






**ORIGINAL RESEARCH**

# Diagnostic Impact of Repeated Expert Review & Long-Term Follow-Up in Determining Etiology of Idiopathic Cardiac Arrest

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**BACKGROUND:** Recognizing the etiology of sudden cardiac arrest (SCA) has an enormous impact on the management of victims and their immediate families. A significant proportion of SCA survivors with a structurally normal heart are not offered a diagnosis and there is no clear consensus on the type and duration of follow-up. We aimed to assess the utility of a multidisciplinary approach in optimizing diagnosis of cardiac arrest etiology during follow-up.

**METHODS AND RESULTS:** We retrospectively assessed 327 consecutive SCA survivors (mean age 61.9±16.2 years, 80% men) who underwent secondary prevention implantable cardioverter defibrillators between May 2015 and November 2018. The initial diagnosis was recorded at the time of admission and follow-up diagnosis was deduced from subsequent clinic records, investigations, and outcomes of multidisciplinary team meetings. Structural heart disease accounted for 282 (86%) of SCAs. Forty-five (14%) patients had a structurally normal heart and underwent comprehensive testing and follow-up (mean duration 93±52 weeks). On initial evaluation, 14/45 (31%) of these received a diagnosis, rising to 29/45 (64%) with serial reviews during follow-up. Discussion in multidisciplinary team meetings and imaging reassessment accounted for 47% of new diagnoses. No additional diagnoses were made beyond 96 weeks. Nineteen (5.8%) fatalities occurred in the entire cohort, exclusively in patients with structural heart disease.

**CONCLUSIONS:** Systematic comprehensive testing combined with multidisciplinary expert team review of SCA survivors without structural heart disease improves the yield and time to diagnosis compared with previously published studies. This approach has positive implications in the management of SCA survivors and their families.

**Key Words:** cardiomyopathy ■ channelopathy ■ defibrillators ■ idiopathic ventricular fibrillation ■ ischemic heart disease ■ sudden cardiac death

**S**udden cardiac arrest (SCA) is defined as the sudden cessation of cardiac activity in the absence of trauma, drowning, respiratory failure or asphyxia, electrocution, drug overdose, or any other non-cardiac cause.<sup>1</sup> It has been widely reported that the most common cause of SCA is ischemic heart disease especially in individuals over the age of 40 years. A smaller proportion of victims have a

structurally normal heart where initial investigations including cardiac imaging and coronary angiography do not yield a diagnosis. These are often attributed to inherited ion channel disorders such as Brugada syndrome, Long QT syndrome, and catecholaminergic polymorphic ventricular tachycardia. Some aetiologies may have an early concealed phase which is not apparent on initial investigations or the

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## CLINICAL PERSPECTIVE

### What Is New?

- The use of a multidisciplinary team approach improves the yield and time to diagnosis in unexplained sudden cardiac arrest survivors compared with previously published studies.
- The diagnostic yield of comprehensive and systematic follow-up beyond 96 weeks is low in unexplained sudden cardiac arrest survivors.

### What Are the Clinical Implications?

- Collaborative communication and open discussion in a cardiac multidisciplinary team setting enhances diagnosis of etiology in sudden cardiac arrest survivors and thereby the management of these patients.
- The study reinforces the need to review all investigations rigorously and highlights the importance of maintaining vigilance for the identification of subclinical but life-threatening cardiac disorders.

## Nonstandard Abbreviations and Acronyms

<b>ARVC</b>	arrhythmogenic right ventricular cardiomyopathy
<b>DCM</b>	dilated cardiomyopathy
<b>ERS</b>	early repolarization syndrome
<b>HCM</b>	hypertrophic cardiomyopathy
<b>LQT</b>	long QT
<b>MDT</b>	multidisciplinary team
<b>SCA</b>	sudden cardiac arrest

arrest itself may be a potential cause for mild structural changes.<sup>2</sup> A more comprehensive evaluation is advocated for assessing such patients including advanced imaging, Holter monitoring, exercise electrocardiography, ajmaline provocation testing, familial screening, and genetic testing.

However, despite systematic cardiac evaluation with these investigations and familial screening, a cause for SCA is not identified in some patients. Rarely, SCA is attributed to idiopathic ventricular fibrillation (IVF), defined as resuscitated cardiac arrest, preferably with documentation of VF, in whom known cardiac, respiratory, metabolic, and toxicological causes have been excluded through clinical evaluation.<sup>3</sup> There is no clear consensus as to how such patients should be managed, or how often the etiology of SCA becomes more apparent over time.<sup>4,5</sup> In this context, we evaluated the incremental utility of the evaluation by a

multidisciplinary team meeting (MDT) follow-up of SCA survivors through examining data from our large tertiary center.

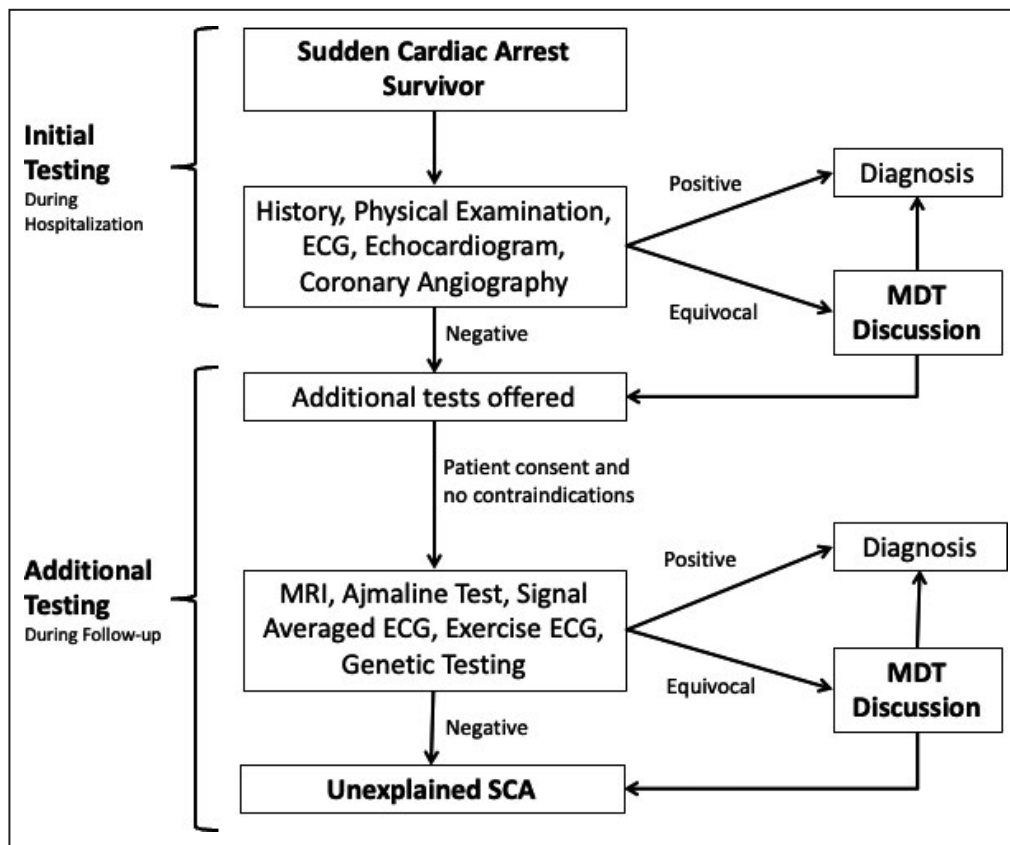
## METHODS

Data were collated from a local registry of cardiac device implants which is shared with the UK National Institute for Cardiovascular Outcomes Research (NICOR). The registry is an electronic database of all cardiac implants performed in our hospital since 2015 and collected via a commercial software (*Medicconnect, Fleischhacker, Germany*). Demographic, device, and clinical data of a patient are entered immediately following a device implant, by a cardiac physiologist. The implanting cardiologist then validates the data entered, completes the procedure report, and uploads the data to the registry. The data entered are audited annually to ensure data quality and to monitor levels of device complications. We retrospectively examined all secondary prevention implantable cardioverter defibrillators (ICDs) including transvenous ICDs, cardiac resynchronisation therapy defibrillators (CRTDs), and subcutaneous ICDs implanted between May 2015 and November 2018 at Barts Heart Centre. All patients were SCA survivors with documented ventricular tachycardia or ventricular fibrillation which terminated spontaneously or required external electrical cardioversion. Patients who did not have SCA, did not have documented VT or VF, or had a primary prevention ICD were excluded.

Barts Heart Centre is one of Europe's largest cardiac units and on average implants >1400 cardiac devices per year and includes specialists in electrophysiology, cardiomyopathy, heart failure, cardiac imaging, inherited arrhythmias, congenital heart disease, and percutaneous coronary intervention. A network of MDT meetings between sub-speciality groups discusses challenges in diagnosis and management by reviewing previous investigations and making further diagnostic recommendations.

Patients who have survived SCA undergo initial comprehensive cardiac testing including a history, physical examination, ECG, echocardiogram, and coronary angiography. Additional investigations are routinely performed if initial tests are inconclusive and include cardiac MRI, Ajmaline challenge test, signal averaged ECG exercise ECG, and genetic testing (Figure 1). These were selected on the basis of patient consent and absence of contraindications.

Patients receiving a secondary prevention device following SCA were analysed. Clinical records including physician entries and investigations were used to determine etiology of the SCA. Sudden cardiac death was defined based on the 2017 AHA/



**Figure 1.** Schematic flow chart for the investigation of SCA survivors and the role of the MDT. MDT indicates multidisciplinary team meeting; MRI, magnetic resonance imaging; and SCA, sudden cardiac arrest.

ACC/HRS Guideline for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death.<sup>1</sup> A structurally normal heart was defined as the absence of ischemic heart disease, absence of evidence of heart muscle disease, valvular heart disease, or congenital heart disease.<sup>1</sup> The initial diagnosis was recorded from clinical notes at the time of admission to hospital with the index episode. Follow up diagnosis and outcomes were deduced from clinic records, outpatient review, and outcomes of MDT meetings.

### Structure and Function of MDT Meetings

Patients with an unexplained cardiac arrest were referred to a specialist Inherited Cardiac Conditions (ICC) MDT on the basis of any new or equivocal findings in the history, physical examination or investigations during systematic follow-up. The MDT convenes weekly and is attended by at least one cardiac imaging specialist, a cardiomyopathy specialist, an electrophysiologist with a specialist interest in inherited arrhythmias, a geneticist, an interventional cardiologist, and a specialist ICC nurse. The entire history, physical examination, and investigations are systematically reviewed in their raw format from electronic records that include

ECG, echocardiograms, cardiac MRIs, coronary angiograms, and genetic results. The outcome of the meeting is documented as a consensus from the majority of attendees and includes a new diagnosis for the SCA (where possible) or further investigations to reach a diagnosis.

### Statistical Analysis and Ethical Approval

Data are expressed as mean±standard deviation (SD), or n (%) as appropriate and analyzed using SPSS, version 22, (IBM, Chicago, IL). Continuous variables were tested for normality using a Shapiro-Wilk test. Group differences were tested with an independent sample t test or Mann-Whitney U test for normally and non-normally distributed variables, respectively. The Fishers exact test and the chi squared test were used to assess categorical data.

The study complies with the Declaration of Helsinki. A locally appointed ethics committee has approved the research protocol and informed consent has been obtained from the relevant institution to retrospectively analyse anonymized data.

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## RESULTS

Between May 2015 and November 2018, 327 SCA arrest survivors received secondary prevention ICDs including 261 (79.8%) men and 66 (20.2%) women with a mean age of 61.9±16.2 years. The etiology of SCA at initial evaluation on index presentation is summarized in Figure 2A. Structural heart disease in the form of ischemic heart disease, cardiomyopathies, valvular heart disease, or congenital heart disease accounted for 282 (86%) of SCAs. The 100 cases of cardiomyopathies observed included dilated cardiomyopathy (n=46), hypertrophic cardiomyopathy (n=17), arrhythmogenic right ventricular cardiomyopathy (ARVC) (n=7), Sarcoid (n=7), myocarditis (n=3), and undifferentiated cardiomyopathy (n=20).

Forty-five (14%) patients had a structurally normal heart. Six of the SCAs observed in those with a structurally normal heart occurred during exertion, the remainder occurred at rest or during sleep. Systematic initial testing yielded diagnoses in 14 (31%) of these 45 cases: Long QT syndrome (n=8), Brugada Syndrome (n=5), and catecholaminergic polymorphic ventricular tachycardia (n=1). The remainder (n=31, 69%) did not have a definitive diagnosis after initial systematic testing and were deemed unexplained.

### Follow-Up of Unexplained SCAs (n=31)

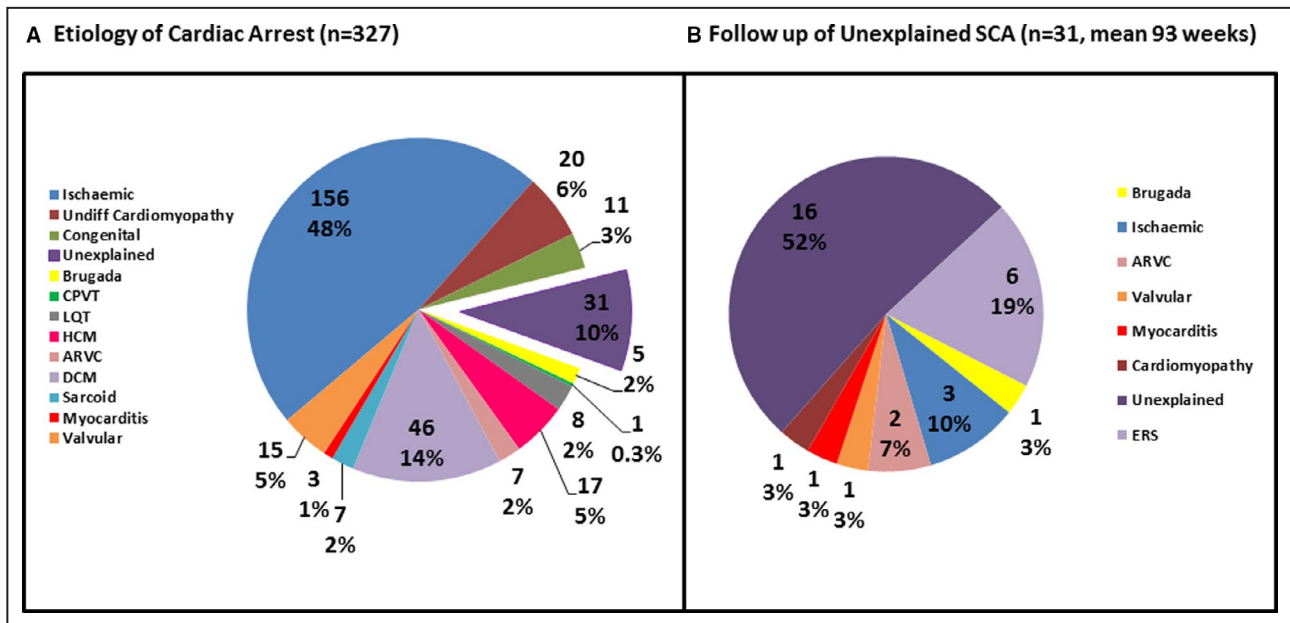
Patients with an unknown etiology were followed up for a mean of 93 (±52) weeks (range 12–166 weeks). During this period, 15 (48%) of this cohort had a newly

established diagnosis for the index SCA (Figure 2B). Details of subsequent diagnosis are displayed in Table with examples in the case vignettes. Investigations and their diagnostic yield in unexplained SCA survivors are shown in Figure 3.

Six (19.4%) patients with unexplained SCA underwent genetic testing with dedicated channelopathy and cardiomyopathy panels. Mutations considered pathogenic were detected in 1 patient (16.7%): a PKP2 mutant consistent with ARVC. The PKP2 mutation facilitated a diagnosis of ARVC on the basis of published diagnostic criteria<sup>6</sup> and allowed potentially life-saving screening in family members.

Six cases (6/31, 19.4%) of unexplained SCA survivors displayed early repolarization (ER) changes on their resting 12-lead ECG. This was exclusively of horizontal ST segment morphology and in the lateral leads. A diagnosis of early repolarization syndrome (ERS) was made on the basis of published ECG criteria<sup>7</sup> and exclusion of other cardiac diagnosis during the follow-up period.

Chronologically, no additional diagnosis was made beyond 96 weeks during this follow-up period (Figure 4). Five (5/31, 16.1%) of unexplained cardiac arrest survivors received either an appropriate shock or appropriate anti-tachycardia pacing (ATP) from their defibrillator device. The mean therapy rate in these patients was 2.7±1.6 shocks or ATP occurring on average at 28±16 weeks. They included a patient with ARVC (see case vignette 1), a patient with a subsequent diagnosis of coronary artery disease and a patient with



**Figure 2. Etiology of SCA in survivors who underwent secondary prevention implantable cardioverter defibrillators.** **A**, Etiology of 327 consecutive SCA survivors at initial assessment. **B**, Follow-up of unexplained SCA (n=31) following a mean duration of 93 weeks. ARVC indicates arrhythmogenic right ventricular cardiomyopathy; CPVT, catecholaminergic polymorphic ventricular tachycardia; DCM, dilated cardiomyopathy; ERS, early repolarization syndrome; HCM, hypertrophic cardiomyopathy; LQT, long QT; SCA, sudden cardiac arrest; and undiff, undifferentiated.

**Table. Patients With Subsequent Diagnosis Following Initial Unexplained SCA**

Sex	Age	Presentation	Final Diagnosis	Notes	Time for Diagnosis (wk)
Female	71	VT	Valvular heart disease	Discussion in ICC MDT with review of imaging data	1
Male	44	VF	Myocarditis	Discussion in ICC MDT and review of cardiac MRI	1
Male	40	VT/VF	Ischemic heart disease	First angiogram showed patent LAD stent, good flow. After subsequent shocks, repeat angiography showed positive pressure wire indicative of impaired perfusion, re-stented	12
Male	79	VF	Ischemic heart disease	Reassessment of symptoms revealed chest pain prior to event and review of initial coronary angiography showed underestimated significant coronary artery disease with >50% stenosis which was medically managed	16
Male	35	VF	Brugada Syndrome	Ajmaline performed late as patient too unwell during initial admission which was complicated by aspiration pneumonia so performed after discharge	42
Male	55	VT	ARVC	Discussion in ICC MDT-Cardiac biopsy after repeat CMR (Case vignette 1)	48
Male	56	VT/VF	Ischemic heart disease	Repeat angiography showed coronary spasm and right coronary artery stenosis (Figure 4)	48
Male	21	VT	ARVC	Non-sustained VT on device interrogation, normal CMR but pathogenic PKP2 mutation on genetic testing	49
Female	70	VF	Mitral valve prolapse and cardiomyopathy	Discussion in ICC MDT-Review of imaging and TEE (Case vignette 2)	92

Diagnosis of early repolarization syndrome is not included. ARVC, arrhythmogenic right ventricular cardiomyopathy; CMR, cardiac magnetic resonance imaging; ICC, inherited cardiac conditions; LAD, left anterior descending artery; MDT, multidisciplinary team meeting; MRI, magnetic resonance imaging; TEE, transesophageal echocardiogram; VF, ventricular fibrillation; and VT, ventricular tachycardia.

mitral prolapse and undifferentiated cardiomyopathy (see case vignette 2). The remaining 2 patients did not have a diagnosis even after follow-up. There were no deaths observed in the follow-up period amongst patients with a structurally normal heart.

### Age Distribution of SCA Survivors

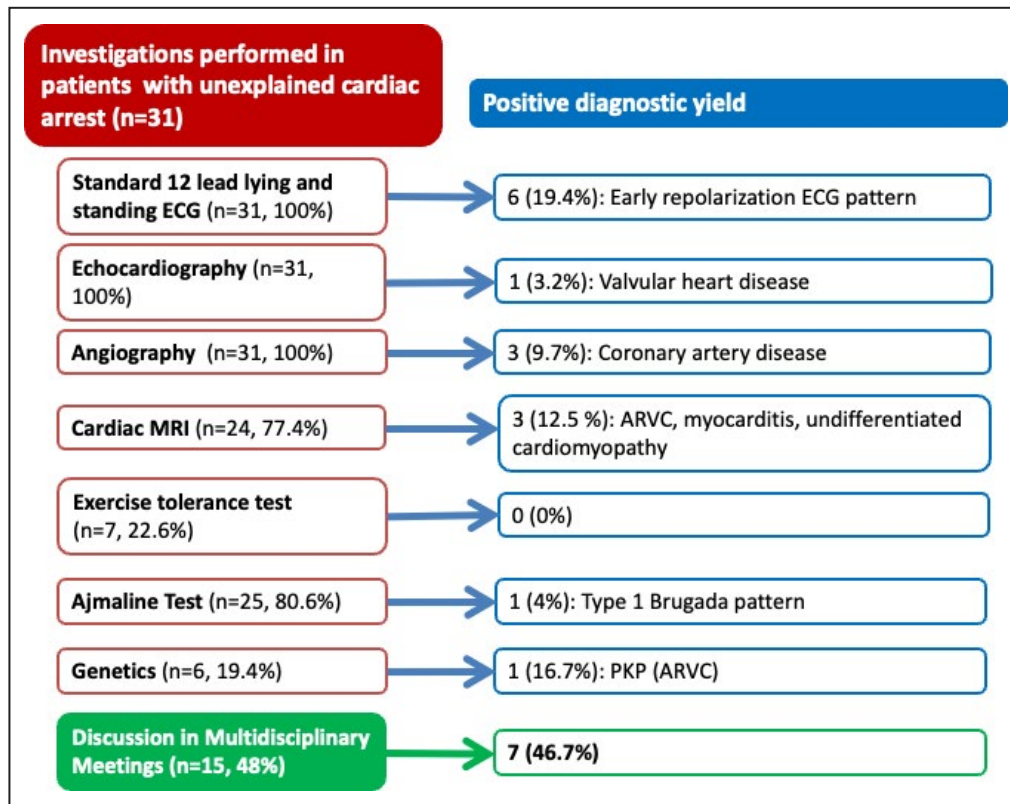
We examined the age distribution amongst SCA survivors after follow up (Figure 5). Two-hundred and sixty-four (80.7%) of the 327 cardiac arrest survivors were over the age of 50 years. Ischaemic heart disease was responsible for ≈57% of cardiac arrests in this cohort. There were only 18 (5.5%) SCA survivors aged ≤35 years. Early repolarization syndrome (ERS) was the most common aetiology (22%) followed by dilated cardiomyopathy (11%) in this age group.

### Utility of Multidisciplinary Team Meetings and Review of Investigations

Fifteen patients, all with unexplained SCA, were discussed in the Inherited Cardiac Disease MDT during the follow-up period. In total, 7 new diagnoses (7/15, 46.7%) arising from the MDT discussion and review of preceding investigations were made (Table). Diagnoses

included ARVC and mitral valve prolapse with underlying cardiomyopathy which are discussed in case vignettes 1 and 2 respectively. The third case was a 71-year-old woman with a clinical finding of a loud systolic murmur but poor echocardiographic windows during the initial admission. On discharge, she was referred for a Transoesophageal echocardiogram which was reviewed in the MDT and determined that the most likely etiology was significant mitral and tricuspid regurgitation in the setting of significant left ventricular systolic impairment. The fourth case was a 44-year-old man who had subtle myocardial oedema detected on review of the cardiac MRI by the MDT 1 week post discharge from hospital. A diagnosis of myocarditis was made.

Notably, 3 additional cases of unexplained SCA were found to have significant coronary artery disease when coronary angiograms were reviewed (Table). These included a 56-year-old man where coronary spasm and a proximal flow limiting stenosis in the right coronary artery was initially missed by a deeply intubated diagnostic Judkins Right 4 (JR4) catheter. Heart monitor tracings (Figure 6A) at the time of admission showed early repolarization changes just prior to the initiation of ventricular tachycardia and



**Figure 3.** The diagnostic yield of investigations in patients with unexplained cardiac arrest at initial assessment and during follow-up including yield of diagnosis following discussion in multidisciplinary team meetings.

ARVC indicates arrhythmogenic right ventricular cardiomyopathy; MRI, magnetic resonance imaging; and PKP, Plakophilin. Yield defined according to first utilisation of the specific test.

then degeneration into VF (Figure 6B). These repolarization changes were not present in the resting initial ECG (Figure 6C) suggesting that coronary spasm may have "mimicked" early repolarization. The second case was of 40-year-old man who had flow limiting in-stent restenosis of a left anterior descending artery stent where further ICD shocks prompted repeat angiography and a positive pressure wire study requiring stenting, and finally a 79-year-old man in whom re-evaluation of the initial coronary angiogram revealed flow limiting coronary stenosis. This was prompted when the patient recalled experiencing chest pain prior to the arrest in a follow-up clinic which was not mentioned at the index presentation.

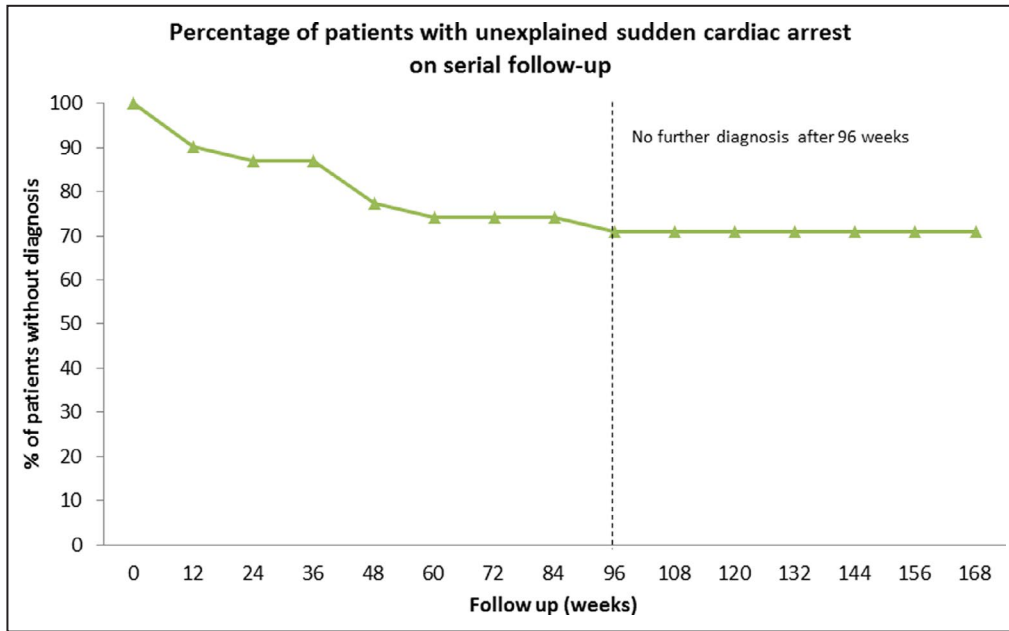
### Follow-Up of SCAs With Structural Heart Disease

Follow-up was available for all patients with structural heart disease (n=282). There were 19 (6.7%) deaths during the follow-up period, 14 were attributed to ischaemic heart disease, 3 to DCM, and 2 to undifferentiated cardiomyopathies. Appropriate shocks or ATP were documented in 86 (36.1%) patients, occurring

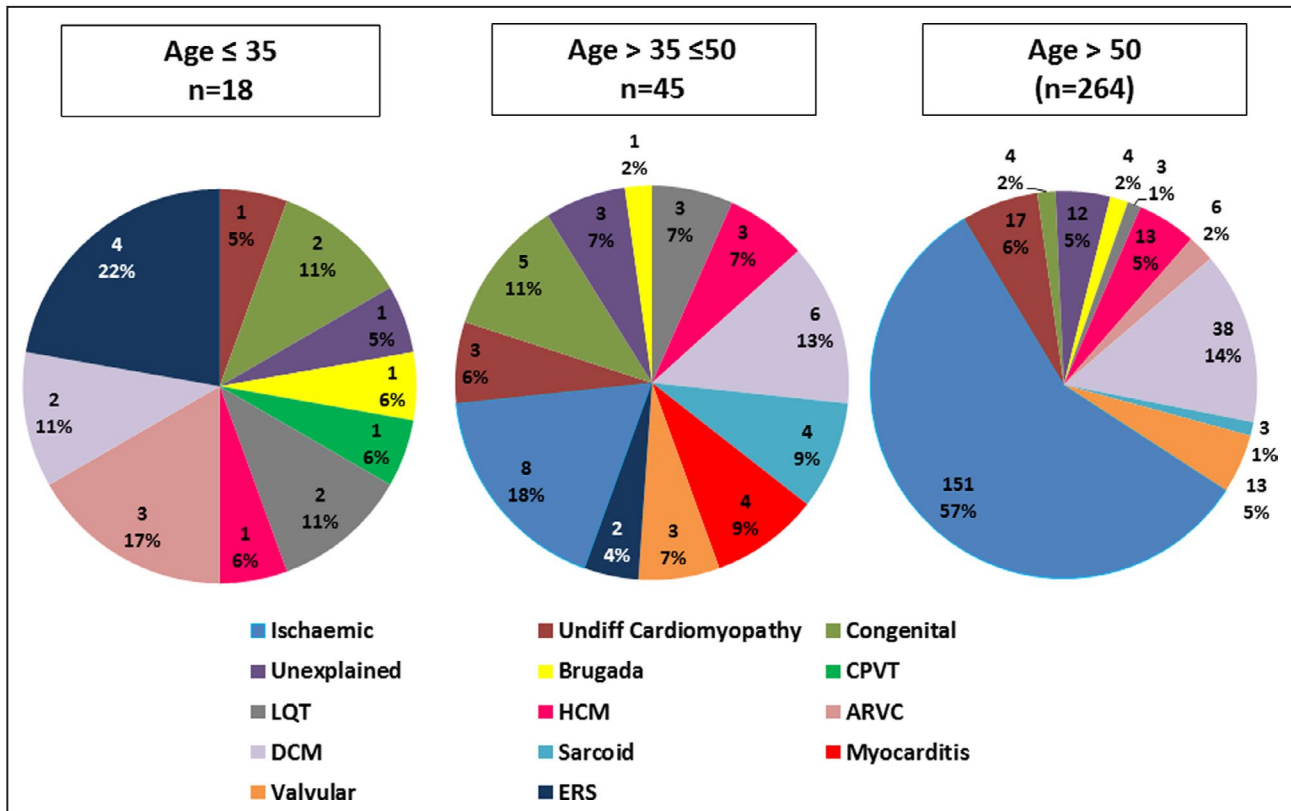
within an average of  $37.5 \pm 47$  weeks from hospital discharge. Appropriate therapies during follow up were more commonly observed in SCA patients with structural disease compared with those with structurally normal hearts (36% versus 15.6%,  $P=0.1$ ).

### Case Vignette 1

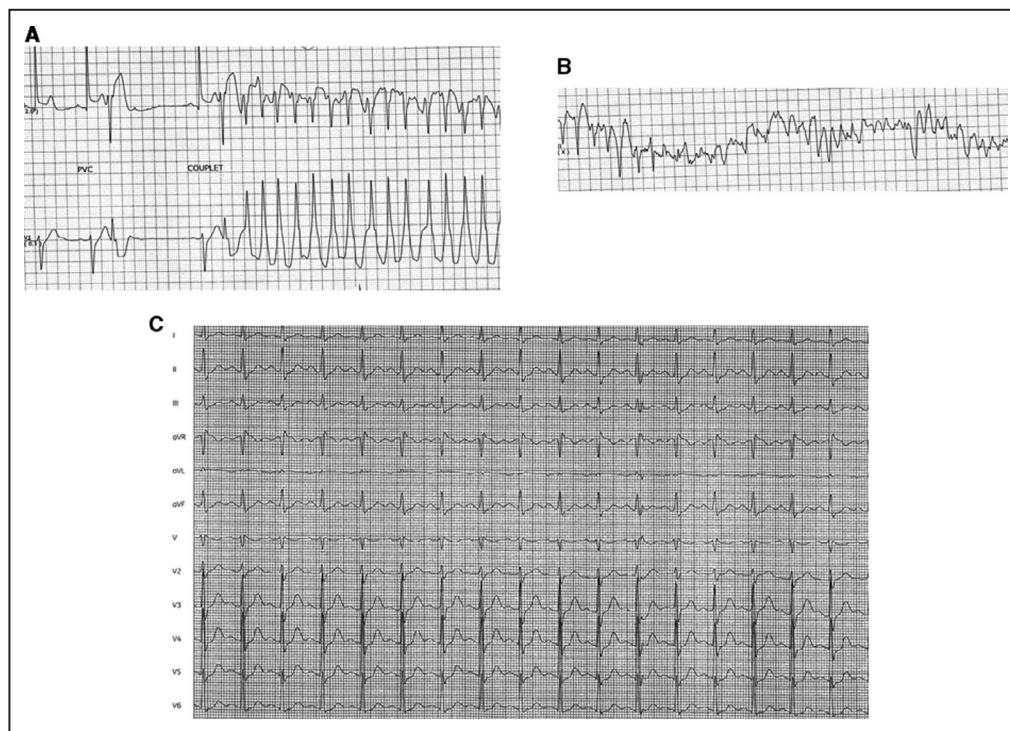
A 55-year-old man had a VT cardiac arrest immediately post-coitally which was successfully externally defibrillated with 360 J by paramedic staff. Initial assessment showed a normal resting ECG with no repolarization abnormalities or QT prolongation, and a normal echocardiogram. Invasive coronary angiography showed minor coronary disease with a 30% right coronary stenosis and mild left coronary disease. An MRI conditional ICD was implanted. The first CMR showed normal biventricular size and function with sub-epicardial late gadolinium enhancement (LGE) involving the basal to mid inferolateral and anterolateral segments and the mid to apical inferior segments. Although this was recognized as abnormal, it was not attributed to a diagnosis. During follow up the patient developed recurrent VT requiring ATP from the device.



**Figure 4.** Percentage of patients with no etiology for sudden cardiac arrest during a mean follow-up of 93 weeks (n=31). No further diagnosis was made after 96 weeks of follow-up.



**Figure 5.** Age distribution amongst SCA survivors after follow-up. ARVC indicates arrhythmogenic right ventricular cardiomyopathy; CPVT, catecholaminergic polymorphic ventricular tachycardia; DCM, dilated cardiomyopathy; ERS, early repolarization syndrome; HCM, hypertrophic cardiomyopathy; LQT, long QT; and undiff, undifferentiated cardiomyopathy.



**Figure 6.** Fifty-six-year-old man with coronary spasm and a proximal flow limiting stenosis in the right coronary artery.

Heart monitor tracing (A) at the time of admission shows early repolarization changes just prior to the initiation of ventricular tachycardia and degeneration into ventricular fibrillation (B). These repolarization changes were not present in the resting initial ECG (C) suggesting that coronary spasm may have "mimicked" early repolarization.

He underwent a successful right ventricular outflow tract (RVOT) VT ablation. A repeat CMR, 45 weeks after the initial SCA, showed interval increases in right ventricular size with a reduction in left ventricular systolic function (53% to 35%). A cardiac biopsy showed myocardial fibrosis with fibrofatty replacement. A diagnosis of ARVC with left ventricular involvement was made at the ICC MDT 48 weeks following the initial presentation based on the revised Task Force criteria.<sup>8</sup> The patient declined genetic testing.

### Case Vignette 2

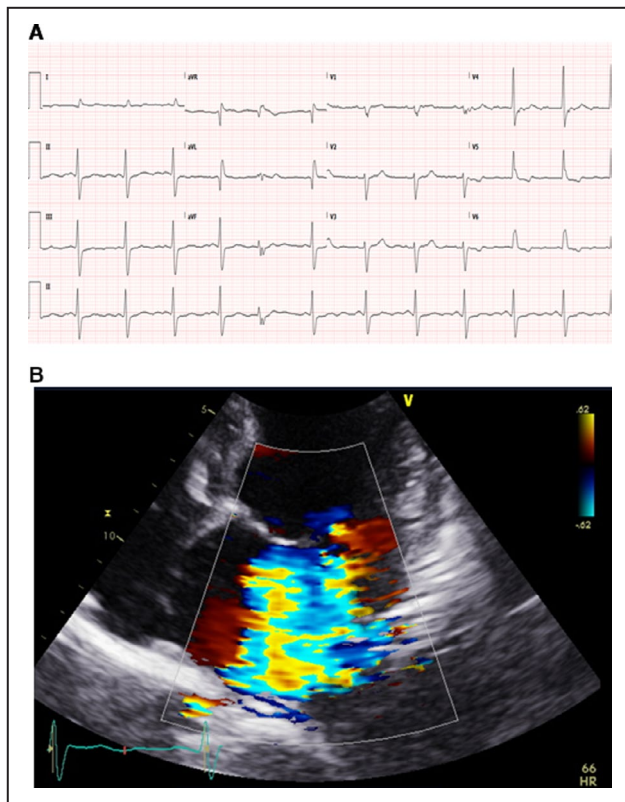
A 70-year-old woman sustained a ventricular fibrillation (VF) arrest and was successfully resuscitated. The patient had a family history of myotonic dystrophy but had no phenotypic features. The 12-lead ECG showed sinus rhythm but T wave inversion in leads V5, V6, and I (Figure 7A), and coronary angiography was normal. The echocardiogram revealed mitral valve prolapse with moderate mitral regurgitation and severe left atrial enlargement (Figure 7B). This was confirmed on CMR which also showed mild LV systolic impairment (LVEF 54%) but no evidence of LGE. A secondary prevention ICD was implanted and the patient was discharged home. Ninety-two weeks later she received

an appropriate shock from the device for VF. A transoesophageal echo showed mitral valve prolapse with severe mitral regurgitation. Following a discussion in the ICC MDT, VF secondary to mitral valve prolapse and an underlying undifferentiated cardiomyopathy was made.

## DISCUSSION

This study evaluated the outcome of 327 cardiac arrest survivors including 45 who had apparently structurally normal hearts. The overall diagnostic yield in apparently normal heart cardiac arrest survivors was 31% at baseline and 64% during follow up. The Cardiac Arrest Survivors with Preserved Ejection fraction Registry (CASPER) which reported 200 patients with a mean follow-up of 3.1 years making a diagnosis in 34% of patients at baseline with a diagnosis emerging in 7% of individuals during follow-up.<sup>9</sup> We observed a 33% additional diagnostic yield in our cohort during a shorter follow up period of 1.8 years ( $P < 0.0001$ ). Reasons for a superior yield might be explained by the smaller single centre study design of our study but more crucially utilisation of cross disciplinary expertise coupled with the uniform review of cardiac imaging to pursue the





**Figure 7. ECG and transthoracic echocardiogram for case vignette 2, 70-year-old woman who sustained a ventricular fibrillation arrest and was successfully resuscitated.**

**A**, The 12-lead ECG shows sinus rhythm but T-wave inversion in leads V5, V6, and I. **B**, The echocardiogram reveals mitral valve prolapse with moderate mitral regurgitation and severe left atrial enlargement.

diagnosis.<sup>2</sup> Subspecialty expert clinicians discussing patients as part of MDT meetings were a central theme in the management of SCA survivors in our cohort. It is conceivable that the expertise from various specialists allows for a more comprehensive evaluation of atypical disease features and those that may have been overlooked in the history, examination, and investigations. Our study therefore supports the current recommendations for shared decision-making in the management of patients with SCA.<sup>1,10</sup> Approximately 15% of unexplained SCA survivors received appropriate therapy from their ICD during the limited follow-up period. This supports the routine implantation of secondary prevention ICDs in victims of SCA without an obvious etiology.<sup>1,10</sup> We observed a 19% prevalence of early repolarization (ER) ECG pattern in unexplained SCA patients. ER is a common electrocardiographic finding that is present in 1% to 5% of the general population<sup>11</sup> and as such was historically viewed as a benign finding. However, several studies have shown that ER, and specifically ER in the inferior and lateral leads is associated with an increased risk of ventricular arrhythmias

and sudden cardiac death.<sup>12</sup> We previously reported a 47% prevalence of ER in a larger (n=66) cohort of idiopathic VF survivors.<sup>13</sup> The present study adds further evidence that ER is not a benign incidental finding in the context of idiopathic ventricular fibrillation.

### Role of Gene Testing and Advanced Imaging Modalities

In this series, genetic testing for known ion channelopathy and cardiomyopathy mutations was not performed routinely unless there was a clinical suspicion of the diagnosis. Six (19.4%) patients with unexplained SCA underwent genetic testing. The yield was 16.7% with a pathogenic mutation in the plakophilin gene consistent with ARVC. This low yield is in keeping with previous studies. A recent series of cardiac arrest survivors have demonstrated mutations in 3% to 9% of cases using gene panels for these conditions.<sup>14,15</sup> A study using whole exome sequencing in 600 cardiac arrest survivors yielded a 2.5% pathogenic variants versus 0% in case controls using 49 cardiovascular disease genes.<sup>16</sup> However, there is a significant burden of variants of unknown significance requiring further investigation with functional studies in cellular and animal models. As understanding of the genetic basis for these events grows, molecular diagnosis will enhance our diagnostic yield and ability to personalize drug and device therapies.

Cardiac MRI yielded 12.5% additional diagnoses during follow-up of unexplained SCA. This is a similar finding in the aforementioned CASPER study who reported an additional 19% diagnostic yield, mainly driven by identification of ARVC features.<sup>9</sup> CMR plays a significant role in determining SCA pathogenesis and prognosis in survivors. In 164 cardiac arrest survivors without coronary artery disease, CMR contributed to the diagnosis in 49%.<sup>2</sup> Furthermore, major adverse cardiovascular events were associated with presence of a CMR diagnosis, extent of late gadolinium enhancement, and left and right ventricular ejection fractions.<sup>2</sup>

### Study Limitations

The number of SCA survivors with a structurally normal heart is relatively low due to the rare nature of the underlying diseases. A larger sample size is required to support our findings. Secondly, this was a single center with highly specialized healthcare professionals—not typical of most hospitals. Moreover, because it is a cardiac specialist center, the patient population may not be reflective of all settings. Our study only examined patients who survived a cardiac arrest and underwent a secondary prevention ICD, therefore conclusions cannot be extended to non-survivors or patients who declined an ICD implant. Provocative testing

with adrenaline challenge was not performed routinely for long QT syndrome due to the high false positive rate in up to 25% of cases promoting QT prolongation and non-specific T wave changes particularly at high doses.<sup>17</sup> Coronary spasm provocation testing was also not routinely performed as in the CASPER registry but recent evidence indicates this may explain ~40% of early repolarization cases of idiopathic ventricular fibrillation even in the absence of chest pain prior to cardiac arrest.<sup>18</sup> This investigation should be considered in such cases. Finally, appropriate ICD shocks or ATP is not a comparable reflection of therapies in patients with and without a structural normal heart due to possible differences in device programming.

## CONCLUSION

Systematic comprehensive testing and expert follow-up improves the diagnostic yield of SCA survivors without structural heart disease. A multidisciplinary team approach enables a shorter duration of follow-up and higher diagnostic yield to obtain a diagnosis in this cohort of patients compared with previously published studies. This has important implications in the management of victims of SCA survivors and their families.

## ARTICLE INFORMATION

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### Disclosures

None.

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