Electromagnetic Interference With Implantable Cardiac Devices

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Although pacemakers and implantable cardioverter-defibrillators (ICDs) are subject to electromagnetic interference (EMI) from many sources, relatively few are capable of causing clinically significant interference. However, in the rapidly evolving technology-driven environment in which we live, new devices that could theoretically cause interference with implanted devices constantly appear both within and outside the hospital environment. It is important that the clinician caring for a patient with an implanted device be aware of these sources to provide appropriate education and protection for the patient. Therefore, even if there are few new threats for the patient with a pacemaker or ICD in 2002, a review of the known sources of EMI is important.

Most sources of EMI are nonbiologic, but biologic sources of interference, such as myopotentials and extremes of temperature or irradiation, also can cause pulse generators to malfunction. In general, contemporary pacemakers and ICDs are effectively shielded against EMI, and the use of a bipolar sensing configuration has reduced the problem even further.

EMI enters an implanted pulse generator by conduction if the patient is in direct contact with the source or by radiation if the patient is in an electromagnetic field, with the pacemaker lead acting as an antenna. Pacemakers and ICDs are protected from interference by shielding of the circuitry, which filters the incoming signal and reduces the distance between the electrodes to minimize the antenna. Contemporary pulse generators are protected from most sources of interference because the circuitry is shielded inside a stainless steel or titanium case. In addition, body tissues provide some protection by reflection or absorption of external radiation.

A bipolar sensing configuration is less susceptible to conducted and radiated interference because the distance between anode and cathode is smaller than that for unipolar leads. Bipolar sensing has largely eliminated myopotential inhibition and crosstalk as pacemaker problems. In addition, with bipolar sensing there is considerably less sensing of external electrical fields and less effect from electrocautery during surgery.

Sensed interference is filtered by narrow bandpass filters to exclude noncardiac signals. However, this still leaves signals in the 5- to 100-Hz range, which overlap the cardiac signal range and are not filtered. These signals can result in abnormal device behavior if they are interpreted as being cardiac events.

There are a number of possible device responses to external interference, including inappropriate inhibition of pacemaker output, inappropriate triggering of pacemaker output, asynchronous pacing, reprogramming to different parameters, and damage to the pacemaker circuitry.

Hospital Environment
The hospital is the most common environment for potential sources of EMI that may cause significant interference with implantable devices.

Electrocautery
Electrocautery continues to be one of the most common potential sources of EMI for patients with implanted devices. Electrocautery involves the use of radiofrequency current to cut or coagulate tissues. It is usually applied in a unipolar configuration between the cauterizing instrument (the cathode) and the indifferent plate (the anode) attached at a distance to the patient's skin. Bipolar cautery uses a bipolar instrument for coagulation. The frequency is usually between 300 and 500 kHz (at frequencies of less than 200 kHz, muscle and nerve stimulation may occur). Cutting diathermy uses a modulated signal, so that bursts of energy are applied, whereas coagulation diathermy uses an unmodulated signal to heat the tissue. Coagulation diathermy is used in radiofrequency ablation of cardiac tissue for the treatment of arrhythmias.
The current generated by electrocautery is related to the distance and orientation of the cautery electrodes relative to the pacemaker and lead. High current is generated if the cautery cathode is close to the pacemaker, and particularly high currents are generated in the pacemaker if it lies between the two cautery electrodes.

Electrocautery can result in multiple clinical responses from an implanted device, including reprogramming, permanent damage to the circuitry, inhibition, reversion to a fallback mode, noise reversion mode, and electrical reset. In addition, the electrocautery signal may induce currents in the pacing lead and cause local heating at the electrode, leading to myocardial damage with subsequent elevation of pacing or sensing thresholds, or both. Threshold alteration is often transient. In the patient with an ICD, electrocautery could result in inappropriate detection of what is interpreted to be a ventricular dysrhythmia or in failure to detect a ventricular arrhythmia.

To prevent inappropriate inhibition of the pacemaker, a magnet is often applied to the chest over the pacemaker during cautery to convert it to the asynchronous mode. This may be successful, but because in some pacemakers this procedure could theoretically make the device more susceptible to reprogramming by the electrocautery signal, it is controversial \[6\].

During surgery, pacemakers with rate-responsive functions may respond with rate increments caused by vibration sensed from intraoperative equipment or vibrations created by the surgical procedure. The electrocautery signal may overwhelm the impedance-measuring circuit of a minute-ventilation rate-responsive pacemaker and cause pacing at the upper rate limit. Minute-ventilation rate-responsive pacemakers may also be susceptible to upper rate limit pacing if a specific type of impedance monitoring is used intraoperatively or postoperatively, and positive pressure ventilation may result in inappropriate rate response \[1,7,8\].

Patients with pacemakers who are to undergo surgery in which electrocautery may be used should be assessed preoperatively (Table 1) to determine the programmed settings and whether the patient is pacemaker-dependent. In patients with ICDs, the "therapies" should be programmed "off" for the duration of the surgical procedure to avoid inappropriate detection of EMI as a ventricular dysrhythmia. The patient must be continuously monitored from the time therapies are programmed "off" until they are reactivated.

<table>
<thead>
<tr>
<th>Table 1: Preoperative Management With Use of Electrocautery in Patients Who Have Implanted Cardiac Devices</th>
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<tr>
<td><strong>Preoperatively</strong></td>
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<tr>
<td>- Identify pacemaker and determine &quot;reset&quot; mode</td>
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<tr>
<td>- Check pacemaker program, telemetry, thresholds, battery status</td>
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<tr>
<td>- Deactivate rate response and, if applicable, Vario function</td>
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<td>- Record pacemaker information</td>
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In the operating room, it is most important that the indifferent plate of the electrocautery device be placed at a distance from the pulse generator, usually on the thigh, and that good contact be ensured. The effect of electrocautery may be difficult to assess because it causes interference on the electrocardiogram (ECG) monitor. Other methods of assessing cardiac rhythm should be used, for example, pulse oximetry or arterial blood pressure monitoring.

Cautery should be used with caution in the vicinity of the pulse generator and its leads. The cathode should be kept as far from the pulse generator as possible, the lowest possible amplitude should be used, and the surgeon should deliver only brief bursts.
During electrocautery, pulse generator function and cardiac rhythm should be carefully assessed. The most likely response is that of transient inhibition or asynchronous pacing, which should cause no significant hemodynamic problem. If persistent pacemaker inhibition occurs, a magnet can be applied to the pacemaker during electrocautery.

Postoperatively, it is critical that the pulse generator be interrogated and reprogrammed to the original settings if any changes have occurred. Ideally, thresholds should be reassessed and compared with preoperative values. If any problems are encountered when the pacemaker is interrogated or reprogrammed to its original settings, the manufacturer should be consulted to determine if malfunction has occurred.

Defibrillation
External transthoracic defibrillation produces the largest amount of electrical energy delivered in the vicinity of an implanted device and has the potential to damage both the pulse generator and the cardiac tissue in contact with the lead [1,6]. The device is protected from damage from high defibrillation energies by special circuitry that electronically regulates the voltage entering the circuit and should prevent high currents from being conducted via the lead to the myocardium. However, the extremely high energies can overwhelm this protection and cause damage to the implanted device or the heart. Internal defibrillation via epicardial or subcutaneous patches or intracardiac defibrillation electrodes delivers smaller amounts of energy but may also interfere with device function. As previously noted, devices with bipolar sensing configuration are less susceptible to interference from defibrillation.

The degree of damage seems to be related to the distance of the defibrillation paddles from the pulse generator. The paddles used for defibrillation should be placed as far as possible from the generator, and when possible, an anterior-posterior configuration is preferred. In the anterior-anterior configuration, the paddles should be 10 cm away from the pulse generator if possible. After defibrillation, the device should be interrogated and the programmed parameters compared with those before defibrillation-cardioversion. A transient rise in threshold should be managed by increasing the energy output if necessary. Rarely, a prolonged, severe increase in threshold occurs, necessitating lead replacement.

Catheter Ablation
Nearly all ablations are now performed with radiofrequency current, which is the same as that used for coagulation electrocautery, that is, unmodulated radiofrequency current at a frequency of 400 to 500 kHz. Effects similar to those of surgical electrocautery have been reported, including inappropriate inhibition, asynchronous pacing, and resetting to backup mode [9,10]. Radiofrequency ablation has been carried out safely in the presence of implanted pulse generators and does not appear to result in any significant myocardial damage at the site of the pacemaker electrode.

Before radiofrequency ablation is done, the implanted pulse generator should be interrogated and programmed settings recorded. A programmer should be available during the radiofrequency procedure. After the procedure, the device should be reinterrogated and reprogrammed if necessary.

Magnetic Resonance Imaging
In magnetic resonance imaging (MRI), a large magnetic field is generated by an electromagnet and is modulated by a radiofrequency electrical signal. Newer MRI scanners have magnets as strong as 3.0 tesla.

When a pacemaker is near an MRI scanner with the electromagnet "on", the reed switch closes and asynchronous pacing occurs. Although there may be competition with the underlying cardiac rhythm, it does not commonly cause a clinical problem.

Measuring the effect of MRI on pacemakers and ICDs is difficult because the radiofrequency pulses cause ECG artifacts. However, several studies of pacemakers in dogs have demonstrated the potential adverse effects. In some pacemakers, the only effect was asynchronous pacing [11]. In other pacemakers, cardiac pacing at the same frequency or a multiple of the frequency of the radiofrequency current occurred; for example, if MRI was operating at 200 ms, pacing rates at 300 bpm were observed in some dogs [11,12]. The radiofrequency signal is detected by the leads acting as an antenna and is then amplified by the pacemaker circuitry to produce sufficient energy to pace the heart.

Reported problems with pacemakers in MRI scanners include magnet-activated asynchronous pacing, inhibition by the radiofrequency signal, rapid pacing induced by the radiofrequency signal [13,14] discomfort at the pacemaker pocket, and death [14]. Reported deaths have presumably been secondary to rapid pacing that led to hemodynamic collapse or induction of ventricular tachycardia or ventricular fibrillation. It is difficult to know with any certainty how many deaths or potentially life-threatening complications have occurred, but the number is not insignificant. Transient reed switch malfunction has also been seen [11].
Investigators have also demonstrated MRI-induced heating of the conductor coil and electrode tip in an animal model [14]. Such heating could result in damage at the electrode-myocardium interface. Clinically, the results could be an increase in pacing and sensing thresholds, complete failure to capture, and a discrete area of myocardial damage. Temporary pacemakers are also subject to interference from MRI, and a patient actively requiring temporary pacing should not be considered for MRI.

As of 2002, MRI should still be considered contraindicated in patients with an implanted device. Several approaches have been used in an effort to accomplish MRI in a patient with an implanted device when other imaging modalities were not adequate for making a specific diagnosis. Methods, concerns, and precautions for the patient with a device undergoing MRI have been reported, but this author does not advocate any of these practices.

If MRI is undertaken in a patient with an implanted device, the patient should be fully informed of the potential complications and the discussion should be documented in the patient's clinical record. Any patient considered for MRI must not be dependent on the pacemaker, that is, must be able to undergo the study without any pacing support. Also, patients must have cardiac monitoring beginning at the time the pacemaker is reprogrammed to yield noncapture and continuing throughout the procedure.

There have been reports of programming the pacemaker to a nonpacing mode, that is, OOO or ODO, or programming the energy output settings, that is, voltage amplitude and pulse width, to subthreshold values to prevent capture [15]. Even if the pacemaker is rendered ineffectual for capture, risks from MRI are not precluded. With the programming described, MRI theoretically could still couple with the implanted lead or leads and result in rapid pacing and subsequent adverse outcomes. In addition, MRI-induced heating of the conductor coil and electrode tip theoretically could still occur.

MRI has also been performed after explantation of the permanent pacemaker. If this is considered, explantation must be done with careful sterile technique. The patient should be informed that even with the best technique, the incidence of infection increases with manipulation of the pacemaker pocket. If the device is explanted, the incision should be closed in a normal fashion and the incision "dressed" until the device is reimplanted. The patient should be continuously monitored during the time the device is not in place or operational. If the implanted device is not at replacement indicators and a new device cannot be justified, two options have been used. The implant suite in which the device has been explanted can be left intact but the room "closed" to any other procedures or even personnel "traffic" until the patient is returned to the room for reimplantation of the device. After the device has been explanted, it should be wiped with an antibiotic solution by the physician or a "sterile" scrub assistant, wrapped in a sterile towel or gauze, and placed on the instrument table, which is then covered until the patient is returned to the room for reimplantation. If the implant room cannot be left unused until the patient returns for reimplantation, the patient's device could be resterilized by accepted techniques, packaged in a sterile manner, and then reimplanted the next day.

In addition to being told that explantation of the implanted device increases the risk of infection, the patient should understand that the indwelling lead or leads can be a source of adverse effects, as previously described. This author does not advocate lead extraction in an effort to perform MRI.

**Extracorporeal Shock Wave Lithotripsy**

Extracorporeal shock wave lithotripsy (ESWL) is a noninvasive treatment for nephrolithiasis and cholelithiasis that delivers multiple, focused hydraulic shocks, generated by an underwater spark gap, to a patient lying in a water bath. The shock is focused on the stones by an ellipsoidal metal reflector. Because the shock wave can produce ventricular extrasystoles, it is synchronized to the R wave.

ESWL is safe to use with implanted pulse generators, provided that the shock is given synchronously with the ECG and that dual-chamber pacemakers have safety pacing enabled. In the pacemaker-dependent patient, it is recommended that a dual-chamber pacemaker be programmed to the VVI, VOO, or DOO pacing mode to avoid ventricular inhibition [16]. Programming of a DDD pulse generator to the VVI, VOO, or DOO mode also avoids rare instances of irregularities of pacing rate, supraventricular arrhythmias that could be tracked or induced, and triggering of the ventricular output by electromechanical interference.

ESWL has not been known to cause any damage to the pacemaker, except that if an activity-sensing pacemaker is placed at the focal point of the ESWL, the piezoelectric crystal could be shattered [17]. Patients with rate-adaptive pacemakers that have piezoelectric crystal activity can probably undergo lithotripsy safely if the device is implanted in the thorax, but lithotripsy should be avoided in these patients if the device is located in the abdomen. Patients with ICDs should have the ICD therapeutic capability deactivated during ESWL. While the therapies are "off," the patient must be on continuous cardiac monitoring.
Transcutaneous Electrical Nerve Stimulation
Transcutaneous electrical nerve stimulation (TENS) is a widely used method for the relief of acute and chronic pain from musculoskeletal and neurologic problems. A TENS unit consists of several electrodes placed on the skin and connected to a pulse generator that applies pulses of between 1 and 200 V and 0 to 60 mA at a frequency of 20 to 110 Hz. The output and frequency of the unit can be adjusted by the patient to provide maximum relief of pain.

The repetition frequency of the TENS output is similar to the normal range of heart rates, so it would be expected that TENS pulses could cause pacemaker inhibition. Although an older study of 51 patients with pacemakers showed no inhibition during TENS stimulation, [18] instances of asymptomatic inhibition of pacemaker output by TENS have been reported [19,20]. Interference is most likely to occur in significantly older pacemakers and pacemakers in the unipolar sensing configuration.

TENS can probably be used safely in most patients with bipolar pacemakers or ICDs. However, it is reasonable to take special precautions in patients who are pacemaker-dependent or have ICDs and monitor them during initial TENS application. If TENS results in interference in pacemaker-dependent patients or is detected as ventricular activity in patients with ICDs, TENS should be avoided. If patients with unipolar pacemakers have interference with use of TENS, the testing can be repeated after reprogramming the sensitivity to a less sensitive value or programming the device to a bipolar configuration if it is polarity programmable and bipolar leads are in place.

Dental Equipment
Dental ultrasound equipment may cause inhibition or asynchronous pacing in older pulse generators, but this reaction appears to be uncommon with contemporary devices [21]. Repetitive activation of other dental equipment may cause inhibition [22]. Dental drilling can cause sufficient vibration to increase the pacing rate of an activity-sensing pacemaker.

Therapeutic Radiation
The dose of radiation used in diagnostic x-ray procedures does not affect pulse generator function either acutely or cumulatively. Therapeutic radiation can cause failure in contemporary implanted devices [23-25].

The amount of therapeutic radiation that causes device failure is unpredictable and may involve changes in sensitivity, amplitude, or pulse width; loss of telemetry; failure of output; or runaway rates. If dysfunction occurs, replacement of the device is required.

Although some changes may resolve in hours to days, the long-term reliability of the pulse generator is suspect, and it should be replaced. It should be emphasized that radiation therapy to any part of the body away from the site of the pulse generator should not cause a problem with the pulse generator, but the pulse generator should be shielded to avoid scatter.

Centers that perform therapeutic radiation should have a protocol for patients with implanted devices [26]. Before radiation begins, the pacemaker should be identified and evaluated. The most common clinical situation is development of malignant breast cancer on the ipsilateral side in a patient with a permanent pacemaker or ICD. The pulse generator must be moved out of the field of radiation because shielding the device would result in suboptimal radiation therapy. The pulse generator can be explanted and a new system implanted on the contralateral side. Alternatively, it is often possible to explant the device and tunnel the existing permanent lead or leads through the subcutaneous tissues to the contralateral side. A new subcutaneous pocket is formed on the contralateral side and the pulse generator reattached to the now-tunneled lead or leads and reimplemented.

Electroconvulsive Therapy
Electroconvulsive therapy is safe in relation to the function of implanted devices, because the high impedance of body tissues keeps all but a minimal amount of electricity from reaching the heart [1]. Because seizures possibly could cause sufficient myopotentials to result in pacemaker inhibition or ventricular tracking, ECG monitoring and interrogation of the implanted device are advisable. In unipolar pacemakers, seizure activity may generate sufficient myopotentials to result in inhibition or ventricular tracking.

Diathermy
Short-wave diathermy consists of therapeutic application of current directly to the skin. Diathermy can be a source of interference and should be avoided near the implantation site, because its high frequency has the potential to inhibit the pulse generator or damage its circuitry by excessive heating.
Nonhospital Environment

Conventional wisdom has been to advise patients with implanted devices to avoid “arc welding” and close contact with combustion engines. However, as previously noted, pacemakers of unipolar sensing configuration remain more susceptible to EMI than pacemakers in a bipolar sensing configuration. For patients whose livelihood involves equipment with potential for EMI, bipolar sensing configuration should be used routinely.

Industrial environments with significant potential for clinically significant EMI with implantable devices include those in which industrial-strength welding equipment (exceeding 500 A), degaussing equipment, and induction ovens are used. If a patient works in one of these environments or potentially some other even more obscure environment that suggests significant potential for EMI, the work environment should be carefully evaluated. If the patient is pacemaker-dependent, consideration should be given to on-site assessment of the work environment. In some cases, the device manufacturer may be able to assist in this assessment. If the patient is not pacemaker-dependent, assessment may be achieved by ambulatory monitoring during exposure to the environment or by review of patient-triggered event records stored within the pacemaker.

From a practical standpoint, most patients who do “arc welding” use low-amperage equipment for hobby welding. If the patient uses welding equipment in the 100 to 150 A range, significant EMI is unlikely to occur [27]. However, before giving a patient permission to return to this activity, the clinician caring for the patient with an implanted device must consider the type of hardware implanted as well as the dependency status.

Testing methods have been designed to allow exposure of the patient with a pacemaker or ICD to progressively stronger fields of EMI. Although this testing is not practical for the individual patient, studies [27,28] have determined levels of interference at a variety of programmed sensitivities (Table 2). This information could be applied to an individual patient if readings of EMI strengths in the work environment were obtainable.

<table>
<thead>
<tr>
<th>Sensitivity setting, mV</th>
<th>Atrial*</th>
<th>Ventricular*</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Unipolar</td>
<td>Bipolar</td>
</tr>
<tr>
<td>0.5</td>
<td>4,509</td>
<td>17,984</td>
</tr>
<tr>
<td>0.75</td>
<td>5,744</td>
<td>20,000</td>
</tr>
<tr>
<td>1.0</td>
<td>7,679</td>
<td>20,000</td>
</tr>
<tr>
<td>1.5</td>
<td>10,143</td>
<td>20,000</td>
</tr>
<tr>
<td>2.0</td>
<td>11,790</td>
<td>20,000</td>
</tr>
<tr>
<td>3.0</td>
<td>15,034</td>
<td>20,000</td>
</tr>
</tbody>
</table>

NA, not available.

Values in milligauss units.

Potential sources of EMI in the nonindustrial and home environments are capable of one-beat inhibition of the pacemaker (Table 3). However, it would be unusual for any of these sources to cause EMI of clinical significance. It is also unlikely that any of the devices in Table 3 can produce sustained interference with an ICD that becomes clinically significant. However, anecdotal reports exist [29-33]. Clinicians must now consider what effect inhibition would have on the patient with a cardiac resynchronization device. Single-beat inhibition probably would not have any significant impact. However, inhibition of a cardiac resynchronization device could lead to alteration in the timing cycles for the device and, in turn, to longer episodes of inhibition and ineffective resynchronization support.
Although few sources are capable of causing clinically significant EMI resulting in pacemaker malfunction, the potential for interference from cellular phones and electronic article surveillance equipment has been of interest because of their widespread use. Before these are discussed in detail, several other potential sources, some of historical importance only, merit mention.

One of the most common questions still asked by pacemaker recipients today is whether they can use a microwave oven. In many areas, signs are still posted warning the patient with a pacemaker not to use a microwave oven. The original warnings were put in place because ineffective microwave shielding and less effective shielding of early pacemakers created the potential for pacemaker interference. Because of better shielding of both microwave ovens and device circuitry, the ovens are no longer a significant source of interference.

Metal detectors are frequently mentioned as a potential problem, and warning signs are often seen at airport security stations. The issue becomes greater in this era of heightened security, especially airport security. A study of patients wearing ambulatory ECG monitors who passed through metal detector gates while their pacemakers were programmed to the most sensitive programmable option showed no effect on pacing, although asynchronous pacing or inhibition could occur for one or two beats without ill effect to the patient. The major reason to discuss metal detectors with patients who have an implanted device is that the metal device may "set off" the detector. Patients should be advised to present their device identification card to security personnel before proceeding through the metal detector. These patients are likely to be escorted around the metal detector and manually searched. A number of new types of detectors and security measures are being introduced. At this time, no specific information can be offered on new types of security technology and the effects on implanted devices. The best advice for now is to have the patient present an identification card.
Electronic Article Surveillance Equipment

Antitheft devices (electronic article surveillance [EAS] equipment) in many retail stores and libraries consist of a tag or marker that is sensed by an electromagnetic field as the person walks through or by a “gate.” Most systems consist of a “deactivator” that is removed or deactivated before the item is taken from the store or library. This allows the customer to purchase an item and leave the store without activating an alarm. These electronic antitheft devices consist of multiple technologic processes that generate electromagnetic fields in various ranges. The devices use the radiofrequency range of 2 to 10 mHz, magnetic material in the range of 50 to 100 kHz, pulsed systems at various frequencies, and electromagnetic fields in the microwave range. In a study of 33 patients with 35 implanted devices (18 pacemakers and 17 ICDs) exposed to six different EAS detectors (three radiofrequency, one magnetoacoustic, and two magnetic), no reprogramming of or damage to pulse generators was noted. Sixteen of the pacemakers demonstrated noise reversion or inhibition when exposed to a magnetoacoustic system at a close range (within 18 in.). Reprogramming the sensitivity of the pacemaker could not abolish this effect. In addition, one epicardial unipolar pacemaker exhibited inhibition or noise reversion in each magnetic device. No EMI effects on any of the ICDs were demonstrated. No EMI was detected in any patient during exposure to the radiofrequency system.

Although a case report stated that a patient with an ICD received inappropriate shocks because the device oversensed the pulsed electromagnetic signal from an EAS detector, a large study of patients with ICDs did not demonstrate any significant adverse effects from EAS equipment unless exposure was prolonged (more than 2 minutes).

At this time, it is reasonable to advise patients to pass rapidly through any obvious EAS equipment and avoid leaning on or standing "near" the EAS detector, that is, "Don't linger, don't lean."  

Cellular Phones

A number of studies have investigated the potential of cellular phones to interfere with pacemakers or ICDs. An early case report described injury to a pacemaker-dependent patient using a digital cellular phone.

In a multicenter study, 980 patients were tested with as many as six cellular phones for 5,533 phone exposures. In this study, a highly variable incidence of interference was observed. The overall incidence, 20%, was high, but to quote this single percentage out of context would be misleading clinically. Interference at the "normal" position on the ear was very low, and none was clinically significant, supporting the safety of "normal" use. The incidences of interference and, specifically, clinically significant interference were also highly variable by combination of phone type, pacemaker manufacturer, and pacemaker model. Eliminating a single cellular phone that is not commercially available from the analysis decreased the incidences of interference and clinically significant interference significantly to 13.1% and 2.8%, respectively.

Although symptoms occurred during 7.2% of the phone exposures, most were due to palpitations. The incidences of interference were highly variable by pacemaker manufacturer. Even for a given manufacturer, incidences differed by pacemaker model, reflecting the effect of design on susceptibility to interference.

The highest incidence of interference occurred when the cellular phone was directly over the pacemaker. Although this situation might exist if an activated phone were carried in a pocket directly over the pacemaker, this position is certainly not "normal" for use of the phone and could be consciously avoided. As stated earlier, minimal interference was found at the ear position. Most adverse effects are eliminated if the phone is kept 8 to 10 cm from the implanted device.

Even though specific pacemaker and ICD design changes, such as feed-through filters, have significantly reduced interference rates, the potential remains that new phone technologies could result in interference with implantable cardiac devices. Therefore, new wireless technologies will require subsequent testing.

Clinical Advice

Nearly all patients can be reassured that EMI will not affect their pacemakers during the course of daily life. Patients in specialized industrial environments should be assessed individually. Improvements in pacemaker and ICD shielding should continue to minimize clinical concerns. However, the potential for EMI should never be taken lightly, and appropriate screening and monitoring should be performed to avoid adverse clinical outcomes. In addition, despite improvements in pulse generator shielding, emerging technologic advances result in new challenges for the patient with an implanted arrhythmia-control device. Assessment of newer technologies for potential interference to the patient with a pacemaker or ICD must continue to be performed.

References

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