The many faces of early repolarization syndrome: A single-center case series

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BACKGROUND Early repolarization syndrome (ERS) is a rare but increasingly recognized cause of malignant ventricular arrhythmias.

OBJECTIVE The purpose of this study was to characterize the presentations and treatments of ERS at our institution.

METHODS We performed a retrospective chart review of all patients presenting to our institution between 2008 and 2019 with ERS. Exclusion criteria included Brugada syndrome, positive provocative testing with class I antiarrhythmic drugs, metabolic disturbances, or structural heart disease.

RESULTS Of 10 patients identified with ERS, 8 were men with a mean age of 30 ± 17 years at diagnosis. Documented arrhythmias included ventricular fibrillation in 7 of 10, polymorphic ventricular tachycardia in 3 of 10, and monomorphic ventricular tachycardia in 3 of 10 patients. Atrial fibrillation was diagnosed in 3 of 10, and atrioventricular block was seen in 2 of 10. J waves and/or electrocardiographic early repolarization patterns were dynamic in 7 of 10. Arrhythmias occurred at rest in 8 of 10 and with exertion in 2 of 10. Only 1 patient had a family history of sudden death, and 4 of 10 patients had variants of uncertain significance on genetic testing. Quinidine effectively suppressed arrhythmias in 5 of 5 patients but required dose escalation to >1 g/d in 3 of 5 patients. Abnormal epicardial electrograms were recorded over the inferolateral left ventricle in 2 patients who underwent mapping and were successfully ablated. Premature ventricular contraction triggers were also targeted for ablation in 3 patients.

CONCLUSION ERS is a heterogeneous condition and may be associated with both atrial and ventricular arrhythmias, atrioventricular block, dynamic electrocardiographic changes, and variable triggers. In addition to targeting premature ventricular contraction triggers, mapping and ablation of abnormal epicardial electrograms may be a potential future treatment strategy.

KEYWORDS Early repolarization syndrome; J wave; Ventricular fibrillation; Cardiac arrest; Catheter ablation

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Introduction

Our understanding of early repolarization syndrome (ERS) has dramatically evolved over the past decade. The early repolarization (ER) pattern, once thought to be a benign finding, is now known to be associated with sudden death. The initial description of ERS by Haissaguerre et al[1] of ST-segment elevation in the inferior or lateral leads and a propensity for ventricular fibrillation (VF) has been broadened. Moreover, debate exists as to whether ERS represents a repolarization or depolarization abnormality.[2] Putative genes, electrophysiological manifestations, and potential targets for ablation require further clarification. We sought to review all cases of ERS from our institution with the aim of describing its range of presentations. We follow the recent American Heart Association statement specifying the electrocardiographic (ECG) pattern observed.[3]

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Methods

We searched our institution's Genetic Arrhythmia Registry to identify all patients between 2008 and 2019 with a diagnosis of ERS. Patients also had to fulfill a diagnosis of at least "possible" ERS with a Shanghai ERS score[4] of ≥3. We excluded Brugada syndrome (BrS), positive provocative testing with class I antiarrhythmic drugs, metabolic disturbances (eg, hypothermia), and ischemia (including coronary spasm) as the primary causes of ECG changes. All patients underwent echocardiography to exclude structural heart disease. Records were reviewed retrospectively to obtain demographic data, clinical course, ECG changes, arrhythmias, outcomes of electrophysiology studies, and events at follow-up (Table 1). Supplemental Table 1 provides a summary of cardiac and genetic testing, and Supplemental Figure 1 shows each patient's ECG. The study was approved by our institutional review board.

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Table 1 Summary of the clinical characteristics of patients in case series

Case	Sex	Age at diagnosis (y)	Presenting symptoms	ECG changes	Arrhythmias	Treatment	Ablation	Follow-up
1	F	20	VF arrest	Global J waves with augmentation at longer coupling intervals	VF, AF	Quinidine (required higher doses), ICD	Nil	6 mo
2	F	17	VF arrest	Global ST-segment elevation with J waves and augmentation at longer coupling intervals	VF, AF, atrial flutter, multifocal PVCs, third-degree AV block	Isoproterenol suppressed PVCs, quinidine, cilostazol, ICD	Nil	8 y
3	M	18	Syncope	Terminal QRS notching in the inferior leads	PMVT, VF, unifocal PVCs	Failed β-blockers, sotalol, flecainide, ICD	Targeted PVC trigger and abnormal substrate in the inferolateral epicardium	2 y
4	M	27	VF arrest Previous syncope	Terminal QRS notching in the inferior leads	VF, PMVT, MMVT, unifocal PVCs	ICD	Targeted PVC trigger, abnormal substrate, mid-diastolic potentials during VT in the inferolateral epicardium	18 mo
5	M	55	Bradycardic arrest	Transient inferior ST-segment elevation	MMVT/organized fascicular arrhythmias, VF	Quinidine (required higher doses), ICD	Nil	2 y
6	M	46	Presyncope	Intermittent J waves inferiorly and anteriorly, transient inferior ST-segment elevation	MMVT, PMVT, third-degree AV block, PVCs	Quinidine (breakthrough VT at <1 g/d), ICD	Right ventricular outflow tract PVCs targeted	2 y
7	M	22	Polymorphic VT arrest	Transient inferior ST-segment elevation, terminal QRS notching in the inferior leads	PMVT	ICD, failed metoprolol, quinidine successful	Nil	7 y
8	M	61	VF arrest	Prominent J waves in the inferior leads	VF	ICD	Nil	10 y
9	M	18	Syncope	Terminal QRS notching in the inferior leads	Nil	ICD	Nil	18 mo
10	M	15	VF arrest	Global ST-segment elevation	VF, PMVT, AF	Metoprolol, ICD	Nil	11 y

AF = atrial fibrillation; AV = atrioventricular; ECG = electrocardiographic; F = female; ICD = implantable cardioverter-defibrillator; M = male; MMVT = monomorphic ventricular tachycardia; PMVT = polymorphic ventricular tachycardia; PVC = premature ventricular contraction; VF = ventricular fibrillation; VT = ventricular tachycardia.

Results

Atrial fibrillation and ERS

Case 1

A 20-year-old woman was admitted following resuscitated VF after collapsing in her kitchen. Her brother had died suddenly at the age of 15. Postdefibrillation, the ECG showed atrial fibrillation (AF) with slow ventricular response and global J waves despite euthermia. These persisted beyond her index presentation. Notably, J waves were apparent only at slower rates and longer coupling intervals (Figure 1A) and were not accentuated with procainamide. She received quinidine 325 mg thrice daily and an implantable cardioverter-defibrillator (ICD). Genetic testing (Supplemental Table 1) revealed variants of uncertain significance (VUSs). Cardioversion for AF briefly restored sinus rhythm; however, AF recurred later that day and she received inappropriate shocks for AF during follow-up. Quinidine was increased to 650 mg thrice daily, and she spontaneously converted to sinus rhythm. On review 6 months later, she is asymptomatic without further arrhythmias.

Case 2

A 17-year-old adolescent girl presented following resuscitated VF arrest while at school. Three weeks previously, she had undergone cardioversion for atrial flutter. Postarrest, the ECG demonstrated AF with slow ventricular response and inferolateral J waves, more prominent at slower rates (Figure 1B). She received amiodarone but continued to have frequent multifocal premature ventricular contractions (PVCs) and developed further VF in the setting of bradycardia and pauses triggered by short-coupled PVCs. Isoproterenol infusion markedly decreased PVCs. A dual-chamber ICD was implanted, and ibutilide was administered for persistent AF. During ibutilide infusion, the QRS width and corrected QT interval prolonged, resulting in torsades de pointes. Its discontinuation combined with ventricular pacing at higher rates facilitated hospital discharge. Three months later, she presented following numerous shocks for VF, with esmolol and theophylline failing to suppress complex ventricular ectopy. Isoproterenol reduced PVCs but resulted in rapid AF with inappropriate shocks. She was stabilized on quinidine 648 mg thrice daily and cilostazol 200 mg thrice daily and has been well for the past 8 years other than an isolated VF recurrence 4 years ago because of noncompliance. In the interim, she has also developed complete heart block and is 100% AV paced.

Epicardial ablation for ERS

Case 3

An 18-year-old man presented with recurrent syncope triggered by exertion and anxiety. The ECG demonstrated an ER pattern with intermittent inferior J waves, becoming

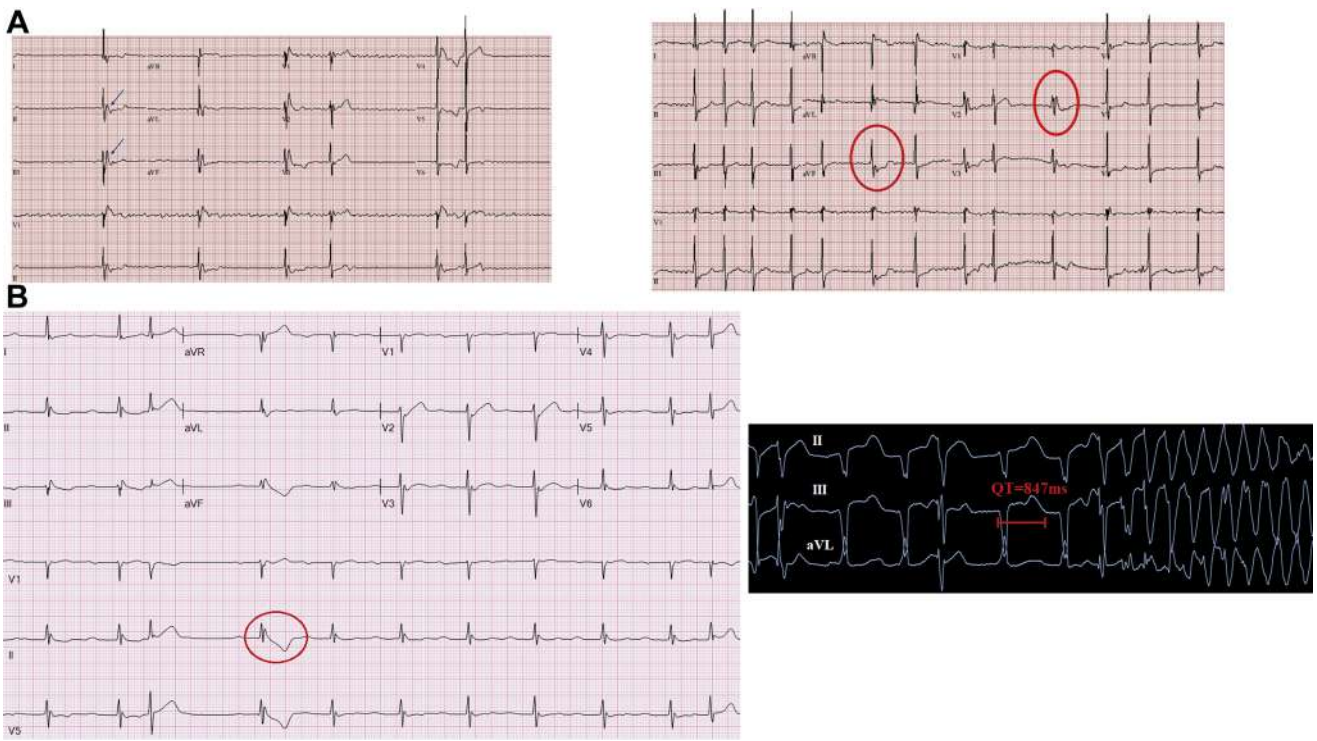

Figure 1 **A:** Case 1: Atrial fibrillation with the early repolarization pattern demonstrating augmentation of J waves. Augmentation of J waves (*arrow*) at slower ventricular rates and beat-to-beat variability with presence of J waves (*circled*) only at longer coupling intervals. Note is made of taller and narrower QRS complexes in beats without J waves. Lead V_1 shows minor right ventricular conduction delay, but not a true Brugada pattern. **B:** Case 2 with more prominent J waves at longer coupling intervals (*left*) and ibutilide causing QRS and corrected QT interval prolongation with early premature ventricular contraction triggering torsades de pointes (*right*).

more prominent at slower heart rates. A loop recorder was inserted, and this documented multiple self-terminating episodes of polymorphic ventricular tachycardia (VT)/VF. An ICD was implanted, and the patient received several appropriate shocks for PVC-triggered VF despite β-blockers, sotalol, and flecainide. He was referred for ablation to target the triggering PVC (Figure 2A). Endocardial mapping of the left ventricle (LV) demonstrated normal endocardial voltages, and activation mapping of occasional PVCs identified the earliest endocardial site in the inferolateral LV "on time" with QRS onset. Epicardial access was performed, and mapping in sinus rhythm identified local abnormal ventricular activities coincident with the J wave, together with late potentials and fragmented electrograms in the inferolateral epicardial region (Figures 2B–2E). Early PVC activation and good pace maps from this area were also demonstrated, and ablation in this region rendered the patient arrhythmia-free over 3 years follow-up.

Case 4

A 27-year-old man presented with resuscitated VF on the background of recurrent syncope while playing basketball. The ECG showed terminal QRS notching in the inferior leads. Genetic testing identified a VUS in the *SCN5A* sodium channel gene. VF was induced during electrophysiology study following aggressive stimulation (400ms pacing drive train and 3 extrastimuli at coupling intervals of 250 ms, 200 ms and 200 ms). A subcutaneous ICD was implanted, but the patient continued to receive shocks for pleomorphic VT with exertion (Figure 3A) despite flecainide and metoprolol. Repeat electrophysiology study demonstrated spontaneous PVCs (Figure 3B; right bundle branch pattern, superior axis) and inducible rapid monomorphic VT. A multipolar catheter advanced into a lateral coronary sinus branch over the inferolateral LV epicardium demonstrated early presystolic local recordings (−76 ms) during VT compared to those recorded directly opposite on the endocardial surface (−34 ms) (Figure 3C). Epicardial access was undertaken, and a small patchy abnormal low-voltage region was found over the inferolateral LV with extreme delayed activation into the region during sinus rhythm (Figure 3D, not visible on cardiac magnetic resonance imaging [CMR]). Discrete fractionated late potentials were recorded in the abnormal epicardial LV that corresponded in timing with ECG J waves during sinus rhythm. Although sustained VT was no longer inducible under general anesthesia, early presystolic potentials (Figure 3B) were recorded during the corresponding PVCs of the same morphology. Epicardial ablation in this region eliminated the PVCs, and the patient has remained asymptomatic in spite of resumption of vigorous activities for 18 months.

Dynamic inferior ST-segment elevation

Case 5

A 55-year-old man with previous bradycardic arrest and dual-chamber pacemaker was transferred following recurrent

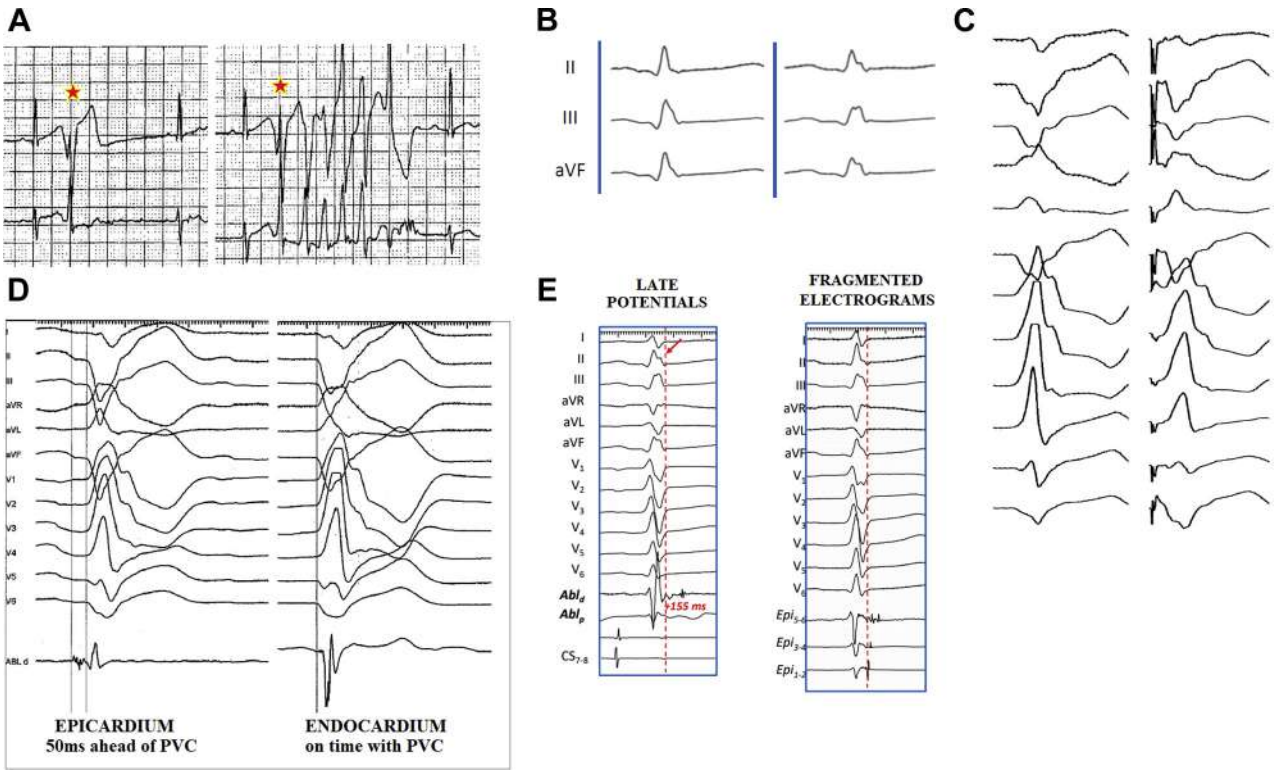

Figure 2 Case 3: **A:** Early-coupled premature ventricular contractions (PVCs) triggering polymorphic ventricular tachycardia. **B:** J waves more prominent at longer cycle lengths (*right beat*). **C:** Pace mapping from the inferolateral epicardium (*right beat*) demonstrated right bundle branch morphology with right superior axis similar to the triggering PVC (*left beat*). **D:** Activation mapping of triggering PVCs with the earliest site 50 ms ahead of QRS in the inferolateral epicardium with the corresponding endocardial site on time with QRS onset. **E:** Abnormal local signals in the inferolateral epicardium with late potentials and fragmented electrograms.

episodes of monomorphic VT with right bundle branch morphology and right inferior axis, suggesting origin in the left anterior fascicle. VT onset was preceded by marked inferior ST-segment elevation without chest pain that was unresponsive to nitrates, and arrhythmias terminated with resolution of these changes (Figure 4A or 4B), as reported previously.[5] The coronary angiogram included a negative acetylcholine challenge for vasospasm. He was upgraded to an ICD and received appropriate therapies for VF at follow-up (Figure 4C). Quinidine 325 mg thrice daily was initiated, resulting in marked reduction in VT episodes. Quinidine was then increased to 650 mg thrice daily, which abolished ST-segment elevation, and he has not had further VT over 2 years follow-up.

Case 6

A 46-year-old man developed presyncope without prodrome. A troponin elevation prompted coronary angiography, which was normal, although he had an episode of monomorphic VT during the procedure. On his first night in the hospital, he collapsed after getting out of bed and required cardiopulmonary resuscitation for complete heart block and pause-dependent VT. A dual-chamber pacemaker was implanted. The ECG at follow-up demonstrated a subtle ER pattern with intermittent terminal QRS notching in leads V_3 through V_5 and II. Genetic testing identified a ryanodine-receptor *RYR2* VUS. He subsequently developed episodes of monomorphic and polymorphic VT triggered by late-coupled PVCs and was upgraded to an ICD. Infrequent spontaneous PVCs were mapped to the low anteroseptal right ventricular outflow tract (RVOT) with a closely matched pace map. Transient periods of asymptomatic inferior ST-segment elevation occurred throughout the procedure (Supplemental Figure 1). Catheter ablation was performed but sustained VT recurred, and quinidine 324 mg thrice daily was initiated. The patient remains well 2 years later with an isolated episode of VT that was successfully treated with antitachycardia pacing.

Case 7

A 22-year-old man with a history of recurrent "seizures" was resuscitated from polymorphic VT occurring at rest. There was no family history of sudden death. The initial ECG demonstrated marked inferior ST-segment elevation (Figure 5A). An ICD was implanted, and he was commenced on metoprolol 50 mg thrice daily but continued to receive appropriate shocks for polymorphic VT during sleep. Genetic testing was unremarkable. He was switched to quinidine 300 mg twice daily and has remained arrhythmia-free for 7 years.

Stable ER pattern

Case 8

A 61-year-old man developed agonal breathing during sleep, and his wife performed cardiopulmonary resuscitation until he was defibrillated for VF. The ECG demonstrated J waves in the inferior leads. The coronary angiogram revealed a diagonal branch stenosis, which was stented; however, this was not felt to be the cause of VF because of its small caliber. VF was

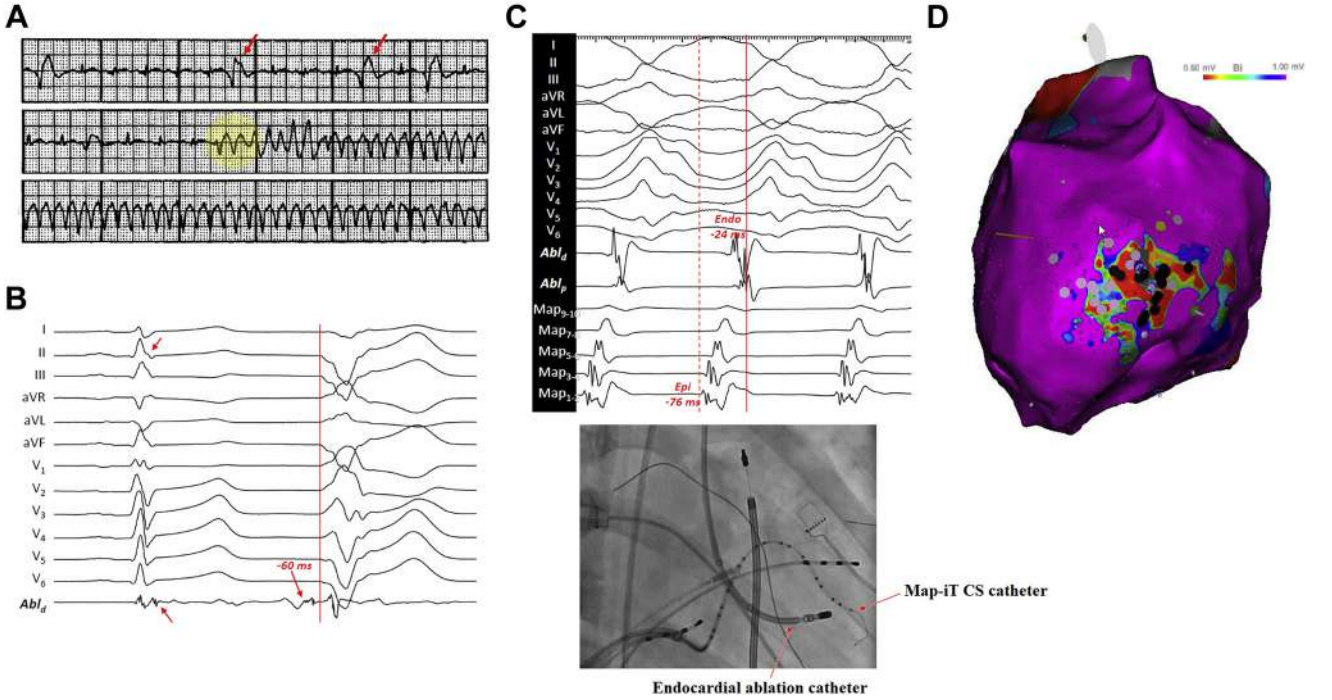

Figure 3 Case 4: **A:** Late-coupled premature ventricular contractions (PVCs) triggering polymorphic ventricular tachycardia (VT). **B:** ST-segment elevation with notching in the inferior leads and lead V_1 and fractionated potentials during the sinus beat (*left*) and an early local electrogram seen in the inferolateral epicardium 60 ms pre-PVC (*right*). **C:** Presystolic potentials during monomorphic VT with simultaneous mapping in the inferolateral left ventricular endo- and epicardium. **D:** Voltage map in sinus rhythm with the isolated region of abnormal electrograms within the inferolateral epicardium. CS = coronary sinus.

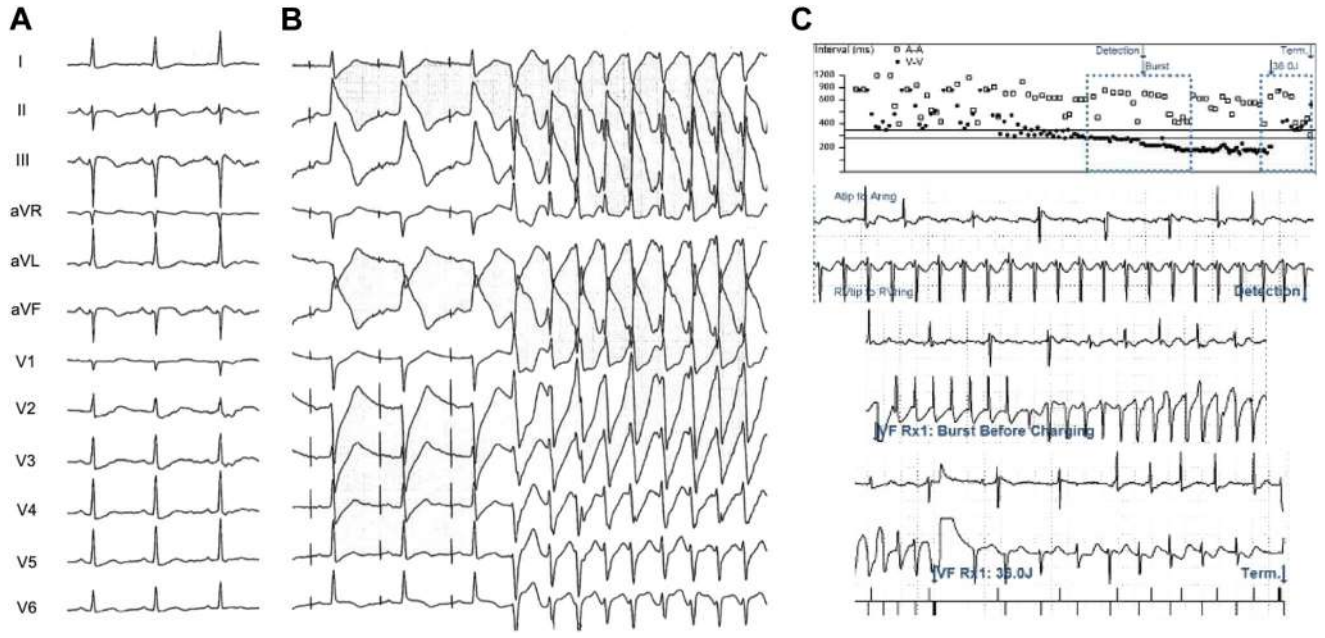

Figure 4 Case 5: **A:** Resting electrocardiogram without abnormalities. **B:** Marked inferior ST-segment elevation before monomorphic ventricular tachycardia (VT) onset. **C:** Degeneration of VT to ventricular fibrillation requiring implantable cardioverter-defibrillator therapy.

inducible with double extrastimuli during electrophysiology study, and an ICD was implanted. Both his son and daughter were found to have ER in the lateral leads but have been asymptomatic. Genetic testing showed a VUS in the *MYH7* gene. The patient has not had any further sustained ventricular arrhythmias over 10 years without antiarrhythmic drugs.

Case 9

An 18-year-old man with a history of recurrent syncope was admitted for a syncopal event without prodrome, resulting in a car accident and associated traumatic brain injury. No significant family history was reported. ECGs intermittently demonstrated ER with terminal QRS notching in the

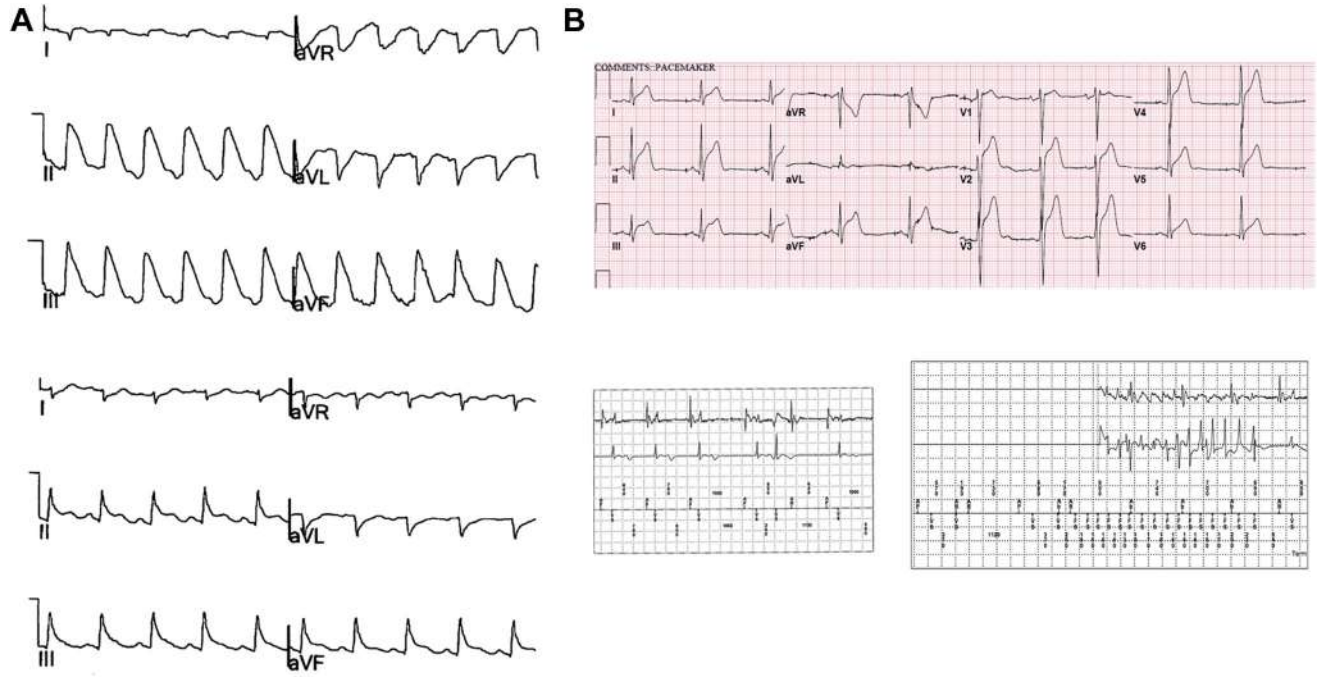

Figure 5 **A:** Case 7: Initial electrocardiogram (ECG) following resuscitation from polymorphic ventricular tachycardia (VT) demonstrating marked inferior ST-segment elevation (*top*) with improvement 15 minutes later (*bottom*). **B:** Case 10: ECG demonstrating global ST-segment elevation (*top*); tight-coupled premature ventricular contractions (PVCs) seen following a short-long sequence triggering polymorphic VT (*bottom*).

inferolateral leads. The decision was made to implant a dual-chamber ICD on the basis of history and potentially malignant J-wave pattern. The patient remains well 18 months later without device therapy.

Case 10

A 15-year-old adolescent boy with a history of a "seizure disorder" presented with resuscitated VF occurring at rest. The ECG demonstrated global ST-segment elevation (Figure 5B), and no structural heart disease or genetic abnormality was found. Electrophysiology study demonstrated dual atrioventricular (AV) nodal physiology, and he underwent slow pathway modification. A single-chamber ICD was implanted but was upgraded to a dual-chamber ICD 17 months later for AF. He has remained on metoprolol 50 mg/d for 11 years, with brief self-limiting episodes of polymorphic VT only but no ICD therapy.

Discussion

This case series of 10 patients highlights the heterogeneous nature of ERS on the basis of current diagnostic criteria. In contrast to the original report by Haissaguerre et al,[1] 3 of 10 patients presented with monomorphic VT. We also emphasize the presence of AF and AV block, as well as the role of bradycardia in arrhythmia initiation. Two patients had successful epicardial catheter ablation of PVC triggers and epicardial substrate modification. Finally, although the therapeutic efficacy of quinidine is accepted, there is no consensus on dose. In this report, we used graded doses and found that >1 g/d may be required.

Dynamic nature of ECG changes

This study highlights the dynamic nature of ECG changes in ERS. Three patients had escalating ST-segment elevation before arrhythmia initiation; 3 patients had consistent J waves with augmentation during long cycle lengths; and 2 showed intermittent and subtle terminal QRS notching. One patient exhibited "narrow and tall" QRS complexes on beats without J waves, postulated to represent either enhanced sodium channel function, enhanced gap junctional conductance and density, or abnormal Purkinje fiber network predisposing to triggered arrhythmias.[6] Development of arrhythmias at rest in 8 of 10 and J-wave prominence at longer coupling intervals argues in favor of a repolarization abnormality in ERS, perhaps related to slow reactivation kinetics of transient outward potassium current (I_{to}) and greater contribution of potassium channels I_{to} and adenosine triphosphate-sensitive potassium channel ($I_{K\text{-}ATP}$) to the action potential spike and dome slope. The presence of fragmented electrograms and late potentials can also occur because of abnormal repolarization,[7] as demonstrated by Szel and Antzelevitch in an isolated arterially perfused canine ventricular wedge preparation model. Fractionated electrograms were seen in the epicardium but not in the endocardium because of heterogeneities in the appearance of the second epicardial action potential upstroke with high-frequency spikes developing because of concealed phase 2 reentry. Similar in vitro models have demonstrated an augmentation of epicardial action potential notch amplitude and J wave at longer cycle lengths[8] and using cholinergic agonists.[9] In a series of "J-wave–associated VF," 15 of 27 displayed significant pause-dependent J-wave augmentation—not seen in matched controls without previous VF.[10] In a study of 4 families with ERS, the Valsalva maneuver augmented the J-wave amplitude in 17 of 20 probands and unmasked ER in 17 relatives.[11]

Role of catheter ablation

While ablation of VF-triggering PVCs in ERS is an attractive option, their sporadic nature makes mapping challenging. In a study of patients identified with ERS undergoing body surface mapping, 2 of 29 had PVC triggers originating from the apical and the inferior LV, respectively, corresponding to the epicardial region with J waves, short activation recovery interval, and steep activation recovery interval gradients.[12] These findings suggest that reactivation of early repolarizing cells from local currents could produce ectopy,[13] as was seen in 2 of 10 patients in the present study whereby the inferolateral region corresponded to the site of abnormal epicardial signals, ECG changes, and PVCs. However, like in related BrS, VF-triggering PVCs have also been identified outside the region of epicardial abnormalities.[14] One patient demonstrated organized fascicular rhythms before VF onset (likely left anterior fascicular origin) and another an RVOT trigger. Previous case reports of ERS have focused on targeting VF-triggering PVC originating in the septal Purkinje systems,[2,15] left posterior fascicle,[16] and RVOT.[17]

"Substrate"-based ablation targeting abnormal potentials in the epicardial RVOT is increasingly used in BrS. It has been postulated that the main difference between BrS and ERS is the region of the heart affected.[18] The inferior wall has been proposed as a "hot spot" for epicardial abnormalities in ERS owing to higher intrinsic I_{to} density,[9] and the J wave may either be intermittent, buried in the QRS complex, or not necessary.[19] Epicardial mapping has rarely been reported in ERS despite increasing evidence that repolarization abnormalities are primarily seen on the epicardial surface. This was first identified by Yan and Antzelevitch,[8] who demonstrated using perfused canine wedge preparations that the J wave represented an exaggeration of the transmural gradient in the amplitude of the I_{to}-mediated transient repolarizing current, with a prominent action potential notch seen in the epicardium but not in the endocardium. Ablation of the corresponding epicardial fractionated low-voltage electrical activity and late potentials in similar canine wedge preparations reduced J-wave amplitude and VF inducibility owing to the destruction of cells with the most prominent action potential notch.[20] Two recent human studies using body surface mapping in ERS demonstrated abnormal epicardial repolarization characterized by areas with short activation recovery intervals, heterogeneous shortening of action potential duration, and abnormal sinus rhythm epicardial

electrograms, while ventricular depolarization appeared normal.[12,19]

In the first study using epicardial mapping via a lateral coronary sinus branch in ERS, similar to our observations in cases 3 and 4, Nakagawa et al[21] observed that prominent potentials were seen corresponding with the surface J wave on the unipolar recording and immediately after the QRS complex on the bipolar recording. These potentials were not recorded within the opposing endocardium and were accentuated with class Ic antiarrhythmic drugs and diminished with isoproterenol in concert with the surface ECG J wave; however, no ablation was performed. Haissaguerre et al[2] argued that in some patients with J wave syndromes, abnormal electrograms may indeed represent delayed depolarization owing to microstructural abnormalities not apparent on noninvasive imaging. Many cases of idiopathic VF may also represent "undiagnosed" J wave syndromes, with abnormal epicardial electrograms reported during invasive mapping in 15 of 24 idiopathic ventricular fibrillation survivors, which were colocated with VF drivers on noninvasive mapping. In our study, an approach targeting triggers and substrate facilitated arrhythmia control in 2 patients and may obviate the need for continued drug or ICD therapy.

Association with AF and AV block

The early onset of atrial arrhythmias in 3 of 10 patients in the absence of an identifiable mutation suggests a common underlying ventricular and atrial proarrhythmic mechanism unrelated to previously reported mutations in potassium channels KCNJ8 and KCNA5.[22] In observational studies, the inferolateral ER pattern is 2–3 times more common in patients with AF than in controls[23] and has been associated with AF recurrence following ablation.[24] In those with ERS and previous VF, AF has been reported in 23% of cases and may relate to prominence of I_{to}-mediated transient repolarizing currents in the atria with short-coupled atrial premature beats triggering phase 2 reentry,[25] a postulated mechanism for VF initiation. Inappropriate shocks for AF have been reported in 20% of patients identified with ERS,[26] suggesting that the association between AF and J wave syndromes is not restricted to BrS.[27]

The association between ERS and heart block, as was present in 2 patients in our series, has not been described previously. In a series of 50 patients with idiopathic VF and the ER pattern, Watanabe et al[28] reported longer PR intervals in cases compared with age-matched controls. Three patients in this series had an *SCN5A* sodium channel mutation, which has also been described in J wave syndromes, early-onset AF, and heart block.[29] Mutations in L-type calcium channels have also been described in ERS,[30] and these mutations in sodium and calcium channels suggest potential depolarization abnormalities in some patients identified with ERS.[2]

Pharmacological therapy for ERS

The class Ia antiarrhythmic drug quinidine has emerged as an important therapy in J wave syndromes because of its unique inhibition of I_{to} channels, while β-blockers, amiodarone, flecainide, ibutilide, and dofetilide appear to be unhelpful or harmful. In this report, we used escalating quinidine doses and found that >1 g/d was required to suppress arrhythmias in 3 of 5 patients. However, both underdosing and compliance may be potential limitations in patient management. A study of 37 patients on quinidine found that 73% had subtherapeutic levels,[31] highlighting the challenges related to its short half-life, frequent dosing intervals, and side-effect profile. Routine monitoring of quinidine levels may be useful in patients with life-threatening arrhythmias on chronic therapy.

Diagnostic challenges

Seemingly atypical presentations of ERS (including AF, AV block, monomorphic VT, sympathetic triggers, and apparent epicardial "substrate") may delay diagnosis, and in our series the diagnosis was often not made during the index presentation. These additional features have not been observed in larger registries of patients with aborted sudden death (J Roberts, MD. written communication, July 18, 2019).[32] Although standardized criteria for description of the ER pattern(s) have been developed,[33] the high prevalence of ER pattern in healthy adults and lack of confirmatory tests create diagnostic challenges. Fleeting ECG changes highlight the importance of prolonged observation and close inspection, particularly at longer coupling intervals. Significant ER was observed in 23% of patients with idiopathic VF from the Cardiac Arrest Survivors With Preserved Ejection Fraction Registry; however, the pattern was variable in 58%. Those with idiopathic VF and ER had greater J-point elevation and wider distribution of changes than those with an established cause of VF.[32] In a series of 35 idiopathic VF survivors, an ER pattern was the strongest predictor of frequent and earlier ICD therapies.[34] These data suggest that ERS may be a more common cause of VF than previously appreciated, and its exquisite response to quinidine and potential ablation targets underscore the importance of making the diagnosis.

Conclusion

ERS was initially defined as a clinical syndrome characterized by J waves in 2 contiguous inferior and/or lateral leads or slurring of the terminal portion of the QRS complex associated with aborted sudden death. Our experience suggests an expanded definition that encompasses monomorphic VT, AF, and AV block. The importance of prompt recognition rests on providing an effective treatment regimen including quinidine therapy and/or catheter ablation.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrthm.2019.09.013.

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