Induction Ovens and Electromagnetic Interference: What is the Risk for Patients with Implanted Pacemakers?

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RICKLI, H., ET AL.: Induction Ovens and Electromagnetic Interference: What is the Risk for Patients with Implanted Pacemakers? *Electromagnetic fields may interfere with normal pacemaker function. Despite the introduction of modern pacemakers and bipolar lead systems, electromagnetic interference (EMI) still remains to be a concern during daily lives when patients are exposed to cellular phones, electronic security systems, and several household appliances. The aim of this study was to evaluate potential EMI risk of induction ovens, which are increasingly used in private households. The study included 40 consecutive patients (22 men, 18 women; age 73 ± 11 years) with implanted DDD, VVI, VDD, and AAI pacemaker systems. The pacemakers were programmed to unipolar sensing and pacing. Sensitivity remained unchanged, if the measured sensing threshold was more than twice the programmed value; otherwise, it was set at half of the measured sensing threshold. Patients were placed in a sitting position at the closest possible distance of about 20 cm between two cooking pots and pacemaker bending the upper part of the body slightly over the induction oven. The energy was increased stepwise to the maximum. One pot was removed and placed again at the highest oven level. Potential interference was monitored continuously. The study showed no incidence of pacemaker malfunction during the entire test while the patients with intrinsic cardiac rhythms were exposed to the induction oven at varying energy strengths. Likewise, there was no external interference when the patients were paced at heart rates of 10–15 beats/min above their heart rates. The programmed parameters remained unchanged after the study. In conclusion, this study shows no EMI risk of an induction oven in patients with bipolar or right-sided unipolar pacemakers. (PACE 2003; 26[Pt. I]:1494–1497)*

electromagnetic interference, pacemaker, pacing, induction oven

Introduction

Implanted pacemaker systems are subject to electromagnetic interference (EMI) from many sources. These sources may be biologic (e.g., myopotentials) or nonbiologic. Nonbiologic sources of EMI are common in the hospital environment (e.g., electrocautery and diathermy) but are also becoming increasingly frequent in daily life. In general, modern pacemakers are effectively shielded and the use of bipolar leads has reduced the incidence of this problem. However, EMI (due to cellular phones and electronic security systems, etc.) still remains to be a public concern and device malfunction is reported to occur in recipients of these devices during activities of daily living.[1–6]

Electromagnetic induction-based ovens are increasingly used in private households instead of gas or electric ovens since they have many advantages as compared to conventional ovens. An in vitro study using induction ovens showed that these appliances could interfere with pacemaker function.[7] However, potential risks or the safety profile of these ovens have not been studied systematically in a clinical study to date. The aim of this study was to evaluate the potential EMI risk of induction ovens when patients with cardiac pacemakers are exposed to these appliances.

Methods

Study Population and Pacemaker Systems

The study included 40 consecutive patients (22 men, 18 women; age 73 ± 11 years) with different pacemakers during routine pacemaker follow-up. Patients were studied 6 ± 4 years after implantation. All patients had an intrinsic heart rate >30 beats/min and were hemodynamically stable during intrinsic rhythm. The pacemaker systems were DDD in 15 patients, VVI in 21 patients, VDD in 3 patients, and AAI in 1 patient. Two patients with VVI pacemakers had left-sided implants. The implanted pacemakers were Elite 7075 (1), Kappa 401 (3), Legend 8419 (5), Minix (1), Prevail (2),

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Thera DR (1), Thera VDD (3) (Medtronic, Inc., Minneapolis, MN, USA); Paragon II (4), Paragon III (3), Regency (1), Sensorithm (1), Trilogy (1) (Pacesetter, Inc., Sylmar, CA, USA); and Actros (3), Kairos DR (2), Neos (3) and Pikos (6) (Biotronik, Inc., Germany). Indications for pacemaker implantation were high degree atrioventricular (AV) block in 20 patients, sick sinus syndrome in 12 patients, and sinus bradycardia and other causes in the remaining 8 patients.

The study was approved by the local hospital ethical committee and all patients gave written, informed consent prior to the study.

Pacemaker Programming

Prior to the study, a routine pacemaker control was performed in each patient that included battery parameters, determination of pacing and sensing thresholds and lead impedance values, and tests for myopotential interference (respiratory maneuvers, arm movements, etc.). The pacemakers were programmed to unipolar sensing and pacing. Sensitivity remained unchanged at the chronic value if the measured sensing threshold was more than twice the programmed value, otherwise, it was set at half of the measured sensitivity value.

Study Design

The induction oven used in this study was the GK 43 TI (V-Zug, Inc., Zug, Switzerland), which contains two generators with a power output of 2,800 W (230 V). An induction oven has a flat ceramic top with conductive coils built into the surface. Induction elements heat cooking utensils by creating a fast changing magnetic field. When an iron or steel (magnetic) pan is placed on the cooktop, this magnetic field heats the pan directly through eddy currents (Fig. 1).

The study setup consisted of a normal cooking pot (diameter 19 cm) filled with water beside an empty saucepan (diameter 21 cm) placed side by side on the induction oven. Patients were placed in a sitting position at the closest possible distance of approximately 20 cm between the base of the cooking pot and pacemaker bending the upper part of the body slightly over the cooking pot. As the patients were holding the pots with one hand, the grounded part of the oven touched with the other hand. The energy was increased stepwise to the maximum (oven levels 1-3-5-7-9 with a minimum of 3 seconds at each level). At the highest oven level the patients were asked to remove the saucepan away from the cooking field to increase the magnetic field exposure. With maximum power, the cooker placed again on the oven. Initially, the test was performed during intrinsic rhythm with a programmed pacemaker rate of 30 beats/min to demonstrate if potential conversion to noise mode would occur. Then, the same test was done with a pacing rate 10–15 beats/min above the intrinsic heart rate to investigate potential inhibition or conversion to noise mode. During the whole procedure, six-channel surface electrocardiograph (ECG) monitoring was performed continuously to detect interference and, if necessary, to terminate the test. After completion of interference testing, the pacemakers were interrogated again and checked for possible changes in the programmed parameters.

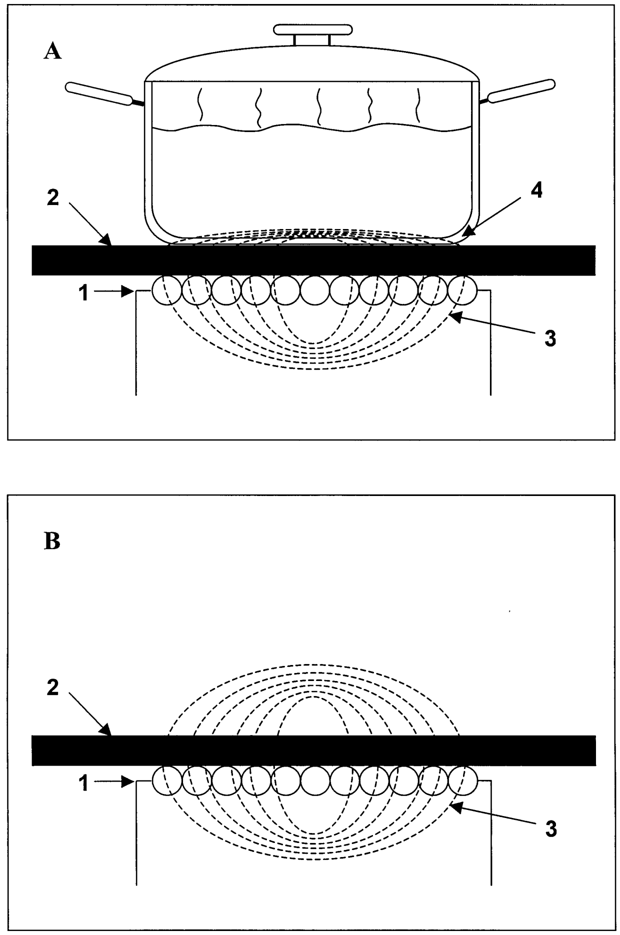

Figure 1. *(A) Operating principle of an induction oven: Induction coils (1) integrated in the ceramic cooktop (2) produce a fast changing magnetic field (3), which heat directly the magnetic base of the pan (4). (B) In the absence of a cooking pan over an active induction oven, the produced magnetic fields are stronger.*

Results

Prior to the interference testing, the magnetic fields generated by the oven were measured. The operating frequency of the oven ranged from 15 to 25 kHz generating a magnetic field of 4–25 μT on the saucepan's base, of 2–6 μT at a distance of 20 cm and <2 μT 50 cm in front of the induction oven. The field was pulsed with a low frequency of 50 Hz.

During routine pacemaker control, the measured ventricular unipolar sensing threshold was 9.5 ± 5.6 mV (mean ± SD). The atrial sensing threshold in unipolar mode was 2.2 ± 0.9 mV. The interference tests were performed using the chronic values of 2.4 ± 0.5 mV in the ventricle (minimum 1.0 mV) and 1.0 ± 0.5 mV in the atrium (minimum 0.18 mV). The left-sided VVI pacemakers had a programmed sensitivity of 2.0 mV. The measured atrial lead impedance was 475 ± 100 Ω and the measured ventricular lead impedance was 656 ± 203 Ω. No myopotential oversensing was observed during the routine pacemaker control.

There was no incidence of pacemaker malfunction during the entire test while the patients with intrinsic cardiac rhythms were exposed to the induction oven at varying energy strengths (oven levels). Likewise, we observed no pacemaker malfunction while the patients were paced at heart rates of 10–15 beats/min above their heart rates. The programmed parameters remained unchanged after the study.

Discussion

Electromagnetic signals emitted by certain sources in the hospital environment and in the industry and those that are present in the non-industrial and home environments may interfere with pacemaker function. Medical equipment, like electrocautery used during surgery, diathermy to treat muscle strain, or magnetic resonance imaging are well-described sources of interference.[8,9] Many potential sources of EMI can be found in daily life. Electronic article surveillance equipment and cellular phones are among the well-known causes of EMI in our daily environment.[1–6]

The possible effects of EMI include inappropriate inhibition or triggering of pacemaker output, asynchronous pacing, reprogramming to backup mode, inappropriate initiation of other features, like mode switching, damage to the pacemaker circuitry, etc. For example, tracking of the interference signal by the atrial sensing circuitry was the most common type of EMI exerted by cellular phones.[10] Clinically there are two important forms of interference: namely, ventricular inhibition and fixed rate pacing in the noise mode. If ventricular inhibition occurs, the patient may drop down, and therefore, move away from the source of interference, so that pacemaker function is usually restored. Fixed rate pacing due to magnet mode may be worse, if ventricular fibrillation is initiated. Pacemakers are particularly sensitive to alternating current energy supplies (50–60 Hz) since the cardiac signals have most of their energy in that frequency range. Modern pacemakers are effectively shielded and are equipped with filters against EMI. Moreover, bipolar lead systems are used commonly today, and therefore, current pacemaker systems are less prone to sensing of extraneous EMI.[4]

The available data regarding the EMI risk of household appliances is scarce. However, the published reports suggest that most of the EMI sources in the home environment are only capable of 1-beat inhibition of the pacemaker.[11] EMI of clinical significance is unusual and limited in most cases to anecdotal reports. The electromagnetic fields produced by some kitchen appliances are shown in Table I.[12] However, the magnetic fields of these appliances are at line frequency and have other qualities than induction oven fields. The likelihood of clinically important EMI with household appliances may depend on different factors: (1) the characteristics of the source (frequency, magnetic flux density and electric field strength emitted from the source), (2) the pacing system (including pacing mode, electrode configuration, sensitivity setting, site and orientation of the pulse generator, and filtering), (3) the distance and orientation of the source relative to the pacemaker electrodes or the pulse generator, and (4) the patient's underlying heart rhythm.[13]

One of the questions often asked by pacemaker recipients today is if they can use induction ovens, which are used increasingly in private households. Induction ovens generate heat by creating a fast changing magnetic field within a metal pan. Suitable cooking wares are flat-bottomed and made

Table I.

Magnetic Flux Densities Produced by Some Kitchen Appliances

Blenders	3–10
Can openers	50–150
Coffeemakers	0.4–1
Dishwashers	1–10
Electric ovens	0.4–2
Electric ranges	2–20
Food processors	2–13
Garbage disposals	6–10
Microwave ovens	10–30
Mixers	3–60
Refrigerators	0.2–4
Toasters	0.5–2

Magnetic field measurements (lowest–highest range) in units of μT at a distance 15 cm from the source.

of magnetic metals, like iron and stainless steel. These appliances have several advantages as compared to conventional gas or electric ovens. Induction ovens heat only the base of the pan without heating the cooktop, making them extremely energy efficient (in terms the amount of heat used for actual cooking versus the total amount of heat delivered by the equipment). Unlike other electric elements, induction ovens provide the precise temperature control of gas burners for gourmet cooks, albeit without creating an open flame. Therefore, it is nearly impossible to start a fire by leaving the induction oven on.

In a sitting position at the closest possible distance of about 20 cm between the pacemaker system and the base of the cooking pot during prolonged exposure at the maximal oven level (and the measured magnetic field of 2–6 μT), no episodes of interference occurred, although the pacemakers were programmed to unipolar sensing. Clinically relevant EMI is unlikely to occur due to relatively low magnetic flux density emitted by the induction ovens used in households. Furthermore, there was no evidence for EMI due to a possible leakage current flow across the patient when the patients touched the pot for longer periods as a grounded part of the oven was touched with the other hand. However, it should also be kept in mind that the leakage current is not equally uniform in all oven brands and depends on grounding of the induction coil and the capacitive coupling between the coil and the pot.

Study Limitations

This study applies only to a limited number of pacemaker models tested under the above specified settings using a single type of an induction oven. The worst-case scenario was not investigated, since maximal sensitivity settings were not used. It is possible that other induction ovens can differ with regard to stray fields and leakage currents. Moreover, at distances closer than 20 cm, there may be clinically significant EMI because the magnetic flux density is correlated with the reciprocal of the square of the distance from the source. Pulsed magnetic fields that may occur due to simultaneous use of two cookers may also theoretically influence pacemaker function and was not systematically investigated in our study. However, according to Faraday's law, the induced voltage is proportional to the induction area. As a consequence, patients with unipolar pacemakers implanted on the left side are most sensitive to magnetic fields. Although this combination is a rarity in clinical practice, the increased likelihood for EMI due to any external source should be considered in these patients. In patients with left-sided implantable cardioverter defibrillators, the large induction area is not a major concern since sensing is bipolar in these devices. However, maximal sensitivity settings to detect fine ventricular fibrillation also necessitate a systematic evaluation in recipients of these devices.

Conclusions

This study shows no EMI risk of an induction oven in patients with bipolar or right-sided unipolar pacemakers. Thus, pacemaker patients can be reassured that EMI is unlikely to affect their devices if induction ovens are used in their kitchens. Induction ovens used in the industrial environment, which have stronger field strengths, require further investigation.

References

1. Altamura G, Toscano S, Gentilucci G, et al. Influence of digital and analogue cellular telephones on implanted pacemakers. Eur Heart J 1997; 18:1632–1641.
2. Harthorne JW. Pacemakers and store security devices. Cardiol Rev 2001; 9:10–17.
3. Irnich W, Batz L, Muller R, et al. Electromagnetic interference of pacemakers by mobile phones. PACE 1996; 19:1431–1446.
4. Naegeli B, Osswald S, Deola M, et al. Intermittent pacemaker dysfunction caused by digital mobile telephones. J Am Coll Cardiol 1996; 27:1471–1477.
5. Nowak B, Rosocha S, Zellerhoff C, et al. Is there a risk for interaction between mobile phones and single lead VDD pacemakers? PACE 1996; 19:1447–1450.
6. Irnich W. Electromagnetic interference in current implantable devices. In PE Vardas (ed.): Cardiac Arrhythmias, Pacing & Electrophysiology. Dordrecht, the Netherlands, Kluwer Academic Publishers, 1998, pp. 427–436.
7. Preumont N, Ahadi N, Rahnama M, et al. Interference with cardiac pacemaker by electric induction cooktops. Acta Cardiol 1997; 5:446.
8. Duru F, Luechinger R, Scheidegger MB, et al. Pacing in magnetic resonance imaging environment: Clinical and technical considerations on compatibility. Eur Heart J 2001; 22:113–124.
9. Sager DP. Current facts on pacemaker electromagnetic interference and their application to clinical care. Heart Lung 1987; 16:211–221.
10. Hayes DL, Wang PJ, Reynolds DW, et al. Interference with cardiac pacemakers by cellular telephones. N Engl J Med 1997; 336:1473–1479.
11. Roelke M, Bernstein AD. Cardiac pacemakers and cellular telephones. N Engl J Med 1997; 336:1518–1519.
12. EMF in Your Environment: Magnetic Field Measurements of Everyday Electrical Devices, U.S. Environmental Protection Agency (EPA) Booklet, 1992. pp. 32.
13. Shan PM, Ellenbogen K. A life after pacemaker implantation: Management of common problems and environmental interactions. Cardiol Rev 2001; 9:193–201.