Cardiac Magnetic Resonance Imaging in Idiopathic Ventricular Arrhythmia: Impact on Clinical Management

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Abstract

Background: Ventricular arrhythmia (VA) without structural heart disease on the echocardiogram is often deemed as idiopathic in origin (IVA). Recent literature however, suggests that a cardiac magnetic resonance (CMR) based assessment strategy can provide insights into subtle abnormalities and tissue alterations not detectable by echocardiography.

Objective: This study prospectively evaluated the diagnostic yield of CMR and its impact on clinical management in patients with IVA.

Methods: CMR was performed in consecutive patients who suffered at least one documented episode of ventricular tachycardia or ventricular fibrillation (VT or VF) and had normal ventricular dimensions and function on echocardiogram. The CMR protocol consisted of cine imaging for ventricular dimensions and function and tissue characterization using T2 weighted and late gadolinium enhanced imaging to evaluate for structural changes.

Results: Thirty patients (38 ± 9 years, 60% males) underwent CMR acquisition. Twelve patients had LBBB morphology during VT and 17 had RBBB morphology during VA. Baseline ECG and echocardiogram in all patients did not show any gross abnormality. CMR showed no structural or functional abnormalities in 21 patients (70%). The remaining 9 patients showed a spectrum of abnormal CMR findings (arrhythmogenic cardiomyopathy 23%, inflammation 3.3%, non-compaction 3.3%).

Conclusion: CMR revealed functional and/or structural abnormalities in a significant number of patients with an initial diagnosis of IVA. These results suggest that the routine use of CMR in the diagnostic work up of this sub-group of patients can have a significant impact on the therapeutic strategy.

Keywords: Cardiac Magnetic Resonance; cMRI; Idiopathic Ventricular Tachycardia; Structural Heart Disease; Ventricular Tachycardia

Introduction

Idiopathic ventricular arrhythmia (IVA) have an estimated incidence of 62 per 100,000-person years; this has significantly increased in the past years [1]. Studies aimed at identifying the underlying arrhythmogenic substrate in this patient group typically utilize an investigative approach limited to electrocardiography and echocardiography when screening for structural heart disease (SHD) [2,3].

Although this strategy is in compliance with the current guideline [4], recent studies have detected structural cardiac abnormalities in patients with IVA using cardiac magnetic resonance imaging (CMR). A recent study applied CMR derived structural and functional information to differentiate between IVA and arrhythmogenic right ventricular cardiomyopathy (ARVC) [5]. More recent results report studying tissue alterations due to myocardial-inflammation [6] or fibrosis [7] using the unique tissue characterization capability of CMR.

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Despite this increased diagnostic yield of a CMR based evaluation in patients with IVA, current guidelines have allocated a moderate recommendation (class IIa) for the use of CMR in this patient group. This is perhaps due to paucity in the available level of evidence.

The goal of this study was to prospectively evaluate CMR for detecting indicators of structural heart disease (edema and fibrosis) in patients with ventricular arrhythmia in presence of a normal echocardiogram and coronary angiogram.

Methods

Patient Population

The study population comprised 30 consecutive patients who had suffered at least one documented episode of sustained VA during last one year, and had a) no gross abnormality on electrocardiogram in sinus rhythm b) normal ventricular dimensions and function on echocardiogram and c) no obstructive coronary artery disease on the angiogram. Patients with PVCs or Non-Sustained VA are not included. The study complied with the declaration of Helsinki. Written informed consent was obtained from all study subjects. The study was approved by the institutional review board of the hospital.

CMR protocol and analysis

All patients underwent CMR acquisition on a 1.5 Tesla Multiva (Philips Medical Systems, Best, Netherlands). Steady state free precession (SSFP) cine imaging was performed in the long-axis (4, 3 and 2 chamber) and short-axis (SAX) covering both ventricles. Typical imaging parameters were: slice thickness 6 mm, slice gap 4 mm, repetition time 32 msec, echo time 1.54 msec, flip angle 578 and an in-plane image resolution of 1.4 by 1.4 mm.

Tissue characterization was performed using T2-weighted imaging in the cardiac views. Late gadolinium enhanced (LGE) imaging was acquired 10 - 15 minutes after 0.2 mmol/kg Dotarem (Guerbet Group, Villepente, France) contrast agent injection using an inversion recovery gradient echo pulse sequence.

Analysis of the CMR was performed by an experienced, ESC level III trained, investigator (PB) blinded to clinical data and results of other imaging modalities. Left and right ventricular Cine images were analyzed for ventricular dimensions and function (ejection fraction) using endocardial contours at end-systole and end-diastole. T2-weighted and LGE images were analyzed for the presence of edema or scar using CV I42 software (Circle Cardiovascular Imaging, Alberta, Canada).

Normal CMR parameters were defined as per the definition of Kawel-Boehm, et al. in Journal of Cardiovascular Magnetic Resonance [8].

Electrocardiography of VA

Twelve lead surface electrocardiograms were acquired and analyzed a) during sinus rhythm, to look for chamber enlargement and/or ST-T changes that fit into standard diagnostic criteria for ARVC, channelopathy or raised suspicion of underlying myocardial disease and b) during ventricular arrhythmia, for documenting ventricular rate, QRS morphology and frontal plain QRS axis.

Echocardiography

Echocardiography was performed by an experienced operator, who was aware of the clinical presentation and characteristics of the VA. AL studies were done on Phillips EPIQ 7 machine (Koninklijke Philips N.V). Particular care was taken to analyze the right and left ventricular volumes and function, including tissue Doppler imaging (TDI).

A repeat Echocardiogram was done by another operator to confirm absence of abnormality, in all patients in whom CMR reported any pathology.

Coronary angiography

Cine coronary angiography was performed in all patients, on Siemens Artis Pure (Siemens AG), to look for obstructive disease or any other abnormality of epicardial coronary vessels.

Statistical analysis

Statistical analysis was performed using IBM SPSS (Version 20.0). Continuous variables were expressed as mean ± standard deviation. Normally distributed data were compared using the independent Student’s t-test. A p < 0.05 was considered to be statistically significant.

Results

Baseline characteristics of the study population are given in table 1. A total of 30 patients were included in this study. Twenty-nine patients presented with palpitations as their chief complaint and one patient presented with syncope. Mean age of the group was 38 ± 9 years (60% males). LV ejection fraction (EF) on echo (58.67 ± 2.8%); this was comparable to that on CMR (57.9 ± 1.75%) (p = 0.11). RVEF was 47.37 ± 2.37% on echo and 47.33 ± 1.93% on CMR (p = 0.47).

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>p value</th>
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</thead>
<tbody>
<tr>
<td>N</td>
<td>30</td>
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<tr>
<td>Age (years)</td>
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<tr>
<td>Male (%)</td>
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<tr>
<td>LVEF TTE (%)</td>
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<td>LVEF CMR (%)</td>
<td>57.9 ± 1.75</td>
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<tr>
<td>RVEF TTE (%)</td>
<td>47.37 ± 2.37</td>
</tr>
<tr>
<td>RVEF CMR (%)</td>
<td>47.33 ± 1.93</td>
</tr>
</tbody>
</table>

**Table 1: Baseline characteristics.**

LVEF: Left Ventricular Ejection Fraction; RVEF: Right Ventricular Ejection Fraction; TTE: Trans-Thoracic Echocardiography; CMR: Cardiac Magnetic Resonance Imaging; IVA: Idiopathic Ventricular Arrhythmia; LBBB: Left Bundle Branch Block; RBBB: Right Bundle Branch Block; QTc: Corrected QT.

Electrocardiography

Baseline ECG of all the patients was normal (including the corrected QT-interval). Seventeen patients had right bundle branch block (RBBB) QRS morphology during VA and twelve patients had left bundle branch block (LBBB) morphology (Table 2). In one patient a polymorphic VT degenerating into VF was observed (Figure 1). There was no abnormality on the QRS morphology during VT to suggest atypical features/myocardial disease (QRS notching, delayed intrinsicoid deflection or atypical QRS axis).

**Figure 1:** ECG recorded from a patient presenting with syncope. ECG recording shows runs of polymorphic VT degenerating into VF. All these runs are preceded by a PVC (arrows).
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Echocardiogram

All patients had normal left and right ventricular structure and function on trans-thoracic echocardiography (TTE). Mean LVEF was 58.67 ± 2.8% and the mean RVEF was 47.37 ± 2.37%. No abnormality of RV/RVOT dimensions/function/structure was observed.

CMR findings

Out of 30 patients, 21 (70%) had no structural or functional abnormality on CMR, whereas 9 had abnormal CMR findings (Figure 2). Mean LVEF was 57.9 ± 1.75% and mean RVEF was 47.33 ± 1.93%.

Table 2: Ventricular Arrhythmia characteristics.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Ventricular Rate (bpm)</th>
<th>QRS morphology</th>
<th>Axis</th>
<th>Final/CMR Diagnosis</th>
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<td>2</td>
<td>174</td>
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<td>Non-Compacted LV</td>
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<td>ARVC</td>
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<tr>
<td>4</td>
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<td>188</td>
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<td>Left</td>
<td>ILVT</td>
</tr>
<tr>
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<td>RVOT VT</td>
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</tbody>
</table>

Ventricular arrhythmia characteristics: bpm: Beats Per Minute; LBBB: Left Bundle Branch Block; RBBB: Right Bundle Branch Block; ARVC: Arrhythmogenic Right Ventricular Cardiomyopathy; ALVC: Arrhythmogenic Left Ventricular Cardiomyopathy; ILVT: Idiopathic Left Ventricular Tachycardia; LVOT VT: Left Ventricular Outflow Tachycardia; RVOT VT: Right Ventricular Outflow Tract Ventricular Tachycardia.

Six patients (20%) had imaging features suggestive of ARVC, including RV dilatation, wall motion abnormalities and presence of LGE (Figure 3, left panel). One patient (3%) had features of isolated ALVC in the form of sub-epicardial enhancement in the left ventricular inferior/lateral wall on the LGE images (Figure 3, right panel). One patient (3%), who had presented with polymorphic VT degenerating into VF, showed localized inflammation. This patient was being evaluated for chronic febrile illness. He presented with syncope secondary to polymorphic VT and required electrical cardioversion. CMR depicted a focal myocardial inflammatory lesion in the infero-posterior LV wall with localized dyskinesia. These findings suggested localized inflammation (Figure 4). One patient (3%) had features of non-compacted LV with a non-compacted to compacted ratio of > 3:1.
Impact of CMR on treatment strategy

CMR identified structural heart disease in 9 patients (30%) initially deemed as IVA. These findings had implications on the clinical management of 5 patients (16.6%) (Figure 5). Treatment strategy in one patient (3%) with inflammation on CMR changed from planned implantation of an automatic implantable cardioverter defibrillator (AICD) to catheter ablation, in addition to medical treatment. Premature ventricular complexes initiating the VF episodes were targeted during catheter ablation (Figure 1). Repeat CMR done after three months in this patient, revealed resolution of previous MR abnormalities. Patient has been arrhythmia free at a follow-up of more than one year.

Figure 4: Localized inflammation.
Stills from CMR showing dyskinetic movement (white arrows) at infero-basal portion of LV (end-systolic and end-diastolic frames). Right panel shows a T2 weighted image with increased signal intensity at the segments with wall motion abnormalities (blue circle).

Figure 5: Changes in clinical management using a CMR-based evaluation.
Findings from the CMR acquisition led to clinical management being changed in 5 patients. One patient (3%) with inflammation on CMR was changed from AICD implantation to radiofrequency ablation (RFA) + medical management. Three patients with 1 major imaging criteria for ARVC (10%) and 1 patient (3%) with ALVC had implantation of an automatic implantable cardioverter defibrillator instead of management with RFA alone.

Three patients (10%) with 1 major imaging criterion for ARVC and 1 patient (3%) with ALVC on CMR, had implantation of an AICD instead of management with catheter ablation alone. The patient with ALVC has had 3 therapies for VT on a follow-up of 18 months, while the other 2 patients have not received any ICD therapy at a mean follow-up of 15 months. Three patients who had only minor imaging criteria but did not fulfill the modified task force criteria of ARVC were treated with medical management (n = 2) and/or catheter ablation (n = 2). All of these three patients are event free at a minimum follow-up of 12 months.

Target for catheter ablation was guided by VT/PVC morphology, local intracardiac electrogram and pace-mapping. Ablation was not directed at areas of the ventricle showing CMR abnormality. Post-hoc analysis of the ablation site showed CMR abnormality at the ablation target site in 2 of the 5 patients. Endocardial Voltage maps during electrophysiology study did not show any area of scar in any patient.

Discussion

Echocardiography is currently the recommended modality according to guidelines for cardiac evaluation in case of ventricular arrhythmia; CMR can improve the quality of imaging in the setting of structural heart disease using its ability for tissue characterization [9]. Various groups are now investigating the potential role of CMR to tailor therapeutic management by evaluating fibrosis and scar location [10-13]. Systematic evaluation of the utility of CMR in the setting IVA has not been widely reported.

Comparative utility of echocardiography vs. CMR

CMR offers a better imaging quality and has the ability for tissue characterization too. The sensitivity of echocardiography is reduced when evaluating the right ventricle in the present study echocardiography failed to demonstrate cardiac abnormalities in significant number of patients who were characterized as idiopathic, on the basis of a normal echocardiogram and coronary angiogram. These findings are in concordance with previous results where it is hypothesized that the focal nature of these subtle abnormalities play a role in the decreased utility of echocardiography in such clinical situations [14,15]. These limitations could explain the lack of association in previous studies between idiopathic VT and underlying structural abnormalities. In line with these findings it may be concluded that echocardiography may no longer be the diagnostic tool of choice for evaluation of patients with VA. Abnormalities detected on CMR had critical impact on management decision in this study. The cohort consisted of a mixed population of patients with VA, but all were characterized as Idiopathic, on the basis of Echocardiography findings.

Available CMR data on IVA

Cardiac MRI has been found to be more sensitive than echocardiography for detecting structural abnormalities in this subset of patients and presence of structural cardiac abnormalities in apparently idiopathic VTs has been noted in a few previous reports. Proclemer, et al. detected right ventricular structural abnormalities in 20% to 27% of patients with right ventricular outflow tract ventricular tachycardia. Abnormalities included right ventricular dilatation and wall motion abnormalities suggestive of arrhythmogenic right ventricular dysplasia [16]. In a study by Krittayaphong R., et al. CMR abnormalities were demonstrated in 24 (58.5%) patients with RVOT VT [17]. Carlson MD., et al. found structural and wall motion abnormalities of right ventricle in 95% (21 of 22) of patients with RVOT VT [18]. In the current study, 9/30 patients (30%) were detected to have structural abnormalities using CMR. These findings had a significant impact on the management of 5 patients (16.6%).

In contrast to our study where patients with all types of IVA were included, previous studies consisted of patients who suffered from RVOT VTs only. Moreover, these studies were performed several years ago; improvement in the technology and ‘learning-curve’ may explain the different rates of detection of structural abnormality.

Limitations

1. There is a limited number of patients in each of the major sub-group of patients i.e; ALVC, Inflammatory Myocardial Disease and ARVC/D
2. Genetic testing of these patients for ARVC is being done, but is not available at the time of this publication.

Conclusion

CMR based assessment reveals functional and structural abnormalities in a significant number of patients with idiopathic ventricular arrhythmia. The findings had a substantial impact on the clinical management of these patients. These results indicate that routine use of CMR in this patient group may be warranted for a tailored therapeutic strategy.
Conflict of Interest
None.
Funding
None.
Author’s Contribution
Vikas Kataria and Pranav Bhagirath both authors contributed equally to this manuscript.

Bibliography


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