Impact of acquired anatomical distortion on implantable cardiac defibrillator efficacy: Lessons from a postpneumonectomy patient

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Introduction

The implantable cardioverter-defibrillator (ICD) has been a mainstay of therapy for primary and secondary prevention of sudden cardiac death caused by malignant ventricular arrhythmias for more than 30 years.[1] Prior to the SIMPLE (Shockless IMPLant Evaluation) and NORDIC (NO Regular Defibrillation Testing in Cardioverter Defibrillator Implantation) trials, routine defibrillation threshold (DFT) testing at implant was considered standard practice to confirm an ICD's ability to terminate dangerous ventricular arrhythmias.[2,3] These trials established safety in omitting DFT testing for most patients; however, specific groups, such as those with significant comorbidities or right-sided implants, were excluded.[2]

The trend toward omitting routine DFT testing has been broadly applied in clinical practice, potentially overlooking certain patient groups excluded from these landmark trials. Patients with acquired anatomical distortions, such as those from a pneumonectomy, represent one such understudied group.

In this report, we present the case of a patient with cardiac displacement owing to a left-sided pneumonectomy who underwent ICD implantation. The case demonstrates the necessity of defibrillation testing in the context of altered cardiothoracic anatomy.

Case report

A 67-year-old male patient with a history of chronic obstructive pulmonary disease, left pneumonectomy (20 years prior owing to malignancy), nonobstructive coronary artery disease, chronic systolic heart failure (left ventricular ejection fraction 20% despite optimized guideline-directed medical therapy) with New York Heart Association class II-III symptoms, and prior left ventricular thrombus presented for primary-prevention ICD implantation. He also exhibited a right bundle branch block/left anterior fascicular block with a QRS duration of 162 ms. While cardiac resynchronization therapy was considered, it was deemed less likely to provide benefit owing to the conduction pattern. Cardiac anesthesia support was planned for the procedure.

KEY TEACHING POINTS

- Understanding cardiac anatomical distortions is crucial for informed preimplantation planning of implantable cardioverter-defibrillators.
- Defibrillation testing remains essential in patients with significant cardiac anatomical displacement, whether acquired or congenital.
- Flexibility is vital for managing complex cases and adapting to intraprocedural challenges.

Procedure

A left-sided venogram confirmed axillary and subclavian vein patency. After pocket creation and venous access, we encountered the patient's unique anatomical challenge: the prior pneumonectomy had caused severe cephalad and leftward displacement of his right ventricular (RV) apex into the infraclavicular region. Conventional RV ICD lead placement at the RV apex was performed (Figures 1 and 2). Adequate sensing, impedance, and pacing thresholds were achieved without evidence of diaphragmatic stimulation.

Although our practice is generally not to perform DFT testing at the time of ICD implant, we were concerned that the patient's altered anatomy may result in an unfavorable defibrillation vector. Initial testing failed to convert ventricular fibrillation (induced via shock-on-T) with 20- and 30-joule shocks, and external defibrillation was required. Shock impedance was 57 Ω. To address this, we implanted a subcutaneous defibrillation coil. Using a tunneling tool and a 2 cm midaxillary incision, the lead was positioned along the patient's back toward the spine. The lead was connected to

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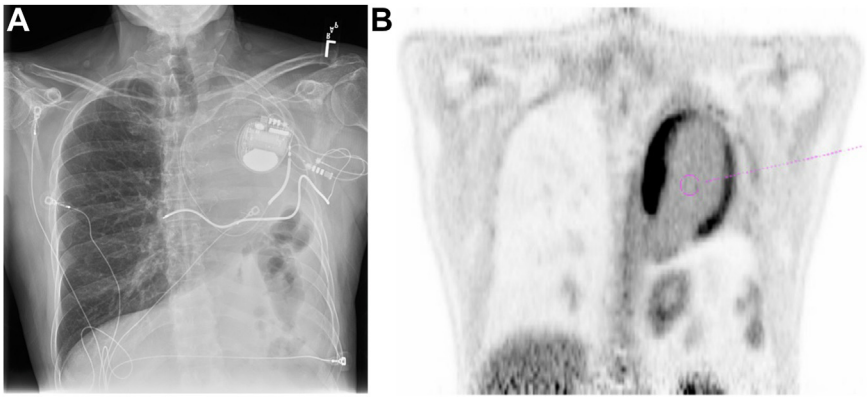

Figure 1 **A:** Posterior-anterior radiograph of implanted implantable cardioverter-defibrillator in pneumonectomy patient. **B:** Prior positron emission tomography fludeoxyglucose-18 scan shows cephalad displacement of cardiac apex with left ventricular myocardium uptake.

the pulse generator via an extender, allowing tunneling to the infraclavicular pocket (Figures 1 and 2).

Repeat DFT testing, with induced VF (shock-on-T), was successful at 20 J (B>AX vector). The shock impedance was 38 Ω. Owing to extended pocket exposure, an antibiotic pouch was used. Closure and wound dressing were completed. The postimplant chest radiograph illustrates the patient's anatomic distortion, the suboptimal vector between the RV coil and the pulse generator, and the improved vector achieved with a posteriorly positioned subcutaneous coil (Figures 1 and 2).

Discussion

Cardiac anatomical distortions pose a well-recognized, variable challenge for optimal defibrillation during and after ICD implantation. While extensive literature addresses DFT concerns in congenital heart disease, acquired causes of cardiac anatomic distortion receive less attention. These causes can include pneumonectomy (partial or total), severe chronic obstructive pulmonary disease, chest wall deformities such as scoliosis and kyphosis, chronic pleural effusions, and thoracic tumors.[4,5] Understanding the range of these acquired anatomic distortions has important implications for pre- and intraprocedural decision-making.

Our case vividly illustrates the complex interplay between postpneumonectomy cardiac anatomical distortion and ICD efficacy. After a pneumonectomy, the mediastinal region undergoes ongoing changes for years, including diaphragmatic and mediastinal displacement, thoracic musculoskeletal changes, and scarring within the pleura and mediastinum.[6–8]

The patient's displaced heart into the left infraclavicular region created significant challenges for defibrillation. First, the shocking vectors were inherently suboptimal owing to this anatomic shift.[6] As seen in Figure 3A, the shocking vector (RV coil to can) primarily traversed the RV-free wall without going through the critical mass of the left ventricular myocardium required for arrhythmia termination.

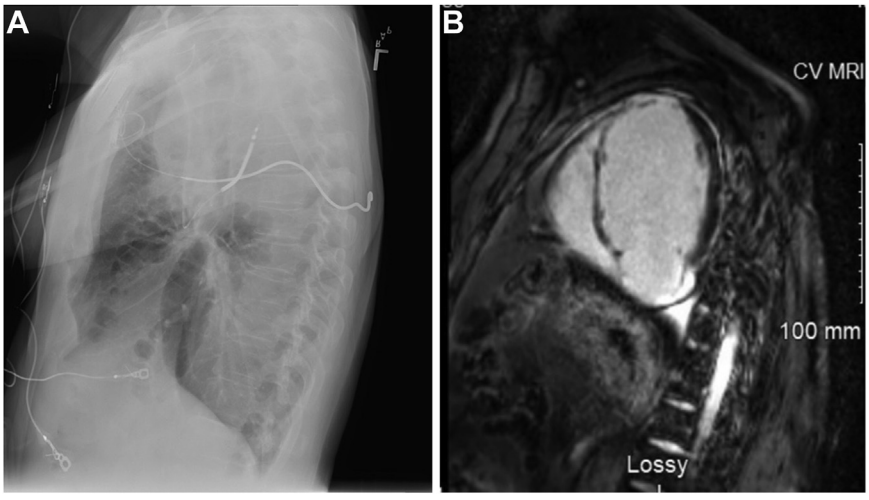

Figure 2 **A:** Lateral radiograph of implanted implantable cardioverter-defibrillator (ICD) in pneumonectomy patient. **B:** Prior lateral magnetic resonance imaging is consistent with right ventricular ICD lead placement at the apex.

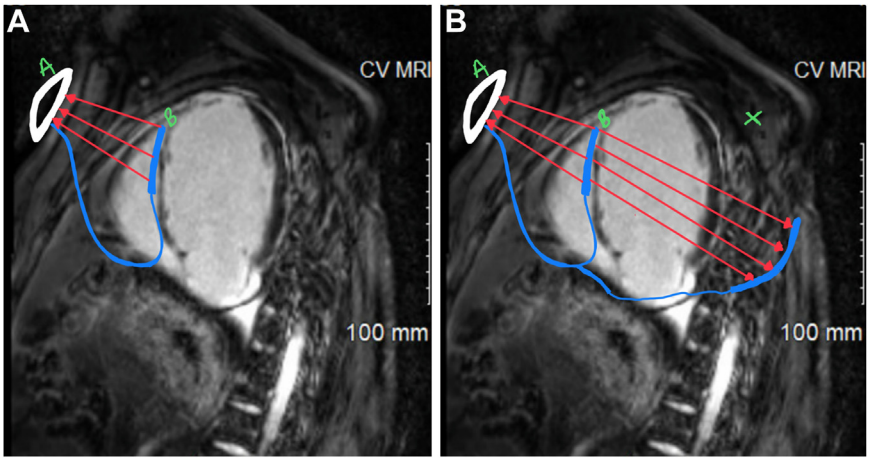

Figure 3 **A:** Initial shock vector (B>A) traversing the right ventricular free wall only, resulting in a failed defibrillation test. **B:** Final shock vector (B>AX) after the addition of a subcutaneous coil, traversing the left ventricular myocardium and resulting in successful defibrillation.

While anatomical changes can affect shock impedance (influenced by tissue-electrode interface and tissue types such as lung, muscle, and fat), the patient's cardiac magnetic resonance imaging showed minimal intervening tissue. The recorded shock impedances (failed shock 57 Ω, successful shock 38 Ω) were both within normal limits, as such alteration of the shock impedance owing to mediastinal changes did not appear to have been a significant factor. Instead, the primary issue in this case was an inadequate shock vector (Figure 3A). Figure 3B illustrates the final shocking vector after adding the subcutaneous coil, which resulted in successful defibrillation.

Identifying patients with anatomical distortions prior to an ICD implant is crucial. Imaging modalities can help anticipate challenges and determine potential adaptations. These adjustments might include alternative RV lead locations and generator pocket positions optimized for the individual's anatomy. Additionally, preemptive use of subcutaneous ICD[7] may be effective when cardiac displacement compromises transvenous vectors.

Intraprocedurally, meticulous and iterative DFT testing may become necessary. If initial DFTs fail, a multifaceted approach may be needed, including alternative vector programming, lead repositioning, use of a higher-energy generator, and implantation of another lead (dual coil, azygos vein, subcutaneous, etc). Finally, if DFTs remain unsuccessful, a nontransvenous solution may be considered, including subcutaneous ICD, intrathoracic extravascular ICD, or surgical epicardial lead placement.[6,7]

Although there have been few case reports of device implants in postpneumonectomy patients,[9–11] none of these specifically addressed DFT failure and further management options. Our case emphasizes that despite improvements achieved with defibrillation in contemporary ICDs (biphasic shocks, "active" generators that are part of the shock vector, higher-energy generators) and after decades of implant experience, significant anatomic distortion can profoundly impact ICD efficacy.

The Canadian guidelines[12] acknowledge the potential for high defibrillation thresholds in postpneumonectomy patients. Short of that, there are no specific, evidence-based guidelines for these patients. Our experience suggests 2 fundamental principles. First, preprocedure planning and intraprocedural adaptation to anatomical challenges are essential. Second, performing DFT testing after initial RV lead placement as standard practice in patients with cardiac displacement is advisable.[6]

Further research investigating tailored strategies for optimal device choice and placement in these unique, high-risk individuals is warranted. Through this, we may develop improved management methods for patients with anatomical variations who stand to benefit from ICD therapy.

Conclusion

This case report highlights the potential for ICD implantation challenges resulting from cardiac displacement secondary to a prior pneumonectomy. To our knowledge, it represents the first documented instance of DFT failure owing to this specific issue. It underscores the importance of individualized preprocedural anatomical assessment and a tailored approach to ensure adequate ICD function when anatomical distortion is present.

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