

Palpitations

An Annoyance That May Require Clairvoyance

Brendan W. Reagan, MD; Robert L. Huang, MD, MPH; Walter K. Clair, MD, MPH

A 38-year-old man presents to his primary care physician for follow-up and review of the results of a 24-hour ambulatory monitor that was placed after an emergency department evaluation for palpitations and chest pain 2 days earlier.

He had been hospitalized 2 months earlier for severe headaches and elevated blood pressure. A workup for secondary causes of hypertension was negative, and he was started on bisoprolol and hydrochlorothiazide. He subsequently began experiencing intermittent episodes of lightheadedness and presyncope. Three days before seeing his primary care physician, he developed palpitations and central chest pressure radiating to his back associated with dyspnea at rest. When his wife, a registered nurse, checked his pulse and blood pressure, his heart rate was 140 to 160 beats per minute and regular. It slowed with a coached Valsalva maneuver. His wife noted his blood pressure was 140/70 mm Hg. He was taken to a local emergency department where, on arrival, his symptoms resolved and his vital signs normalized. The evaluation in the emergency department included electrolytes, a troponin, and a chest film that were all reportedly normal. He was discharged wearing a 24-hour ambulatory monitor with instructions to follow up with his primary care physician. He reported no syncopal episodes and denied orthopnea, paroxysmal nocturnal dyspnea, or lower-extremity edema.

His past medical history includes hypertension and degenerative joint disease. His only medications are the bisoprolol, hydrochlorothiazide, and an occasional non-steroidal anti-inflammatory drug for back pain. He has no allergies, but he had had an intolerable cough when taking an angiotensin-converting enzyme inhibitor for his hypertension in the past. He has no history of tobacco or illicit drug use. He occasionally drinks alcohol and 1 caffeinated beverage daily. He is married with 2 young daughters and is employed as a mechanical engineer. He recalls that a paternal cousin died shortly after receiving morphine for a kidney stone and that a paternal cousin died in his twenties of uncertain causes. He gives no family

history of premature coronary artery disease or confirmed sudden cardiac death.

On physical examination, his temperature is 98.0°F, blood pressure is 114/64 mm Hg while lying down, pulse is regular at 77 beats per minute, and respiratory rate is 18 breaths per minute with an oxygen saturation of 98% on room air. On standing, his blood pressure falls to 94/61 mm Hg and heart rate increases to 93 beats per minute. He is a muscular white man in no distress. There is no thyromegaly, and his jugular venous pressure is <8 cm H₂O. The carotid upstrokes are brisk without bruits. On cardiac examination, the point of maximal impulse is not displaced with a normal S₁ and S₂. There is no murmur, rub, or gallop. The lungs are clear to auscultation. The abdomen is soft and without pulsatile masses or bruits. The extremities are without edema. The femoral and pedal pulses are easily palpable.

Dr Clair: Palpitations are among the most common concerns of patients seen in our arrhythmia clinic. Their significance can range from benign annoyance to harbinger of sudden cardiac death. Thus, the evaluation of palpitations can be both frustrating and rewarding for the physician and patient.

When consulted regarding palpitations, there is generally a suspicion that the patient has an arrhythmia. However, nonarrhythmic causes of the sensation that one's heart beat is not right can occur. These may result from any source of induced (physical or mental) stress, excitement, fear, or anxiety. Most people are aware of these causes and seldom seek medical care because the sensation is predictable and self-limited. Although patients in this situation may not use these terms, most are experiencing sinus tachycardia, enhanced inotropy, or both. Several other conditions may result in similar sensations of a more sustained duration. These include anemia, hyperthyroidism, menopause, and drug (caffeine or nicotine) or alcohol intoxication or withdrawal. Occasionally these conditions may result in frank arrhythmias, such as premature atrial contractions, premature ventricular contractions, nonsustained ventricular tachycardia

From the Division of Cardiovascular Medicine, Vanderbilt University Medical Center, Nashville, TN (B.W.R., W.K.C.); and Division of Cardiology, Erlanger Medical Center/University of Tennessee College of Medicine, Chattanooga, TN (R.L.H.).

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Correspondence to Walter K. Clair, MD, MPH, Vanderbilt Heart and Vascular Institute, Vanderbilt University Medical Center, 1215 21st Ave South, 5th Floor MCE-North Tower, Suite 5209, Nashville, TN 37232-8802. E-mail walter.clair@vanderbilt.edu

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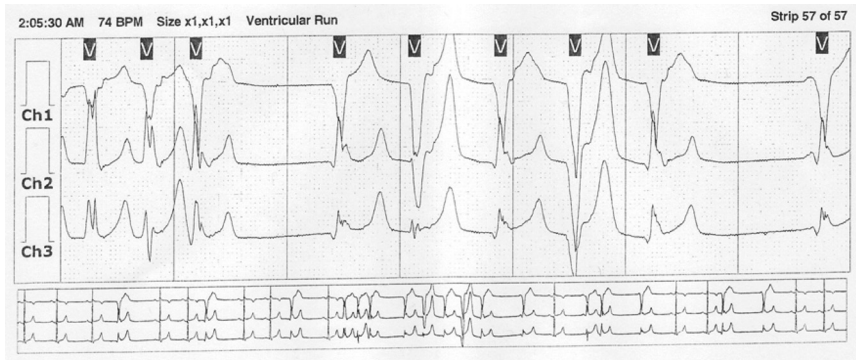


Figure 1. A representative strip from the 24-hour ambulatory monitor shows non-sustained ventricular tachycardia.

(NSVT), or a variety of atrial tachyarrhythmias (holiday heart¹).

Palpitations associated with dyspnea, syncope, or chest pain are more likely to be a result of a genuine arrhythmia. Consequently, palpitations in these situations are less likely to be benign and require more urgent evaluation. In this patient's case, chest discomfort and dyspnea imply that his palpitations are worthy of prompt evaluation. This involves an attempt to see whether one can correlate his palpitations with an actual arrhythmia, and a search for evidence of structural cardiac pathology, as well.

The 24-hour ambulatory monitor (Figure 1) documents multiple episodes of NSVT lasting as long as 26 beats. It also records 4665 premature ventricular contractions. His physician advises that he be immediately hospitalized, so he is sent to the general cardiology service of our hospital for further evaluation and management.

Dr Clair: This man's ambulatory monitor documents that frequent and complex ventricular ectopy is responsible for his palpitations and dyspnea. However, his ventricular ectopy (VE) does not seem to have a predominant morphology, and ambulatory monitoring is generally not helpful when characterizing the morphologies that are observed. Ideally, a 12-lead ECG of his ectopy would be more helpful. The morphology of VE often gives a clue to its site of origin and suggests a framework for thinking about clinical entities that may result in VE and tachycardia.² The most common cause of frequent and complex VE is ischemic heart disease either as a result of a scar or ischemia. A scar usually yields a single morphology, and ischemia is more likely to result in polymorphic VE. When there is a single morphology, it seems intuitive that, with the left ventricle accounting for most of the cardiac muscle, it should account for most of the VE, and thus, one would not be surprised to see a right bundle-branch morphology when a 12-lead ECG is able to capture beats of ventricular origin. However, because the septum may be considered part of the left ventricle, right or left bundle branch morphology ectopic beats may be seen in ischemic heart disease. When the morphology has only a left bundle branch block configuration, one should broaden the differential diagnosis to include conduction over an accessory pathway, bundle branch reentry, right ventricular outflow tract ventricular tachycardia, or VE resulting from right ventricular dysplasia or cardiomyopathy.³

Most patients who present with palpitations or NSVT on ambulatory monitoring will be in sinus rhythm when a 12-lead ECG is done. Nonetheless, inspection of the PR interval, the terminal portion of precordial QRS, the precordial ST segments, and the length of the QT interval can give some hints as to whether a specific arrhythmic syndrome is present. If the PR interval is short, one should look for hints of preexcitation. On the other hand, if it is long, consider whether or not the patient could be having intermittent degrees of heart block. A wide QRS suggests disease in the His-Purkinje system that could also result in intermittent heart block. Incomplete or complete right bundle-branch block makes one suspicious of arrhythmogenic right ventricular cardiomyopathy (ARVC) or Brugada syndrome. One should inspect the terminal portion of the QRS for evidence of an epsilon wave or prolongation of the S wave in the precordial leads. Either of these may also be seen in patients with ARVC. In the inferior limb leads and lateral precordial leads one should look for J-point elevation, which may be seen in idiopathic ventricular fibrillation. The ST segment in the right precordial leads must be reviewed for the ECG changes characteristic of a Brugada pattern. Finally, the QT interval must be assessed to see if it is long or unusually short.⁴

On arrival at our hospital, his ECG (Figure 2) demonstrates normal sinus rhythm, incomplete right bundle branch block, and multiple T-wave abnormalities. Complete blood cell count, electrolyte, renal function, and thyroid function testing results are all normal.

Dr Clair: His ECG reveals an incomplete right bundle-branch block with abnormal depolarization in the terminal portion of his QRS in leads III, AVF, and V1 to V3. There are flipped T waves in leads II and AVF, and biphasic T waves in leads V1 to V3, as well. Thus, he has evidence of depolarization and repolarization abnormalities on his ECG suggesting structural cardiac pathology as the source of his electric pathology. His abnormal ECG, in association with chest discomfort, compels us to look for evidence of coronary artery disease or its sequelae. It is prudent to avoid stress tests in patients who are reporting chest discomfort in association with frequent VE, unless there is thought to be a very low likelihood of ischemia. One should still consider the possibility that this man may have a dilated, inflammatory, infiltrative, hypertrophic, or dysplastic cardiomyopathy. Balancing test sensitivity, invasiveness, risks, and expense, I

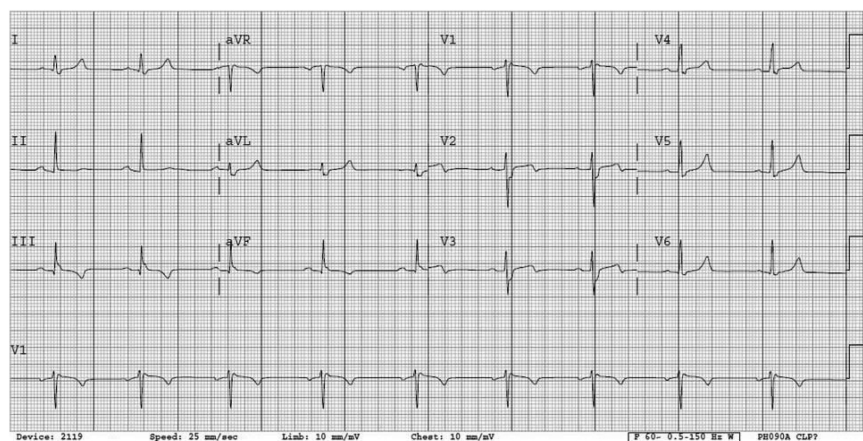


Figure 2. The ECG shows sinus rhythm, multiple nonspecific T-wave abnormalities, and abnormal precordial QRS complexes with an incomplete right bundle branch block and unusual terminal portion.

would next order an echocardiogram and cardiac catheterization.

A transthoracic echocardiogram shows normal left ventricular function and chamber size, normal right ventricular function with its size at the upper limits of normal, and no valvular or pericardial abnormalities. No aneurysms are observed. (See online-only Data Supplement Movie I.) Cardiac catheterization reveals normal coronary arteries and a normal left ventricular ejection fraction of $>65\%$. On telemetry, he continues to have frequent VE that is associated with his palpitations and chest discomfort. Next the Cardiac Arrhythmia Service is consulted.

Dr Clair: Despite his history of hypertension, the echo shows no evidence of left ventricular hypertrophy; nor is there evidence of hypertrophic cardiomyopathy. This leaves us with a man with frequent VE associated with palpitations and chest discomfort. In addition to his abnormal ECG, the echo is not completely normal with right ventricular dimensions described as the upper limits of normal. At cardiac catheterization, neither a biopsy nor a right ventriculogram was performed. Because these data are unavailable, I would next request a cardiac magnetic resonance study looking for evidence of a cardiomyopathy, myocarditis, right ventricular dysplasia, or foci of abnormal myocardium that may be a source of his arrhythmias.

Cardiovascular MRI (Figure 3 and online-only Data Supplement Movie II) shows a borderline dilated left ventricle with normal LV mass and systolic function. The right ventricle is dilated with normal global right ventricular systolic function, although the distal one-third of the right ventricle is akinetic. There is subendocardial delayed enhancement of the distal one-third of the right

ventricle. The ratio of the RV end-diastolic volume to body surface area is 97.82 mL/m^2 .

Dr Clair: The technique of delayed myocardial enhancement MRI was initially developed as a means of characterizing myocardial scarring after myocardial infarction. It is now known that this technique is useful in a variety of disorders. Regardless of the associated pathological process, delayed enhancement identifies noncontracting scar or fibrotic tissue that serves as an arrhythmogenic substrate. Although we do not have the necessary tracings to correlate the morphology of his VE with the described area of right ventricular akinesia, the MRI results provide us with a probable explanation for some of his ECG abnormalities and ectopy. He has no evidence of coronary artery disease to account for his RV akinesia; nor does he have a history of myocarditis.

With the data we now have, a diagnosis of ARVC is very likely. However, there is no single test that confirms this diagnosis. Rather, the diagnosis is made on the basis of a combination of major and minor criteria. His aneurysm on MRI along with his several thousand premature ventricular contractions on a 24-hour ambulatory monitor are not sufficient to fulfill recommended diagnostic criteria, and his ECG findings are borderline. The signal-averaged ECG is a tool used to measure localized areas of slowed conduction in abnormal, scarred, or infarcted myocardium. Areas of slowed conduction may serve as components of ventricular arrhythmia circuits and are often targets when ablation therapy is used to treat arrhythmias. These sites generate microvolt-level signals that are termed "late potentials." Based on the association of late potentials on the signal-averaged ECG with the diagnosis of ARVC,⁵ a positive signal-averaged ECG is one of the minor criteria for diagnosing ARVC and should be ordered next.

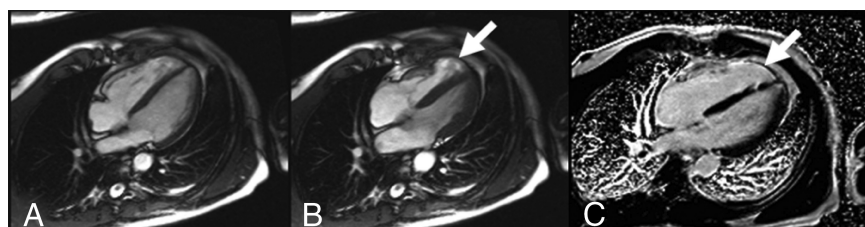


Figure 3. The cardiac MRI shows diastolic (A) and systolic (B) still frames with the akinetic segment of the distal RV denoted by the white arrow (B). C, The delayed enhancement image shows subendocardial enhancement of the distal third of the RV (white arrow).

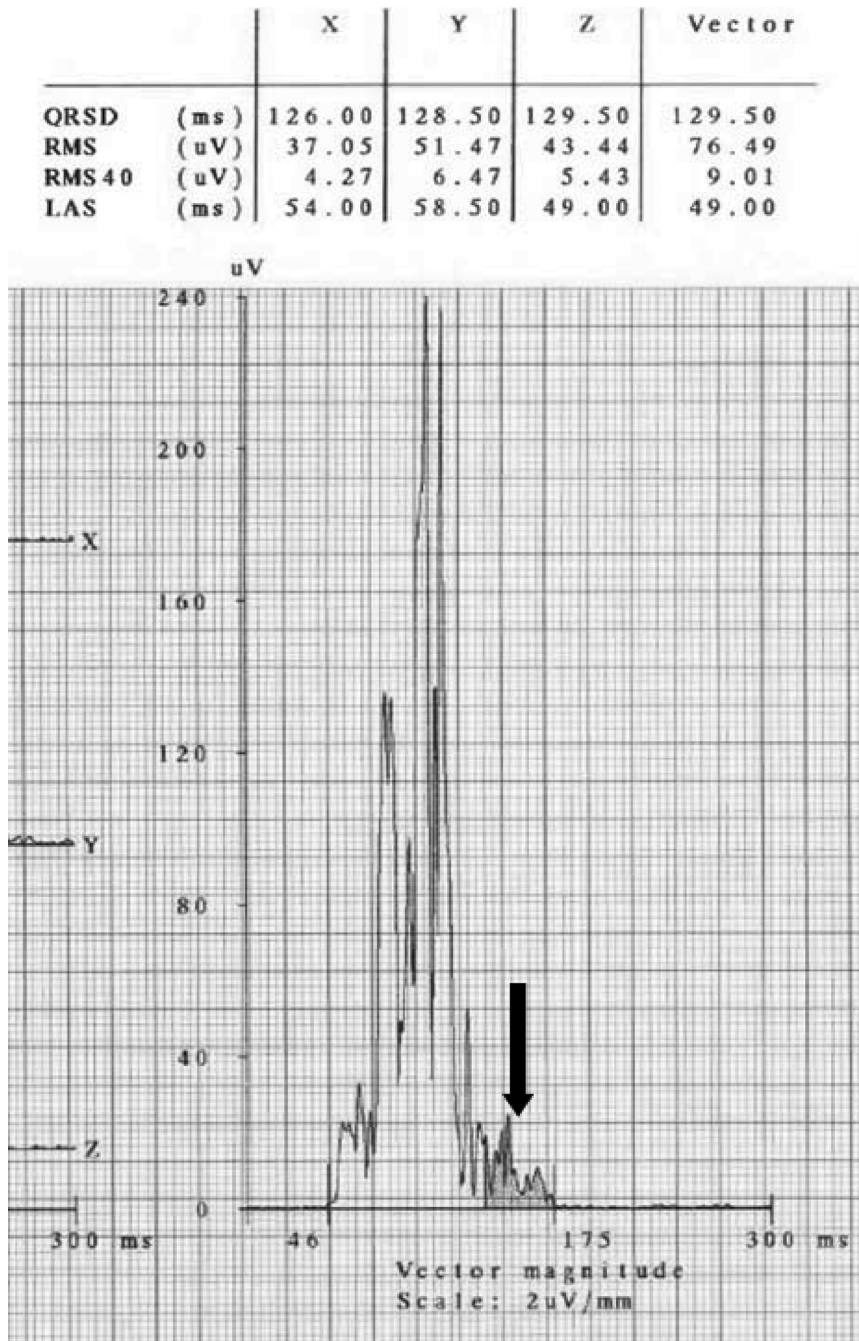


Figure 4. The signal-averaged ECG-filtered vector magnitude shows abnormalities of all 3 parameters: the filtered QRS duration (QRSD), the low-amplitude signal duration below 40 μ V (LAS), and the root-mean-square voltage of the last 40 milliseconds of the QRS (RMS-40). The delayed afterdepolarization is indicated by the solid arrow.

A signal-averaged ECG (Figure 4) is positive for late potentials and his bisoprolol and hydrochlorothiazide are switched to metoprolol followed by a significant decrease in his VE. He is advised that he meets criteria for the diagnosis of ARVC and an implantable defibrillator is recommended.

Dr Clair: Using the 1994 International Task Force guidelines,⁶ this man has one major (RV akinesis) and 2 minor (> 1000 premature ventricular contractions in 24 hours and late potentials) criteria for the diagnosis of ARVC. A biopsy or genetic testing could strengthen the diagnosis, but negative results with either of these would not likely alter treatment.

In treating this patient, it is important to deal with his prognosis, and his ongoing symptoms, as well. The evolving knowledge about ARVC must be conveyed to this patient in an honest and caring manner if his physician is to cultivate confidence and compliance on his part. Explaining to this man that he has a potentially life-threatening illness that may have serious implications for his daughters is best done in the setting of a scheduled meeting with his wife present rather than during the course of morning rounds. His palpitations are for him the most tangible manifestation of his cardiomyopathy. Although an attempt to suppress his ectopy is appropriate, allowing him to focus on this misses the big picture. There is general agreement that in patients with ARVC who

have had sustained ventricular tachycardia (VT) or ventricular fibrillation an implantable cardioverter defibrillator (ICD) should be implanted.⁷ This is also true if the patient has extensive disease or has a family member who has had sudden death for unclear reasons. Because this man has not had a previous cardiac arrest or sustained VT, an ICD would be considered primary prevention and would depend on the clinical judgment of those caring for him. I feel that, in light of his right ventricular akinesis and frequent ectopy, an ICD should be strongly considered. It is our most reliable way to decrease his chances of dying suddenly. I would also advise him to avoid strenuous exercise or competitive athletics. With regard to his family, I would refer him to our genetics clinic.

He initially declines an ICD, but later agrees to have 1 implanted in addition to using medical therapy to suppress his VE. He is also advised to avoid strenuous physical activity. He is evaluated in the cardiac genetics clinic, but his health insurance provider declines to pay for genetic testing. Interrogation of the ICD 2 months after implantation demonstrates 7 episodes of VT terminated with antitachycardia pacing and several episodes of NSVT. His blood pressure continues to be elevated, and an angiotensin-receptor blocker is started. Because of concern about erectile dysfunction, sotalol is substituted for metoprolol. The burden of VE worsens, and the patient is admitted following 3 episodes of VT successfully terminated by ICD shocks. He is finally switched from sotalol to amiodarone with rare episodes of NSVT and no episodes of arrhythmias requiring antitachycardic pacing or shocks during an additional 12 months of follow-up. Now that the price of genetic screening has decreased, the patient is considering paying for it out of pocket.

Dr Clair: The man presented in this case was diagnosed using the 1994 criteria before the proposed modification of the criteria was published in 2010⁸ (Table). Under the 2010 proposed criteria, his MRI findings would have been considered minor and he would have been classified as possible rather than definite ARVC. This likely would have led to more testing. Genetic testing would have taken weeks, but a biopsy or electrophysiology study could have been done and would have been paid for by his insurance company. Even without these data, his appropriate shocks for VT several months after his ICD implantation support his need for the ICD. Nonetheless, genetic testing to potentially strengthen the accuracy of the diagnosis is functionally more important to his daughters than to him.⁹ Therefore, he should be strongly encouraged to have genetic testing now that the cost is more affordable.

Discussion

Arrhythmogenic right ventricular cardiomyopathy is a rare disorder characterized by both a cardiomyopathy and an inheritable arrhythmia syndrome resulting from mutations in genes involved in the structure and function of desmosomes.^{10,11} In $\approx 50\%$ of cases, it is transmitted in an autosomal dominant pattern with variable penetrance and presents with symptomatic ventricular arrhythmias or sudden cardiac death in young adults. The early literature focused on the

pathological findings of adipose and fibrous tissue replacing myocytes in the right ventricle. Advances in cellular, molecular, and genetic biology have revealed that what was initially thought to be a dysplastic disorder of the right ventricle is actually the most common variant of cardiomyopathic disorders of cardiac myocyte adhesion that can involve the left ventricle as well.¹² Naxos disease is an autosomal recessive inherited disorder manifested as a triad of right ventricular dysplasia, wooly hair, and ketatoderma. The identification of a plakoglobin gene mutation in families with Naxos disease sparked research on a variety of genes that code for related genes. As a result, we now understand that these cardiomyopathies are the result of a variety of mutations in the genes that are essential for the normal functioning of the desmosomes, which are specialized intercellular junctions of cardiac and epithelial cells.¹⁰ Malfunction of desmosomes results in deterioration of the structure of the myocardium making the right ventricle and, to a lesser extent, portions of the left ventricle, vulnerable to shear forces.

The seriousness of the worse phenotypic features of ARVC resulted in attempts to characterize the clinical features of these cardiomyopathies and guide prognosis and treatment long before a genetic basis was discovered. Most of the current literature is based on the use of the 1994 International Task Force Criteria for the diagnosis of arrhythmogenic right ventricular cardiomyopathy/dysplasia.⁶ These were the criteria used to make the diagnosis in the patient being discussed. More recently, in an attempt to utilize advances in diagnostic techniques and to enhance the sensitivity for detection of early-stage disease and familial disease, proposed modifications of these criteria have been made.⁸ Unlike the 1994 criteria, the new 2010 Task Force Criteria assign patients a definite, borderline, or possible diagnosis of ARVC based on the number of major and minor criteria fulfilled in 6 separate categories. These modified criteria are actually more specific in the echocardiographic and MRI parameters required for the diagnosis. Although both of these modalities can be used to diagnose ARVC, as demonstrated in the case presented, echocardiography may fail to detect abnormalities that are captured by MRI. In addition, MRI has become the more preferred modality when one is working up cardiomyopathies noninvasively or when one is seeking reassurance that the heart is structurally normal.

The new criteria also include inverted T waves in the right precordial ECG lead as a major criterion and specify the requirements for late potentials on the signal-averaged ECG as a minor criterion. The epsilon wave, which is a low amplitude signal at the end of the QRS in the precordial leads, continues to be a major criterion.

The most contemporary addition to the 2010 Task Force Criteria has been the inclusion of the identification of a pathogenic mutation as a major criterion. Obviously, this criterion has only recently been scientifically possible. As demonstrated by the patient presented, genetic testing is often not economically practical for some patients.¹³ Furthermore, not all probands have a mutation that can be detected by using currently available screening technology. Because the role of genotyping in familial assessment and management is still

Table. 2010 Revised Task Force Criteria

Major	Minor
Global or regional dysfunction and structural alterations	
By 2D echo:	By 2D echo:
<ul style="list-style-type: none"> Regional RV akinesia, dyskinesia, or aneurysm And 1 of the following (end diastole): <ul style="list-style-type: none"> PLAX RVOT ≥ 32 mm (corrected for body size [PLAX/BSA] ≥ 19 mm/m²) PSAX RVOT ≥ 36 mm (corrected for body size [PSAX/BSA] ≥ 21 mm/m²) Or fractional area change $\leq 33\%$ 	<ul style="list-style-type: none"> Regional RV akinesia or dyskinesia And 1 of the following (end diastole): <ul style="list-style-type: none"> PLAX RVOT ≥ 29 to < 32 mm (corrected for body size [PLAX/BSA] ≥ 16 to < 19 mm/m²) PSAX RVOT ≥ 32 to < 36 mm (corrected for body size [PSAX/BSA] ≥ 18 to < 21 mm/m²) Or fractional area change $> 33\%$ to $\leq 40\%$
By MRI:	By MRI:
<ul style="list-style-type: none"> Regional RV akinesia or dyskinesia or dyssynchronous RV contraction And 1 of the following: <ul style="list-style-type: none"> Ratio of RV end-diastolic volume to BSA ≥ 110 mL/m² (male) or ≥ 100 mL/m² (female) Or RV ejection fraction $\leq 40\%$ 	<ul style="list-style-type: none"> Regional RV akinesia or dyskinesia or dyssynchronous RV contraction And 1 of the following: <ul style="list-style-type: none"> Ratio of RV end-diastolic volume to BSA ≥ 100 to < 110 mL/m² (male) or ≥ 90 to < 100 mL/m² (female) Or RV ejection fraction $> 40\%$ to $\leq 45\%$
By RV angiography:	
<ul style="list-style-type: none"> Regional RV akinesia, dyskinesia, or aneurysm 	
Tissue characterization of wall	
<ul style="list-style-type: none"> Residual myocytes $< 60\%$ by morphometric analysis (or $< 50\%$ if estimated), with fibrous replacement of the RV free wall myocardium in ≥ 1 sample, with or without fatty replacement of tissue on endomyocardial biopsy 	<ul style="list-style-type: none"> Residual myocytes 60% to 75% by morphometric analysis (or 50% to 65% if estimated), with fibrous replacement of the RV free wall myocardium in ≥ 1 sample, with or without fatty replacement of tissue on endomyocardial biopsy
Repolarization abnormalities	
<ul style="list-style-type: none"> Inverted T waves in right precordial leads (V1, V2, and V3) or beyond in individuals > 14 y of age (in the absence of complete right bundle-branch block QRS ≥ 120 ms) 	<ul style="list-style-type: none"> Inverted T waves in leads V1 and V2 in individuals > 14 y of age (in the absence of complete right bundle-branch block) or in V4, V5, or V6 Inverted T waves in leads V1, V2, V3, and V4 in individuals > 14 y of age in the presence of complete right bundle-branch block
Depolarization/conduction abnormalities	
<ul style="list-style-type: none"> Epsilon wave (reproducible low-amplitude signals between end of QRS complex to onset of the T wave) in the right precordial leads (V₁ to V₃) 	<ul style="list-style-type: none"> Late potentials by SAEKG in ≥ 1 of 3 parameters in the absence of a QRS duration of ≥ 110 ms on the standard ECG Filtered QRS duration (fQRS) ≥ 114 ms Duration of terminal QRS < 40 μV (low-amplitude signal duration ≥ 38 ms) Root-mean-square voltage of terminal 40 ms ≤ 20 μV Terminal activation duration of QRS ≥ 55 ms measured from the nadir of the S wave to the end of the QRS, including R', in V₁, V₂, or V₃, in the absence of complete right bundle-branch block
Arrhythmias	
<ul style="list-style-type: none"> Nonsustained or sustained ventricular tachycardia of left bundle-branch block morphology with superior axis (negative or indeterminate QRS in leads II, III, and aVF and positive in lead aVL) 	<ul style="list-style-type: none"> Nonsustained or sustained ventricular tachycardia of RV outflow configuration, left bundle-branch block morphology with inferior axis (positive QRS in leads II, III, and aVF and negative in lead aVL) or of unknown axis > 500 ventricular extrasystoles per 24 hours (Holter)
Family history	
<ul style="list-style-type: none"> ARVC/D confirmed in a first-degree relative who meets current Task Force Criteria ARVC/D confirmed pathologically at autopsy or surgery in a first-degree relative Identification of a pathogenic mutation categorized as associated or probably associated with ARVC/D in the patient under evaluation 	<ul style="list-style-type: none"> History of ARVC/D in a first-degree relative in whom it is not possible or practical to determine whether the family member meets current Task Force Criteria Premature sudden death (< 35 y of age) due to suspected ARVC/D in a first-degree relative ARVC/D confirmed pathologically or by current Task Force Criteria in second-degree relative

Diagnostic terminology is as follows: definite diagnosis, 2 major or 1 major and 2 minor criteria or 4 minor from different categories; borderline, 1 major and 1 minor or 3 minor criteria from different categories; and possible, 1 major or 2 minor criteria from different categories. PLAX indicates parasternal long-axis view; RV, right ventricular; RVOT, RV outflow tract; BSA, body surface area; PSAX, parasternal short-axis views; ARVC/D, arrhythmogenic right ventricular cardiomyopathy/dysplasia; BSA, body surface area; and SAEKG, signal-averaged ECG.

Adapted from Marcus et al permission.⁸

evolving,¹⁴ it is best handled in the context of genetic counseling.

The majority of patients who currently have implantable defibrillators for ARVC were most likely diagnosed using the 1994 criteria. As they consider generator changes, the results of genetic testing, and follow-up of these patients and their families, physicians should be clear on the differences between the 2 sets of criteria. As in the case presented, it may be found that some of these patients fall into the possible or borderline categories of the new criteria. Disease progression, genetic testing, and diagnostics from their ICDs will help investigators assess how many of these patients might have been misclassified. However, there is no consensus on how to manage new patients who are assessed as possible or borderline under the 2010 Task Force Criteria. The patients' and their physicians' risk tolerance in combination with the clinical presentation (arrhythmia or heart failure) will likely guide management.

There are no therapies that specifically target the progression of ARVC.^{11,15} Therefore, most of the current management centers around mitigating the risk of sudden death and controlling symptoms while heart failure therapies are administered on an as needed basis with a small percentage of patients progressing to heart transplantation. There is general agreement that in patients with ARVC who have had sustained VT, ventricular fibrillation, and aborted sudden cardiac death, an ICD should be implanted if the patient would likely survive another year. This is no different from any other cardiac arrest survivor. Although no consensus has been formed on the basis of clinical trials, there is a growing feeling that observational studies justify primary prevention ICD implantation in ARVC patients who demonstrate certain risk factors, such as nonsustained VT on monitoring, inducible sustained VT or ventricular fibrillation, extensive involvement of the right ventricle, or male sex.⁷ The potential benefits of a primary prevention ICD implantation must be considered in the context of the implantation risks, burden of follow-up, and the socioeconomic impact on the patient and family.

Patients should be counseled to avoid competitive sports and strenuous physical exercise, because these have been thought to increase the risk of sudden cardiac death as a result of acute RV overload and sympathetic stimulation.¹⁶ Contemporary antiarrhythmic therapy includes β -blockers and class III antiarrhythmics (sotalol and amiodarone). The recommendations for these agents have mainly been based on anecdote, extrapolation from other conditions, and studies that did not differentiate among agents.¹⁷ In 1 study, sotalol was shown to decrease recurrent VT and sudden cardiac death¹⁸; however, limitations of this study include the lack of ICDs (and their ability to detect recurrent VT) in all patients and the use of electrophysiology studies to guide pharmacological therapy.¹⁹ A more recent study questioned the use of sotalol and β -blockers as first-line therapy and found that amiodarone was more effective in suppression of ventricular arrhythmias. Unfortunately, this was a very small study and only 10 patients received amiodarone.²⁰ Thus, the role of antiarrhythmic drug therapy is adjunctive and directed at decreasing the frequency, duration, and severity of the asso-

ciated VE. Radiofrequency ablation plays a similar adjunctive role. In the setting of frequent sustained VT, ablation can have an acute success rate of $\approx 80\%$, but long-term there is often recurrence of VT. Because ARVC is a progressive disease with an evolving electric substrate,²¹ this should not be surprising.

The assessment of the impact of the proposal for revised criteria for the diagnosis of ARVC has resulted in a renewed interest in ARVC. Additionally, there is continued reflection on the best use of MRI²² and genotyping to accurately diagnose and manage this disorder. Until we develop disease-modifying or curative therapies,²³ the ICD offers our best safety net for affected patients and their families.

Disclosures

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Brendan W. Reagan, Robert L. Huang and Walter K. Clair

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