Novel Automatic Shocking-Vector Adjustment Algorithm: A Life Saving Feature of a Modern Defibrillator.

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Abstract

Background: Failed delivery of appropriate shocks against fatal arrhythmias can be the result of low impedance on high-voltage leads. This malfunction might be missed on routine interrogation. We describe a case of 66 year-old male with a high-voltage lead short circuit who was successfully rescued with the use of an overcurrent detection and automatic shocking vector adjustment algorithm. Case Report: A 66-year-old male with severe nonischemic cardiomyopathy was admitted after receiving two shocks from his cardiac resynchronization therapy cardioverter-defibrillator (CRT-D). Interrogation confirmed two consecutive episodes of ventricular fibrillation. For each episode, the initial shock therapy was aborted due to low impedance (<10 ohms) detected on the default shocking configuration: right ventricle to superior vena cava/can. As a result, the device algorithm excluded the superior vena cava coil and immediately delivered a shock of 40 joules between the right ventricular coil and the CRT-D can (Figure 1B). This successfully terminated the ventricular fibrillation. All other lead measurements were normal. Conclusions: High voltage lead malfunctions can lead to failed therapy of life threatening arrhythmias. Malfunctions such as low impedance of high-voltage leads may not be detected on routine interrogation. Fortunately, the overcurrent detection algorithm recognized the low impedance and another shocking configuration was selected and successfully terminated the ventricular arrhythmias. With these algorithms - overcurrent detection and automatic shocking vector adjustment, this patient was successfully rescued. We recommend this feature be included in all modern defibrillators.

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Disclosures: None

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Background:

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Case Report:

A 66-year-old male with severe nonischemic cardiomyopathy was admitted after receiving two shocks from his cardiac resynchronization therapy cardioverter-defibrillator (CRT-D). Interrogation confirmed two consecutive episodes of ventricular fibrillation. For each episode, the initial shock therapy was aborted due to low impedance (<10 ohms) detected on the default shocking configuration: right

ventricle to superior vena cava/can. As a result, the device algorithm excluded the superior vena cava coil and immediately delivered a shock of 40 joules between the right ventricular coil and the CRT-D can (Figure 1B). This successfully terminated the ventricular fibrillation. All other lead measurements were normal.

Conclusions:

High voltage lead malfunctions can lead to failed therapy of life threatening arrhythmias. Malfunctions such as low impedance of high-voltage leads may not be detected on routine interrogation. Fortunately, the overcurrent detection algorithm recognized the low impedance and another shocking configuration was selected and successfully terminated the ventricular arrhythmias. With these algorithms - overcurrent detection and automatic shocking vector adjustment, this patient was successfully rescued. We recommend this feature be included in all modern defibrillators.

Introduction:

Failed delivery of appropriate shocks by a defibrillator can be the result of low impedance detected on high-voltage leads.[1] Malfunctions such as these might be missed on routine interrogations and thus might go unrecognized.[2,3] Herein we describe a case of successful rescue of a patient with a high-voltage lead malfunction with the use of a novel algorithm.

Case Report:

A 66-year-old African American male with a history of severe nonischemic dilated cardiomyopathy with a severely reduced left ventricular ejection fraction, ventricular fibrillation (VF), and persistent atrial fibrillation was admitted to the hospital after receiving two shocks from his cardiac resynchronization therapy cardioverter-defibrillator (CRT-D), after a witnessed brief loss of consciousness.

Upon interrogation of his Quadra Assura 3365-40C (Abbott, Plymouth, MN, USA) defibrillator there were two confirmed consecutive episodes of ventricular fibrillation (figure 1A). For each episode, the first attempt to terminate the VF with implantable cardioverter-defibrillator (ICD) shock therapy was unsuccessful from the dual coil high voltage right ventricular lead, Durata 7120 (Abbott, Plymouth, MN, USA). For each episode, the initial shock therapy was not delivered due to low impedance (<10 ohms) detected on the superior vena cava (SVC) coil (Figure 1B). The default shocking configuration was right ventricle (RV) to SVC/Can. As a result of the low impedance, the device algorithm (overcurrent detection and DynamicTX^{TM} algorithm) excluded the SVC coil and immediately delivered a rescue shock of 40 joules between the RV coil and the CRT-D generator can (Figure 1C). This successfully terminated the VF. In addition, with the first shock therapy from the ICD, his persistent atrial fibrillation was converted back to normal sinus rhythm as well. All other lead measurements were within normal limits, with RV pacing impedance of 400 ohms and LV pacing impedance of 940 ohms with pacing vector of M3-M2. The RV pacing threshold was 0.5V at 0.5 ms and a LV pacing threshold 0.5V at 1.0 ms (M3-M2). RV sensing was found to be greater than 12.0mV (Bipolar). Afterwards, the SVC coil was turned off due to failure to deliver shock therapy from the low impedance.

Since the patient had recurrent VF and subsequently his SVC coil was turned off, it was decided to perform a defibrillation threshold test. VF was successfully induced with high-voltage high-frequency right ventricular pacing. Successful termination of VF was achieved with a single 30 joule shock with RV coil to CRT-D can shocking vector.

Discussion:

The annual rate of ICD lead defects reaches ˜20% in a 10 year follow up.[3] In the prior study, 56% of major causes of lead failure were due to lead insulation breaks.[3] Nearly 2/3 of lead defects can be detected on electrical parameters during routine follow up, but in 1/3 of the cases, the lead defects are found after failed shock therapy.[3] High voltage lead malfunctions can lead to failed therapy of life threatening arrhythmias. In our case the high-voltage lead malfunction occurred between the RV coil and the SVC/Can as the impedance was below the detection limits (<10ohms). Fortunately, the overcurrent detection algorithm recognized the low impedance and the initial shock was not delivered. The automatic shocking vector adjustment algorithm (DynamicTX^{TM}) then excluded the SVC coil and a 40 joules shock therapy was delivered with RV-Can shocking-vector configuration with successful termination of VF.

The novel overcurrent detection algorithm is exclusive to the Ellipse, Fortify Assura, Quadra Assura, and Unify Assura series (Abbott, Plymouth, MN, USA) systems. The overcurrent detection algorithm is designed for a dual coil system with an active SVC coil (Figure 3). During shock delivery, when low impedance is detected (<10 ohms) in the initial configuration, the overcurrent detection algorithm will abort the shock therapy. This helps prevent damage to the ICD system. After a low impendence is detected in a given shocking vector, the DynamicTX^{TM} algorithm selects an alternative configuration. Vector switching sequence varies based on programmed configuration (Figure 3). In our case, the initial configuration (RV to SVC/Can) failed, therefore it was changed to RV to Can with delivery of shock therapy and successful termination of VF (Figure 1). At the end of the rescue, the device defaulted back to the initial programmed shocking vector (RV to SVC/Can). Activation of the Dynamic Tx algorithm results in multiple alerts to indicate the presence of a high voltage lead failure and initiation of an alternative shock configuration. A vibratory alert, if turned on, will also be delivered to the patient.

A case, published by Mizobuchi et al.[4] described a patient with low lead impedance detected on SVC coil on a Riata lead (Abbott, Plymouth, MN, USA) while performing a defibrillation threshold test at the time of ICD generator replacement. In their case a successful rescue shock was delivered from the RV coil to the Can using the overcurrent detection and DynamicTX^{TM} algorithm. The Food and Drug Administration classified the Riata family of ICD leads as a class I recall due to inside-out abrasions underneath the shocking coils.[5] Chung et al. described a patient with recurrent VF in the setting of a high voltage lead short circuit with successful rescue using the DynamicTX^{TM}algorithm. [6] In their case a, shock therapy was delivered through a SPL SP02 dual-coil RV ICD lead (Ventritex, Sunnyvale, CA, USA). To our knowledge the present case is the first to show the efficacy of the DynamicTX^{TM} algorithm in a currently implanted ICD lead. In addition, our case further highlights the importance of overcurrent detection and the success of DynamicTX^{TM} algorithm in a clinical setting.

Conlcusion:

Without this algorithm, patients such as ours might not be successfully rescued. We would recommend these features be included in all modern defibrillators.

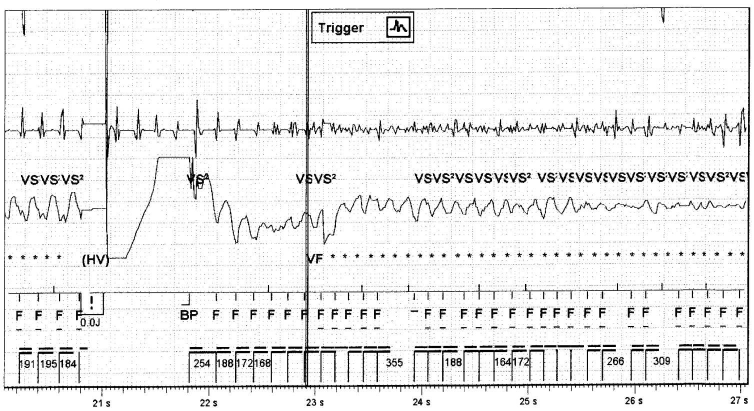
Figure 1:

Episode: VF (279 bpm / 215 ms) (Continued)

Jan 4, 2018 9:15 am

1: A Sense Amp AutoGain (10 mm/mV)
2: V Sense Amp AutoGain (0.6 mm/mV)
3: Discrimination AutoGain (1.7 mm/mV)
4: Markers

Sweep Speed: 25 mm/s



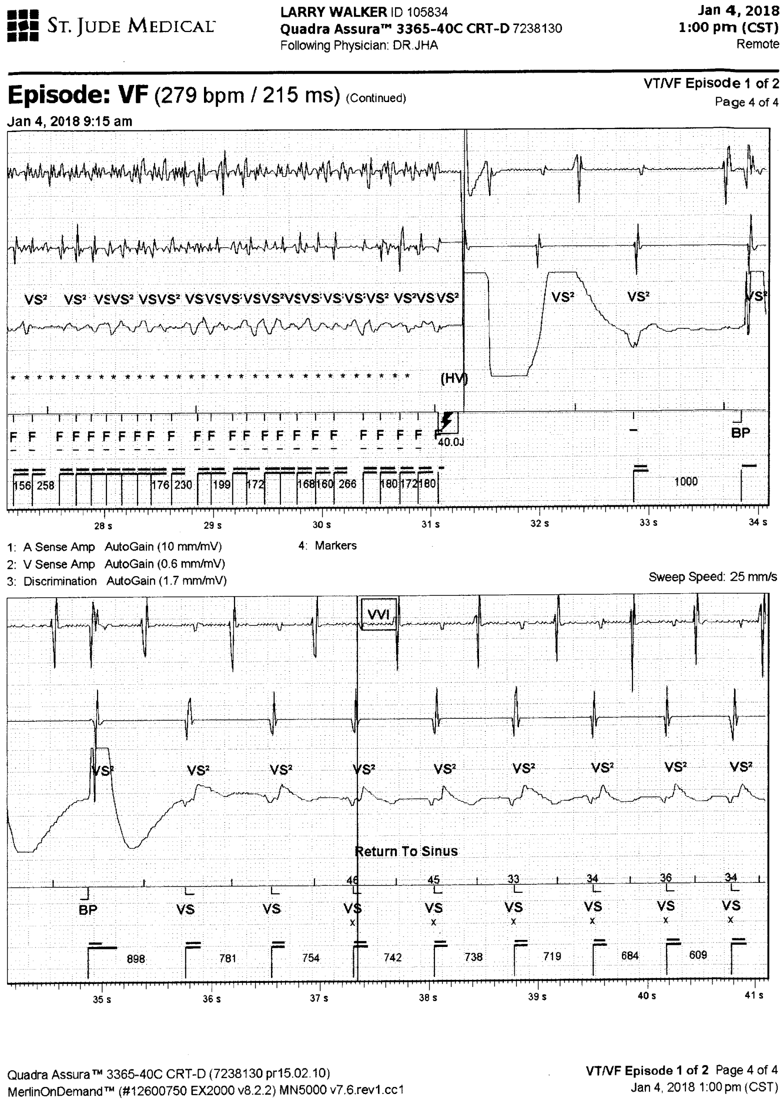
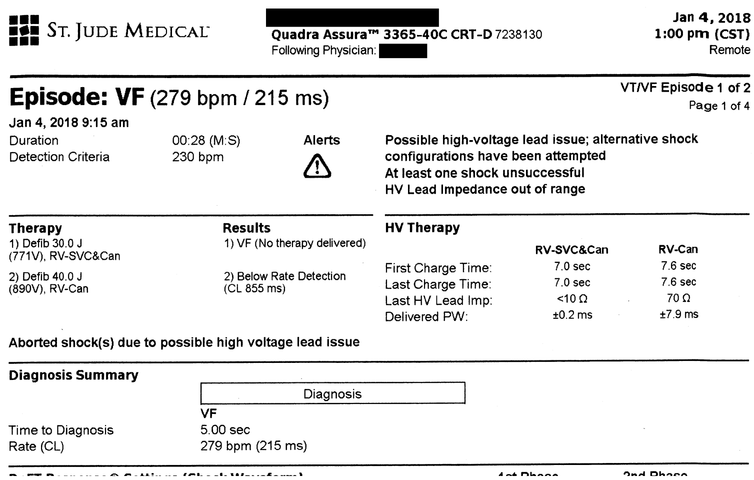

ST. JUDE MEDICAL
LARRY WALKER ID 105834
Quadra Assura™ 3365-40C CRT-D 7238130
Following Physician: DR.JHA
Jan 4, 2018
1:00 pm (CST)
Remote
Episode: VF (279 bpm / 215 ms) (Continued)
VT/VF Episode 1 of 2
Page 4 of 4
Jan 4, 2018 9:15 am
(HV)
40.0J
BP
1000
1: A Sense Amp AutoGain (10 mm/mV)
2: V Sense Amp AutoGain (0.6 mm/mV)
3: Discrimination AutoGain (1.7 mm/mV)
4: Markers
Sweep Speed: 25 mm/s
VVI
Return To Sinus
BP
VS
898
781
754
742
738
719
684
609
Quadra Assura™ 3365-40C CRT-D (7238130 pr15.02.10)
MerlinOnDemand™ (#12600750 EX2000 v8.2.2) MN5000 v7.6.rev1.cc1
VT/VF Episode 1 of 2 Page 4 of 4
Jan 4, 2018 1:00 pm (CST)

Figure 2:


ST. JUDE MEDICAL

[redacted]
Quadra Assura™ 3365-40C CRT-D 7238130
Following Physician: [redacted]

Jan 4, 2018
1:00 pm (CST)
Remote

Episode: VF (279 bpm / 215 ms)

VT/VF Episode 1 of 2
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Jan 4, 2018 9:15 am

Duration	00:28 (M:S)	
Detection Criteria	230 bpm	

Alerts
Possible high-voltage lead issue; alternative shock configurations have been attempted
At least one shock unsuccessful
HV Lead Impedance out of range

Therapy	Results
1) Defib 30.0 J (771V), RV-SVC&Can	1) VF (No therapy delivered)
2) Defib 40.0 J (890V), RV-Can	2) Below Rate Detection (CL 855 ms)

HV Therapy

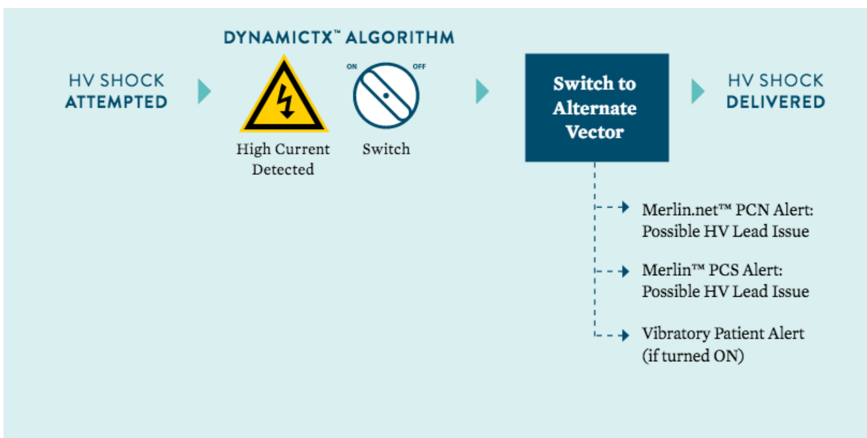
	RV-SVC&Can	RV-Can
First Charge Time:	7.0 sec	7.6 sec
Last Charge Time:	7.0 sec	7.6 sec
Last HV Lead Imp:	<10 Ω	70 Ω
Delivered PW:	±0.2 ms	±7.9 ms

Aborted shock(s) due to possible high voltage lead issue

Diagnosis Summary

	Diagnosis
	VF
Time to Diagnosis	5.00 sec
Rate (CL)	279 bpm (215 ms)

Figure 3:



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