Proarrhythmic Characteristics of Automated Implantable Cardioverter Defibrillators

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ABSTRACT

Introduction: Automated implantable cardioverter defibrillator (AICD) interventions have the potential to be proarrhythmogenic. This is related to suboptimal programming and technical limitations of the device. We sought to categorize the stored events in Boston Scientific Latitude remote monitoring system to appropriate and inappropriate shocks and identify the proarrhythmic event. **Methods:** Currently patients with an AICD are monitored and stored remotely. We reviewed the Boston Scientific Latitude database for stored events and categorized them. Shocks delivered for deleterious arrhythmias (ventricular fibrillation) were considered appropriate. Shocks delivered for relatively benign arrhythmias (ex-sinus tachycardia treated with anti-tachycardic pacing) were considered inappropriate. Worsening of baseline arrhythmia secondary to implantable cardioverter-defibrillator treatment is considered proarrhythmic (ex-sustained ventricular tachycardia [VT] treated with shock resulting in ventricular fibrillation). **Results:** Of the 3049 stored events, 380 shock events were identified. Among them, 132 events were induced during AICD implantation for testing purposes and thus excluded. One hundred and eighty were considered appropriate as the device shocked them out of sustained VT. Nine events were considered appropriate and proarrhythmic. Fifty-five were considered inappropriate as the shock was delivered for supraventricular arrhythmia. Four events were considered inappropriate and proarrhythmic as the AICD shocked the clinically inappropriate rhythm resulting in worsening of arrhythmia. **Conclusion:** We noted 13 proarrhythmic events. Most of them are due to inadvertent recognition of supraventricular arrhythmia and delivering of therapies. Proarrhythmogenicity can be minimized by careful programming of the AICD.

Keywords: Anti-arrhythmic agents, anti-tachycardia pacing, defibrillators, implantable, implantable/adverse effects, quality of life, supraventricular tachycardia, sudden cardiac death, tachycardia therapy, ventricular tachycardia

INTRODUCTION

Automated implantable cardioverter defibrillators (AICD) have proven to prevent sudden cardiac death (SCD) in high risk patients.[1] AICDs are very effective in this role, but they can also cause complications including provocation of fatal and non-fatal arrhythmias, reduced physical functioning[2] and mental well-being[3] and patient's discomfort. Only few studies[4] have investigated the etiology of inappropriate shocks and analyzed the ways to prevent it. We sought to review the inappropriate shocks and classified them into proarrhythmic and non-proarrhythmic events in patients followed through remote monitoring in our device clinic.

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METHODS

Currently patients with AICDs are monitored remotely. This allows documentation of arrhythmias stored within the memory of the AICD in a database. We collected all the shock events from the stored electrograms. Approval from the Institutional Human Research Review Board was obtained. All patients in the Boston Scientific Latitude database were enrolled in the study. A total number of 281 patients were enrolled. Through the latitude database, all arrhythmic events and all device therapies from these patients were downloaded and reviewed. Arrhythmic events induced at the time of AICD implantation for testing purposes were excluded from the study. Episodes of shocks and or anti-tachycardia pacing (ATP) delivered were

categorized as appropriate and inappropriate as follows. Shocks delivered for deleterious, life-threatening events such as ventricular fibrillation and sustained ventricular tachycardia (VT) were considered appropriate. Events from the same person were considered as one event.

A clinically inappropriate therapy is defined as shocks and or ATP that was delivered during a cardiac rhythm for which that therapy was not intended. These include shocks delivered for supra ventricular tachycardias (SVTs) such as sinus tachycardia or atrial fibrillation.

We then defined the proarrhythmogenicity of shocks and or ATP by identifying the events that were delivered for relatively benign rhythm resulting in worsening of the baseline rhythm. Examples include sustained VT treated by a shock resulting in ventricular fibrillation and ventricular pacing for pauses resulting in ventricular arrhythmias. As only the electrograms were reviewed, no corresponding clinical events were documented.

RESULTS

From 281 patients in the database, a total of 3049 stored electrograms were retrieved and reviewed. Within these electrograms, we identified 380 events that showed device interventions. Of these therapies, 132 events were induced during AICD implantation for testing purposes and hence excluded. The remaining 248 events were then further analyzed to determine the appropriateness of the intervention and were included in our study (Table 1). The events with similar characteristics from the same patient were considered a single event. The events were also assessed for proarrhythmogenicity. Classification of these events showed that 59 events were inappropriate, and 189 events were identified to be appropriate. Of all the study events, 13 events (from 13 patients as an event with similar characteristics from the same patient were considered one event) were identified to be proarrhythmic. The appropriate shocks (Figure 1) are events due to appropriate reasons resulting in termination of arrhythmic event.

Table 1 Total included events in our study and its classification

Classification	Total no. of events
Appropriate non-proarrhythmic	180
Inappropriate non-proarrhythmic	55
Appropriate proarrhythmic	9
Inappropriate proarrhythmic	4
Excluded (as the events were induced at the time of AICD implantation for testing purposes)	132
Grand total	380

AICD: Automated implantable cardioverter defibrillator

Appropriate and proarrhythmic

Of these 13 proarrhythmic events, six of them were initiated by VT resulting in ventricular fibrillation with subsequent shock to bring the rhythm back to baseline (Figure 2). One event was triggered by ventricular pause related pacing resulting in VT warranting a shock with eventual conversion to baseline.

Inappropriate non-proarrhythmic

Fifty-nine events were categorized to be inappropriate. Of these events, 55 were considered non-proarrhythmic. All of these non-proarrhythmic events were initiated by atrial fibrillation with rapid ventricular response (Figure 3). This was resulted in shock or pacing them out to their baseline.

Inappropriate proarrhythmic

In those inappropriate events, four were considered to be proarrhythmic. These events were initiated by atrial tachycardia resulting in shock. This put the patient in sustained ventricular fibrillation with subsequent shock bringing them out to baseline (Figure 4).

DISCUSSION

AICDs are widely considered to be an effective intervention in preventing SCD in high-risk patients.[2] But the interventions provided could actually be proarrhythmogenic with some of them causing clinical and hemodynamic[5,6] bradyarrhythmias and tachyarrhythmias. With subsequent addition of pacers, bradyarrhythmias are becoming less common. Stored electrograms help us in identifying these arrhythmias and improvise the system.[7] The electrograms being stored can be classified as Inappropriate and appropriate pacing or shocks (henceforth called interventions). Proarrhythmic characteristics can be defined based on the initiating arrhythmias, therapy delivered and ensuing event.

Inappropriate interventions

Anti-tachycardia therapies (such as ATP, defibrillations, shocks), anti-bradycardia therapies (pause related pacing), signal oversensing are some of the common interventions that could potentially be delivered in an inappropriate setting.[8] These interventions have been reported as many as 13% in multicenter automatic defibrillator implantation trial II study.[4] In our study, we noted the 3.4% proarrhythmic events (13/380). Pinski and Fahy[8] reported proarrhythmic

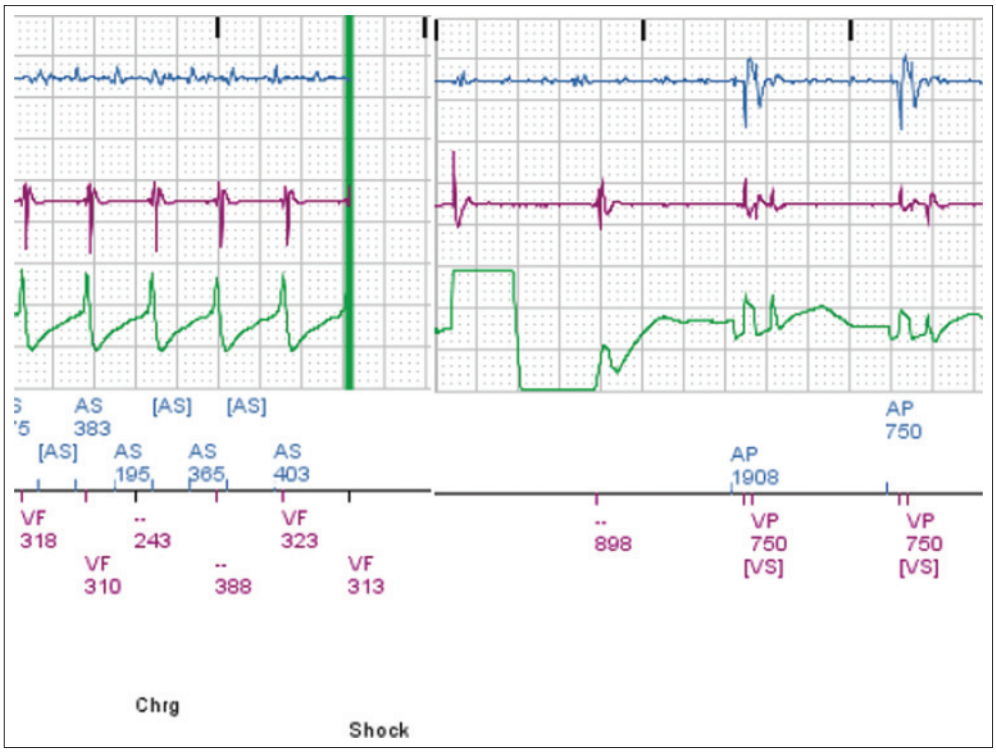

Figure 1. Appropriate event.

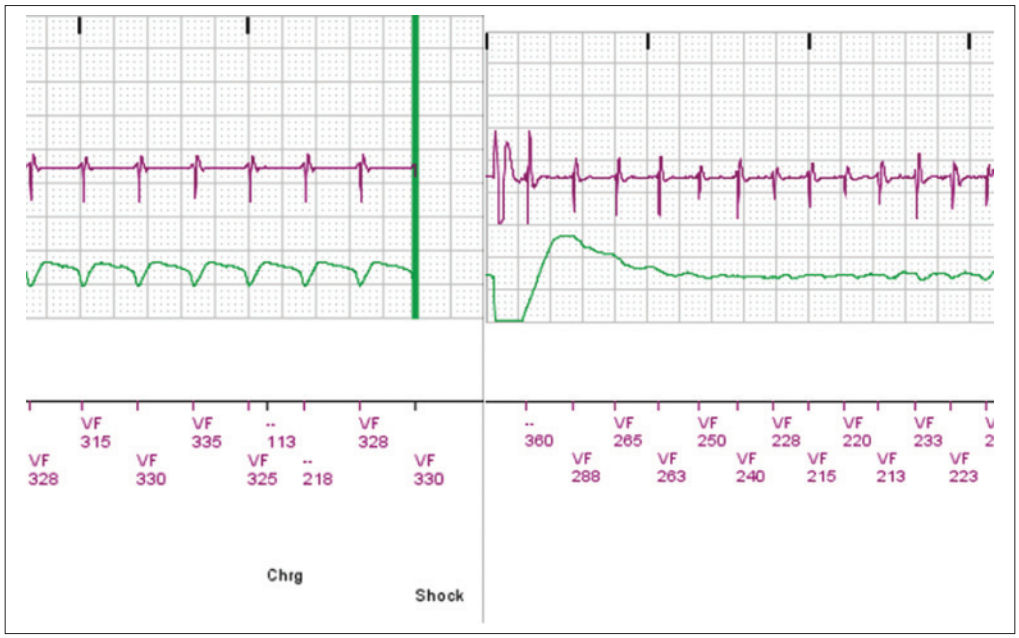

Figure 2. Appropriate proarrhythmic event.

event between 1% and 6% in AICD. We believe the incidence is decreasing due to better understanding of proarrhythmic characteristics and the protocols designed to manage the proarrhythmogenicity. Atrial fibrillation has been the major culprit in initiating inappropriate shocks as observed in our patient population followed by other SVTs. These patients with increased frequency of inappropriate shocks had a history of atrial fibrillation, smoking and/or diastolic hypertension.[4,9] Other investigators also observed the similar correlation.[9]

Outcomes in inappropriate interventions

The occurrence of inappropriate shock was associated with proarrhythmogenicity, increased mortality and morbidity. In our observation, we found about four incidences where

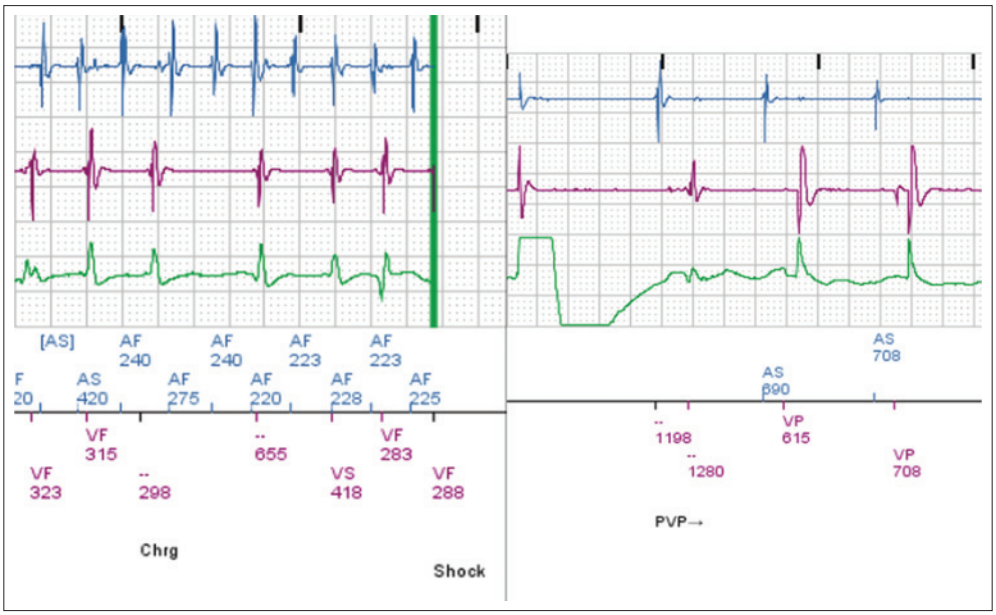

Figure 3. Inappropriate event.

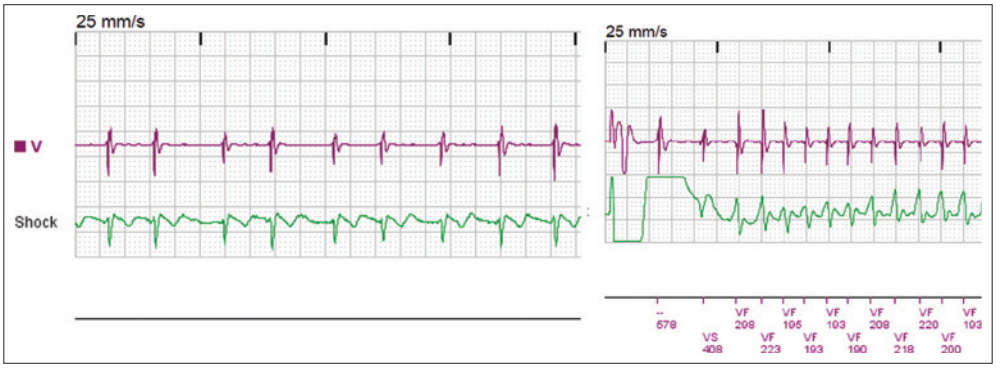

Figure 4. Inappropriate proarrhythmic event. (Inappropriate, Proarrhythmic: Baseline Atrial fibrillation becomes VF after shock)

inappropriate interventions resulted in proarrhythmic events. All these events led to shocks, which increased the morbidity burden. Possible explanations for increased mortality include direct mechanical,[10] arrhythmic,[4] and hemodynamic[11] adverse effect of the shock.

Minimizing inappropriate shocks

Various mechanisms have been proposed in reducing inappropriate shocks. One such mechanism is the usage of SVT-VT discriminator in such patients, which have shown to reduce the incidence of inappropriate detection. There is a theoretical risk of under detection of true malignant ventricular arrhythmias, but current data suggest that such under detection is infrequent.[12,13] The effectiveness of such discriminator is reduced when atrium fires at rates more than 170/min.[14] This finding is consistent in our population as most of the inappropriate shocks (proarrhythmic and non-proarrhythmic) were secondary to atrial fibrillation at rates more than 170/min. Other mechanism proposed was the role of medications in preventing inappropriate shocks. Few studies have shown that sotalol[15] and amiodarone[16] reduced inappropriate shock, data on beta-blockers remain divided.[17,18] Conversely, concomitant beta-blockers have shown to improve survival in patients with implantable cardioverters.[19]

Programming the AICDs to a higher detection rate reduces the sensing and misinterpretation of atrial arrhythmias as ventricular arrhythmias.[13] But, this could lead to potential under detection of relatively slow monomorphic VTs, polymorphic ventricular arrhythmias or ventricular fibrillation due to intermittent undersensing.[13]

Use of dual-chamber devices have shown to decrease the odds of inappropriate detection when compared to single-chamber detection.[20,21] Another mechanism that has shown to decrease the shocks is the use of ATP despite a higher rate of misclassification of SVT that received

inappropriate ventricular therapies. ATPs may prevent shocks for inappropriate detections by various mechanisms including terminating atrioventricular (AV) node dependent SVTs, delaying shocks long enough to permit spontaneous slowing or termination of SVT, and slowing of SVTs by concealed retrograde penetration of the AV node.[22,23]

Study limitations

As we analyzed the rhythms retrospectively, clinical symptoms were not correlated and documented. Also, we reviewed one of three databases in our office setup. We did not categorize the AICDs into single or dual chamber devices. This may be of significance as the differences in the device may confer reduced inappropriate shocks.[14] Error in classifying shocks would have occurred.[15]

CONCLUSION

AICDs are indicated to prevent life-threatening arrhythmias. They are generally safe without any major side-effects. Careful programming of the AICD to avoid pause related pacing could minimize the proarrhythmic potential of AICDs. The treatment for non-lethal arrhythmias will require tailoring of device settings for the individual patient's clinical scenario. As proarrhythmic shocks cause significant morbidity and mortality, prevention of such shocks is of importance.

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