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Case Report

The Potential Impact of Intrathoracic Impedance on Defibrillation Threshold Testing in S-ICDs

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ABSTRACT

A man with an ischemic cardiomyopathy and chronic obstructive pulmonary disease underwent subcutaneous implantable cardioverter-defibrillator (S-ICD) placement under general anesthesia. Following induction of ventricular fibrillation (VF), defibrillation testing (65J) failed, requiring external rescue. Repeat shock testing with reversed polarity (65J) failed. A third shock and external defibrillation failed (80J and 200J), followed by a second external defibrillation (200J), which did not immediately terminate VF, and a device shock 2 seconds later (80J, successful). Repeat shock testing (80J) under conscious sedation without mechanical ventilation was successful. We discuss this case of failed defibrillation testing during S-ICD placement, potentially due to lung hyperinflation, requiring double sequential defibrillation.

RÉSUMÉ

Un homme présentant une cardiomyopathie ischémique et une maladie pulmonaire obstructive chronique a subi une intervention sous anesthésie générale visant à mettre en place un défibrillateur cardioverteur implantable (DCI) sous-cutané. Après l'induction d'une fibrillation ventriculaire (FV), le test de défibrillation (65 J) a échoué, et une intervention de secours externe a dû être pratiquée. Un deuxième test de défibrillation en polarité inversée (65 J) a échoué. Un troisième test de défibrillation (80 J) accompagné d'une défibrillation externe (200 J), suivis d'une deuxième défibrillation externe (200 J) qui n'a pas immédiatement mis fin à la FV et d'un dernier choc administré par le DCI 2 secondes plus tard (80 J), ont été efficaces. Un autre test de défibrillation (80 J) réalisé sous sédation consciente sans ventilation artificielle a aussi été concluant. Les auteurs présentent ce cas de test de défibrillation infructueux survenu à la mise en place d'un DCI sous-cutané, possiblement en raison d'une hyperinflation des poumons, et qui a exigé une double défibrillation séquentielle.

Case

A 58-year-old man with ischemic heart disease and severe left ventricular dysfunction (ejection fraction [EF] 33%) despite optimized medical therapy, was referred for primary prevention subcutaneous implantable cardioverter-defibrillator (S-ICD). He was known to have advanced chronic obstructive pulmonary disease (COPD) and a normal body mass index (BMI) of 23.7 kg/m^2. He passed S-ICD screening in the secondary position (lead tip-to-can), in both supine and sitting postures and along the right and left sternal margins.

The patient was intubated, mechanically ventilated, and underwent S-ICD implantation under general anesthesia. The S-ICD was placed in the lateral pocket using an intermuscular technique, and the lead was tunneled subcutaneously along the right sternal border. As part of routine defibrillation testing, ventricular fibrillation (VF) was induced through the device. The device delivered a 65J shock (71Ω impedance) with no success, requiring external rescue (246J delivered, 88Ω impedance, total VF duration 28 seconds). The shock testing was repeated, using reverse polarity, and failed again (65J, 72Ω impedance), requiring external rescue (246J delivered, 88Ω impedance). During the third shock test, the device was programmed to shock at 80J. The device shock (80J, 74Ω impedance) failed and, after 16 seconds, was followed by external defibrillation failure (236J delivered, 83Ω impedance). The external defibrillator was immediately recharged, delivered a second shock (233J delivered, 83Ω impedance), followed 2.2 seconds later by another device shock (80J, 73Ω impedance), resulting in successful conversion (Fig. 1).

Further shock testing was aborted, and the patient was brought back for repeat testing the following day. Under conscious sedation and without intubation, the device successfully defibrillated at 80J (61Ω impedance). Plain chest radiographs demonstrated appropriate positioning of the S-ICD (Fig. 2).

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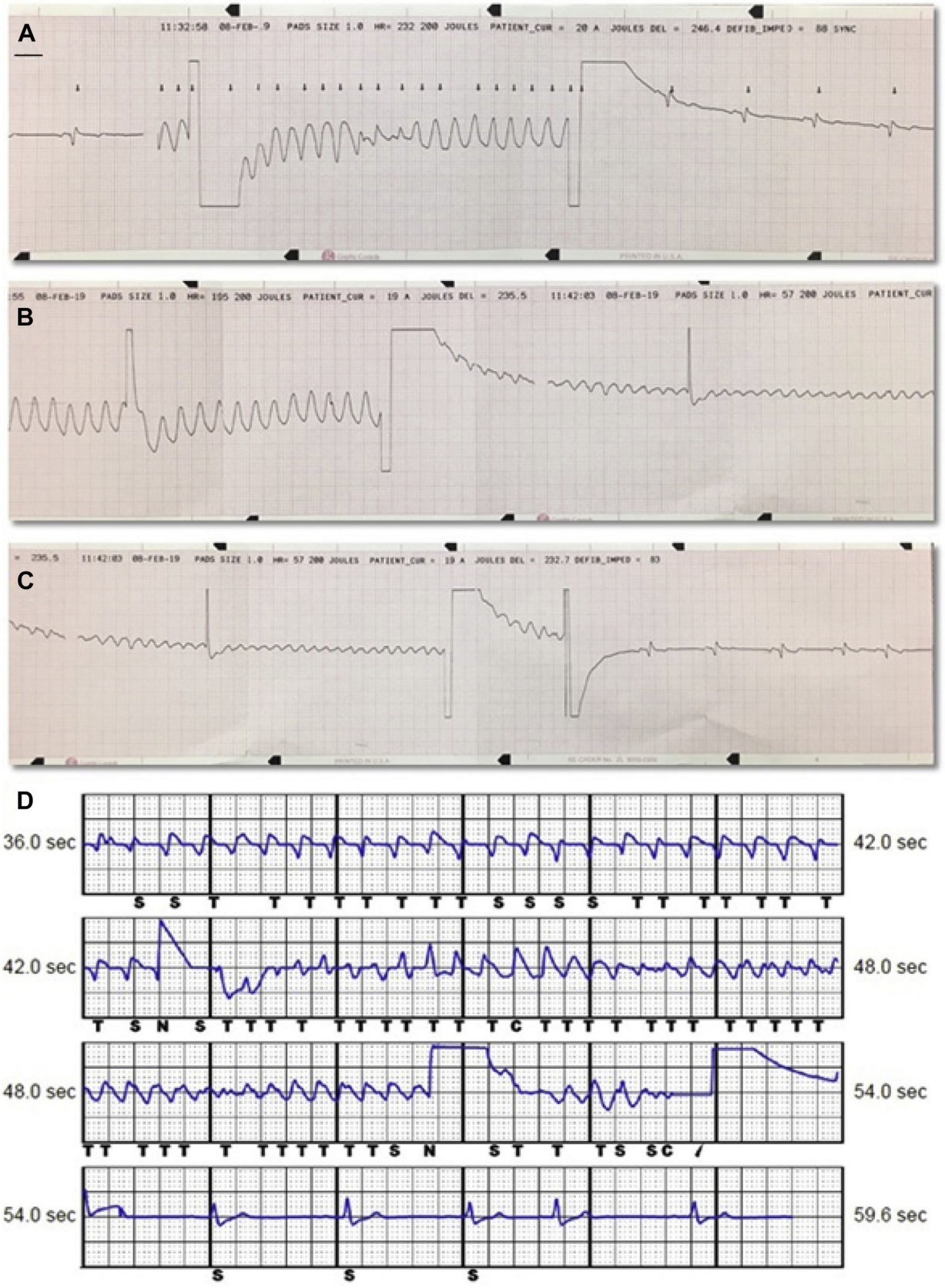

Figure 1. Defibrillation threshold testing with S-ICD demonstrated (**A**) failed S-ICD shock with successful external rescue, (**B**) failed S-ICD and external shocks, (**C**) sequential external and S-ICD shocks with successful conversion, and (**D**) sequential shocks demonstrated on S-ICD electrogram.

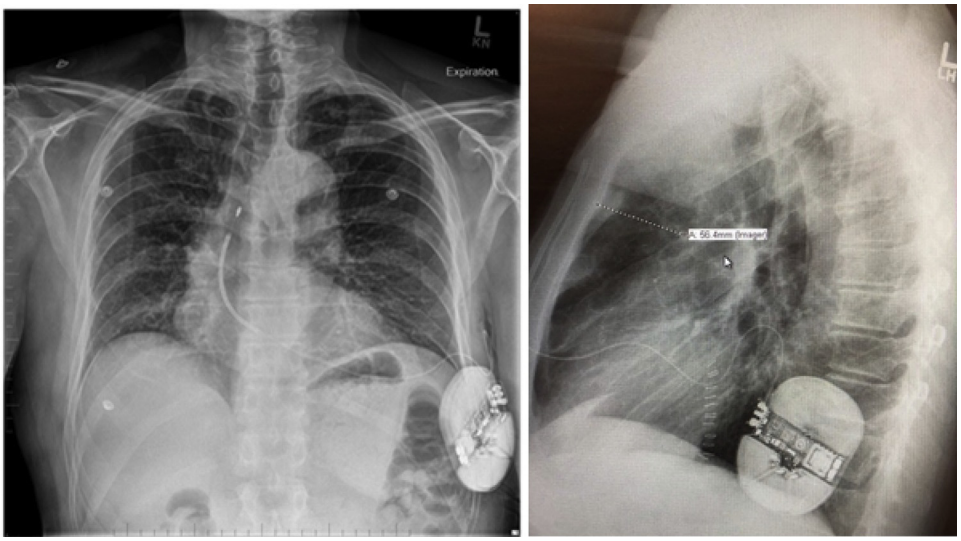

Figure 2. Posterior-anterior and lateral chest radiographs demonstrating appropriate position of the S-ICD lead and pulse generator and measurement of increased retrosternal airspace (**line**).

Discussion

Patients receiving S-ICD placement routinely undergo shock testing as recommended in the 2015 HRS/EHRA/APRHS/SOLAECE expert consensus statement.[1] In transvenous ICDs, routine shock testing at device implantation was not associated with a reduction in arrhythmic death or failed appropriate shock and therefore has been largely abandoned.[2] Studies with S-ICDs have suggested that intraoperative shock testing is successful in only 75% of cases and often requires reversal of shock polarity, lead repositioning, or pulse-generator repositioning.

The PRAETORIAN score is a clinical risk score used to estimate the risk of failed shock. It is derived using a measurement of subcoil fat, subgenerator fat, and the anterior positioning of the S-ICD generator on chest radiographs.[3] In its simplest form, the components of the PRAETORIAN score are surrogates for increased shock impedance. PRAETORIAN scores of $\geq$ 150 points were considered high risk for failed defibrillation testing. In this case, we calculated a low-risk PRAETORIAN score, which is associated with 99.8% successful conversion.[3] Although the PRAETORIAN score may be useful in the majority of patients with S-ICDs, for whom the effects of subcutaneous fat on shock impedance are paramount, the score does not account for intrathoracic shock impedance, which may be most important in patients with lung hyperinflation due to COPD.

Higher intrathoracic impedance, relating to hyperinflation in COPD, and mechanical ventilation with positive end expiratory pressure, may be an important factor associated with defibrillation failure for S-ICDs. Case reports have identified intrathoracic impedance caused by pneumothorax to be associated with failed defibrillation. Similarly, COPD is a risk factor for failed cardioversion in patients with atrial fibrillation. The retrosternal airspace—the measurement of space between the posterior aspect of the sternum (3 cm below the sternomanubrial joint) to the anterior margin of the aorta (normal 2.5-4.5 cm)—on chest x-ray is increased in COPD and may indicate increased intrathoracic impedance. In our patient, the retrosternal airspace was markedly increased, measuring 5.6 cm (Fig. 2). Intrathoracic impedance can also be measured preoperatively or intraoperatively by delivering a low energy external defibrillation (ie, 50J) before implantation of the device.

Apart from intrathoracic impedance from mechanical ventilation, other potential contributors to failed defibrillation on the first day and success on the second day in our patient include shifts in fluid balance, ischemia related to an initial failed defibrillation, and the stochastic relation between shock energy and defibrillation. Our patient was ultimately converted with double sequential defibrillations delivered by the external defibrillator and the S-ICD. Double sequential external defibrillation (DSED) is a novel approach that may be considered in patients with refractory VF and has been reported in a case series.[4] The mechanism of DSED is unclear but may relate to a larger cumulative current delivered or an alternate vector reaching more myocardium.[5]

Novel Teaching Points

- Defibrillation testing following S-ICD implantation may prompt reversal of shock polarity and lead or pulse generator repositioning.
- The PRAETORIAN score can predict failed defibrillation testing, accounting for subcoil fat, and lead and generator position.
- Pulmonary hyperinflation may be an important contributor to intrathoracic impedance and may lead to defibrillation failure.
- Double sequential defibrillation may be useful in select cases of refractory VF.

Conclusions

In this report, we present a unique case of failed defibrillation testing during S-ICD placement, with failed device and external shocks, and success using double sequential

defibrillation. COPD and mechanical ventilation may have contributed to increased intrathoracic impedance, leading to failed shock testing. Intrathoracic impedance may be an important predictor of S-ICD shock failure.

Disclosures

The authors have no conflicts of interest to disclose.

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