance imaging (NMRI). The findings by multislice computerized axial tomography (CAT) were certified to the NMRI (Figure 1).

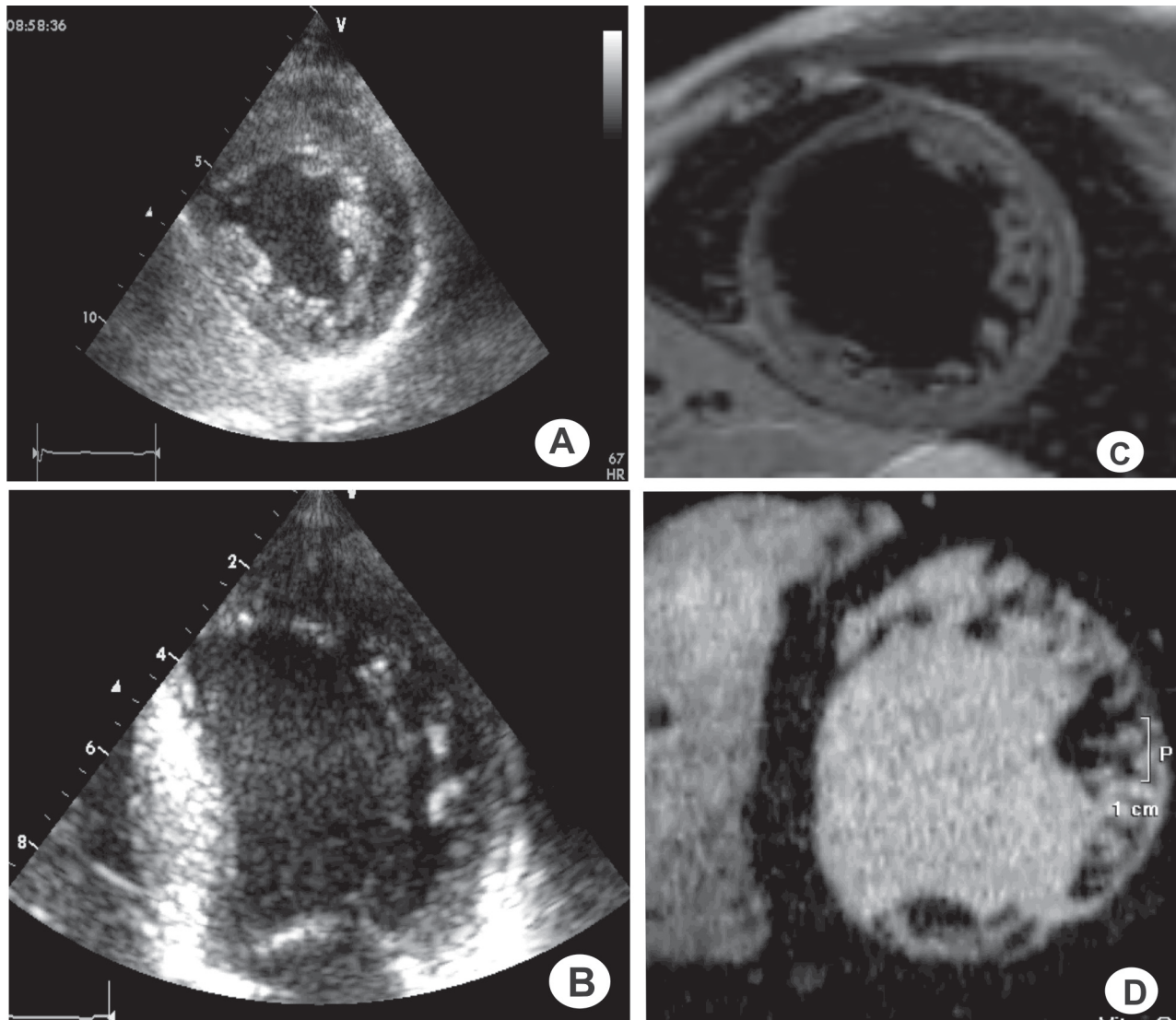
Echocardiographic criteria: Chin et al. proposed the presence of an  $X / Y \leq 0.5$  relation, where X is the distance from the epicardial surface to the depth of trabecular recess and Y is the distance from the epicardial surface to trabecula peak (at the apex level of the LV, at the end-diastole, in parasternal views or four cameras). (3)

Jenni and et al.'s criteria include LV wall, notoriously thickened by the presence of a compact, thin, epicardial layer and a thickened layer with prominent, manifold trabeculae, and deep recesses, with a maximum radius of non-compact / compact  $> 2:1$  myocardium, measured in systolic short axis; the trabeculations should be located in the medioventricular or apical segments of LV with evidence of flow within the intertrabecular recesses by colour Doppler; absence of coexisting structural cardiopathy. (9)

The Stollberg et al. criteria include more than 3 trabeculations protruding from the LV wall, apicals to the papillary muscles, which should synchronously move with the myocardium and should have the same echogenicity; evidence of flow from the LV cavity, within of intertrabecular recesses by colour Doppler. (10)

Recently, Stollberg and Finsterer proposed a complementary set of diagnostic criteria to define the presence of non-compaction cardiomyopathy (11):

- Final diagnosis: If Stollberg and Jenni's criteria are kept.
- Probable diagnosis: If only a set of criteria is kept.
- Possible diagnosis: Cases with less than 4 trabeculations or relationship non-compact/compact  $<2$  myocardium.



**Fig. 1.** Diagnosis. **A y B.** cardiac Echo-Doppler. Short axis (A) and four focused cameras. (B): Trabeculations and intertrabecular recesses in a relationship  $> 2$  non-compact/compact myocardium. **C.** Cardiac NMRI with T1-cut: multiple trabeculation and  $> 2.5$  non-compact/compact relationship. **D.** Multislice CAT: Prominent, multiple trabeculation and  $> 2.5$  non-compact/compact relationship.

Cardiac NMRI criteria: The criterion that distinguishes it most is a relationship non-compact / compact  $> 2.3$  myocardium in diastole and long axis or  $> 2.5$  in short axis and four cameras. (12-14)

The diagnostic criteria by multislice CAT were approved by NMRI. Initially, we only carry out the diagnosis with echocardiographic criteria, used as they were communicating. (3, 9, 11)

In recent years, we combine echocardiographic criteria with NMRI and multislice CAT criteria.

This study evaluated total mortality and sudden death. In the case of patients with AICD, appropriate shock was also evaluated because of VT / VF, arrhythmias that can potentially cause SD.

### Statistical analysis

Data of continuous variables with normal distribution is reported using a mean value and its standard deviation. The

comparison between both groups was carried out by two-tailed t-test.

Both variables with dichotomous data as ordinal variables were arranged in tables of contingency and statistical significance was established by test of independence through chi-square calculation.

When at least the value of an expected frequency was less than 5, Yates correction was applied in chi-square calculation.

In the case of monitoring variable that has not normal distribution, the median and interquartile range (percentiles 25-75) and the maximum and minimum values are reported. The comparison of both medians was carried out through the test of medians for two samples, placing in a table of contingency the number of individuals above and below the overall median in each tested group.

In all cases, it was considered statistically significant a p value less than 0.05.



## RESULTS

Of 80 patients with non-compaction cardiomyopathy, 26 (32.5%) received an AICD.

Table 1 shows basal characteristics of patients without AICD (n = 54) and with AICD (n = 26). Comparing both groups, no significant difference was found in the case of age, sex and functional class (NYHA). There was a higher and significant incidence of sudden death, syncope, SVT, non-sustained VT and lower LVEF in patients with AICD, as it was to expect because a high-risk population was selected rather than to carry out the implantation of an AICD in all patients as ACC / AHA / HRS 2008 guidelines indicated. (8)

The risk stratification criteria which were used for the indication and the implantation of an AICD are shown in Table 2. For secondary prevention (SP) it was considered the history of sudden death and / or SVT, while for primary prevention (PP) it was taken into account the presence of < 30% or  $\geq 2$  LVEF risk factors for sudden death.

Table 3 shows the outcome of patients with and without AICD implantation according to the selected stratification criteria.

In the group without AICD, 2 patients died from progression of heart failure and 3 patients underwent a heart transplant. There was no sudden death.

In the group with AICD there were not deaths, 2 patients received heart transplant, 3 had appropriate shocks (2 shocks in 2 patients with previous VT / VF and 1 shock in 1 patient with <30% LVEF) and 4 patients, inappropriate shocks for sinus tachycardia.

15.4% of patients had high defibrillation thresholds (DU > 20 joules in 2 consecutive shocks).

## DISCUSSION

Non-compaction cardiomyopathy is a myocardial disease apparently caused by an alteration in the endomyocardial morphogenesis during embryonic development.

**Table 1.** Comparative data of patients with or without AICD

Basal Characteristics	Group without AICD (n = 54)	Group with AICD (n = 54)	p
Mean age, years	42.2	38.3	ns
Male, n (%)	36 (66.6)	17 (65.3)	ns
NYHA Class III-IV, n (%)	12 (22.2)	8 (30.7)	ns
Previous SD, n (%)	–	3 (11.5)	< 0.01
Syncope, n (%)	4 (7.4)	6 (23)	< 0.04
Previous SVT n (%)	–	2 (7.7)	< 0.04
NSVT, n (%)	4 (7.4)	11 (42.3)	< 0.001
LVEF, %	42 $\pm$ 12	31 $\pm$ 10	< 0.0001
(Median) Follow up, months	12.15	16.61	ns

SD: Sudden Death. SVT: Sustained Ventricular Tachycardia. NSVT: Non Sustained Ventricular Tachycardia. LVEF: Left Ventricular Ejection Fraction. ns: Non significant

**Table 2.** Risk stratification criteria for the indication of AICD

AICD Group (n = 26)	
Secondary prevention (n = 3)	Primary prevention (n = 23)
Previous SD, n (%) 3 (11.5)	LVEF < 30%, n (%) 10 (38.4)
Previous SVT, n (%) 2 (7.7)	LVEF < 30% + FHSD, n (%) 1 (3.8)
	LVEF < 30% + syncope, n (%) 1 (3.8)
	LVEF < 30% + NSVT, n (%) 5 (19.2)
	NSVT + syncope, n (%) 3 (11.5)
	NSVT + FHSD, n (%) 2 (7.7)
	NSVT with induced SVT, n (%) 1 (3.8)

SD: Sudden Death. SVT: Sustained Ventricular Tachycardia. NSVT: Non Sustained Ventricular Tachycardia. LVEF: Left Ventricular Ejection Fraction. FHSD: Family History of Sudden Death.

**Table 3.** Outcome of patients with and without AICD

	Group without AICD (n = 54) Follow up 21 $\pm$ 16 months	Group with AICD (n = 26) Follow up 28 $\pm$ 22 months
Death (Advanced HF), n (%)	2 (3.7)	–
Heart Transplant (Advanced HF), n (%)	3 (5.5%)	2 (7.6)
Appropriate shocks (VT/VF), n (%)		3 (11.5)
Inappropriate shocks (sinusal tachycardia),		4 (15.4)
HDT (> 20 joules), n (%)		4 (15.4)

AICD: Automatic Implantable Cardioverter Defibrillator. HF: Heart Failure. VT/VF: Ventricular Tachycardia/Ventricular Fibrillation. HDT: High Defibrillation Threshold

Its prognosis depends on the degree of left ventricular dysfunction, severity of emerging arrhythmias and the occurrence of thromboembolic events. Most published cases belong to small series consisting of patients with different degree of compromise of the LV, which makes difficult its comparison.

Initial communications suggested that non-compaction cardiomyopathy, in both adults and children, had an adverse prognosis. However, it was about groups of patients with advanced and very symptomatic cardiopathy.

With the development of knowledge and its early detection by various imaging techniques (echocardiography, cardiac NMRI, multislice CAT) showed that the disease presents a broad-spectrum of clinical progress ranging from non-symptoms to an advanced LV comprime with a high rate of death from heart failure, thromboembolism, and ventricular arrhythmias.

For the moment, for mild and asymptomatic cases, close follow-up seems most appropriate.

For patients who develop mild to moderate heart failure, medical treatment seems sufficient.

When it is added atrial fibrillation and higher LV dysfunction, anticoagulation seems obligatory.

When heart failure is very advanced, cardiac resynchronization therapy and heart transplant seem to be the only viable alternatives.

For patients recovered from cardiac arrest or with recurrent or poorly tolerated VT, the AICD, as secondary prevention is accepted.

Table 4 shows the outcome of patients with non-compaction cardiomyopathy in the main published works about adults and children; (15-22) together to them we have added the results of our register.

The so dispar findings in relation to their natural outcome, arrhythmogenic potential, and with risk of sudden death make them to seem inappropriate, for the moment, to suggest which patients may be benefited from an AICD as primary prevention.

Although in this sense ACC / AHA / HRS 2008 guidelines recommended the implantation of an AICD in all patients with non-compaction cardiomyopathy to reduce the risk of sudden death, it is important the development of randomized studies and clinical registers that may guide us in risk stratification to select patients who would be benefited from an AICD instead of carrying out the implantation in all cases.

In this study population, only 32.5% of patients with non-compaction cardiomyopathy received the implantation of an AICD, according to selected criteria prior stratification of higher risk of SD.

In 88.5% of them AICD implantation was carried

out as primary prevention due to low LVEF or  $\geq 2$  risk factors for sudden death.

There was no sudden death in the group without AICD. Patients died of progressive heart failure.

In the group with AICD, the incidence of appropriate and inappropriate shocks was similar to that is reported for patients with ischemic or dilated cardiomyopathy.

The selection of patients in a matter of secondary or primary prevention with low LVEF or  $\geq 2$  risk factors appears to be useful for risk stratification of sudden death and the choice of patients who would be benefited most with the implantation of an AICD, due to the observation of absence of sudden death in the group without AICD and the presence of appropriate (VT/VF) shocks in AICD group.

More records and/or studies are needed to understand better this cardiomyopathy and obtain predictors of risk for an adequate indication of the devices.

**RESUMEN**

**Miocardiopatía no compactada. E estratificación de riesgo de muerte súbita para indicación de cardiodesfibrilador automático implantable**

**Introducción**

La miocardiopatía no compactada es una entidad rara. Su historia natural incluye insuficiencia cardíaca, eventos tromboembólicos, arritmias y muerte súbita (MS). En ausencia de datos de estudios aleatorizados o

(A) Adults	Oechslin (15)	Sengupta (16)	Murphy (17)	Lofiego (18)	Stollberger (19)	Galizio (Fundación Favaloro)
n	34	32	45	65	86	80
Mean age, years	40	49	37	47	52	41
Male, (%)	74	53	62	37	76	64
Follow up, years	> 11		> 15		> 8	> 2
Heart failure (%)	68	62,5	62	61	70	42.5
Embolic events, (%)	21		4			3.75
Death, (%)	35		2		22	2.5
Heart transplant, (%)	12				1	6.25
SVT, (%)	41		20			2.5

(B) Pediatric	Chin (3)	Ichida (20)	Alenhan (21)	Waid (22)
n	8	27	9	22
Mean age, years	7	5	9	3.9
Male, %	63	56	89	40
Follow up, years	> 5	> 17	> 5	> 16
Heart failure, %	63	30	55	54
Embolic events, %	38	0	0	0
Death, %	38	7	22	14
Heart transplant, %	0	4	0	9
SVT, %	38	0	0	15

**Table 4.** Outcome of patients with non-compaction cardiomyopathy. Publications

registros, las Guías ACC/AHA/HRS 2008 recomiendan el cardiodesfibrilador automático implantable (CDAI) en todos los pacientes con miocardiopatía no compactada para reducir el riesgo de muerte súbita.

### Objetivo

Describir la evolución de pacientes con miocardiopatía no compactada de acuerdo con criterios seleccionados de estratificación de riesgo de muerte súbita para decidir el implante de un CDAI.

### Material y métodos

Se analizaron 80 pacientes. El diagnóstico se estableció mediante criterios ecocardiográficos y de resonancia magnética nuclear cardíaca. Los criterios para el implante de un CDAI como prevención secundaria incluyeron muerte súbita y taquicardia ventricular sostenida (TVS); como prevención primaria comprendieron fracción de eyección del ventrículo izquierdo (FEVI) < 30% o  $\geq 2$  factores de riesgo (antecedentes familiares de muerte súbita [AFMS], síncope y TV no sostenida).

### Resultados

Grupo CDAI (n = 26) para prevención secundaria (n = 3): 3 pacientes sufrieron muerte súbita (2 TVS). Grupo CDAI para prevención primaria (n = 23): 10 pacientes tuvieron FEVI < 30%, 1 FEVI < 30% + AFMS, 1 FEVI < 30% + síncope, 5 FEVI < 30% + TV no sostenida, 3 TV no sostenida + síncope, 2 TV no sostenida + AFMS y 1 TVS en estudio electrofisiológico.

El seguimiento fue de una mediana de 16,61 meses. Dos pacientes fueron sometidos a un trasplante cardíaco, 3 recibieron choques apropiados y 4 pacientes, choques inapropiados. Grupo sin CDAI (n = 54): 4 pacientes tuvieron síncope y 4 TV no sostenida. El seguimiento fue de una mediana de 12,15 meses. Dos pacientes fallecieron por insuficiencia cardíaca y 3 fueron sometidos a un trasplante cardíaco.

### Conclusiones

El 32,5% de los pacientes con miocardiopatía no compactada recibieron un CDAI, el 88,5% por prevención primaria; el 11,5% recibieron choques apropiados. No hubo muerte súbita en pacientes sin CDAI; la muerte sobrevino por progresión de la insuficiencia cardíaca. Este registro sugiere que los pacientes con miocardiopatía no compactada podrían estratificarse para seleccionar a aquellos que tienen mayor riesgo de muerte súbita y podrían beneficiarse con el implante de un CDAI.

**Palabras clave** > Cardiomyopathies - Cardiac Ventricles - Risk - Cardiac Sudden Death - Prognosis

### BIBLIOGRAPHY

1. Bellet S, Gouley BA. Congenital heart disease with multiple cardiac anomalies. Report of a case showing aortic atresia, fibrous scar in myocardium and embryonal sinusoidal remains. *Am J Med Sci* 1932;183:458-65.
2. Engberding R, Bender F. Identification of a rare congenital

anomaly of the myocardium by two-dimensional echocardiography: persistence of isolated myocardial sinusoids. *Am J Cardiol* 1984;53:1733-4.

3. Chin TK, Perloff JK, Williams RG, Jue K, Mohrmann R. Isolated noncompaction of left ventricular myocardium. A study of eight cases. *Circulation* 1990;82:507-13.

4. Maron BJ, Towbin JA, Thiene G, Antzelevitch C, Corrado D, Arnett D, et al; American Heart Association; Council on Clinical Cardiology, Heart Failure and Transplantation Committee; Quality of Care and Outcomes Research and Functional Genomics and Translational Biology Interdisciplinary Working Groups; Council on Epidemiology and Prevention. Contemporary definitions and classification of the cardiomyopathies: an American Heart Association Scientific Statement from the Council on Clinical Cardiology, Heart Failure and Transplantation Committee; Quality of Care and Outcomes Research and Functional Genomics and Translational Biology Interdisciplinary Working Groups; and Council on Epidemiology and Prevention. *Circulation* 2006;113:1807-16.

5. Elliott P, Andersson B, Arbustini E, Bilinska Z, Cecchi F, Charron P, et al. Classification of the cardiomyopathies: a position statement from the European Society of Cardiology Working Group on Myocardial and Pericardial Diseases. *Eur Heart J* 2008;29:270-6.

6. Finsterer J. Cardiogenetics, neurogenetics, and pathogenetics of left ventricular hypertrabeculation/noncompaction. *Pediatr Cardiol* 2009;30:e659-81.

7. Xing Y, Ichida F, Matsuoka T, Isobe T, Ikemoto Y, Higaki T, et al. Genetic analysis in patients with left ventricular noncompaction and evidence for genetic heterogeneity. *Mol Genet Metab* 2006;88:71-7.

8. Epstein AE, DiMarco JP, Ellenbogen KA, Estes NA 3rd, Freedman RA, Gettes LS, et al; American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices); American Association of Thoracic Surgery; Society of Thoracic Surgeons. ACC/AHA/HRS 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices): developed in collaboration with the American Association for Thoracic Surgery and Society of Thoracic Surgeons. *Circulation* 2008;117(21):e350-408.

9. Jenni R, Oechslin E, Schneider J, Attenhofer Jost C, Kaufmann PA. Echocardiographic and pathoanatomical characteristics of isolated left ventricular non-compaction: a step towards classification as a distinct cardiomyopathy. *Heart* 2001;86:666-71.

10. Stöllberger C, Finsterer J, Blazek G. Left ventricular hypertrabeculation/noncompaction and association with additional cardiac abnormalities and neuromuscular disorders. *Am J Cardiol* 2002;90:899-902.

11. Finsterer J, Stöllberger C. Definite, probable, or possible left ventricular hypertrabeculation/noncompaction. *Int J Cardiol* 2008;123:175-6.

12. Stöllberger C, Kopsa W, Tscherny R, Finsterer J. Diagnosing left ventricular noncompaction by echocardiography and cardiac magnetic resonance imaging and its dependency on neuromuscular disorders. *Clin Cardiol* 2008;31:383-7.

13. Petersen SE, Selvanayagam JB, Wiesmann F, Robson MD, Francis JM, Anderson RH, et al. Left ventricular non-compaction: insights from cardiovascular magnetic resonance imaging. *J Am Coll Cardiol* 2005;46:101-5.

14. Fazio G, Novo G, D'Angelo L, Visconti C, Suter L, Grassedonio E, et al. Magnetic resonance in isolated noncompaction of the ventricular myocardium. *Int J Cardiol* 2010;140:367-9.

15. Oechslin EN, Attenhofer Jost CH, Rojas JR, Kaufmann PA, Jenni R. Long-term follow-up of 34 adults with isolated left ventricular noncompaction: a distinct cardiomyopathy with poor prognosis. *J*

Am Coll Cardiol 2000;36:493-500.

**16.** Sengupta PP, Mohan JC, Mehta V, Jain V, Arora R, Pandian NG, et al. Comparison of echocardiographic features of noncompaction of the left ventricle in adults versus idiopathic dilated cardiomyopathy in adults. *Am J Cardiol* 2004;94:389-91.

**17.** Murphy RT, Thaman R, Blanes JG, Ward D, Sevdalis E, Papra E, et al. Natural history and familial characteristics of isolated left ventricular non-compaction. *Eur Heart J* 2005;26:187-92.

**18.** Lofiego C, Biagini E, Ferlito M, Pasquale F, Rocchi G, Perugini E, et al. Paradoxical contributions of non-compacted and compacted segments to global left ventricular dysfunction in isolated left ventricular noncompaction. *Am J Cardiol* 2006;97:738-41.

**19.** Stöllberger C, Winkler-Dworak M, Blazek G, Finsterer J. Prognosis of left ventricular hypertrabeculation/noncompaction is dependent on cardiac and neuromuscular comorbidity. *Int J Cardiol* 2007;121:189-93.

**20.** Ichida F, Tsubata S, Bowles KR, Haneda N, Uese K, Miyawaki T, et al. Novel gene mutations in patients with left ventricular noncompaction or Barth syndrome. *Circulation* 2001;103:1256-63.

**21.** Alehan D. Clinical features of isolated left ventricular noncompaction in children. *Int J Cardiol* 2004;97:233-7.

**22.** Wald R, Veldtman G, Golding F, Kirsh J, McCrindle B, Benson L. Determinants of outcome in isolated ventricular noncompaction in childhood. *Am J Cardiol* 2004; 94: 1581-4.