Subcutaneous Implantable Cardioverter Defibrillator Lead Repositioning for Preventing Inappropriate Shocks Due to Myopotential Oversensing in a Post-Fulminant Myocarditis Patient

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Summary
A 28-year-old female presented with fulminant lymphocytic myocarditis. She developed cardiogenic shock, frequent sustained ventricular tachycardia, and fibrillation (VT and VF). The left ventricular ejection fraction improved from 5% to 40% after medical therapy, but the right ventricular systolic dysfunction and enlargement persisted. In addition, sustained VTs, requiring direct current cardioversion, occurred during oral administration of amiodarone following intravenous amiodarone, even after percutaneous stellate ganglion block. Standard body surface electrocardiogram (ECG) screening for an implantation of a subcutaneous implantable cardioverter-defibrillator (S-ICD) (EMBLEM™ S-ICD, Boston Scientific, Marlborough, MA, USA) demonstrated that two of the three sensing vectors were eligible in spite of very low-amplitude QRS complexes in the body surface ECGs. After implantation of the S-ICD, the patient experienced repetitive, inappropriate shocks due to pectoral myopotential oversensing, which could not be resolved by reprogramming the device settings. Thus, the S-ICD lead was changed from the standard left parasternal position to the midline of the sternum to reduce muscular noise due to myopotentials. Thereafter, the patient experienced appropriate ICD shocks for sustained VT and VF but no inappropriate ICD sensing or shocks. Lead repositioning may be one of the feasible solutions in S-ICD patients with low-amplitude QRS complexes and inappropriate shocks due to myopotential oversensing which cannot be resolved by reprogramming the device settings.

Key words: Cardiac implantable electronic device, Sudden cardiac death, Ventricular tachyarrhythmia, Low-amplitude QRS complexes

SUBCUTANEOUS IMPLANTABLE CARDBIOERTER DEФIBRILLATOR (S-ICD) has emerged as a therapeutic option for preventing sudden cardiac death. Despite several advances in programming S-ICDs, i.e., algorithms to accurately distinguish cardiac signals from external noise or noncardiac signals, inappropriate shocks still remain common. We present a case of repetitive inappropriate S-ICD shocks due to pectoral myopotential oversensing in a post-fulminant lymphocytic myocarditis patient with very low-amplitude QRS complexes in the body surface electrocardiograms (ECGs), which could not be resolved by reprogramming the device settings but could be successfully resolved by repositioning the S-ICD lead from the standard left parasternal position to the midline of the sternum.

Case Report
A 28-year-old female presented with fulminant lymphocytic myocarditis. She developed cardiogenic shock with a left ventricular ejection fraction (LVEF) of 5% and frequent episodes of sustained ventricular tachycardia and fibrillation (VT and VF), which required intra-aortic balloon pumping, extracorporeal membrane oxygenation, and direct current cardioversion to stabilize the hemodynamic status. The LVEF improved from 5% to 40% after medical therapy for one month with a beta-adrenergic blocker and aldosterone antagonist, but the right ventricular systolic dysfunction and enlargement persisted. In addition, sustained VTs requiring direct current cardioversion occurred several times during an oral administration of amiodarone following intravenous amiodarone, even after a percutaneous stellate ganglion block.

Standard body surface ECG screening, using a dedicated screening tool, demonstrated that two of the three sensing vectors, the secondary and alternate sensing vectors, were eligible for an implantation of an S-ICD (EMBLEM™ S-ICD, Boston Scientific, Marlborough, MA, USA), in spite of very low-amplitude QRS complexes in the body surface ECGs (Figure 1). An S-ICD generator was implanted on the mid-axillary line near the left ventricular apex, and an S-ICD lead was placed along the left parasternal line. The alternate vector was selected as the sensing vector based on the automated S-ICD algorithm.
Figure 1. Body surface electrocardiogram at rest. The electrocardiogram revealed very low-amplitude QRS complexes.

Figure 2. Frequency of appropriate and inappropriate S-ICD shocks and treatment for the VT and VF after the S-ICD implantation. The patient experienced 9 episodes of inappropriate shocks but no appropriate shocks after the S-ICD implantation, and after the S-ICD lead repositioning, experienced 3 episodes of appropriate shocks but no inappropriate shocks.

After hospitalization for three months, the patient was discharged with amiodarone of 100 mg, bisoprolol of 3.75 mg, and spironolactone of 12.5 mg once daily, and with device settings of the shock-only zone of 220 bpm and conditional zone of 200 bpm.

During the first four postoperative months, nine inappropriate shocks due to pectoral myopotential oversensing occurred (Figure 2), and could not be resolved with changing the sensing vector and gain settings. The shock-only zone and conditional zone were increased from 220 bpm to 250 bpm and from 200 bpm to 220 bpm, respectively, after the initial five inappropriate shocks. Even after that, an additional four inappropriate shocks occurred. Low R-wave signals and myopotential noise were observed in all three vectors with a programmed gain setting of 2x during provocative maneuvers of muscular noise (Figure 3A-C). Thus, the S-ICD lead was replaced on the midline of the sternum to reduce the muscular noise due to myopotentials. In addition, the S-ICD lead position was changed to a site a little below the initial lead position, because the surface ECG recording at the lower position along the sternum exhibited a slight increase in the R-wave signals during screening before lead repositioning (Figure 4). During lead repositioning, the lead could not be extracted by simple traction, and could be successfully extracted using a mechanical dilator sheath, because of adhesions of the lead implanted for four months. Myopotential noise signals significantly decreased in the primary sensing vector with a programmed gain setting of 1x during provocative maneuvers of muscular noise after the lead repositioning (Figure 3E). During the first two postoperative months, the patient experienced three episodes of appropriate S-ICD shocks for sustained VT and VF (Figure 3F), and underwent radiofrequency catheter ablation of the VT and VF originating from the right ventricle. The oral amiodarone dose was then increased from 100
mg to 200 mg per day. No inappropriate ICD sensing or shocks have been observed for four months after the S-ICD lead repositioning (Figure 2).

**Discussion**

To the best of our knowledge, this is the first case report describing the effectiveness of S-ICD lead repositioning for preventing repetitive, inappropriate shocks in a post-myocarditis patient implanted with an S-ICD. This report also provided several important implications about pre-implantation screening of an S-ICD, especially in patients with low-amplitude QRS complexes. Not only the standard left parasternal position, but also different posi-

**Figure 3.** Device interrogation electrograms. The primary (A), secondary (B), and alternate (C) sensing vectors (all 2x gain) during provocative maneuvers of muscular noise before the lead repositioning revealed low R-wave signals and myopotential noise. The alternate vector before the lead repositioning, which had the lowest myopotential noise level among the three vectors, revealed myopotential oversensing, which led to an inappropriate shock (D). The primary vector (2x gain) revealed less myopotential oversensing during provocative maneuvers of muscular noise after the lead repositioning (E). The primary vector (1x gain) after the lead repositioning revealed appropriate sensing of sustained VF, which led to a shock therapy to successfully terminate the VF (F).

**Figure 4.** Chest radiographs in the posterior-anterior and lateral views showing the position of the subcutaneous implantable cardioverter defibrillator lead and generator before (A, B) and after (C, D) the lead repositioning.
tions, such as the right parasternal or sternal midline position and a slightly higher or lower position relative to the sternum, should be tested for a lead implantation, in order to record as large an R-wave signal as possible. Further, pre-implantation screening should be performed in various postures, such as supine, sitting, and standing positions, because posture-related changes in the amplitude of the R-wave signals may lead to inappropriate S-ICD shocks.5-9

An inappropriate shock is one of the problems to be resolved in S-ICD patients, and the inappropriate shock rate is reported to be 13.1% at 3 years.6 The mechanisms of inappropriate S-ICD shocks are as follows: T-wave oversensing (39%), supraventricular arrhythmia (24%), low-amplitude signals (21%), and noncardiac oversensing (8%).4,5 Taguchi, et al. reported an inappropriate shock due to entrapped subcutaneous air early after an S-ICD implantation.7 Myopotential oversensing may tend to occur more in S-ICD patients than in transvenous ICD (TV-ICD) patients, because an S-ICD senses subcutaneous signals from the two sensing electrodes, or from either electrode and the generator, and has a lower minimum sensitivity of 0.08 mV than a TV-ICD. Furthermore, low R-wave signals are likely to increase the risk of inappropriate shocks due to myopotential oversensing. Previous clinical studies reported that reprogramming the device settings, for example, by changing the sensing vectors and gain settings, could resolve inappropriate shocks.5,8 However, device reprogramming was ineffective in preventing inappropriate shocks due to myopotential oversensing.9 Previous clinical studies reported that reprogramming the device settings, for example, by changing the sensing vectors and gain settings, could resolve inappropriate shocks.5,8 However, device reprogramming was ineffective in preventing inappropriate shocks due to myopotential oversensing.9 Lead repositioning on the sternum, should be tested for a lead implantation, in order to record as large an R-wave signal as possible. Furthermore, low R-wave signals are likely to increase the risk of inappropriate shocks due to myopotential oversensing.9 Lead repositioning on the sternal midline was eventually helpful for both preventing inappropriate shocks due to myopotential oversensing and delivering appropriate shocks. Berne, et al. reported a case of a catecholaminergic polymorphic VT patient implanted with an S-ICD, in whom repositioning the generator increased the R-wave amplitude and eliminated the inappropriate shocks secondary to myopotential oversensing.10 The present case did not undergo generator repositioning, because the body surface ECG testing at various sites over the left axially region did not exhibit any significant increase in the R-wave signals compared to that at the initial generator position, and there was a potential risk of an increased defibrillation threshold for VT and VF.

Conclusions

Lead repositioning may be one of the feasible solutions in S-ICD patients with inappropriate shocks due to myopotential oversensing, which cannot be resolved by reprogramming the device settings. This case may suggest that the position of an S-ICD lead and generator should be carefully considered especially in patients with very low-amplitude QRS complexes, and more precise pre-implantation screening methods should be developed.

Disclosures

Conflicts of interest: No author has a real or perceived conflict of interest.

References