Interactions Between Electronic Article Surveillance Systems and Implantable Cardioverter-Defibrillators

William J. Groh, MD; Scott A. Boschee, BS; Erica D. Engelstein, MD; William M. Miles, MD; M. Erick Burton, MD; Peter R. Foster, MD; Barry J. Crevey, MD; Douglas P. Zipes, MD

**Background**—In patients with implantable cardioverter-defibrillators (ICDs), inappropriate shocks have been reported with exposure to electronic article surveillance systems. The risk to patients with ICDs of walking through or lingering near surveillance systems requires further investigation.

**Methods and Results**—We evaluated the response in ICD function in 170 subjects during a 10- to 15-second midgate walk-through of and during extreme (2 minutes within 6 in of the gate) exposure to 3 common article surveillance systems. Complete testing was done in 169 subjects. During a 10- to 15-second (very slow) walk-through of the 3 surveillance systems, no interactions were observed that would negatively affect ICD function. During extreme exposure (169 subjects) and during extreme exposure and pacing via the ICD (126 subjects), interactions between the ICD and the article surveillance systems were observed in 19 subjects. In 7 subjects, this interaction was clinically relevant and would have likely (3 subjects) and possibly (4 subjects) resulted in ICD shocks. In 12 subjects, the interaction was minor.

**Conclusions**—It is safe for a patient with an ICD to walk through electronic article surveillance systems. Lingering in a surveillance system may result in an inappropriate ICD shock. *(Circulation. 1999;100:387-392.)*

**Key Words:** heart-assist device ▪ cardioversion ▪ defibrillation ▪ electromagnetic fields ▪ arrhythmia

Three case studies have reported that patients have received inappropriate implantable cardioverter-defibrillator (ICD) shocks believed to be associated with exposure to electronic article surveillance systems. These antitheft surveillance systems emit an electromagnetic field used to detect a metal alloy tag and signal a theft. ICDs normally sense cardiac electrical activity and deliver antitachycardia pacing or shocks for rapid rates. Electromagnetic fields such as those generated by an electronic article surveillance system may lead to inappropriate therapies if detected on the sensing circuit of the defibrillator.

Electronic article surveillance systems are in common use in retail and public places; one estimate is that as many as 800 000 systems are in use worldwide. ICDs also are common, with estimates of 400 000 devices implanted worldwide. Exposures to article surveillance systems in those with ICDs occur and will continue to occur frequently; thus, an understanding of possible negative interactions is mandatory. We assessed the effects of electronic article surveillance systems on ICD function in 170 individuals.

**Methods**

**Subjects and Study Design**

The 3 participating centers have active pacemaker and defibrillator clinics. Over a 4-month period, all individuals with ICDs were informed of the study and asked to participate.

The study design was approved by the Institutional Review boards at each center, and subjects gave informed consent before participation.

Three electronic article surveillance systems similar to those used in antitheft applications were set up at each location. The 3 systems evaluated were manufactured by Sensormatic Electronics Corporation (Boca Raton, Fla); a pulsed acoustomagnetic system (Ultra-Max) and 2 different electromagnetic systems, Aislekeeper and P-Magnetic. These systems were chosen for 3 reasons: (1) case reports implicating electronic article surveillance equipment as a cause of inappropriate defibrillator shocks have occurred with 2 of these systems (2 with Ultra-Max and 1 with Aislekeeper); (2) other studies have shown interactions with pacemakers and these systems; and (3) these electronic article surveillance systems are commonly used worldwide.

ICD sensing parameters for tachyarrhythmia detection were left as clinically programmed but with the actual delivery of therapies inactivated. Continuous ECG monitoring in the presence of a standby external defibrillator was used during the time period that therapies were inactivated. Exposure during 3 gate transits with each surveillance system was tested.

1. Routine exposure. Subjects were asked to walk through the middle of the gates over a 10- to 15-second period. This very slow transit was intended to replicate the exposure that the absolute slowest person might experience routinely.

2. Extreme exposure. Subjects stood in the surveillance system within 6 in of the gate transmitter for 2 minutes. Subjects slowly rotated near (or leaning on) the gate transmitter to assure exposure despite directional field effects.

3. Extreme exposure with pacing. We tested exposure during pacing because in many ICDs, the maximal sensitivity for detecting cardiac events (or noise) occurs during pacing. In addition, pacing at a fixed rate...
allows determination of whether any oversensing (of noise) by the ICD occurs, because such a response would delay pacing. Subjects who agreed to pacing for the time of the testing were paced at 20 bpm faster than their resting heart rates. For dual-chamber ICDs, pacing was done in both the atrium and ventricle.

A continuous ECG was recorded during gate transit. After each gate transit, the ICD was interrogated to determine whether any events were detected by the device or whether defibrillator reprogramming occurred.

In subjects who had a separate pacemaker, no changes were made in pacemaker programming. The pacemaker was interrogated before and after gate transits to ensure that no reprogramming occurred.

### Data Analysis

Subject and ICD characteristics were recorded. The ICD sensing circuit was categorized into 1 of 3 types: (1) endocardial tip ring (true bipolar), (2) endocardial tip coil (integrated bipolar), and (3) epicardial. Any interaction between the ICD function and the specific surveillance systems was noted. An interaction that could possibly result in an inappropriate defibrillator therapy was defined as clinically relevant. Continuous variables are given as mean ± SD. Statistical tests included χ² analysis with Pearson’s formulation and Fisher’s exact test. Student’s t test was used for continuous variables. Multivariate analysis was conducted by means of a Cox regression analysis. All tests were conducted with a 2-sided α risk level of 0.05.

### Results

Of the 170 patients tested, 169 completed the study. One individual did not complete testing and was excluded from analysis. The manufacturer, model number, implant location, and ventricular sensing type of the defibrillators tested are given in Table 1.

### Routine Exposure

No alteration in baseline cardiac rhythm was observed with gate transit. After a slow walk through the middle of each surveillance system, interrogation of the ICDs revealed no interactions or any reprogramming. Defibrillators manufactured by Ventritex (St Jude Medical) do not provide information regarding tachyarrhythmia detection unless therapies are activated. In addition, Ventritex defibrillators manifested a noise reversion mode in which noise sensing may appropriately deactivate therapies temporarily. In newer Ventritex models, (V-115, V-145, and V-180), an
internal ECG recording was activated to determine device sensing during transit. In these 15 defibrillators, no spurious sensing was detected. In older Ventritex devices (V-100 and V-110), there was no capability to determine device sensing except during pacing.

**Extreme Exposure**

In 3 subjects undergoing extreme exposure to the 3 surveillance systems, the ICDs showed inappropriate tachyarrhythmia detection (Table 2). All occurred with the Ultra-Max surveillance system, and all would likely have resulted in shocks based on the ICD therapies. The first of these occurred in a subject with a Medtronic model 7219 ICD. Sensing revealed continuous noise with gate exposure interpreted by the ICD as ventricular fibrillation (Figure 1). Both the second and third subjects had model 7146 defibrillators from Cardiac Pacemaker, Inc (CPI). In both subjects, sensing revealed continuous noise with gate exposure interpreted by the ICD as ventricular fibrillation (Figure 2). No ICD reprogramming was observed in any of the ICDs.

### Extreme Exposure With Pacing

The pacing effect on ICD–article surveillance system interaction was evaluated in 126 subjects. Five subjects were characterized as dependent on their ICDs for pacing, and in 121 subjects, pacing at 20 bpm faster than resting heart rate was done. Pacing resulted in oversensing of the T wave in 6 individuals with Medtronic ICDs before surveillance system exposure. In these subjects, ICD sensitivity was decreased by 0.15 mV sequentially until T-wave oversensing was not observed, similar to what might be done during normal clinical practice.

During extreme surveillance system exposure with pacing, ICDs in 19 of 126 subjects showed evidence of oversensing. No ICD reprogramming was observed. The results showing ICD oversensing are summarized in Table 2. In 12 subjects, the interaction was not clinically relevant. In these subjects, only an intermittent delay in pacing caused primarily by noise-augmented T-wave oversensing was observed (Figure 3). In 7 subjects, the interactions were clinically relevant. In 5 subjects, complete pacing inhibition occurred with surveillance system exposure. Three of these subjects had inappropriate ICD detec-

### TABLE 2. Extreme Exposure (and Pacing): ICD–Surveillance System Interaction

<table>
<thead>
<tr>
<th>No.</th>
<th>Manufacturer/Model No.</th>
<th>Time Since Implant, y</th>
<th>Time Since Revision, y</th>
<th>ICD Location</th>
<th>Sensing Circuit</th>
<th>Sensed R Wave, mV</th>
<th>Interaction Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>CPI 1746</td>
<td>4.4</td>
<td>1.5</td>
<td>Abdominal</td>
<td>Endocardial tip coil</td>
<td>5.4</td>
<td>Inappropriate ICD VF detection (Ultra-Max); complete pacing inhibition (Ultra-Max)</td>
</tr>
<tr>
<td>2*</td>
<td>CPI 1746</td>
<td>4.8</td>
<td>1.4</td>
<td>Abdominal</td>
<td>Endocardial tip coil</td>
<td>5.0</td>
<td>Inappropriate ICD VF detection (Ultra-Max); complete pacing inhibition (Ultra-Max)</td>
</tr>
<tr>
<td>3</td>
<td>Medtronic 7219</td>
<td>3.6</td>
<td>...</td>
<td>Pectoral</td>
<td>Endocardial tip ring</td>
<td>8.0</td>
<td>Delay in pacing (Ultra-Max); delay in pacing (Aislekeeper)</td>
</tr>
<tr>
<td>4</td>
<td>Medtronic 7219</td>
<td>6.0</td>
<td>2.6</td>
<td>Abdominal</td>
<td>Epicardial</td>
<td>9.0</td>
<td>Delay in pacing (Ultra-Max)</td>
</tr>
<tr>
<td>5*</td>
<td>Medtronic 7219</td>
<td>4.5</td>
<td>4.4</td>
<td>Abdominal</td>
<td>Endocardial tip ring</td>
<td>2.0</td>
<td>Inappropriate ICD VF detection (Ultra-Max); complete pacing inhibition (Ultra-Max)</td>
</tr>
<tr>
<td>6</td>
<td>Medtronic 7219</td>
<td>7.2</td>
<td>2.8</td>
<td>Pectoral</td>
<td>Endocardial tip ring</td>
<td>4.0</td>
<td>Delay in pacing (Ultra-Max); delay in pacing (Aislekeeper)</td>
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<td>Delay in pacing (Aislekeeper)</td>
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<td>...</td>
<td>Abdominal</td>
<td>Epicardial</td>
<td>4.5</td>
<td>Delay in pacing (Ultra-Max)</td>
</tr>
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<td>4.6</td>
<td>3.9</td>
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<td>Endocardial tip ring</td>
<td>5.0</td>
<td>Prolonged pacing inhibition (Aislekeeper); delay in pacing (P-Magnetic)</td>
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<td>9.0</td>
<td>Prolonged pacing inhibition (Aislekeeper); delay in pacing (P-Magnetic)</td>
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<tr>
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<td>Epicardial</td>
<td>9.0</td>
<td>Complete pacing inhibition (Aislekeeper)</td>
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<tr>
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<td>9.7</td>
<td>3.1</td>
<td>Abdominal</td>
<td>Epicardial</td>
<td>4.0</td>
<td>Prolonged pacing inhibition (Ultra-Max); complete pacing inhibition (Aislekeeper)</td>
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<td>9.0</td>
<td>Delay in pacing (Aislekeeper)</td>
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<td>Endocardial tip coil</td>
<td>8.0</td>
<td>Delay in pacing (Ultra-Max); delay in pacing (Aislekeeper)</td>
</tr>
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<td>...</td>
<td>Pectoral</td>
<td>Endocardial tip coil</td>
<td>9.0</td>
<td>Delay in pacing (Aislekeeper)</td>
</tr>
<tr>
<td>16</td>
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<td>...</td>
<td>Pectoral</td>
<td>Endocardial tip coil</td>
<td>6.0</td>
<td>Delay in pacing (Aislekeeper)</td>
</tr>
<tr>
<td>17</td>
<td>Ventritex V-145</td>
<td>1.8</td>
<td>...</td>
<td>Pectoral</td>
<td>Endocardial tip coil</td>
<td>9.0</td>
<td>Delay in pacing (Aislekeeper)</td>
</tr>
<tr>
<td>18</td>
<td>Ventritex V-145</td>
<td>8.3</td>
<td>0.8</td>
<td>Abdominal</td>
<td>Epicardial</td>
<td>6.0</td>
<td>Delay in pacing (Aislekeeper)</td>
</tr>
<tr>
<td>19</td>
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<td>0.5</td>
<td>...</td>
<td>Pectoral</td>
<td>Endocardial tip coil</td>
<td>6.0</td>
<td>Delay in pacing (Aislekeeper)</td>
</tr>
</tbody>
</table>

* Clinically relevant interactions.
Correlates of Defibrillator–Surveillance System Interference

Subject and ICD characteristics were analyzed to determine factors increasing the likelihood of surveillance system–defibrillator interaction. Characteristics found to predict an interaction through univariate analysis are summarized in Tables 3 and 4. With multivariate analysis, a diminished R-wave amplitude and a Ventritex ICD were the only characteristics that independently predicted an increased likelihood of any interaction (R wave, \( P<0.01 \); Ventritex, \( P<0.01 \)) or a clinically relevant interaction (R wave, \( P=0.05 \); Ventritex, \( P=0.02 \)).

Discussion

Major Findings

Our study evaluated interactions between ICDs and electronic article surveillance systems. In 169 subjects, no evidence of any ICD interference was seen during a 10- to 15-second walk-through of the surveillance systems. During a protracted exposure of 2 minutes within 6 in of the gate transmitter, 19 subjects had evidence of defibrillator–surveillance system interference. In 12 of these subjects, this interference was not clinically relevant, with evidence of only minor oversensing. In 7 of the subjects, the interference was clinically relevant, with 3 interactions likely to produce inappropriate ICD shocks and 4 possibly producing inappropriate ICD shocks. These 7 subjects also had complete or prolonged inhibition of pacing during extreme exposure. Only 1 subject was pacing via his defibrillator before testing, and he remained asymptomatic during pacing inhibition. The likelihood of any surveillance system–ICD interaction and a clinically relevant interaction increased in older ICD implants (or revisions), in abdominal implants, with decreased R-wave sensing amplitude, and in Ventritex ICDs. The only independent characteristic that predicted any or a clinically relevant interaction were decreased R-wave sensing amplitude and a Ventritex ICD. The fact that abdominal ICD location and older implants did not independently predict interactions is likely related to an interdependence of these 2 characteristics. In fact, all 7 subjects with clinically relevant interactions had abdominal ICD implants. Older ICDs such as the Medtronic 7219 and the Ventritex V-110 were more likely to show interference. The correlation of decreased R-wave sensing amplitude with interactions is the result of a decreased signal-to-noise ratio. The sensing of low-amplitude electromagnetic interference is more likely as the ICD increases in sensitivity to detect the lower amplitude R-wave. With Ventritex defibrillators, the predominant interaction was with Aislekeeper, 1 of the electromagnetic article surveillance systems. With the Medtronic and CPI defibrillators, the predominant interaction was with the pulsed acoustomagnetic article surveillance system, Ultra-Max. The sensing circuit of the ICD did not alter the likelihood of an ICD–surveillance system interaction. This result was different from those seen in a previous study in which minor interference with pacemaker function was more common in unipolar compared with bipolar lead systems. The difference with ICDs may be that even with epicardial or endocardial tip coil sensing, the sensing circuit is more localized than that in a unipolar lead pacemaker in which the generator provides 1 pole of the sensing circuit.

Previous Reports

Three case reports have described defibrillator shocks related to surveillance system exposure.\(^3\) As in our study, the shocks in these 3 patients occurred with close or protracted exposure to the surveillance system, with abdominal implants (2 of 3), and with exposure to a pulsed acoustomagnetic (Ultra-Max) or an electromagnetic (Aislekeeper) surveillance system.

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system. A single study has evaluated interactions in patients with ICDs and surveillance systems. In this study, no interference was found in 25 subjects despite close and protracted exposure. No pacing was done in this study; therefore, minor interference might not have been recognized.

**Study Limitations**

Our study evaluated only 1 manufacturer’s surveillance systems. It is likely that other systems using similar electromagnetic fields would interact similarly. No testing of swept-radiofrequency surveillance systems was done. A sin-

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**Figure 2.** Ventricular fibrillation (VF) detection in CPI model 1746 defibrillator with extreme exposure to Ultra-Max Surveillance System. Top, Defibrillator-sensed electrogram. Surveillance system-induced noise is seen between normal QRS signals. Bottom, Detected R-R intervals (ms) determined by defibrillator. Baseline heart rate rhythm is atrial fibrillation. With extreme exposure, detected intervals as short as 137 ms are seen, consistent with noise sensing. This led to detection of ventricular fibrillation event that would have likely resulted in defibrillator shock in active device. VS indicates ventricular-sensed event and VP, ventricular pacing.

**Figure 3.** Noise-induced augmentation of T-wave oversensing in Ventritex model V-145 defibrillator with extreme exposure to the Aislekeeper surveillance system. Shown is defibrillator-sensed electrogram. Ventricular pacing is seen in first 3 beats. Delay in ventricular pacing occurs secondary to T-wave oversensing (arrows). This T-wave oversensing resulted from electromagnetic interference.
The previous study evaluating pacemakers and article surveillance systems has not shown any interference with the swept-radiofrequency systems. Because of the presence of a noise reversion mode in Ventritex ICDs, what was considered a clinically relevant interaction might only result in pacing output inhibition and not lead to an inappropriate ICD shock. ICDs manufactured by CPI also have a noise-sensing window that could influence electromagnetic interference.

Conclusions and Recommendations

On the basis of our study, it does not appear that electronic article surveillance systems pose a threat to patients with ICDs if exposure is kept to a 10- to 15-second (ie, very slow) walk-through. More intense exposure in both time and proximity may lead to inappropriate shocks. The already minimal risk of an interaction should diminish even more as older and abdominal ICDs are replaced with newer pectoral defibrillators.

The Food and Drug Administration (FDA Safety Notification, September 28, 1998) and the American Heart Association (AHA Science Advisory, November 17, 1998) have reviewed the available data and issued statements agreeing that significant interactions are unlikely and that the public should be informed but not alarmed. Our study supports this message. What would seem most prudent is to ensure that physicians who manage patients with ICDs (or pacemakers) understand and inform their patients of the potential interactions associated with electronic article surveillance systems. Recognition of surveillance systems by the public should be possible to avoid protracted or close exposure. Surveillance systems that are not in plain view of the public should have signage indicating their presence. This policy should allow patients with ICDs (or pacemakers) to walk through such systems without lingering and therefore be seemingly at no risk of any interaction.

Acknowledgments

This work was supported in part by a grant from Sensormatic Electronic Corporation (Boca Raton, Fla). We acknowledge David A. Greene for his assistance with this project.

References

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Circulation. 1999;100:387-392
doi: 10.1161/01.CIR.100.4.387
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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