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SPOTLIGHT

Arrhythmic triad in an implantable cardioverter-defibrillator recipient with severe hypokalemia

Giovanni Domenico Ciriello MD[1] | Gabriella Gaudieri MD[1] | Flavio Cesaro MD[2] | Raffaele Merenda MD[3] | Vincenzo Russo MD PhD[1]

[1]University of Campania "Luigi Vanvitelli", Naples, Italy

[2]Unit of Emergency Medicine and Surgery and First Aid, C.T.O. Hospital, Naples, Italy

[3]Department of Cardiology and Cardiac Intensive Care Unit, Monaldi Hospital, Naples, Italy

Correspondence
Giovanni Domenico Ciriello, MD, Department of Medical Translational Sciences, University of Campania "Luigi Vanvitelli" - Monaldi Hospital, Via Leonardo Bianchi, 1, 80131 Naples, Italy.
Email: gdciriello@gmail.com

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A 56-year-old man was admitted to the Emergency Department of Monaldi Hospital for palpitations suddenly followed by syncope. He had a medical history of post-myocarditis dilated cardiomyopathy with reduced cardiac systolic function treated by implantable cardioverter defibrillator (ICD) implantation, systemic arterial hypertension, chronic kidney disease (CKD), chronic obstructive pulmonary disease, and deep venous thrombosis. His family history was unremarkable. At hospital admission, he was taking ACE inhibitor (ramipril 5 mg once daily), beta-blocker (bisoprolol 2.5 mg once daily), non-potassium sparing diuretics (hydrochlorothiazide 25 mg once daily and furosemide 25 mg twice a day) and non-vitamin K oral anticoagulant (apixaban 2.5 mg twice a day). The patients' anamnesis revealed several episodes of diarrhea and vomiting few days before the hospital admission. His physical examination was unremarkable. The 12 leads electrocardiogram (ECG) showed sinus rhythm at 75 beats per minute, normal PR interval and QRS complex duration, no ST segment alterations, low voltage T waves, and extreme correct QT prolongation (QTc 651 ms in DII, QTc 674 ms in V5 according to Bazett formula) (Figure 1). Chest x-ray was negative. Laboratory tests showed severe hypokalemia (serum K^+ value 1.9 mmol/L) and hypomagnesemia (serum Mg^{++} value 1.1 mg/dL). Serum creatinine was 1.8 mg/dL and glomerular filtration rate according to MDRD formula was 39 ml/min/1.73 m^2. Transthoracic echocardiography (TTE) showed a slightly dilated left ventricle (left ventricular end-diastolic diameter [LVEDD] 60 mm) with reduced left ventricular ejection fraction (LVEF 40% according to Simpson Biplane's method), grade I diastolic dysfunction (E/A ratio < 0.8), left atrial enlargement (antero-posterior diameter 47 mm) and mild mitral regurgitation. No significant anomalies of regional wall motion of both left and right ventricles were found. Compression ultrasonography of the lower limb veins was negative. Intravenous infusion (IV) of potassium chloride (KCl 20 mmol/h for 2 h followed by maintenance dose of 10 mmol/h) and magnesium sulfate ($MgSO_4$ 1 g/h) was started.

Implantable cardioverter defibrillator interrogation revealed a sustained ventricular tachycardia (VT) with variable cycle length (range 180–340 ms) triggered by premature ventricular complex with very short coupling interval (R-on-T phenomenon) (Figure 2). The first ICD shock was delivered at 35 Joules in standard polarity (biphasic waveform from the right ventricular coil to ICD generator) and was ineffective; VT deteriorated to ventricular fibrillation (VF). The second ICD shock was delivered at 35 Joules in reverse polarity (biphasic waveform from ICD generator to the right ventricular coil) and restored sinus rhythm following a short period of paced rhythm. Ventricular defibrillation threshold (DFT) value was <30 J at the time of implantation; moreover, two previous VT/VF episodes were effectively treated with single 35 J shock in standard polarity. Electrical lead parameters were stable over the time. The patient was referred to Cardiac Intensive Care Unit for further investigations. At the normalization of electrolytes' serum levels, the ECG showed sinus rhythm with normal *T* waves voltage and corrected QT interval duration (QTc 419 ms). TTE was repeated and resulted unchanged. Coronary angiography did not show epicardial coronary stenosis or other vascular abnormalities. The patient was dismissed

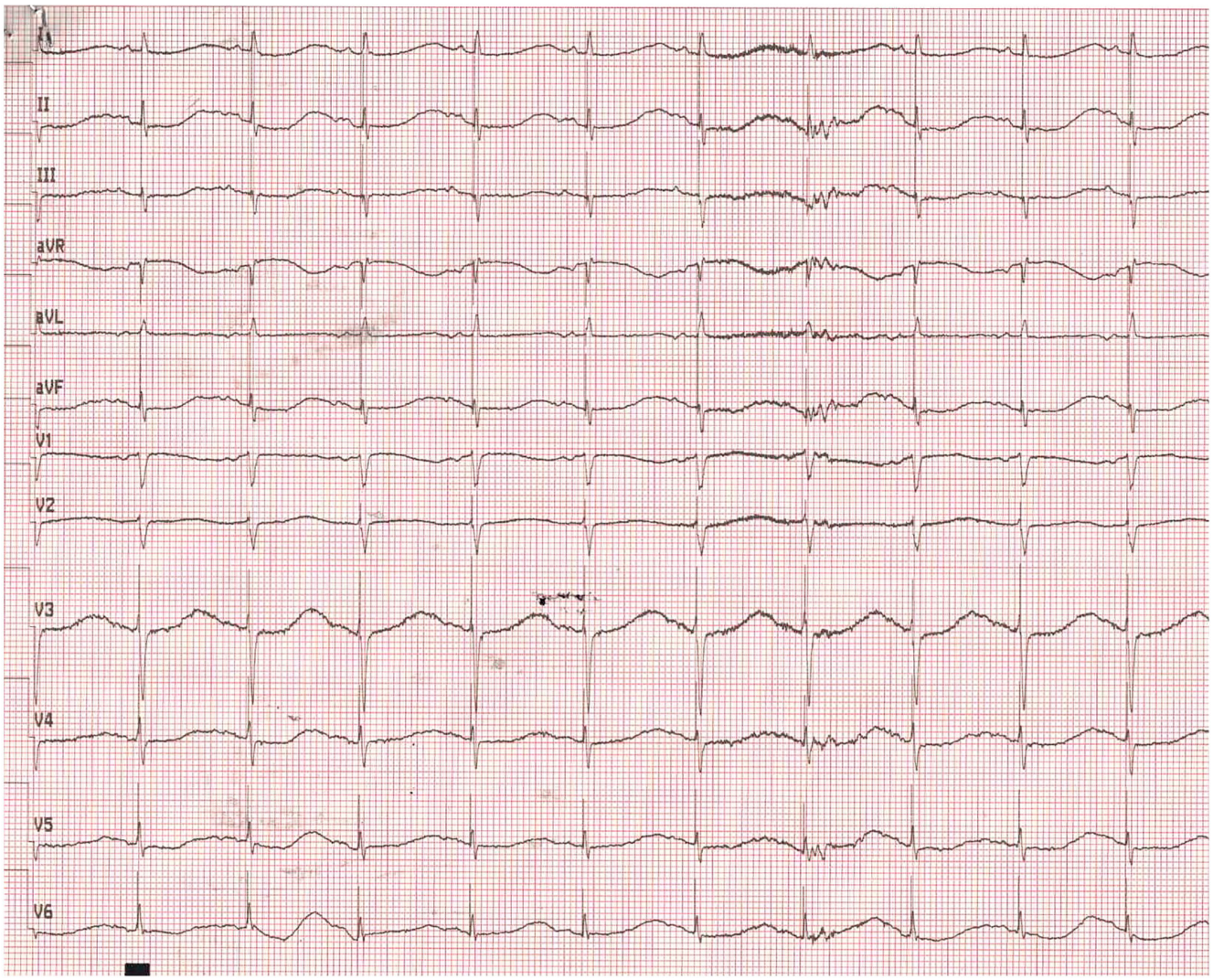

FIGURE 1 Sinus rhythm with marked QTc prolongation and low voltage *T* waves on electrocardiographic recording at admission.

3 days later. At one-month follow-up, no palpitations, syncope or appropriate ICD therapies were experienced by the patient.

Electrolyte imbalance is a frequent complication in patients with heart failure (HF). Hypokalemia is defined as serum potassium concentration <3.5 mmol/L and occurs in up to 50% of HF patients on pharmacological therapy. Hypokalemia is often iatrogenic and related to administration of both loop and thiazide diuretics. According to the latest guidelines, HF patients should be periodically screened with routine blood tests to exclude electrolyte abnormalities caused by medical therapy. Low potassium serum levels may cause lethal ventricular arrhythmias and increase the mortality risk. This approach is even more important for ICD recipients, since the effect of fluctuations of potassium serum level might impact on ventricular DFT. Little is known about the influence of the extracellular and intracellular potassium concentration upon DFT in experimental models,[1,2] and no studies are still available in humans.

We reported the case of increased DFT in ICD recipient with post-myocarditis cardiomyopathy and syncope due to VT/VF. No reason, other than the electrolyte imbalance, leading to increased DFT and the subsequent ineffective ICD shock was found. Even if the association between hypokalemia/hypomagnesemia and VT/VF has been previously reported,[3,4] we described an arrhythmic triad characterized by extreme QTc interval prolongation, malignant ventricular arrhythmia, and increased DFT leading to ineffective ICD shock. This clinical scenario should be early recognized, since the life-threatening ventricular arrhythmias risk among patients with QTc prolongation is enhanced by the concomitant increased DFT due to electrolyte imbalance among ICD recipients, leading to less survival.

We hypothesized that the onset of diarrhea and vomiting in a patient with CKD who was taking high dose of non-potassium sparing diuretics may have led to severe hypokalemia and hypomagnesemia. Hypokalemia is one of the most important risk factors for QT interval prolongation; it is frequently encountered as a side effect of diuretic treatment in patients with cardiovascular comorbidities.[3] Severe hypokalemia predisposes to development of ventricular premature complexes and prolonged QT interval: this combination can promote R-on-T phenomena and trigger

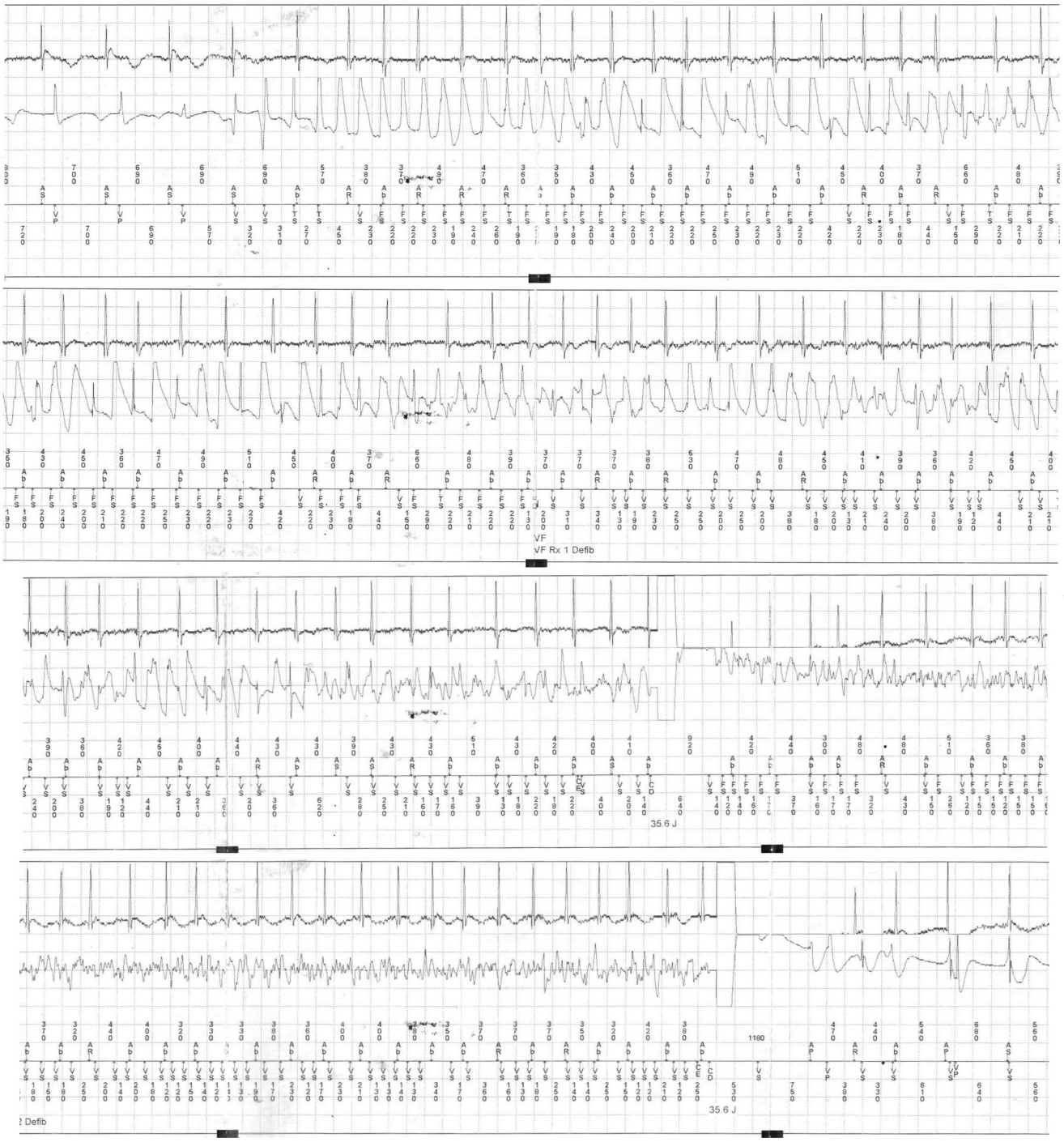

FIGURE 2 Intracardiac electrograms (IEGMs). R-on-T phenomenon-induced ventricular tachycardia. VT had a short cycle length, therefore was detected in the VF shock zone. The first electrical shock (35 J) was appropriate but ineffective and VT degenerated to VF. ICD delivered a second 35 J shock with reverse polarity that was successful.

potentially life-threatening ventricular tachyarrhythmias, including polymorphic VT, Torsades de Pointes, and VF. It is reasonable that hypomagnesemia may have played a role as concomitant cause of increased DFT in our patient, since it was observed that magnesium sulfate infusion was associated with a significant decrease in the electrical requirements for defibrillation in experimental models.[5] The present clinical case highlights the need of a careful monitoring of electrolyte serum levels as part of follow-up of ICD recipients on drug polytherapy in order to avoid the risk of a life-threatening arrhythmic triad including extreme corrected QT interval prolongation, malignant ventricular arrhythmia, and ineffective ICD shock. Further studies are required to better understand the relationship between electrolyte disorders and ventricular DFT changes in ICD recipients.

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None.

CONFLICT OF INTEREST

No conflict of interest to declare.

ETHIC APPROVAL STATEMENT

Not applicable.

PATIENT CONSENT STATEMENT

Informed consent was obtained from the patient.

CLINICAL TRIAL REGISTRATION

Not applicable.

DISCLOSURES

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ORCID

Giovanni Domenico Ciriello https://orcid.org/0000-0001-6115-9435
Vincenzo Russo https://orcid.org/0000-0002-9227-0360

REFERENCES

1. Babbs CF, Whistler SJ, Yim GK, Tacker WA, Geddes LA. Dependence of defibrillation threshold upon extracellular/intracellular K+ concentrations. J Electrocardiol. 1980;13(1):73–8. https://doi.org/10.1016/s0022-0736(80)80013-6
2. Ujhelyi MR, Schur M, Frede T, Bottorff MB, Gabel M, Markel ML. Mechanism of antiarrhythmic drug-induced changes in defibrillation threshold: role of potassium and sodium channel conductance. J Am Coll Cardiol. 1996;27(6):1534–42. https://doi.org/10.1016/0735-1097(96)00027-7
3. Laslett DB, Cooper JM, Greenberg RM, Yesenosky GA, Basil A, Gangireddy C, et al. Electrolyte abnormalities in patients presenting with ventricular arrhythmia (from the LYTE-VT study). Am J Cardiol. 2020;129:36–41. https://doi.org/10.1016/j.amjcard.2020.04.051 Epub 2020 May 15. PMID: 32565090.
4. Efstratiadis G, Sarigianni M, Gougourelas I. Hypomagnesemia and cardiovascular system. Hippokratia. 2006;10(4):147–52. PMID: 22087052; PMCID: PMC2464251.
5. McDaniel WC, Curtis JJ, Walls JT, Madsen RW. Effects of magnesium sulfate on electrical ventricular defibrillation of dogs. J Electrocardiol. 1998;31(2):137–43. https://doi.org/10.1016/s0022-0736(98)90045-0 PMID: 9588660.

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