

Arrhythmogenic ventricular cardiomyopathy and sudden cardiac death: Left or right?

Rachoin Rachoin, MD,^a Bernard Abi Saleh, MD,^b Bilal Mansour,^c
Rayan Jo Rachwan, MD,^d and Wael AlJaroudi, MD, FACC^e

^a Division of Cardiovascular Medicine, Hospital Notre Dame des Secours, Beirut, Lebanon

^b Division of Cardiovascular Medicine, Electrophysiology, American University of Beirut Medical Center, Beirut, Lebanon

^c Division of Radiology, Clemenceau Medical Center, Beirut, Lebanon

^d Division of Internal Medicine, American University of Beirut Medical School, Beirut, Lebanon

^e Division of Cardiovascular Medicine, Cardiac Imaging, Clemenceau Medical Center, Beirut, Lebanon

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Arrhythmogenic right ventricular cardiomyopathy is a leading cause of sudden cardiac death among athletes in Italy and the Mediterranean region. Although it often involves the right ventricle causing scarring, dilation, systolic impairment with aneurysm formation, it can also involve the left ventricle or present as isolated left ventricular cardiomyopathy. Cardiac magnetic resonance imaging is considered the gold standard in confirming the diagnosis. We summarize four cases of arrhythmogenic ventricular cardiomyopathy with different presentations observed over the past 2 years.

Key Words: Arrhythmogenic cardiomyopathy • cardiac MRI • sudden death • ventricular arrhythmias

Abbreviations		2DE	2-dimensional echocardiogram
ALVC	Arrhythmogenic left ventricular cardiomyopathy	RV	Right ventricular/ventricle
ARVC	Arrhythmogenic right ventricular cardiomyopathy	LV	Left ventricular/ventricle
CMR	Cardiac magnetic resonance imaging		

BACKGROUND

Arrhythmogenic right ventricular cardiomyopathy (ARVC) is a leading cause of sudden cardiac death among athletes in Italy and the Mediterranean region.¹⁻⁴ Although it often involves the right ventricle (RV) causing scarring, dilation, systolic impairment with aneurysm formation, it can also involve the left ventricle (LV) or present as isolated left ventricular cardiomyopathy (ALVC).¹ We present four cases observed over a relatively short period of time and highlight the role of multi-modality imaging in confirming the diagnosis.

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Rachoin Rachoin and Bernard Abi Saleh have contributed equally to this paper.

Reprint requests: Wael AlJaroudi, MD, FACC, Division of Cardiovascular Medicine, Cardiac Imaging, Clemenceau Medical Center, Beirut, Lebanon; wjaroudi@hotmail.com, wael.jaroudi@cmc.com.lb

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Case 1

A 46-year-old female with hypertension presented to an outside emergency room with nausea and vomiting. She suddenly became severely drowsy and lethargic. Her blood pressure and pulses were not palpable. She had no known history of cardiac disease, syncope, palpitation, or family history of sudden cardiac death and cardiomyopathy.

An electrocardiogram showed ventricular tachycardia originating from the apex of the RV (Figure 1, panel A) and she was successfully shocked back to normal sinus rhythm with electrical cardioversion. Her baseline electrocardiogram was remarkable for inverted T waves in V1-V6 with epsilon waves in the anterior leads (Figure 1, panel B, arrow).

A 2-dimensional echocardiogram (2DE) showed dilated RV with dyskinetic segments (Figure 1, panel C, arrow). A cardiac magnetic resonance imaging (CMR) confirmed the findings and showed severely dilated RV with dyskinetic and aneurysmal segments in the RV-free

wall, apex, and outflow tract (Figure 1, panels D-F, arrows, videos 1, 2) with moderately to severely impaired systolic function, and significant scar by late gadolinium enhancement (Figure 1, panels G-H, arrow).

Patient was diagnosed with ARVC and received an implanted cardiac defibrillator. Two months later, she received an appropriate shock.

Case 2

A 39-year-old female, sister of the patient in case 1, presented for screening after the diagnosis of her sibling. Her electrocardiogram showed T wave inversion in V1-V3 (Figure 2, panel A, arrow), and T wave inversion in the inferior leads, V4 and borderline V5 (Figure 2, panel A). The 2DE showed dilated RV (Figure 2, panel B) with mildly reduced systolic function. CMR showed focal dyskinetic segments of the RV lateral wall (Figure 2, panel C, arrow) and prominent epicardial fat pad particularly around the LV (Figure 2, panel C,

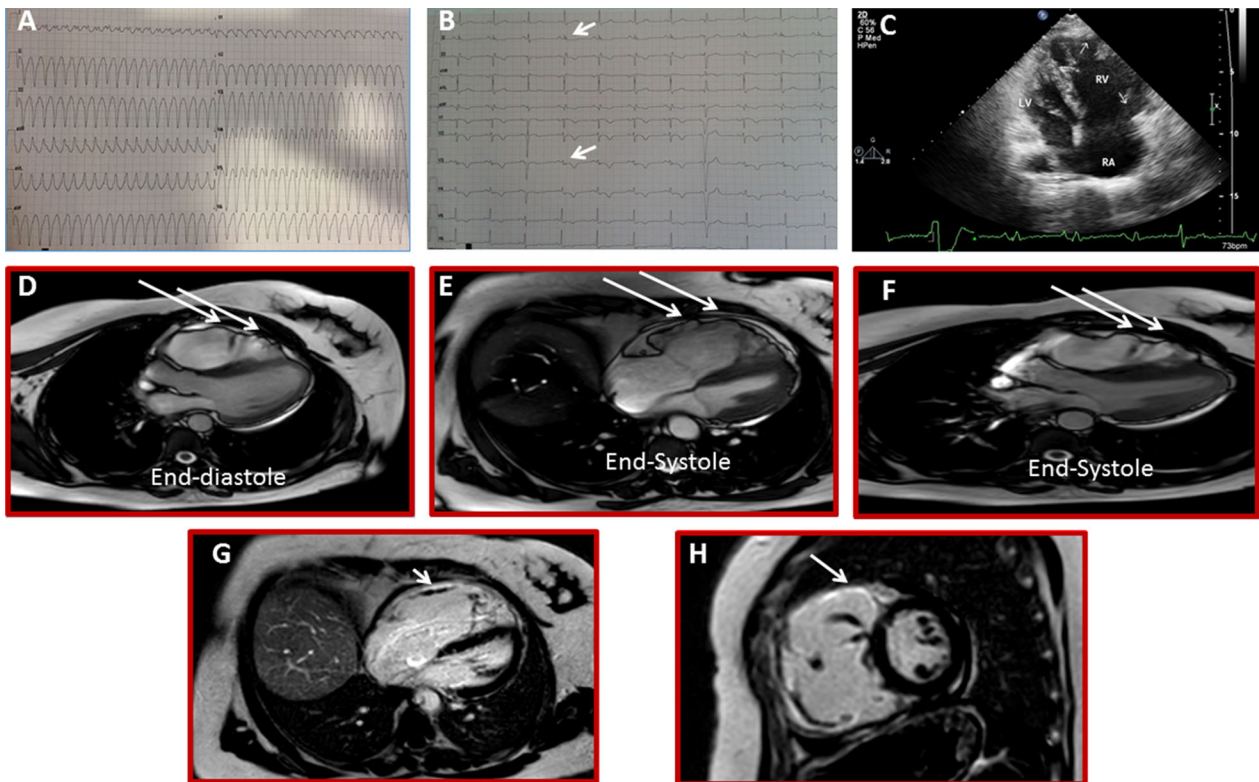


Figure 1. Electrocardiogram showing rapid ventricular tachycardia originating the RV apex (panel A). After cardioversion, there were inverted T waves in the anterior leads with epsilon wave (panel B, arrow). 2-dimensional echocardiogram showing dilated right ventricle (RV) with dyskinetic segments (panel C, arrow). CMR cine images obtained at end-diastole and systole showing dilated right ventricle with significant aneurysmal walls (panels D-F, arrows). Images obtained after gadolinium administration showing significant late gadolinium uptake and areas of scar and fibrosis in the right ventricle-free wall and near the outflow tract (panels G-H, arrows).

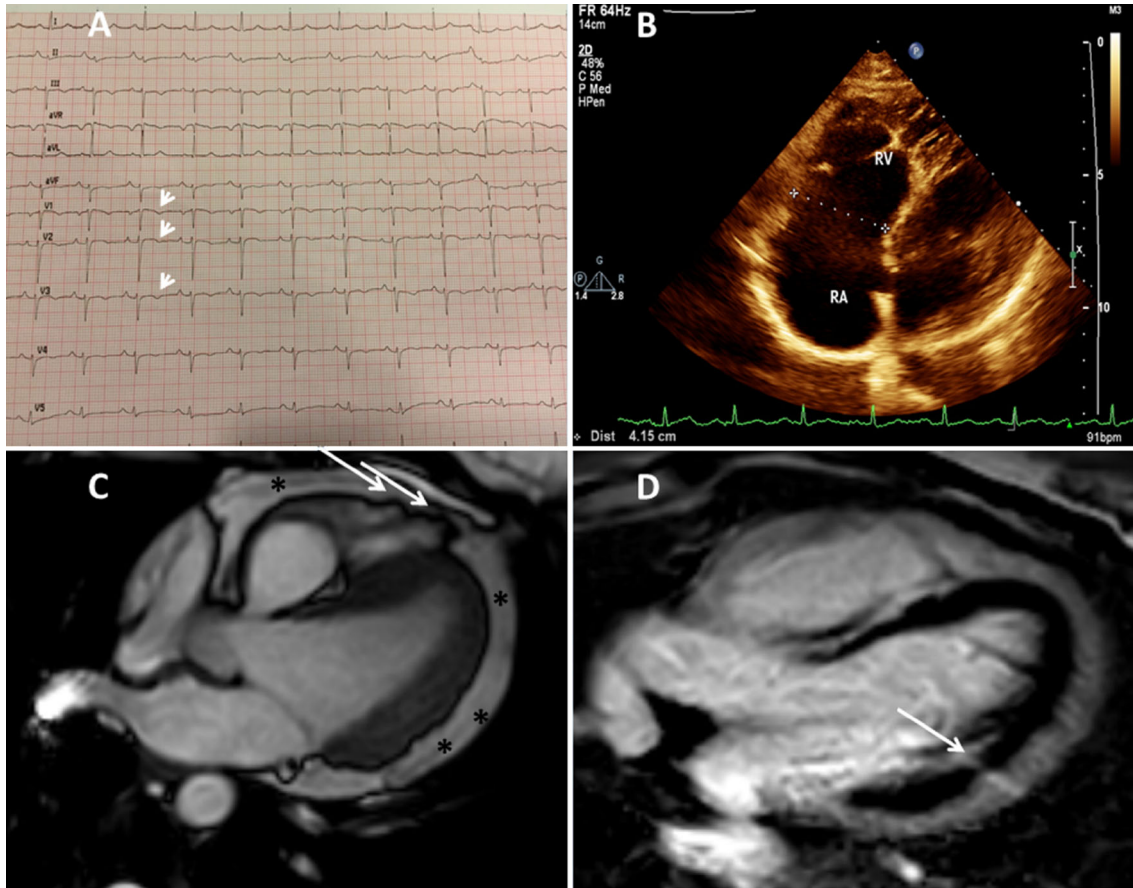


Figure 2. Baseline electrocardiogram showed inverted T waves in V1-V3 (panel A, arrows) and inverted T waves in inferior leads and in V4, borderline in V5. Panel B showed dilated right ventricle on the 2-dimensional echocardiogram. CMR cine image (panel C) shows focal dyskinetic segments in the right ventricular lateral wall (panel C, arrow) with prominent epicardial fat pad surrounding the left ventricle (panel C, asterisk), with the evidence of focal late gadolinium enhancement (panel D, arrow).

asterisk); after gadolinium administration, there was a focal enhancement of the LV mid-lateral wall (Figure 2, panel D, arrow). The findings were suggestive of arrhythmogenic ventricular cardiomyopathy with RV and early LV involvement. Subsequently, she received an implantable cardiac defibrillator for primary prevention.

Case 3

A 23-year-old male with positive family history of sudden cardiac death presented with palpitations and syncope. A rhythm strip showed a run of ventricular tachycardia (Figure 3, panel A, arrow). The baseline electrocardiogram was remarkable for abnormal Q waves in the lateral leads concordant with his LV location of the dysplasia (Figure 3, panel B, arrow), and a premature ventricular beat originating from the RV outflow tract (Figure 3, panel B, asterisk).

Subsequently, a 2DE (Figure 3, panel C, arrow) was performed followed by CMR (Figure 3, panel D, arrow) that showed normal RV size with mildly reduced systolic function and focal dyskinetic segments (arrow); however, there was a significant epicardial fat surrounding and infiltrating the lateral and anterolateral aspect of the LV (Figure 3, panel D, asterisk) with hypokinesia of the lateral and anterior walls (videos 3, 4) and corresponding areas of late gadolinium enhancement (Figure 3, panels E-F, arrows). Patient was diagnosed with arrhythmogenic RV and LV cardiomyopathy and received an implantable cardiac defibrillator.

Case 4

A 64-year-old male presented with ventricular tachycardia. He had no recent history of viral illness and his past medical history was unremarkable. Coronary angiography showed normal coronary arteries and

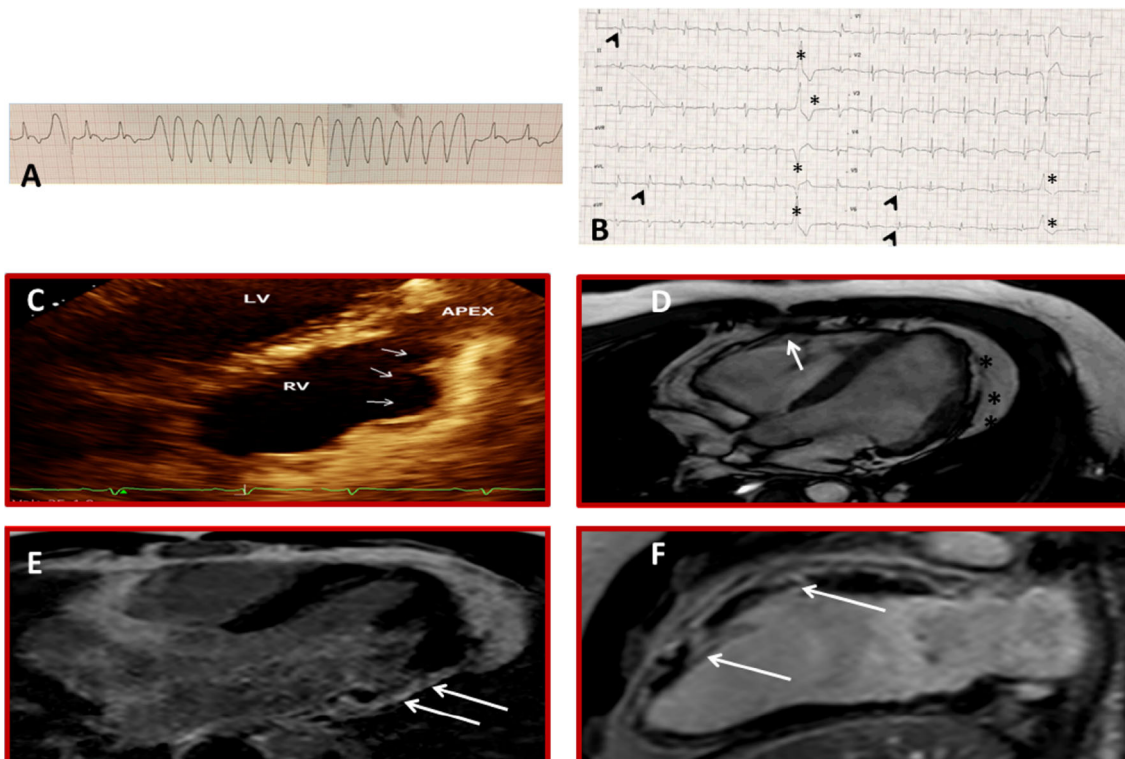


Figure 3. Rhythm strip showing a run of ventricular tachycardia (*panel A*). Resting electrocardiogram showed premature ventricular beat originating from the RV outflow tract (*panel B*, *asterisk*) and abnormal Q-waves (*panel B*, *arrow*) in the lateral leads concordant with his LV location of the dysplasia. 2DE showing dyskinetic segments in the right ventricular-free wall (*panel C*, *arrow*), also seen on CMR cine (*Panel B*, *arrow*). Prominent epicardial fat pad involving the lateral wall of the left ventricle (*panel D*, *asterisk*) with the evidence of significant late gadolinium enhancement (*panels E, F*, *arrows*).

normal LV function by left ventriculography. CMR was performed and showed mild LV and RV dilatation with low normal systolic function, dyskinetic segment of the distal RV-free wall (Figure 4, panels A, B, arrow). There was also a large epicardial fat pad distal to the RV that wrapped around the LV apex and the distal lateral wall (Figure 4, panel C, asterisk). Post gadolinium administration, there was a patchy mid-myocardial enhancement in the distal lateral wall of the LV (Figure 4, panel D, arrow), consistent with arrhythmogenic cardiomyopathy involving both ventricles.

DISCUSSION AND CONCLUSIONS

We have presented four cases of arrhythmogenic ventricular cardiomyopathy involving the RV, LV, or both (Table 1). This is an inherited condition that may present with arrhythmia, heart failure, or sudden cardiac death.⁵ The electrocardiographic manifestation of ARVC includes right ventricular parietal block, reduced QRS amplitude, epsilon wave, T wave inversion in V1-3 and ventricular tachycardia with left bundle branch

block morphology⁶, while ALVC presents with inverted T waves in the inferolateral leads.⁷ CMR plays an important role in the diagnosis by evaluation RV/LV volumes, ejection fraction, regional wall motion abnormalities that are often missed on 2DE, as well as LGE in either ventricles. Indeed, recent guidelines have adopted CMR and set major and minor criteria for the diagnosis.⁸ It is important to recognize and diagnose this cardiomyopathy early on, and screen family members given the genetic predisposition of the disease. The presence of baseline electrical and CMR abnormalities identifies a high-risk group that will benefit from a prophylactic implantable defibrillator.^{9,10} CMR also allows differentiation of arrhythmogenic ventricular cardiomyopathy from other mimickers and vice versa.¹¹ In fact, myocarditis occasionally is related to arrhythmogenic cardiomyopathy and might overlap in the early phases.¹² Certain mutations may increase susceptibility of myocarditis in arrhythmogenic ventricular cardiomyopathy.¹² Indeed, there are similarities between myocarditis, dilated cardiomyopathy and arrhythmogenic ventricular cardiomyopathy (particularly ALVC)

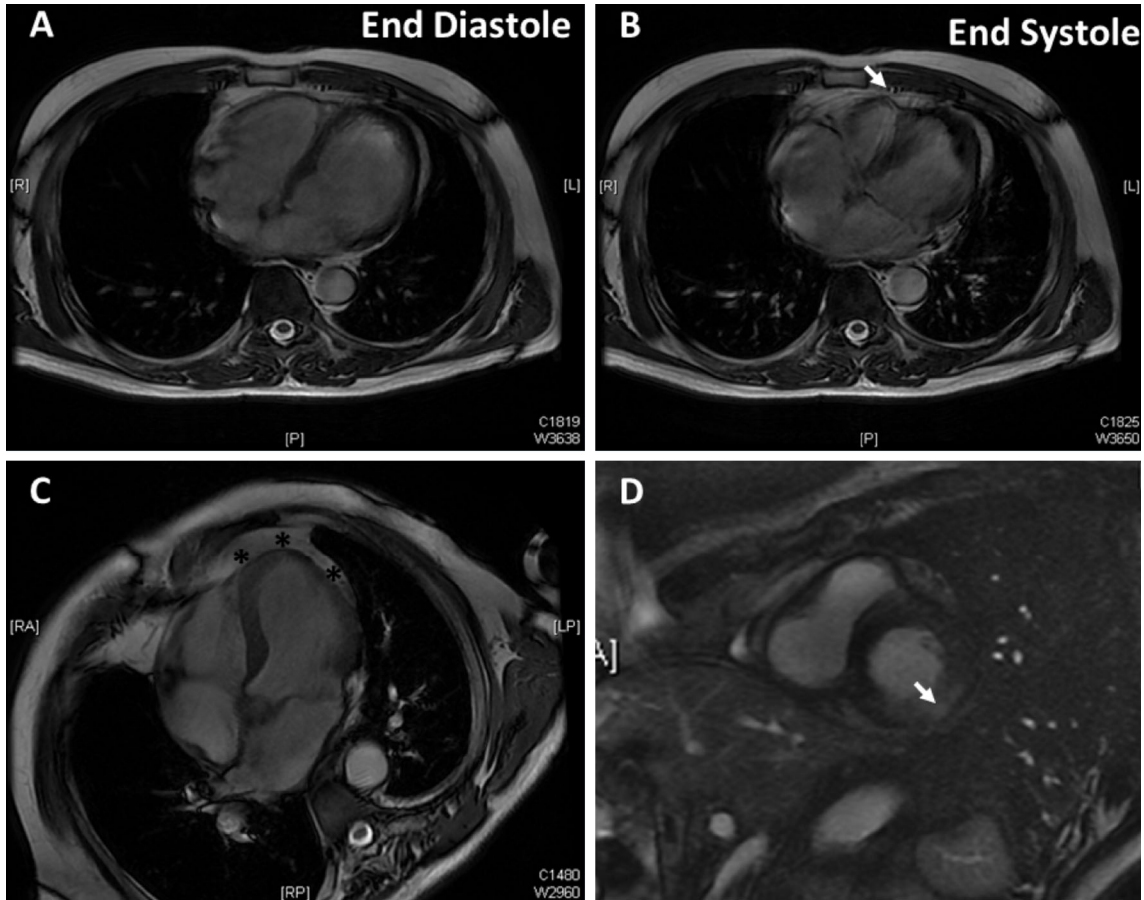


Figure 4. Still frame of a CMR cine image in end-diastole and end-systole showing dyskinetic segment of the distal right ventricular-free wall (*panels A, B, arrows*). A large epicardial fat pad starting from the distal right ventricle and wrapping the left ventricle distal lateral wall and apex is evident on CMR (*panel C, asterisk*) with patchy mid-myocardial late gadolinium enhancement of the lateral left ventricular wall (*panel D, arrow*).

Table 1. Ventricular volumes and ejection fractions

	LV end-diastolic volume index (ml/m²)	LV ejection fraction (%)	RV end-diastolic volume index (ml/m²)	RV ejection fraction (%)
Case 1	68	60	178	29
Case 2	72	53	107	40
Case 3	92	43	96	41
Case 4	101	55	113	49

Table 2. Mimickers of arrhythmogenic left ventricular cardiomyopathy

	Arrhythmogenic LV cardiomyopathy	Myocarditis	Dilated cardiomyopathy
Genetic predisposition	++	-	++
Involvement of the RV	++	-	±
Electrocardiogram	Inverted T waves inferolaterally	Non-specific	Non-specific
Arrhythmia	Ventricular tachycardia out of proportion to the EF (mean EF is low normal) More specific for ALVC	EF is usually depressed when patients present with arrhythmia Maybe seen in myocarditis	Usually significantly depressed EF
Regional wall motion abnormalities in the	Very specific/co-existent	Not seen	Usually global systolic dysfunction
Aneurysmal walls in the RV	Mid-septum/patchy	Mid-myocardial or epicardial (inferolateral most commonly)	Mid-septum (most commonly)
Late Gd enhancement	Epicardial/diffuse (more specific) May be extensive without significant regional wall motion abnormalities or systolic dysfunction	Extent often correlated with systolic dysfunction	If extensive, usually is associated with significant systolic dysfunction

EF, Ejection fraction; LV, left ventricle; RV, right ventricle

and distinction between the entities is necessary, although sometimes difficult (Table 2).

Authors' contributions

BA, RachR, RayR, and WA drafted the manuscript; RayR, BM, and WA revised the manuscript; BM and WA obtained the CMR images; RachR provided and interpreted the echo images; and BA and RayR provided and interpreted the ECGs. BA, RachR, WA, BM, and RayR participated in the collection of data and design of the case series; BM, WA, and RachR participated in the coordination of data. All authors read and approved the final manuscript.

Disclosures

The authors declare they have no competing interests.

Informed Consent

We have obtained the consent from the patients involved in the presented cases. Furthermore, the images were de-identified and we maintained patients' confidentiality.

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