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CASE REPORT
Arrhythmias/electrophysiology

Iatrogenic pacemaker-induced ventricular arrhythmia: a case report

Vivetha Pooranachandran [1,2]*, Tim Hodson[3], Will Nicolson [1,3], and Ghulam Andre Ng [1,2,3]

[1]Department of Cardiovascular Sciences, University of Leicester, Leicester, UK; [2]NIHR Leicester Biomedical Research Centre, Leicester, UK; and [3]Department of Cardiology, University Hospitals of Leicester NHS Trust, Leicester, UK

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Background Minimizing right ventricular (RV) pacing to reduce the progression of heart failure is an established practice. Proprietary algorithms to reduce unnecessary RV pacing have been incorporated into both simple and complex cardiac pacemaker devices, for reducing the possibility of heart failure and arrhythmias.

Case summary We present a case of a 43-year-old male implanted with a dual-chamber primary prevention implantable cardioverter-defibrillator (AUTOGEN EL, Boston Scientific) for sudden cardiac death. At the time of implant, the patient had hypertrophic cardiomyopathy with mild left ventricular (LV) systolic impairment, and sinus rhythm with intact atrioventricular (AV) conduction. The patient developed progression of his disease with symptoms (dyspnoea) and LV impairment. This led to a decision to activate the minimal RV pacing algorithm (RYTHMIQ™). A deterioration in AV conduction caused intrinsic ventricular beats to fall in the atrial blanking period, and subsequent VVI backup pacing resulted in R on T pacing. This induced ventricular arrhythmia. RYTHMIQ™ was subsequently deactivated, and the patient has had no further device-induced arrhythmias.

Discussion Numerous studies have demonstrated the adverse effect of RV pacing on LV function. Minimizing RV pacing is, therefore, encouraged in individuals with intact AV conduction. However, underlying conduction abnormalities must be assessed prior to activating algorithms designed to minimize RV pacing. This case demonstrates the importance of careful intracardiac electrogram interpretation and individual case-based device programming, to avoid device-induced complications.

Keywords Case report • Implantable cardioverter-defibrillator • Ventricular arrhythmia • RYTHMIQ

ESC Curriculum 5.6 Ventricular arrhythmia • 5.10 Implantable cardioverter defibrillators

Learning points

- RYTHMIQ™ should be used with caution in patients with known intermittent atrioventricular (AV) dissociation.
- In patients with no ventricular pacing indication, a Wenckebach pacing test or pacing at sensor indicated rate may be performed to assess AV conduction abnormalities.

* Corresponding author. Tel: +44 116 250 2366, Email: vp147@le.ac.uk
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Introduction

Widespread research has demonstrated that although dual-chamber pacing restores atrioventricular (AV) synchrony, right ventricular (RV) pacing-induced mechanical dyssynchrony may lead to progressive left ventricular (LV) dysfunction, promoting heart failure.[1] This encouraged the design of programmable device algorithms to reduce unnecessary RV pacing. Here, we present an iatrogenic case of device-induced ventricular arrhythmia.

Timeline

Date	Events
2009	Presented with Dyspnoea. Diagnosis of hypertrophic cardiomyopathy with mild left ventricular (LV) systolic impairment and family history of sudden cardiac death. No other past medical history. Implanted with primary prevention implantable cardioverter-defibrillator (ICD).
2015	Elective ICD generator replacement
2016	Presented with worsening dyspnoea. Echocardiogram demonstrated moderate LV systolic impairment. RYTHMIQ™ was programmed on.
17 May 2017	Device check demonstrated normal function and parameters
18 May 2017	Device-induced ventricular arrhythmia. Physical examination demonstrated no abnormalities.

Case presentation

A 43-year-old male was implanted with a dual-chamber implantable cardioverter-defibrillator (ICD) for primary prevention. The patient presented with dyspnoea and had a family history of sudden cardiac death (SCD), hypertrophic cardiomyopathy, and mild LV systolic impairment (Class IIB recommendation for an ICD with a 5% risk of SCD at 5 years). No other abnormalities were detected. The underlying rhythm was sinus with first-degree AV Block (PR interval 340 ms) and a QRS duration of 90 ms. The ICD (AUTOGEN EL, Boston Scientific) was programmed to DDDR mode with rates of 70–120 b.p.m., and sensed and paced AV delays of 80 ms and 110 ms, respectively. Subsequent device follow-ups demonstrated normal device function and measurements, >95% atrial and ventricular pacing, and patient was symptomatically improving.

Seven years after the initial presentation, patient presented with symptoms of progressive dyspnoea and a follow-up echocardiogram demonstrated moderate LV systolic impairment (*Table 1*). As a result, RYTHMIQ™ and AV Search+ device features were enabled to minimize RV pacing. A device check 7 months later verified normal device and lead parameters (*Figure 1*). Atrial and ventricular pacing were 100% and 1%, respectively. As patient's symptoms were improving, no changes to the device settings were made. The following day, the patient experienced a single episode of appropriate device (shock) therapy for ventricular fibrillation. Interrogation of device electrograms demonstrated initiation of ventricular arrhythmia due to R on T pacing.

The alert demonstrated an episode of shock delivered for ventricular arrhythmia. The trace (*Figure 2A*) begins with atrial pacing and ventricular sensing (VS) at the sensor indicated rate (SIR) (120 ppm) (1,2). As the RYTHMIQ™'s criteria were met (VS within A-A + 150 ms), the device remained in AAIR mode. In the presence of AV block and subsequent ventricular beats falling in the atrial blanking period (*Figure 2B*), the device failed to detect the intrinsic ventricular events: [VS] (3). This initiated mode switch to backup VVI pacing [lower rate limit (LRL) set at 70 ppm, therefore, VVI backup is 55 ppm (1090 ms)], with ventricular paced beats on the 3rd, 6th, and 9th beats (4). We believe the closely coupled V-V timing resulted in R on T pacing (5), initiating ventricular fibrillation.

Discussion

RYTHMIQ™ and AV Search+

RYTHMIQ™ is a Boston Scientific feature designed to encourage intrinsic conduction. It is a programmable feature and is nominally set

Table 1 Echocardiogram parameters of hypertrophic cardiomyopathy[2]

Left ventricular dimensions and volumes	Initial echocardiogram	Echocardiogram in 2016	Normal range (male)	
IVS diastole (mm)	17	18	6–12	
LVPW diastole (mm)	9.5	8.8	6–12	
LVID diastole (mm)	40	42	37–56	
LVEDV indexed ml/m^2	71.4	78.1	30–79	
LVEF %	Mildly impaired (visually)	Moderately impaired (visually)	≥55%	
			Eccentric	**Concentric**
Relative wall thickness in left ventricular hypertrophy	0.66	0.64	≤0.42	>0.42

IVS, interventricular septum; LVPW, left ventricular posterior wall; LVID, left ventricular internal diameter; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction.

Figure 1 Device measurements taken 1 day prior to shock.

to off. RYTHMIQ™ operates in AAI(R) pacing mode with asynchronous VVI backup pacing during normal AV conduction. A loss of AV synchrony will automatically switch the device to DDD(R) mode, and a return in normal AV conduction will switch back to AAI mode with VVI backup.

RYTHMIQ™:

- AAI(R) pacing is delivered at the LRL and/or SIR.
- VVI backup pacing is delivered at a rate of 15 ppm below the programmed LRL, i.e. LRL programmed at 60 ppm, VVI backup will be

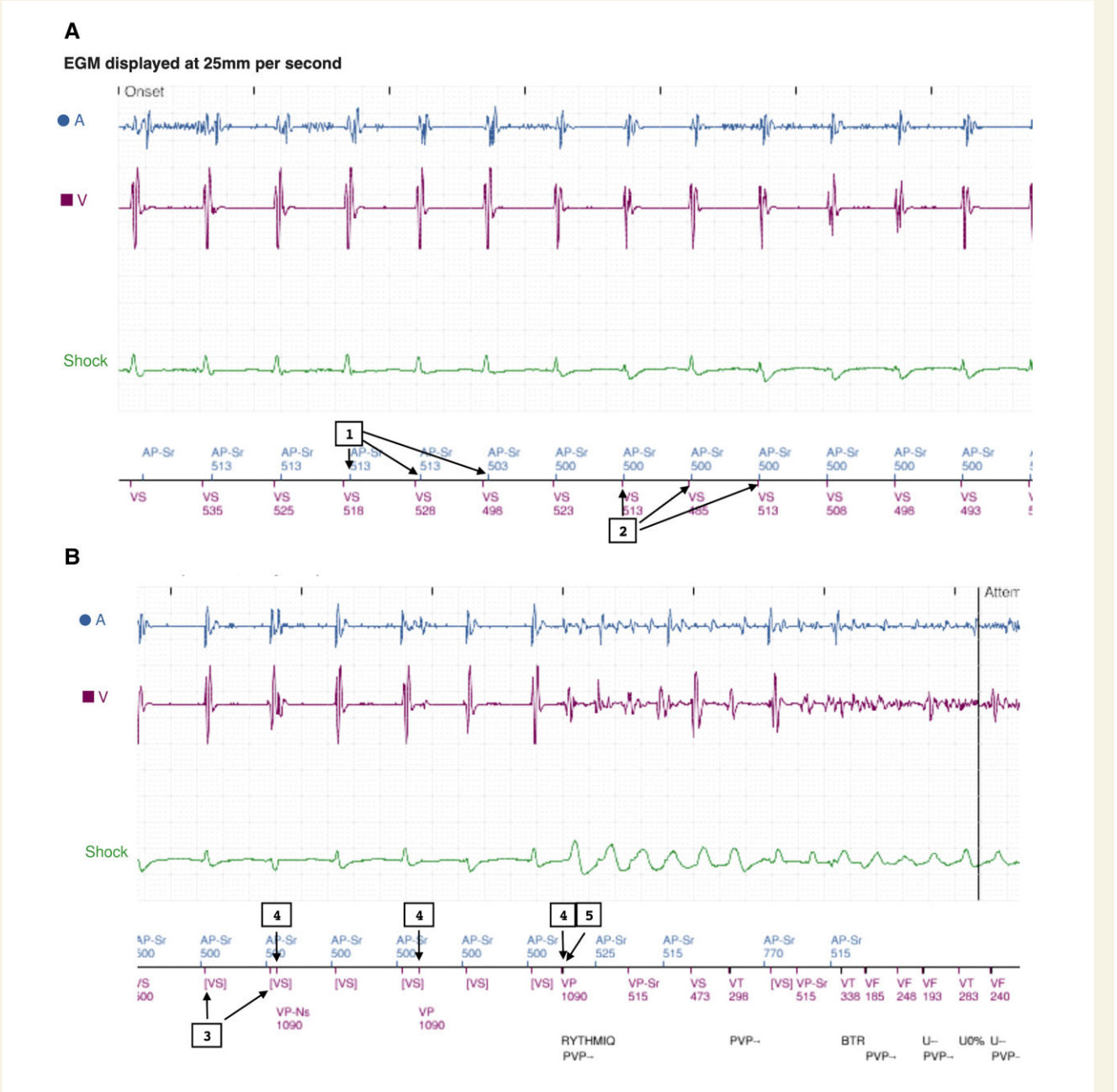

Figure 2 Example of ventricular arrhythmia in the context of RYTHMIQ. (*A*) Device functioning in AAIR mode at sensor indicated rate and (*B*) back up VVI pacing followed by R on T pacing-induced ventricular arrhythmia.

Table 2 Device algorithms designed to reduce ventricular pacing

Boston Scientific

RYTHMIQ™

- Atrial based pacing with asynchronous VVI backup pacing (lower rate limit minus 15 ppm). Switch to DDD(R) mode occurs if:

  (1) Three slow ventricular beats are detected in a window of 11 beats

  (2) If V-V intervals are longer than A-A + 150 ms

AV Search+

- Intrinsic atrioventricular (AV) conduction is assessed by increasing AV delay periodically for up to eight consecutive paced or sensed cardiac cycles. If present, the longer AV Search+ AV delay will remain active. AV delay will revert to the programmed setting:

  (1) When no intrinsic ventricular activity is detected during the periodic search cycle or

  (2) When two ventricular paced (VP) events are detected within a 10-cycle moving window

Medtronic

Managed ventricular pacing (MVP)

- Atrial based pacing [AAI(R)] with switch to DDD(R) mode if:

  (1) 2 out of 4 intrinsic ventricular activity is absent

  (2) Average PR interval over four consecutive cycles exceeds the programmed PR value (by default the long PR function of the algorithm is switched OFF). Search AV+

- Intrinsic AV conduction is assessed in the 16 most recent cycles and adjusts the sensed and paced AV delays to promote intrinsic activation of the ventricles. Based on the AV conduction time, the AV delays are either lengthened by 62 ms or shortened by 8 ms for the next 16 pacing cycles.

St. Jude Medical™

Ventricular intrinsic preference (VIP)

- Intrinsic AV conduction is assessed using AV hysteresis (up to 450 ms) at regular intervals (AV extension, search intervals and number of cycles are programmable). If intrinsic conduction is absent for a programmed number of cycles (i.e. ventricular pacing at the end of extended AV delay), AV delay will shorten to the programmed value until the next search interval.

Sorin

SafeR

- Atrial based pacing AAI(R) with switch to DDD(R) mode if:

  (1) PR interval exceeds the 'long PR interval' (programmable) for six consecutive beats (AV block I criteria)

  (2) 3/12 non-conducted atrial events (AV block II criteria)

  (3) Two consecutive non-conducted atrial events (AV block III criteria)

  (4) Ventricular pauses of 2–4 s (programmable)

Biotronik

AV hysteresis

- Intrinsic AV conduction is assessed using AV hysteresis (AV delay extended to 450 ms) for eight cycles. Mode switch to ADI(R) if 6/8 beats are ventricular sensed events. VP suppression
- Mode switch to DDD(R) if:

  (1) PR interval >450 ms in two cycles

  (2) No intrinsic ventricular activity ≥2 s

  (3) Two consecutive non-conducted atrial events

  (4) Three non-conducted atrial events in a rolling window of eight events

Table 3 Cardiac defibrillator options for patients with left ventricular dysfunction and a left ventricular ejection fraction of ≤35%

QRS duration	New York Heart Association			
	I	II	III	IV
<120 ms	ICD if at high risk of SCD			ICD and CRT not clinically indicated
120–149 ms without left bundle branch block	ICD			CRT-P
120–149 ms with left bundle branch block	ICD	CRT-D	CRT-P or CRT-D	CRT-P
≥150 ms with or without left bundle branch block	CRT-D		CRT-P or CRT-D	CRT-P

Adapted from National Institute for Health and Care Excellence [TA314].[10]
ICD, implantable cardioverter-defibrillator; CRT-P, cardiac resynchronisation therapy-pacemaker; CRT-D, cardiac resynchronization therapy-defibrillator.

45 ppm. The backup VVI pacing rate is limited to a minimum of 30 ppm and maximum of 60 ppm.

- The device switches from AAI(R) to DDD(R) mode when three slow ventricular beats are detected in a window of 11 beats. A slow ventricular event is defined as: (i) ventricular paced beat, (ii) V-V interval greater than A-A interval + 150 ms.

In DDD(R) mode, the device uses AV Search + algorithm to assess the return of normal AV conduction.

AV Search+:

- AV Search+ promotes intrinsic conduction by periodically extending the AV delay. This occurs every 32–1024 ventricular cycles with AV Search delay of 30–400 ms (both programmable search parameters).
- If <2 out of the last 10 ventricular events are paced or sustained conduction is detected for ≥25 beats, the device will switch to AAI(R) mode with VVI backup.

Note: If AV Search+ is programmed off, switch from AAI(R) with VVI backup to DDD(R) mode will only occur once, until the device is reprogrammed.

Atrioventricular conduction disease is a common indication for device implantation. As per the European Society of Cardiology guideline for cardiac pacing and cardiac resynchronization therapy, AV synchronous pacing is recommended in advanced AV block, however, ventricular pacing for prolonged first-degree AV delay is an ongoing debate.[3]

A prolonged AV delay impairs LV filling, and reducing ventricular pacing may not be desirable in view of the haemodynamic response.[4] On the contrary, several studies have demonstrated RV pacing to be associated with an increased risk of death and heart failure hospitalization, ventricular dyssynchrony and propensity to atrial fibrillation, questioning the optimal device setting in patients with prolonged AV delay.[5,6]

To provide an appropriate level of AV synchronous pacing, many pacemaker manufacturers (St Jude Medical/Abbott, Boston Scientific, Sorin, Biotronik, and Medtronic) have incorporated a minimal RV pacing feature into both simple and complex devices. With the exception of RYTHMIQ™, other algorithms are designed to provide a backup synchronous ventricular response to A-A intervals that are missing ventricular sensed events (number of allowed non-conducted atrial events and programmable AV interval vary between manufacturers). Thus, reducing the likelihood of R on T pacing (*Table 2*).

The RYTHMIQ™ feature, which is present in simple pacemaker devices, may have proven fatal for our patient if he did not have a defibrillator. Similar incidences with RYTHMIQ™ were previously reported to be proarrhythmic, though these were as a result of short-long-short coupling intervals.[7,8]

Our case highlights the importance of regular follow-up and individual case-based device programming to prevent potential device issues. RYTHMIQ™ stores a 20 s electrogram data in the Arrhythmia logbook which must be carefully interpreted to distinguish between pathological and algorithm-induced arrhythmias. In addition, a simple Wenckebach pacing test or pacing at SIR may be performed to assess AV conduction abnormalities before activating RYTHMIQ™. A Wenckebach test involves pacing a patient's heart at a faster rate than their AV node can handle (most often at the programmed max sensor/track rate). In some cases, this can result in 1st degree AV block or Wenckebach, which can be viewed on the paced electrocardiogram. This will help determine appropriate settings to avoid possible complications.[9] Patients with heart failure who require ventricular pacing due to AV conduction disease may additionally benefit from cardiac resynchronization therapy (*Table 3*).[10] This will help restore ventricular synchrony and may improve LV systolic function.[11] Our patient did not meet the criteria for a cardiac resynchronization therapy (QRS duration; 90 ms, mild LV function), however, this patient may benefit from the emerging conduction system pacing, which hopes to preserve or normalize biventricular activation with pacing.[12] In light of this arrhythmia episode, RYTHMIQ™ was deactivated in the patient's ICD. A subsequent 3 year follow-up demonstrated no further device-induced arrhythmias.

RYTHMIQ™ has been designed to promote intrinsic conduction with the safety of backup pacing. We highlight the need for careful individual assessment prior to programming this feature on, to avoid pacing-induced arrhythmias.

Lead author biography

Vivetha is a PhD candidate at the University of Leicester. Research interests include Ventricular Arrhythmia and Sudden Cardiac Death.

Supplementary material

Supplementary material is available at *European Heart Journal—Case Reports* online.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written consent for the submission and publication of this case, including images, has been obtained from the patient in line with COPE guidance.

Conflict of interest: None declared.

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