ESC European Society of Cardiology

European Heart Journal - Case Reports (2023) **7**, 1–4
https://doi.org/10.1093/ehjcr/ytad577

CASE REPORT
Electrophysiology

An intuitive method to reduce the defibrillation threshold: a case report

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Received 22 May 2023; revised 6 November 2023; accepted 16 November 2023; online publish-ahead-of-print 30 November 2023

Background Defibrillation threshold (DFT) testing is done to assess whether proper sensing of ventricular fibrillation and adequate safety margin for defibrillation are present in an implantable cardioverter defibrillator (ICD). This case report presents an intuitive method for lowering the DFT. It may be used on a larger scale in other patients with high DFTs when other methods for lowering the DFT (changing medications, adjusting the device, and adding coils) are not feasible or preferable to use.

Case summary A 64-year-old male presented to the emergency room with failed appropriate shocks from his ICD. Device interrogation revealed that he failed his first maximum output shock before subsequent shock at the same polarity and output succeeded, suggesting a high DFT. Therefore, the DFT needs to be lowered in our patient. After considering the potential efficacy and risk of a number of traditional options, we used an intuitive method whereby the right ventricular (RV) coils of two separate leads were combined via a y-adapter. This method successfully lowered the patient's DFT, and he received successful shocks from his ICD over the next 9 months before reaching end-stage heart failure. He received a transplant, and the device and transvenous leads, except for the superior vena cava coil, were successfully removed.

Discussion Combining two RV coils from different locations may lower the DFT. This method may be considered in the larger population in cases where using traditional methods are not safe or possible for certain patients. This method may work by lowering shock impedance and increasing the shock tissue surface area.

Keywords Implantable cardioverter defibrillator • Defibrillator threshold testing • Right ventricular coil • Subcutaneous coil • Extraction • Case report

ESC curriculum 5.6 Ventricular arrhythmia • 5.10 Implantable cardioverter defibrillators • 6.5 Cardiomyopathy • 7.5 Cardiac surgery • 6.2 Heart failure with reduced ejection fraction

Learning points

Case: A patient who presented with multiple implantable cardioverter defibrillator shocks secondary to ventricular tachycardia.

- When the first shock at maximum output is ineffective and the second shock at maximum output is effective, there is a major concern for a high defibrillation threshold (DFT) and should therefore be reduced. To do so, there are various methods available, which unfortunately are not always adequately effective or feasible to reduce the DFT and are sometimes associated with higher risk.
- Combining two separate right ventricular (RV) coils using a y-adapter could provide a way to improve the DFT by lowering the overall shock impedance of the coils and increasing shock tissue surface area in the RV when other methods are not adequately effective or feasible.

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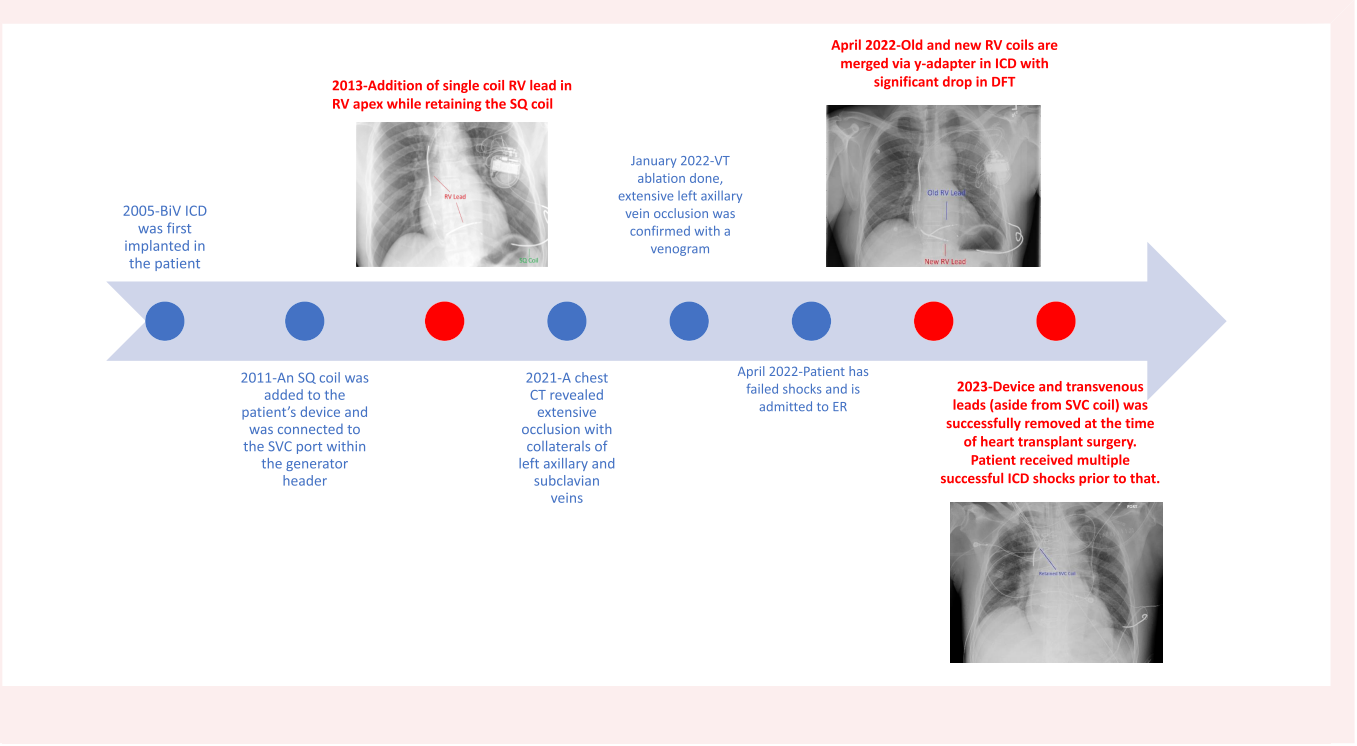
Handling Editor: Constantine Bakogiannis
Peer-reviewers: Henrike Aenne Katrin Hillmann; Linh Ngo
Compliance Editor: Nikolaos Spinthakis

Introduction

Implantable cardioverter defibrillators (ICDs) are recommended in patients with primary and secondary prevention indications for sudden cardiac death caused by ventricular arrhythmia.[1] In patients with unusual lead location [not in the right ventricular (RV) apex], or right-sided ICDs, defibrillation threshold (DFT) testing is done to ensure at least a 10 J margin between the maximum ICD shock energy of the device and the DFT. The DFT can vary significantly at any time depending on several variables. If the safety margin is inadequate, the DFT needs to be lowered.[2] Traditional methods of lowering the DFT are changing medications (using medications that lower the DFT), making device-related adjustments (reversing polarity or using a higher-output generator), and adding coils [adding a second subcutaneous (SQ) coil or placing a coil in the azygous vein].[2] In this study, we present a case where we were able to successfully lower our patient's DFT using an intuitive method, which we believe can be used on a larger scale in other patients with high DFTs.

Summary figure



Case presentation

A 64-year-old male experienced two shocks from his dual-chamber biventricular ICD. Because of these shocks, he presented to our hospital emergency room (ER). A physical examination found his vitals to be normal. He reported being free from chest pain. His troponin level was mildly elevated. The creatinine level was 1.8 mg/dL. The rest of his basic metabolic profile and complete blood count were normal. An electrocardiogram showed atrial fibrillation with biventricular pacing.

His device was implanted in 2005 due to severe non-ischaemic cardiomyopathy (NICM), sustained ventricular tachycardia (VT), and left bundle branch block (QRS 155 ms).[3] A dual-coil Medtronic 6949 RV Sprint Fidelis DF-1 ICD lead, Medtronic CapSureFix Novus MRI SureScan Model 5076 lead, and Medtronic Attain Model 4193 lead were placed in the RV high septum, right atrium, and coronary sinus (CS) lateral venous branch, respectively. Following failed ICD shocks, a Medtronic 6996 SQ coil was added in 2011 and connected to the superior vena cava (SVC) port in the generator header (*Figure 1*) with successful DFT testing at 25 J. Because of a concern that the patient was pacemaker dependent and secondary indication for his ICD, a new, single-coil Medtronic 6935 RV Quattro DF-1 ICD lead was added in the RV apex in 2013. At this time, his old RV lead was capped, and the old SQ coil was kept connected to the SVC port (*Figure 2*), with successful DFT testing done at 25 J. The patient had one more generator change in 2017.

He was previously placed on sotalol for recurrent VT with associated multiple ICD shocks, but he later had to be switched to amiodarone and mexiletine because of failure and worsening chronic kidney disease (Stages II and III). A VT ablation was done, but later his VT and ventricular fibrillation (VF) events restarted, and his NICM continued to progressively worsen, resulting in more ICD shocks that caused our patient's aforementioned presentation to the ER.

Device interrogation revealed that the patient failed his first shock at the maximum output of 35 J. However, the second one with the same output and polarity succeeded. The rest of his device interrogation (threshold, impedance, and sensitivity) for all leads and coils shock impedance were normal. It was therefore determined that he had an elevated DFT that needed to be lowered.

We decided to replace the current 35 J generator, which was close to elective replacement indicator (ERI), with a Medtronic Cobalt DETPB2D1 ICD 40 J generator. Notably, 1 year prior to the ablation procedure, an incidental finding on chest computed tomography revealed extensive occlusion with collaterals of his left axillary vein and subclavian vein. We performed a venogram, which confirmed occlusion (see Supplementary material online, *Video S1*), with possible extent to the azygos vein origin, meaning that adding a second coil to the azygos vein would be challenging. The next options in this patient managment were to reverse polarity of the ICD or eliminate the can from DFT testing. However, they were unlikely to adequately and persistently lower the DFT.

We decided to use a novel method to lower the DFT. We used a Medtronic DF-1 6726 y-adapter (see Supplementary material online, *Figure S1*) to combine the RV coils of the Quattro lead and abandoned

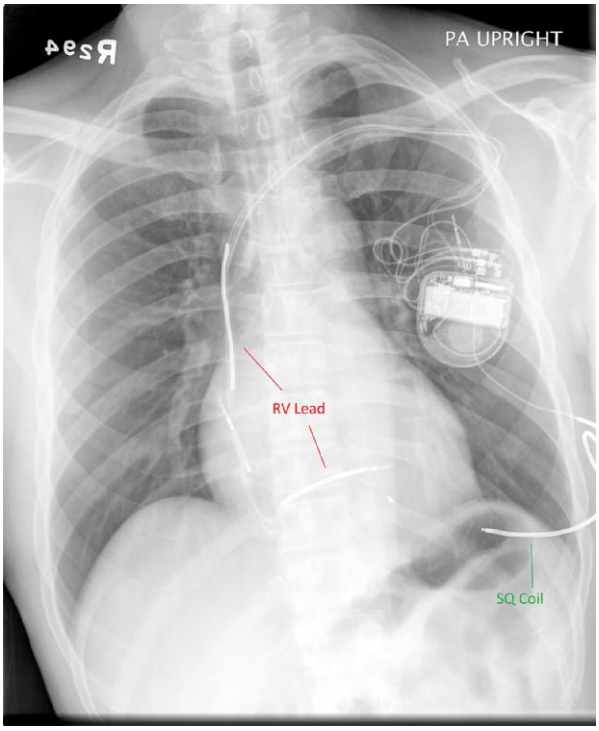


Figure 1 Chest X-ray of a dual-chamber dual-coil biventricular implantable cardiac defibrillator with the addition of a subcutaneous coil.

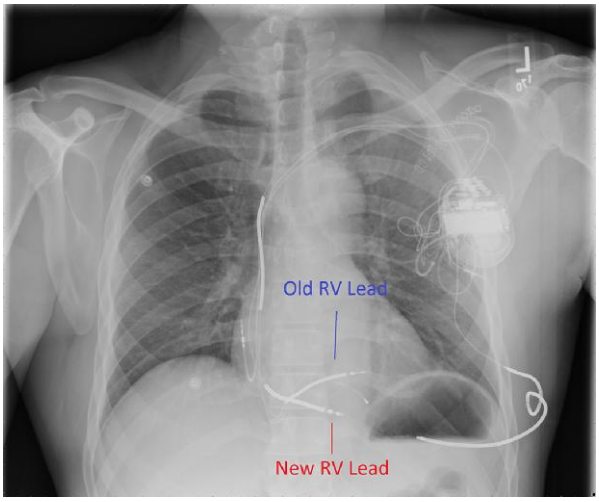


Figure 2 A new single-coil implantable cardioverter defibrillator lead was placed in the right ventricular apex, replacing the old dual-coil implantable cardioverter defibrillator lead.

the Fidelis lead. Because two DF-1 coils are plugged into this y-adapter, they will function as a single, combined coil. A new shock pathway is added in parallel to the functioning Quattro RV coil, and therefore impedance of the combined coil is lower than the individual coil.[2] Furthermore, adding a second coil increases the overall surface area of shockable tissue, making a successful shock more likely.[2] After we merged the RV coils, DFT testing

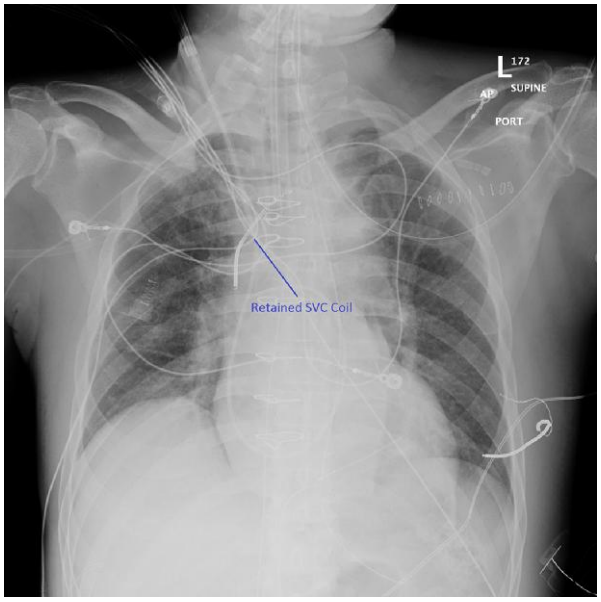


Figure 3 Manual extraction, at the time of the heart transplant, was successful for all the transvenous leads, except the superior vena cava coil.

was performed twice successfully at 15 J, thus confirming that the DFT was effectively and sufficiently lowered. The RV lead pacing threshold was 0.8 V at 0.4 ms, 418 Ω impedance, and 8.3 mV sensing.

If merging the RV coils had failed, we would have added a second SQ coil and merged it with the previous SQ coil. Had that failed, we would have done extraction and reimplanted a new coil in the CS vein/branches. These approaches would be more invasive in our patient.

After 9 months, the patient reached end-stage heart failure, during which time he received multiple successful shocks from his ICD. The patient then received a heart transplant. His device and the transvenous leads were successfully removed at the time of the transplantation surgery, except for the SVC coil (*Figure 3*), confirming that an SVC coil extraction would be challenging.

Discussion

The need to lower the DFT in an ICD is not uncommon. Many different approaches have been described to achieve this goal. Options include:

(1) To use medications that lower the DFT. However, our patient required amiodarone and mexiletine, which are both anti-arrhythmic drugs known to increase the DFT.[4,5] This is not uncommon for patients with recurrent VT/VF. Initially, we used sotalol, which lowers the DFT. However, later on, our patient required amiodarone and mexiletine, which increases the DFT.[4,5]

(2) Device-related approaches to lower the DFT. This includes using a generator that can deliver a higher maximum energy shock. However, we did not feel that the 5 J difference was sufficient and further intervention was needed. Reversing polarity might help in some patients. However, since the device was nearing ERI, we did not test that. Furthermore, reversing polarity usually only marginally affects the DFT.[2] Interestingly, it was later not possible in our patient due to the potential for reduced energy shock that originated from short-circuit protection.[6] Finally, adding a coil is another option to lower the DFT. Our patient already had an SQ coil, which is known to lower the DFT.[2,7] Adding an SVC coil has shown

mixed results and overall small benefit from this approach.[8] Regardless, since it was not previously beneficial in our patient, we left the SVC coil abandoned. Adding an azygos or CS vein coil would be beneficial.[9,10] However, extraction for such an old dual-coil ICD lead from a chronically occluded SVC vein is risky.[11] In a similar case, placing another RV DF1 lead and using a y-adapter to merge the leads is an easier approach. Furthermore, if an infection occurs after the procedure and extraction is needed, there is likely a greater risk in extracting the coil from the azygos or CS vein than from the RV septum.

To our knowledge, there are no previously published cases where two RV coils were merged in order to lower the DFT. From the literature review, we did find a mention of anecdotal accounts that suggest using the y-adapter to merge SQ coils as an effective way to lower the DFT.[2] Although our approach may not be most optimal in all cases, it can be used as a safer and more effective approach to lower the DFT in many patients like in this case. We also believe that it can be used in a patient with a high DFT and as an indication for another RV lead for high pacing thresholds. Instead of adding a new RV pacing lead and a new separate coil (such as SQ or an azygous vein coil), we need to add only one. Perhaps, if further data supported our approach findings, it can be used in any patient who has a high DFT and need for a new coil, as it can be seen as an easier and safer alternative method.

Conclusion

Combining two RV coils from different locations may be an effective and less traumatic way to lower the DFT, particularly when other methods have failed or cannot be used. This method likely works by adding a parallel shock pathway to the RV coil currently in use and lowering the overall shock impedance of the newly combined RV coil. This method also increases the shock tissue surface area to improve the shock success rate.

Lead author biography

Hayyan Asim Chaudry is currently a medical student at the University of Toledo College of Medicine and Life Sciences. He recently graduated from the University of Michigan with a major in Neuroscience and has worked as a research assistant at Henry Ford Hospital. He has interests in primary care and in cardiology.

Supplementary material

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

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

Conflict of interest: None.

Funding: W.M. has a research grant from Medtronic. No funding is related to this case report.

Data availability

Data available on request.

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