CASE REPORT

Inappropriate shock in a subcutaneous cardiac defibrillator due to residual air

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Key Clinical Message
Inappropriate shock due to residual air in subcutaneous implantable cardiac defibrillators is not a well-known complication. Obtaining overpenetrated X-rays, recognizing electrocardiogram findings, limiting blunt finger dissection, and switching to sense at another vector are techniques which might lead to avoidance of unnecessary wound exploration or device removal.

Keywords
Defibrillator, ICD, inappropriate shock, subcutaneous air, subcutaneous ICD.

Case Presentation
A 55 year-old man with hypertrophic cardiomyopathy and nonsustained ventricular tachycardia underwent a subcutaneous cardiac defibrillator (S-ICD; Cameron Health/Boston Scientific) implant for primary prevention of sudden cardiac death. A S-ICD was chosen, as he was relatively young, had no indications for pacing, and pre-ECG screening showed that he was appropriate for this device.

A standard three-incision technique was performed. After the coils and generators were placed and closed in three layers, ventricular fibrillation was induced and detected in the primary vector. Sinus rhythm was effectively restored with a submaximal 65-J shock. A post-op PA chest X-ray confirmed device and lead placement. Roughly 6 h after the procedure on the telemetry floor, the patient received a shock. Device interrogation revealed oversensing in the primary vector (Fig. 1). Handgrip maneuver and manipulation (manual percussion) over the leads of the device did not reproduce any noise. Moreover, the impedance of the device was within normal limits, suggesting no lead fracture. An overpenetrated PA and lateral chest X-ray showed air around the subxiphoid node (Fig. 2). The device was reprogrammed to sense at the secondary vector, and the patient was discharged. He followed up in electrophysiology clinic 2 weeks later with no complaints of shock, and a repeat lateral chest film showed resolution of air around the subxiphoid node (Fig. 3).

Discussion
As the Food and Drug Administration approved the use of the S-ICD in 2012 [1], its usage and popularity have grown. The EFFORTLESS S-ICD Registry (an international database of S-ICD users) has demonstrated that S-ICDs have appropriate performance as well as similar outcomes in quality of life and similar rates of inappropriate shock (roughly 7% in a mean follow-up of 1 year) compared to transvenous ICDs [2, 3]. Follow-up of these patients after a mean of 2 years demonstrated that programming of sensing with the primary vector reduced the risk of inappropriate shock. Most inappropriate shocks were due to oversensing of T waves; other causes included oversensing of “low amplitude signals,” supraventricular tachycardias and noncardiac oversensing (which included electromagnetic interference) [4, 5]. For example, Frommeyer et al. [6] reported an inappropriate shock from a S-ICD due to artifact from electrical interference from a street lantern.
There has been sparse literature about oversensing from artifact due to subcutaneous air. In 1979, entrapped air within the device pocket was first reported as a cause for complete cessation of myocardial stimulation in a unipolar pacemaker [7]. Since then, air has been recognized as a potential insulator that prevents direct tissue contact with the electrode. In fact, Boston Scientific recently updated its user’s manual for S-ICDs and recommends that residual air should be evacuated prior to closing and suturing to optimize sensing and deliver therapy. Flushing the sternal track with saline, massaging the skin over the leads, and proper suturing over the sensing electrodes have been suggested as techniques to reduce dead space air within subcutaneous tissue [8].

Zipse et al. [9] reported the first case of inappropriate shock in a S-ICD due to subcutaneous air surrounding the distal electrode, causing oversensing in the secondary vector. Another case by Yap et al. [10] reported...
subcutaneous air surrounding the proximal electrode, causing oversensing in the alternate vector. In both cases, shocks were delivered within 48 hours of device implanta-
tion. The devices were reprogrammed to sense at a differ-
etent vector, which was effective at preventing any further inappropriate shocks. Resolution of air around the elec-
trodes was confirmed on lateral chest films after several
days in both cases.

S-ICDs are traditionally implanted by a three-incision
technique, but an alternative approach employing only
two incisions (the superior parasternal incision is
avoided) has also been used. Does an extra incision
with the traditional technique risk air introduction?
Review of literature is conflicting. A prospective cohort
by Knops et al. [11] evaluated the safety and efficacy of
the two-incision technique in S-ICD implantations.
After an 18-month follow-up, 39 patients with implanta-
tion using a two-incision technique had no inappro-
priate sensing [11]. However, Chinitz et al. [8] reported
two cases of inappropriate shock due to subcutaneous
air surrounding electrodes in patients whom the two-
incision technique was utilized and argue that the
three-incision technique reduces this complication [8].
Finally, despite their own experience of an inappro-
priate shock after a two-incision technique, Gamble et al
[12], argue that the two-incision technique is less likely
to result in air around the distal electrode as they had
found radiographic evidence of subcutaneous air
surrounding the proximal electrode only.

In our discussions with Boston Scientific, we discussed
this patient and the overall issue and collaboratively have
the following recommendations:

1 It is important to recognize the unique electrocardio-
gram in this case, which is the characteristic of artifact
secondary to subcutaneous air. Air causes a rise in
impedance leading to a baseline shift from the isoelec-
tric point (seen in Fig. 1 in the 48.0–55.6 sec bracket)
and decreased amplitude of QRS signaling leading to
oversensing. Recognizing these features on interroga-
tion would avoid unnecessary wound exploration after
an inappropriate shock.

2 Surgical technique is important, and it is imperative to
use the tunneling tool (provided in Boston Scientific’s
kit) to tunnel the coils through, and limit blunt finger
dissection. The tunneling tool is much thinner than the
operator’s finger, and the smaller diameter of the tool
reduces the chance of air coming through. Flushing sal-
ine through the sheath and masaging air along the tract
would help to expel any air out prior to closing.

3 Finally, we recommend overpenetrated PA and lateral
chest films immediately after S-ICD placement to
detect the presence of air. If air is detected, the
device should be reprogrammed to sense at another

vector until air resorbs, usually without intervention,
in 1–2 weeks.

Conflict of Interest
None declared.

Authorship
SL: was responsible for writing up initial drafts, obtaining
patient consent, and coordinating correspondences and
meetings between authors. Nektarios Souvaliotis: was
responsible for obtaining electrocardiogram tracings and
images and assistance in writing of initial drafts and sub-
sequent edits. DM: was responsible for the literature
search and assistance in subsequent edits and finalizing
manuscript. RS: was responsible for the literature search;
and assistance in subsequent edits and finalizing manu-
script.

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