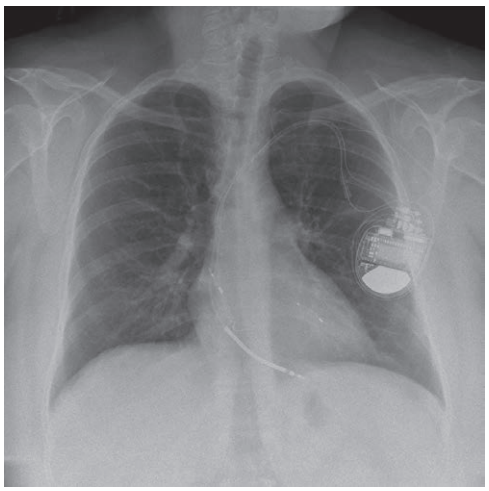
Intraoperative Electrosurgical Electromagnetic Interference in Patients with Implantable Cardioverter Defibrillators

Is It Safe?

G. Alec Rooke, M.D., Ph.D.

Most anesthesiologists understand that electromagnetic interference from monopolar electrosurgery may adversely impact the normal functioning of cardiovascular implantable electrical devices, including pacemakers and implantable cardioverter defibrillators. The most common consequences of electromagnetic interference are (1) pacing inhibition that could cause bradycardia and hypotension, and (2) inappropriate delivery of antitachycardia therapy, which can cause myocardial injury and might even increase mortality. Although previous studies have attempted to quantify how often intraoperative electromagnetic interference is detected by cardiovascular implantable electrical devices, the current study by Schulman *et al.*[1] examines this question prospectively and more thoroughly by defining three categories of electromagnetic interference: (1) any detectable electromagnetic interference; (2) electromagnetic interference that would have triggered antitachycardia therapy based on the implantable cardioverter defibrillator's actual programming ("clinically meaningful"); and (3) electromagnetic interference that would have triggered antitachycardia therapy if conservative programming strategies intended to reduce the risk of inappropriate antitachycardia therapy had been employed. Implantable cardioverter defibrillators record all tachyarrhythmia events, and that information can be downloaded. Implantable cardioverter defibrillators manufactured by Medtronic (USA) and Boston Scientific (USA) can be programed to a "monitor only" mode. This feature preserves the detection of arrhythmias, but prevents any therapies from being delivered, allowing safe use for surgery above the umbilicus. However, implantable cardioverter defibrillators by St. Jude Medical (USA) and Biotronik (USA) do not have this capability, and therefore those devices could only be used for surgeries below the umbilicus.



"There are two options to disable therapy [implantable cardioverter defibrillators]: place a magnet or reprogram the device. Both have their drawbacks."

Understanding how cardiovascular implantable electrical devices sense events is essential. Cardiovascular implantable electrical devices define a sensed event (*i.e.*, depolarization) whenever the voltage difference between the lead electrodes exceeds a predetermined threshold. Monopolar electrosurgery creates electromagnetic interference that produces high frequency, nonphysiologic signals (fig. 1), not all of which can be filtered out. Implantable cardioverter defibrillators are particularly prone to "oversensing" nonphysiologic signals because they must be sensitive enough to appropriately detect events of genuine ventricular arrhythmias. implantable cardioverter defibrillators categorize high-rate events as ventricular tachycardia or fibrillation based on rate and other proprietary criteria. If criteria for a ventricular arrhythmia are met, the implantable cardioverter defibrillator then delivers overdrive pacing or shocks.

The study's overall incidence (20%) of any electromagnetic interference in surgeries above the umbilicus during noncardiac surgery was lower than I expected. At least two possible explanations exist. This study consistently placed the dispersive ("ground") pad at the guideline-recommended location to direct the electrosurgery current return path away from the cardiovascular implantable electrical

Image: J. P. Rathmell.

Corresponding article on page 530.

Accepted for publication December 18, 2018. From the Department of Anesthesiology and Pain Medicine, University of Washington, Seattle, Washington.

<zdoi;10.1097/ALN.0000000000002625>

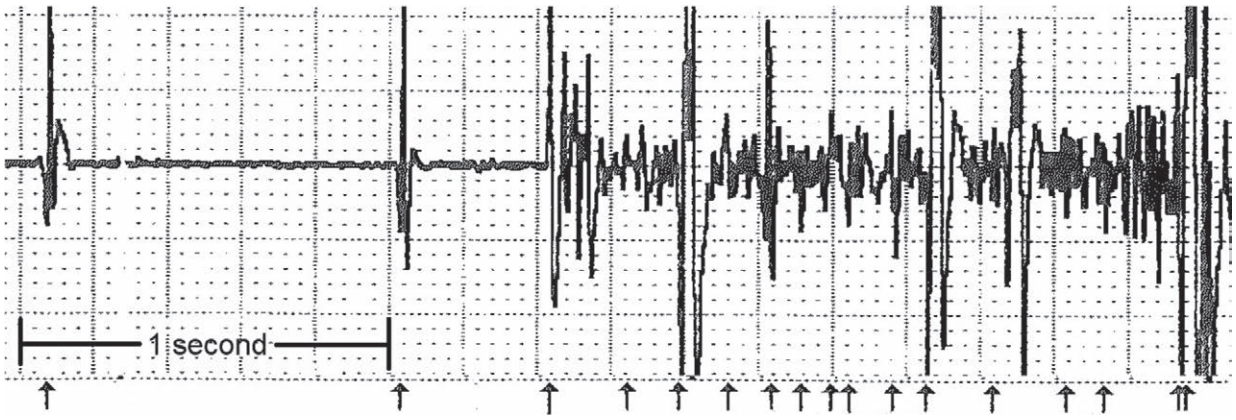


Fig. 1. An electrogram from a bipolar lead demonstrates what is observed by the lead. Two sinus rhythm beats are followed by electrosurgery electromagnetic interference. Each upward pointing *arrow* indicates where the device considers a sensed beat to have occurred. The criteria for delivering overdrive pacing or a shock can be complicated, but the criteria include the presence of rapid sensing.

devices.[2,3] In theory, this strategy should reduce detection of electromagnetic interference, but when the authors compared their results for specific surgical locations (*e.g.*, head/neck), they observed rates of electromagnetic interference that were similar to the prior literature. This failure to reduce electromagnetic interference detection questions the utility of the pad placement guidelines, but until more is known about the influence of pad location, the prudent strategy is to continue to position the dispersive pad to direct cautery current away from the device and leads. The more likely explanation for the low electromagnetic interference rate was that higher risk surgeries (thoracic, head/neck) were underrepresented and lower risk locations (abdomen) overrepresented in comparison to previous studies. In contrast, electromagnetic interference was very common using the underbody dispersive pad. The explanation may be as simple as the fact that cardiac surgery creates a very high risk of electromagnetic interference detection. But it could also be that the underbody pad disperses current too widely, providing sufficient current near the electrodes to generate detectable electromagnetic interference. Only additional studies will be able to determine if the underbody pad is less safe than the standard dispersive pad.

The most important issue, however, is whether or not the observed electromagnetic interference was sufficient to trigger antitachycardia therapy. Even with the stringent criteria, antitachycardia therapy would have been delivered to 3% of patients having noncardiac surgery above the umbilicus, a value that is still unacceptably high. Steps must be taken to mitigate that risk. Mitigation may also be necessary for surgeries below the umbilicus, given the current study's finding of one patient who demonstrated electromagnetic interference detection below the umbilicus and a recent case report of implantable cardioverter defibrillator discharge during knee surgery.[4] There are two options to disable therapy: place a magnet or reprogram the device. Both have their drawbacks. Correct magnet placement is not always the center of the device. Only some implantable cardioverter defibrillators provide audible feedback that the device has sensed the magnet. Magnets may slip during surgery, or may be difficult to place (*e.g.*, prone patient, near the surgical field). Some companies allow the implantable cardioverter defibrillator to be programed to ignore the magnet, though at present this is a highly unlikely scenario. Programming a device for surgery requires qualified personnel. Coordinating care for the consultation may cause case delays, and sometimes those specialists are unavailable. Programming also poses the risk of failing to restore implantable cardioverter defibrillator function postoperatively, leaving the patient unprotected. To circumvent these barriers, a few centers have trained anesthesiologists to accomplish this task.[5]

It is less clear what this study tells us about how electrosurgical electromagnetic interference will affect the pacing function of pacemakers and implantable cardioverter defibrillators. Any electromagnetic interference could inhibit demand pacing, but whether that causes bradycardia to the point of hypotension depends on many factors, including how close the surgical site is to the lead electrodes, and the frequency and duration of cautery. One factor that decreases the risk of pacing inhibition in pacemakers is that pacemaker leads are always the true bipolar model as opposed to the integrative bipolar leads that may be used with implantable cardioverter defibrillators. This study nicely documented that integrated bipolar leads are considerably more prone to detect electromagnetic interference than true bipolar leads. The electrodes of true bipolar leads are typically only about 1 cm apart, so it is more difficult for electromagnetic interference to generate different voltages at the two electrodes. For surgeries above the umbilicus,

electromagnetic interference inhibition of pacing cannot be reliably eliminated, so management during surgery for a patient with true pacing dependency at high risk of electromagnetic interference exposure requires either magnet placement (if the cardiovascular implantable electrical device is a pacemaker) or reprogramming (sole choice with an implantable cardioverter defibrillator, optional choice with a pacemaker). If a magnet is placed on a pacemaker, then the caregiver must be comfortable with a pacing rate that could be as high as 100 beats/min.

Another interesting observation from the study was that 8% of the devices had issues that were discovered during the interrogation just before surgery. At least half of those problems could have been corrected in advance of surgery, and some problems could have caused device malfunction in the operating room. This deficiency speaks to the need for systematic evaluation of cardiovascular implantable electrical devices prior to surgery as recommended by the guidelines.[2,3] Device evaluation is not an easy task to accomplish on a consistent basis, and many institutions struggle to achieve this goal.

In summary, the study by Schulman *et al.*[1] suggests that the likelihood of clinically dangerous electromagnetic interference from electrosurgery is relatively low for noncardiac cases above the umbilicus, but not low enough to ignore the need to inactivate the antitachycardia therapies of an implantable cardioverter defibrillator. The study also raises questions about whether the position of the dispersive pad affects the likelihood of detecting electromagnetic interference and suggests that the underbody pad may actually increase detection. The only solution to eliminate the risk of inappropriate therapy is if technological advances would entirely filter out electromagnetic interference and leave the true electrical signal of the myocardium undisturbed.

Competing Interests

The author is not supported by, nor maintains any financial interest in, any commercial activity that may be associated with the topic of this article.

Correspondence

Address correspondence to Dr. Rooke: rooke@uw.edu

References

1. Schulman PM, Treggiari MM, Yanez ND, Henrikson CA, Jessel PM, Dewland TA, Merkel MJ, Sera V, Harukuni I, Anderson RB, Kahl E, Bingham A, Alkayed N, Stecker EC: Electromagnetic interference with protocolized electrosurgery dispersive electrode positioning in patients with implantable cardioverter defibrillators. Anesthesiology 2019; 130:530–40
2. Crossley GH, Poole JE, Rozner MA, Asirvatham SJ, Cheng A, Chung MK, Ferguson Jr TB, Gallagher JD, Gold MR, Hoyt RH, Irefin S, Kusumoto FM, Moorman LP, Thompson A: The Heart Rhythm Society Expert Consensus Statement on the perioperative management of patients with implantable defibrillators, pacemakers and arrhythmia monitors: Facilities and patient management. Heart Rhythm 2011; 8:1114–54
3. American Society of Anesthesiologists: Practice advisory for the perioperative management of patients with cardiac implantable electronic devices: Pacemakers and implantable cardioverter-defibrillators: an updated report by the American Society of Anesthesiologists task force on perioperative management of patients with cardiac implantable electronic devices. Anesthesiology 2011; 114:247–61
4. Kleinman B, Ushomirsky S, Murdoch J, Loo J, Radzak J, Cytron J: Unintended discharge of an ICD in a patient undergoing total knee replacement. Anesthesia Patient Safety Foundation Newsletter 2017; 32:10–1
5. Rooke GA, Lombaard SA, Van Norman GA, Dziersk J, Natrajan KM, Larson LW, Poole JE: Initial experience of an anesthesiology-based service for perioperative management of pacemakers and implantable cardioverter defibrillators. Anesthesiology 2015; 123:1024–32