

# Left axillary active can positioning markedly reduces defibrillation threshold of a transvenous defibrillator failing to defibrillate at maximum output



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## Introduction

The problem of elevated defibrillation threshold (DFT) in current-generation transvenous implantable cardioverter-defibrillators (ICDs) has been significantly reduced with technological advances, including use of active can generators, higher-output devices, reversing shock polarity, and biphasic waveforms.<sup>1,2</sup> Several randomized clinical trials have demonstrated the effectiveness of current ICDs in the absence of defibrillation testing (DT), leading the Heart Rhythm Society to issue a recent consensus statement that it is reasonable to omit DT for left pectoral transvenous devices at implant (class IIa).<sup>3–6</sup>

Nonetheless, approximately 2%–4% of patients have been reported to have an unacceptably elevated DFT at implant or during generator replacement, but in nearly all cases this may be mitigated through a combination of approaches, summarized in Table 1.<sup>7–11</sup> Most of these remedies were available when ICD leads had both a right ventricle (RV) and superior vena cava (SVC) coil and the header had at least 4 ports, which allowed flexibility of configuration, such as adding a subcutaneous array. Recent studies suggest that dual-coil leads may not be superior to single-coil leads with respect to defibrillation efficacy and may be prone to more lead-related complications.<sup>12,13</sup> With the increasing use of DF-4 devices along with a trend favoring the use of single-coil vs dual-coil leads, implementation of many of the DFT reduction options listed in Table 1 is now limited. The case described herein illustrates a new, relatively simple surgical approach that may markedly lower the DFT without additional leads or generator replacement.

## Case report

The patient is a 48-year-old man who presented with palpitations and near syncope in 2012. Electrocardiogram and

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## KEY TEACHING POINTS

- Defibrillation thresholds may increase significantly from initial implant to the time of generator replacement owing to multiple factors, which can only be detected by defibrillation threshold (DFT) testing.
- Axillary positioning of the active can in transvenous implantable cardioverter-defibrillator systems may significantly lower the DFT and is an easily achieved technique to lower an elevated DFT at the time of implant or replacement.
- Newer quadripolar transvenous systems have fewer options for addition of coils or arrays when an elevated DFT is encountered; however, axillary generator positioning may be accomplished relatively easily to lower the DFT compared to more invasive and costly approaches.

echocardiogram were compatible with arrhythmogenic right ventricular cardiomyopathy (ARVC) and electrophysiology study revealed several morphologies of hemodynamically unstable ventricular tachycardia (VT) from the right ventricle. A dual-chamber DF-4 ICD system (Medtronic, Minneapolis, MN; Model D314DRM pulse generator with a Medtronic 4076 right atrial lead and a Medtronic right ventricular dual-coil 6947M high-voltage DF-4 lead) was implanted and the RV lead was placed in the mid septum owing to poor R-wave sensing at the apex. The generator was placed in the left subclavicular area in a suprapectoral pocket. DT at implant was performed under diprivan anesthesia. T-wave shock induced ventricular fibrillation (VF) with successful defibrillation at 15 joules (J) but not at 12 J, using a biphasic waveform with RV coil (anode)–to–SVC coil/can shock vector. The patient had subsequently undergone epicardial VT ablation in 2013 for recurrent VT and was also placed on flecainide 150 mg twice daily (bid) following ablation. He had no further sustained episodes until 2014, when he received 1 shock for

**Table 1** Techniques to achieve lower defibrillation thresholds and limitations in DF-4 implantable cardioverter-defibrillator systems

Approach to treat patients with high DFT	Possible with DF-4 systems without lead or generator replacement
Reverse shock polarity	Yes
Adjust biphasic tilt	Yes (some generators)
Reposition RV coil/lead	Yes
Higher output generator	Yes
Add/delete SVC coil to defibrillation circuit	Yes (with programming)
Add additional coil	No
Add subcutaneous array	No
Add medications to lower DFT	Yes

DFT = defibrillation threshold; RV = right ventricular; SVC = superior vena cava.

Adapted from References 7, 8, 9, 11.

monomorphic VT. He underwent noninvasive ICD testing on flecainide. VT was not inducible; however, VF was induced and terminated with 15 J shock. He underwent an endocardial VT ablation in 2016 and flecainide was decreased to 75 mg bid. No further device therapy occurred. He presented for ICD generator battery replacement in 2018. Because of the fact that the ICD lead was not in an apical position (Figure 1A), the ongoing use of flecainide, and echocardiographic evidence of enlargement of the right ventricle (diameter increased from 2.9 cm to 4.3 cm), he underwent DFT testing during generator replacement (Medtronic model DDMC3D4). Left ventricular size and function had not changed and left ventricular ejection fraction had remained stable at 55%–60%. VF was induced with T-wave shock; however, the device was unable to terminate VF at 15 J as well as with a subsequent 35 J shock and required external defibrillation. The following changes were then tried sequentially with retesting: (1) reversing polarity (RV cathode); (2) defibrillation between the RV coil and the can (SVC removed from circuit by programming); (3) RV coil to SVC coil (can removed). In each case the device failed at maximum energy. Shock lead impedances were all within

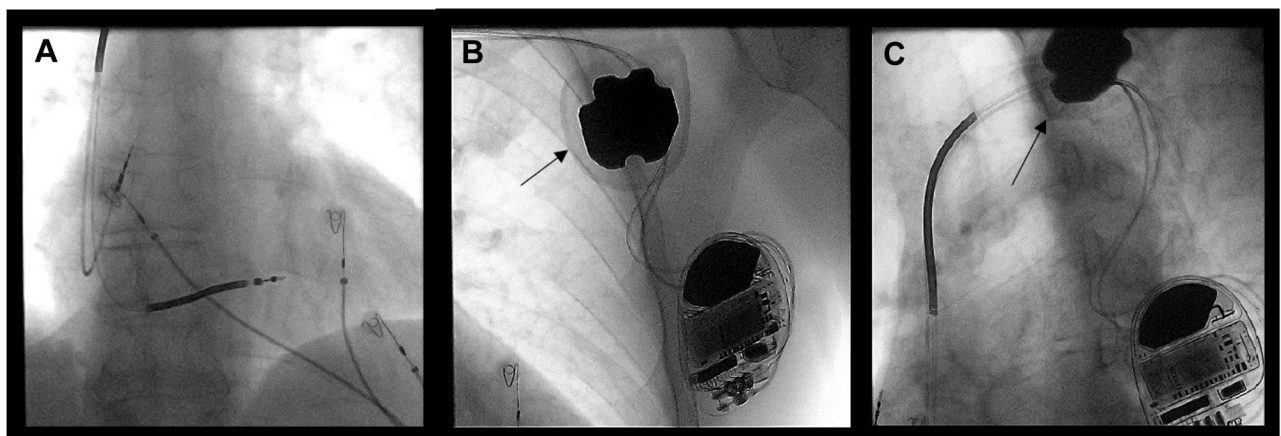
the normal range. Owing to this being a DF-4 ICD system, adding an array was not possible without changing both the ICD lead and generator or using an adapter. Consideration was given to trying to move the RV lead more apically to improve DFT; however, the original reason for proximal lead placement was owing to poor R waves at the apex. This would then require adding a separate RV rate sense lead. Additionally, since the lead was 6 years old, it was not felt safe to attempt these interventions without laser extraction as a standby option. With failure at 35 J, it was not clear that a higher-output generator would allow an adequate safety margin.

The decision was then made to extend the left subclavicular pocket more inferiorly and laterally to place the generator between the anterior to mid axillary line, which would theoretically include more of the septum and left ventricle within the defibrillation wavefront. This was done through the existing incision using a combination of sharp and blunt dissection with electrocautery. The new position of the device compared to initial position is shown in Figure 1B (anterior-posterior) and Figure 1C (left anterior oblique 45 degrees). The device was not sutured in place owing to inability to access a deep anchoring site from the initial incision, which was subclavicular; however, a separate layer of resorbable suture was used at the superior margin of the generator to prevent migration. Repeat DT was performed using the RV coil (anode) to active can vector and was now successful at 35 and 25 J. Further testing was not done owing to the number of inductions already done. Table 2 summarizes the details of DT testing.

The patient was brought back for DT testing 1 month later. This revealed that the DFT was  $\leq 6$  J in the RV coil (anode)–to–active can configuration. The patient also noted that the axillary position of the device was more comfortable and noticed less motion of the device than in the previous subclavian position.

## Discussion

This case illustrates (1) that in some patients, the DFT may significantly rise with time; and (2) the importance of active



**Figure 1** Fluoroscopic positioning of leads and generators. **A:** Right atrial and right ventricular (RV) lead position. Note RV defibrillation lead is mid septal and not apical. **B:** Anterior-posterior view of left lung field with generator moved to an axillary position. A phantom generator (black arrow) was placed on the skin over the site of the previous generator position. **C:** Left anterior oblique 45-degree view of the generators and leads.

**Table 2** Implantable cardioverter-defibrillator testing details at time of generator replacement

#	Induction	Rhythm	Therapy	Impedance	Path	Device
1	T shock 500/320 1 J	VF	15J/35J/external360J	44 (RV-SVC-can)	B>AX	Failed
2	T shock 500/320 1 J	VF	25J/35J/external 360J	63 (RV-SVC)	B>AX	Failed
3	T shock 500/320 1 J	VF	25J/35J/external 360J	43 (RV-SVC-can)	AX>B	Failed
4	T shock 500/320 1 J	VF	35J/external 360J	52 (RV-can)	B>AX	Failed
5	T shock 500/320 1 J	VT	35J (Can axillary)	54 (RV-can)	B>AX	Success
6	T shock 400/320 0.8 J	VF	25J (Can axillary)	52 (RV-can)	B>AX	Success

AX = active can + superior vena cava (SVC) coil; B = right ventricular (RV) coil; VF = ventricular fibrillation; VT = ventricular tachycardia.

can positioning in minimizing DFT, particularly in the current era of single-coil or dual-coil DF-4 ICD systems, which do not allow for as many reconfiguration options without costly, invasive approaches or the use of adapters.

Although this patient had a dual-coil lead, the initial generator position failed to defibrillate at maximum output whether the SVC coil was programmed on or off. The impedance with the SVC coil included was 44 ohms (Table 1, row 1), but it was 52 ohms (Table 1, row 4) when off. These impedances would be considered within the normal range for a transvenous ICD system.

The possibility of air in the pocket cannot be completely excluded as a cause for the elevated DFT, although the deep layer of the pocket had been closed prior to testing. In the axillary position, the deep layer was also closed prior to testing. Since testing was done under similar conditions aside from relocating the generator, the role of pocket air leading to such a large difference in DFT is less likely, but not totally excluded.

The importance of lateral axillary active can positioning is well documented for subcutaneous defibrillators in order to achieve an acceptable DFT.<sup>14</sup> A recent report even described adding a subcutaneous ICD system to a transvenous system that was unable to defibrillate at 41 J.<sup>15</sup>

In this case, with a transvenous ICD, the degree of DFT reduction with axillary positioning of the active can was pronounced, since the original active can position in the usual left subclavicular position was unable to defibrillate the patient at maximum output. Possible causes of the increased DFT in this patient may be related to initial proximal positioning of the RV defibrillation lead; the use of flecainide, which may have affected the DFT; progressive RV enlargement and fibrosis owing to ARVC; or interim epicardial and endocardial ablations, which may have led to increased scarring and endocardial impedance changes. It is also recognized that not every possible permutation of cathode/anode and lead configurations was tested prior to repositioning the device.

This case suggests that more inferior and lateral positioning of the active can, which can be achieved from a standard subclavicular incision, may have advantages over the usual placement of the active can in an anterior subclavian pocket. Some limitations to consider before implementing this technique would include having enough length of ICD and pacing leads to allow repositioning. In some patients, body habitus and anatomic constraints may not allow axillary

pocket creation and generator repositioning without a second, more lateral incision in order to achieve safe dissection and adequate hemostasis.

## Conclusion

Axillary positioning of the active can in left-sided transvenous ICD systems may offer significant advantages by lowering DFT. In some cases, this position may be associated with greater comfort to the patient as well. It should be considered in any patient with an elevated DFT, but particularly in those with single-coil quadripolar systems in whom modifications of the system are difficult and costly. Larger controlled clinical trials would be needed to determine whether axillary active can positioning should be considered as a preferred option to obtain the lowest DFT in the general left pectoral transvenous ICD population.

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