Electromagnetic interference caused by common surgical energy-based devices on an implanted cardiac defibrillator

Alessandro Paniccia, M.D.\textsuperscript{a,} Marc Rozner, Ph.D., M.D.\textsuperscript{f}, Edward L. Jones, M.D.\textsuperscript{a}, Nicole T. Townsend, M.D.\textsuperscript{a}, Paul D. Varosy, M.D.\textsuperscript{b}, James E. Dunning, M.S.E.E.\textsuperscript{c}, Guillaume Girard, Ph.D. Eng\textsuperscript{d}, Christopher Weyer, D.O.\textsuperscript{e}, Gregory V. Stiegmann, M.D., F.A.C.S.\textsuperscript{a}, Thomas N. Robinson, M.D., M.S., F.A.C.S.\textsuperscript{a,}\textsuperscript{*}

\textsuperscript{a}Department of Surgery, University of Colorado School of Medicine, Aurora; \textsuperscript{b}Division of Cardiology, University of Colorado School of Medicine, Aurora; \textsuperscript{c}Covidien, Boulder, CO; \textsuperscript{d}Medtronic, Inc., Minneapolis, MN; \textsuperscript{e}Dermatology and Plastic Surgery of Arizona, Sierra Vista, AZ; \textsuperscript{f}Department of Anesthesiology and Perioperative Medicine and Department of Cardiology, University of Texas MD Anderson Cancer Center, Houston, TX

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Abstract

\textbf{BACKGROUND:} Surgical energy-based devices emit energy, which can interfere with other electronic devices (eg, implanted cardiac pacemakers and/or defibrillators). The purpose of this study was to quantify the amount of unintentional energy (electromagnetic interference [EMI]) transferred to an implanted cardiac defibrillator by common surgical energy-based devices.

\textbf{METHODS:} A transvenous cardiac defibrillator was implanted in an anesthetized pig. The primary outcome measure was the average maximum EMI occurring on the implanted cardiac device during activations of multiple different surgical energy-based devices.

\textbf{RESULTS:} The EMI transferred to the implanted cardiac device is as follows: traditional bipolar 30 W .01 $\pm$ .004 mV, advanced bipolar .004 $\pm$ .003 mV, ultrasonic shears .01 $\pm$ .004 mV, monopolar Bovie 30 W coagulation .50 $\pm$ .20 mV, monopolar Bovie 30 W blend .92 $\pm$ .63 mV, monopolar instrument without dispersive electrode .21 $\pm$ .07 mV, plasma energy 3.48 $\pm$ .78 mV, and argon beam coagulator 2.58 $\pm$ .34 mV.

\textbf{CONCLUSION:} Surgeons can minimize EMI on implanted cardiac defibrillators by preferentially utilizing bipolar and ultrasonic devices.

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Cardiac implantable electronic devices (CIEDs), such as a pacemaker or cardioverter defibrillator, are vulnerable to interference by nearby energy sources.\textsuperscript{1-3} Surgical energy-based devices are used in virtually every operation and frequently applied in close proximity to these CIEDs. The radiofrequency energy used by most common surgical energy-based devices (eg, the monopolar “Bovie” and bipolar instruments) is emitted, or broadcast, into the air and couples (transfers without direct contact) to other nearby electronic devices through a phenomenon termed electromagnetic interference (EMI).\textsuperscript{4-6} EMI can disrupt the function of CIEDs, and practice advisories have delineated measures surgeons can take to minimize this EMI.\textsuperscript{7,8} However, these practice advisories are suboptimal because they are based on low-level evidence (eg, case reports and expert opinion).

The purpose of this study was to quantify the maximum EMI transferred to an implanted cardiac defibrillator (ICD) from commonly used surgical energy-based devices in vivo. The specific aims were to compare the maximum EMI occurring on an ICD among common devices: monopolar “Bovie” instrument, traditional bipolar, advanced bipolar, ultrasonic shears, monopolar instrument without a dispersive electrode, plasma energy, and the argon plasma energy.

**Methods**

An anesthetized pig underwent placement of an implantable cardiac defibrillator. The study received approval from the Animal Care and Use Committee. Before device placement, general anesthesia was induced with telazol and glycopyrrolate subcutaneously, followed by gentanyl and diazepam intravenously. Anesthesia was maintained with isoflurane, vecuronium, fentanyl, and low-dose propofol. The animal was continuously monitored utilizing electrocardiography, invasive arterial blood pressure monitoring, pulse oximetry plethysmography, side stream capnography, and temperature. End tidal carbon dioxide was maintained between 35 and 45 mm Hg.

The implantable cardiac defibrillator was placed in a fashion similar to human placement. Endocardial electrodes were placed under fluoroscopy through the left internal jugular vein in a fashion similar to human implantation. The device generator was positioned in the left prepectoral fascia. A Protecta D334 TRM dual chamber cardiac defibrillator (Medtronic, Minneapolis, MN) with 5076-58 cm right atrial lead and a 6947-65 cm dual coil true bipolar right ventricular lead was implanted. To quantify the EMI occurring on the implanted defibrillator, the generator was engineered to include external sensing wires that connected to the atrial and ventricular endocardial leads and emerged from the connection port header. To minimize EMI coupling directly to the external sensing wires, these wires were twisted and extruded through the sutured wound away from the site of energy device application. Final lead impedances (atrium 489 ohms, ventricle 692 ohms), signal amplitudes (atrium 2.5 mV, ventricle 3.0 mV), and pacing thresholds (atrium .5 V/.4 msec, ventricle .5 V/.4 msec) were consistent with human implant parameters. The implanted defibrillator was set to the atrial pacing, atrial sensing with inhibition mode because the pigs demonstrated sufficiently long Q wave and T wave intervals during ventricular pacing to interfere with internal cardiac defibrillator function. The pacing rate was set to 80 beats/minute, confirmed to be at least 15% above the native heart rate. Lead sensitivities and pacing outputs were also comparable with human parameters.

Surgical energy-based devices were used similarly. Each device was activated for 5 second intervals at a uniform location (2.5 cm inferior to the generator’s lower edge). Each experimental condition was repeated 10 times. The energy-based devices were tested using clinically relevant generator output settings: monopolar instrument 30 W coagulation mode (Force FX; Covidien, Boulder, CO), monopolar 30 W blend mode (V-mode, Triad; Covidien), traditional bipolar 30 W (Force FX; Covidien), advanced bipolar setting 3 bars (Ligasure; Covidien), ultrasonic shears setting Max (Harmonic scalpel; Ethicon, Cincinnati, OH), monopolar instrument without dispersive electrode 10 W (Hyfrecator; ConMed, Utica, NY), plasma energy setting 6 coagulation (Peak Plasma Blade; Medtronic, Minneapolis, MN), and argon plasma energy 30 W coagulation mode (Argon Beam Coagulator, ConMed, Utica, NY). The cords of all instruments were draped uniformly from the foot of the bed along the left side of the animal.

The primary outcome measure was the average maximum EMI recorded in millivolts measured by an oscilloscope and a spectrum analyzer from the external wires connected to the ICD’s generator-lead connection for each device. The baseline background EMI “noise” in the procedure room was recorded (.23 mV) and subtracted from the EMI measured on the generator.

Surgical energy-based devices were grouped based on the amount of EMI created on the ICD: low risk (<.2 mV), intermediate risk (≥.2 to 1.0 mV), and high risk (>1.0 mV). The 3 thresholds were chosen based on the mathematical distribution of the different measured EMIs for each device. We observed reproducible patterns of EMI for different devices whereby their mean EMI (±standard deviation) would never cross certain thresholds. This allowed us to classify the devices into the proposed 3 groups. We chose the mentioned thresholds (<.2 mV, ≥.2 to 1.0 mV, and >1.0 mV) for their reproducibility, and because they allow grouping of the different instruments into 3 practical categories based on measured quantities. The risk categories presented are in fact relative risk categories among the different devices tested.

An average maximum EMI value was calculated for all instruments in each risk group and the resulting means were compared among the 3 groups: low, intermediate, and high risk. Statistical analysis was performed using 2-sided Student t test with equal variances not assumed (STATA version 12.2; StataCorp, College Station, TX).
Results

The maximum average EMI occurring on the ICD was compared for all 8 energy-based devices tested (Table 1). The traditional bipolar 30 W (.01 ± .004 mV), the advanced bipolar (.004 ± .003 mV), and the ultrasonic shears (.01 ± .004 mV) created EMI on the ICD, which was not different from background EMI of the room (P > .05 for all 3 devices). These 3 devices were classified as low risk (EMI created was <.2 mV). Intermediate risk devices included the monopolar Bovie 30 W coagulation mode (.50 ± .20 mV), the monopolar blend mode (.92 ± .63 mV), and the monopolar instrument without dispersive electrode (.21 ± .07 mV), which created an EMI between .1 and 1 mV. The argon beam coagulator (2.58 ± .34 mV) and the peak plasma blade (3.48 ± .78 mV) transferred the most energy and were classified as high risk. The mean EMI for each of the 3 risk groups were significantly different from one another (P < .001 for all comparisons) (Fig. 1).

Comments

Commonly used surgical energy devices are known to generate EMI, which can disrupt the function of other nearby electronic devices. This study utilized a live animal model to record the EMI generated on an ICD device following the uniform use of commonly used surgical energy-based devices. Our results found that bipolar and ultrasonic devices caused the least EMI and that plasma-based radiofrequency energy devices created the most EMI on the implanted cardiac defibrillator.

These findings are consistent with the basic electrical principle that higher voltage creates increased EMI. The surgical devices having the lowest voltage during use in the operating room (traditional bipolar, advanced bipolar, and ultrasonic shears) created the least EMI on the ICD. In contrast, the surgical devices which generate the highest voltage (plasma energy and argon plasma energy) created the highest EMI. Voltage is the electromotive force that pushes the electrons through an electrosurgical circuit thereby creating the coupling mechanisms (eg, inductive, conductive, capacitive, and radiative [antenna]), which cause EMI.

This study provides the first measurement of EMI generated by common energy-based surgical devices on an ICD. These results remain consistent with current clinical advisories that recommend the use of bipolar and ultrasonic energy-based instruments in place of the monopolar instruments based mostly on low-level evidence. In addition, as higher EMI is more likely to cause CIED malfunction, we propose a simple classification system based on risk: low risk (0 to < .2 mV), intermediate risk (.2 to 1 mV), and high risk (>1 mV). This system provides a

### Table 1 Surgical energy-based devices and electromagnetic interference occurring on implanted cardiac device

<table>
<thead>
<tr>
<th>Device type</th>
<th>Low risk (EMI &lt; .2 mV)</th>
<th>Intermediate risk (EMI .2–1 mV)</th>
<th>High risk (EMI &gt; 1 mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional bipolar</td>
<td>.01 ± .004 mV</td>
<td>.21 ± .07 mV</td>
<td>2.58 ± .34 mV</td>
</tr>
<tr>
<td>Advanced bipolar</td>
<td>.00 ± .003 mV</td>
<td>.50 ± .20 mV</td>
<td>3.48 ± .78 mV</td>
</tr>
<tr>
<td>Ultrasonic shears</td>
<td>.01 ± .004 mV</td>
<td>.92 ± .63 mV</td>
<td>3.02 ± .64 mV</td>
</tr>
</tbody>
</table>

Energy-based devices were grouped based on the amount of EMI created on the implanted defibrillator. Statistical analysis: low vs intermediate, P < .001; low vs high, P < .001; intermediate vs high, P < .001.

EMI = electromagnetic interference.
practical guide to allow surgeons to understand the relative risk of their surgical device causing EMI on an implanted cardiac device during an operation.

The monopolar instrument without a dispersive electrode evaluated in this study was the Hyfrecator (a high-frequency desiccator). The Hyfrecator is a mono-terminal instrument, meaning that it has one active electrode but it does not utilize a dispersive electrode. The energy released by the active electrode goes into the tissue, gets dispersed in the patient, and then goes to the ground (rather than back to the generator).

It is well known that the operating room environment is surrounded by EMI. This knowledge was confirmed in this experimental study as we recorded our background EMI at the time of the experiments at .23 mV. The background interference was, in fact, higher than the EMI generated by the bipolar instruments or the ultrasonic instruments. Many surgical and nonsurgical electronic devices present in the operating room contribute to ambient EMI. Examples of these electronic devices would be patient monitoring devices, the healthcare provider’s cell phone, or the radio present in the operating room. Increasing the distance between these electronic devices and the ICD would be an important factor in reducing disruption of the ICD from extraneous EMI in the operating room environment.9

This study has several limitations. First, the CIED was implanted immediately before the execution of the experiments, which prevented the natural scarring and fibrosis that typically develop around endocardial leads and the generator connection.10 The lack of fibrotic tissue could have altered energy conduction resulting in more or less EMI. Second, the externalized wires that were used to measure the EMI could have received energy themselves via capacitive and/or antenna coupling.11,12 Thus, the measured EMI could represent capacitive and antenna coupling that would not take place in a typical patient who does not have externalized leads. Finally, while we were able to quantify the amount of EMI transferred to the defibrillator, the clinical impact of this remains unknown and warrants further study.

In summary, commonly used surgical energy-based devices transfer a measurable amount of energy to implanted cardiac electronic devices. Awareness of such phenomenon and familiarity with the EMI generated by each device should guide a surgeon’s choice of instruments to decrease the risk of cardiac device malfunction during surgical procedures. Further studies are needed to correlate the EMI generated by each energy-based device with clinically relevant changes in pacemaker or defibrillator function.

References

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Discussion

Discussant: Dr Dean Mikami (Columbus, OH). This is a very timely manuscript and presentation on the principle of surgical energy in the operating room. As a member of the SAGES Fundamental Use of Surgical Energy Group, I congratulate the authors on bringing light to a commonly misunderstood and overlooked component of the surgical suite. This paper discusses the electromagnetic interference that can occur with commonly used energy-based devices on implantable cardiac devices. The authors compared commonly and not-so-commonly used energy devices in the operating room, which included traditional bipolar at 30 watts, advanced bipolar, ultrasonic energy, monopolar electrosurgical pencils at 30-watts, monopolar pencils at 30 watt (blend mode), monopolar instruments without dispersive electrodes, plasma energy, and argon beam coagulators. My questions are as follows: 1. Can you explain how a monopolar instrument works without a dispersive electrode? 2. Can other electrical equipment have an effect on implantable cardiac stimulators, ie, the radio playing in the room, your cell phone that’s sitting on the table, or some other laparoscopic equipment, such as the towers or
the laparoscopic cords? If so, what measures should we do to protect our patients from this background electrical interference?

The last question is a more practical question. When you are taking a patient to the OR in an emergency situation and you do not know what kind of cardiac device is in your patient but you know they have one, what is the safest energy device to use?

**Dr Alessandro Paniccia:** You raise very fundamental questions. I will start with addressing your first question. The monopolar instrument without dispersive electrodes is not commonly used by general surgeon practitioners; it’s a device commonly used by dermatologists or by physicians that deal with skin disease. The instrument is also known as Hyfrecator. It stands for a high frequency desiccator, because what, in fact, it does here is it evaporates water from the tissue and mummifies the tissue superficially.

It’s a monoterminial instrument, meaning that has one active electrode but it doesn’t need a dispersive or inactive electrode. So the energy released by the active electrode goes into the tissue and then gets dispersed in the patient.

It can do so because the power of the system is very low. It’s an instrument with low power, high voltage, low amperage, and high frequency commonly used by dermatologists. It’s very important in their practice because they like to take care of patients with ICD in their office without having to deactivate the implantable cardiac pacemaker/defibrillator.

Regarding your second question, our environment is surrounded by electromagnetic interference. It’s interesting that you asked that question because we recorded our background electromagnetic interference at the time of the experiments at 23 millivolts. The background interference was, in fact, higher than the electromagnetic interference generated by the bipolar instruments or the ultrasonic instruments.

Many surgical and non-surgical devices contribute to the electromagnetic interference present in the operating room such as the devices used by the anesthesiologist in order to monitor patients during the procedure or the radio playing in the corner. The recommendations released by the American Heart Association are vague, but they mainly focus on establishing a reasonable distance from the device emitting electromagnetic interference and the patient’s implantable cardiac device. It would be reasonable to say that any time you have an instrument that releases electromagnetic interference or can interfere with a pacemaker or any ICDs, it is important to maintain distance from the ICD.

There are additional interventions that can be done for example whilst using laparoscopic instruments, it is recommended to avoid crossing the surgical instrument wire over the implantable cardiac device. In addition, it is critical to consider the energy vector generated by the active electrode that will be inevitably directed toward the dispersive electrode (commonly known as “grounding pad”). The dispersive electrode (or “grounding pad”) should be positioned in a way that the vector of energy going from the active electrode to the pad will not cross either of the leads or the generator.

The third question, what to do in an emergency case when the exact typology of implantable cardiac device in place is not known? Based on available studies and also confirmed in our study, the safest instruments to use are the bipolar instruments, followed by ultrasonic energy based instruments. One of the caveats is that the bipolar instruments are mainly used to achieve coagulation, when the cutting effect is the objective, an ultrasonic instrument might be necessary. If a monopolar instrument must be used the advice is to utilize the least amount of energy possible in short bursts of activation, at the greatest distance from the cardiac device with the current vector directed away from the cardiac device.

As a general rule, for each patient presenting with an ICD the surgeon should be familiar with the kind of ICD in place and its functional settings. In addition, it is critical to understand to what extent the patient is dependent on the ICD itself especially when the patient is being paced. In such a scenario, one of the most common interventions to prevent electromagnetic interference on the ICD, the use of a magnet, will not help.

**Dr John Moore** (Denver, CO). I think you are bringing out an area that most of us don’t truly understand and that we need to explore more closely. I think you touched on it there at the end. Usually, when we have patients with defibrillators, we’ll deactivate them before going in because the Bovie has been known to fool it and it will start shocking the patient potentially. Now, a pacemaker is much different, obviously. It just fools it and it just shuts itself down.

Do you have recommendations on when we do know what the device is what we should do or not do as the case may be?

**Dr Alessandro Paniccia:** Dr. Moore, thank you for your interesting question. The following are not my personal recommendations, but these are recommendations released by an expert consensus statement on the topic. The first advice is to contact the hospital electrophysiologist and assure that the anesthesiologist and/or the cardiologist are aware of the patient and the type of device. The information that should be given to the hospital’s CIED team should include type or procedure, anatomic location of procedure, if the monopolar “bovie” instrument will be used, and discharge plan. This team can then provide intra-operative recommendation for managing the cardiac device.

In the emergent setting, the most critical factor is determining if the patient is pacer dependent. This can be accomplished by obtaining an EKG and if pacer spikes are found in front of all or most of the QRS complexes, then the patient is pacer dependent. If there is no evidence of pacing, in general the surgeon can proceed with the surgery with a magnet in the room. If the patient is pacer dependent, then the operating team needs to take steps to ensure continued pacing. There is a nice practice advisory statement by the American Society of Anesthesiology and the American Heart Association that goes over safe management practices of cardiac devices in the operating room.