

## Editorial

# Electromagnetic interference in patients with implanted pacemakers or cardioverter-defibrillators

Electromagnetic radiation may interact adversely with implanted pacing systems and implantable cardioverter-defibrillators (ICDs).<sup>1-4</sup> Modern life exposes us all to an ever increasing number of potential sources of electromagnetic interference (EMI) and patients with implanted pacemakers or ICDs often ask about the use of microwave ovens, walking through airport metal detectors, and the use of cellular phones. This article gives an overview of the current knowledge of the effects of EMI on pacemakers and ICDs.

### Microwave ovens

Although no recent studies have been performed which test the effect of household microwave energy on pacemakers and ICDs, it is widely believed and accepted that all modern pacemakers are adequately shielded from microwave energy produced by modern appliances.<sup>5</sup> Pacemaker manufacturers therefore recommend that patients with implanted devices do not need to take special precautions in the use of microwaves or other common household equipment such as televisions, radios, toasters, and electric blankets.

### Metal detector gates

The effect of metal detector gates on implanted pacemakers was studied more than 10 years ago.<sup>6</sup> In 103 patients who were monitored as they passed through typical metal detectors, alarms invariably were activated when the patients walked through the gates. In none of the patients was the pacemaker function affected. None of the devices was reset to the programmed noise protection mode (most often V00) or spontaneous fixed rate mode of function, nor were any of the devices' outputs inhibited in paced patients, or inappropriately delivered in patients who had normal cardiac rhythm. It is therefore accepted practice to advise patients that while airport screening devices may detect the pacemaker or ICD metal case the device will not be adversely affected. Patients should carry their device identification card for the purpose of obtaining security clearance.

### Mobile phones and pacemakers

Several studies have shown that cellular phones might cause EMI with complex medical equipment<sup>7-8</sup> including pacemakers.<sup>9-13</sup>

From *in vitro* studies there is convincing evidence that especially the digital technology used in commercially available global systems for mobile communication (GSM) mobile phones has great potential to interfere with medical equipment, in contrast to analogue systems.<sup>14-18</sup> The explanation for this phenomenon may be the repetition rate of the digital burst signals of 2 and 8 Hz.

In a large study, Hayes and colleagues<sup>19</sup> evaluated the interactions of five types of GSM phones with pacemakers in a randomised cross-over evaluation. This study confirmed that in order to cause interference the cellular phone needed to be closer than 10 cm from the pacemaker pocket; the highest incidence of telephone induced EMI

occurred when the telephone was positioned directly over the pulse generator. In contrast, the incidence of EMI when the telephone was positioned next to the patient's ear was very low. None of the interference episodes were of clinical significance (prolonged the inhibition of the pacemaker output causing presyncope, syncope, dizziness or shortness of breath; provocation of spontaneous tachyarrhythmias or rapid paced ventricular rates; changes in programmed pacemaker settings) when the cellular telephone was held next to the patient's ipsilateral ear. Analogue cellular phones are much less likely than digital devices to interfere with pacing system function. However, there is a large variability in interference phenomena among pacemaker manufacturers and models. The inclusion of modern filters lessens the likelihood of EMI in both unipolar and bipolar systems.

Hayes and colleagues<sup>19</sup> showed a similar incidence of interference occurred in both unipolar and bipolar sensing configurations. Dual chamber pacemakers are more likely to be influenced by EMI, probably because the atrial channels are programmed to be more sensitive in order to sense and respond appropriately to low voltage spontaneous P waves. Oversensing of environmental signals in the atrial channel will cause ventricular paced rhythms. Dual chamber pacemakers are also more susceptible to noise reversion pacing, in which asynchronous pacing can occur. Hayes and colleagues reported that no significant symptoms were observed when the cellular telephone was sufficiently (> 10 cm) distant from the pulse generator.

Thus, cellular telephones generally pose little hazard to patients with permanent pacemakers so long as the cellular telephone is kept at least 10 cm away from the pacemaker, preferably at the contralateral ear.

### Mobile phones and ICDs

Until now, possible interactions between North American and European cellular phones in patients with ICDs have been studied in a relatively small number of patients. Fetter and colleagues tested one phone with various ICD models of a single manufacturer and found no interactions between the tested phone and ICDs.<sup>20</sup> In contrast, Bassen and associates<sup>18</sup> found severe malfunctions of ICDs during *in vitro* testing of two ICDs of different manufacturers. This raises the question of manufacturer related sensitivity to cellular phones. However, during the *in vivo* phase of this study, none of the 41 patients were affected by oversensing independent of the pocket locations. The recommendation that patients with ICDs should not carry or place a digital cellular telephone within 15 cm of the device evolved from that single study.

European cellular phones are different from those used in North America. The NADC (North American digital cellular) phones work on a carrier frequency of 835 MHz. For data transmission a pulse amplitude modulation of 50 pulses/s is used (TDMA-50) and the peak power of the handset is limited to 0.6 W. In contrast, the peak power of digital phones used in the European GSM-net is 2 W for

D-net and 1 W for E-net.<sup>21</sup> The D-net works on a carrier frequency of 900 MHz modulated with 217 Hz; the E-net works on a carrier frequency of 1800 MHz.

Since North American cellular phones are different from those used in Europe the susceptibility of tiered single chamber ICDs to EMI or other dysfunction caused by commercially available digital mobile telephones was evaluated in our own study.<sup>22</sup> For our evaluations, two different types of European digital cellular phone systems were used.

We prospectively analysed 97 patients with different ICDs and exposed them to two different types of European digital cellular handy phones (Ericsson GH337, 900 MHz, and NOKIA NHK1EA, 1.8 GHz). The effect of high radio-frequency output was tested during continuous recording of the marker channel and intracardiac ECG. During the recordings the handy phones were put in a calling position close to the patient's ear and on top of the device. We noticed episodes of interference (loss of communication or temporary inactivation of the device during interrogation) in 38 patients, most of them (93%) during testing close to the device.

The main finding of our study was that EMI transmitted by digital cellular handheld D- or E-net phones, commonly used in Europe, did not interfere with normal ICD function of tested single chamber devices under daily life conditions. Inappropriate sensing and detection of ventricular tachyarrhythmias were not found. These observations are in accordance with the results described by Fetter and colleagues,<sup>20</sup> Occhetta and colleagues,<sup>23</sup> Barbaro and colleagues,<sup>24</sup> and Jimenez and associates.<sup>25</sup> In contrast to Fetter and colleagues,<sup>20</sup> we did not see any temporary suspension of the ICD function by static magnetic field (magnetic reversion counter = 0) generated by the speaker in the cellular phone's earpiece which may be in part explained by a less strong static magnetic field of the evaluated GSM phones. Implantation technique did not have any relation to interference with the function of the ICD.

We concluded that there is no evidence of harm related to the use of the tested European GSM handsets for the tested single chamber ICDs independent of the used GSM net. Since most episodes of interference were recorded when the GSM phones were within a short distance of the ICDs, patients should be advised not to carry their GSM phone close to the device. This is in accordance with the findings of *in vitro* studies with American GSM phones.<sup>18</sup>

As ICD interrogation is the most susceptible phase for interference, the use of GSM phones should be prohibited in hospital areas where interrogation takes place.

### Electronic article surveillance systems

Electronic article surveillance systems have recently been recognised as having the potential to interact with implanted rhythm devices.<sup>26</sup> The commercial use of such scanning devices is widespread, and case reports have been published in which patients received inappropriate ICD therapies while lingering between or touching electronic article surveillance gates.

Electronic surveillance systems use three different technologies to detect the presence of a metal alloy tag within an electromagnetic field created between two parallel gates: magnetic audio frequency, swept frequency, and acoustomagnetic or pulsed low frequency. The detection of such a tag signals a theft. The literature suggests that significant EMI with implanted rhythm devices is most likely to occur with the acoustomagnetic mode of electronic article surveillance, and that pacemakers are more likely to be affected than ICDs. Due to electromagnetic fields of six different electronic article surveillance devices, no significant interference with normal ICD function was seen. In

another study, patients with ICDs with pacing capability performed routine walking through electronic article surveillance gates as well as prolonged exposure within the gates, with and without pacing from the implanted device. Under conditions of extreme exposure, seven of 169 patients exhibited some interaction between the ICD and the electronic article surveillance device (noise sensing that resulted in complete or prolonged inhibition of the device output). Such output inhibition might have been clinically relevant, and the noise could also have resulted in inappropriate ICD shocks. Older generation devices, and those implanted in the abdomen, were more likely to manifest these interactions than newer generation, subpectorally implanted devices. In general, electronic surveillance systems do not pose a threat to the tachycardia functions of ICDs under reasonably normal conditions. More prolonged exposures or closer proximity to the transmitter can result in inappropriate shocks.

Acoustomagnetic electronic surveillance devices can interact with permanent pacemakers. Asynchronous pacing (noise reversion), atrial and ventricular oversensing, and surveillance device induced pacing have been described during a real life walk through these gates. No difference in electronic article surveillance device effect on pacemakers was observed between unipolar and bipolar sensing configurations. Since these effects on pacemakers occur only while the patient is within the electronic article surveillance device's magnetic field, it is prudent to advise patients to avoid prolonged exposure to electronic article surveillance systems and direct contact with the gates. Although data are lacking, it is likely that the same considerations and cautions apply to the pacing functions of ICDs which are part of all currently available systems.

### Magnetic resonance imaging

The safety of magnetic resonance imaging in patients with implanted pacemakers and ICDs has been debated for years. In general, the presence of these devices is an absolute contraindication to undergoing magnetic resonance imaging, since cardiac pacing and total inhibition of output can occur during magnetic resonance exposure.<sup>27</sup> However, it has been suggested that if patients are positioned so that the thorax does not enter the magnet bore no significant interaction occurs. Furthermore, it has been shown<sup>28</sup> that magnetic resonance imaging at 0.5 T can be safely performed in patients with implanted pacemakers in carefully selected clinical circumstances when appropriate strategies (programming to an asynchronous mode, adequate monitoring techniques, limited radiofrequency exposure) are used.

These data need to be confirmed before magnetic resonance imaging of the extremities can be allowed in patients with implanted devices.

### Electrocautery devices

Electrocautery devices have long been known to have the potential for interfering with pacemaker function. These devices generate a high energetic electromagnetic field with a frequency that may pass through the filters of ICDs and pacemakers. This may result in oversensing, independent of whether unipolar or bipolar coagulation mode is used. This oversensing leads to a pacemaker inhibition or false detection of ventricular tachyarrhythmias. Therefore, for surgical procedures using electrocautery devices, pacemaker dependent patients should be programmed into an asynchronous pacing mode. Usually, ICD patients should be programmed to detection-off using a programmer. Nevertheless, detection of ICDs may be temporarily inactivated using a pacemaker magnet placed above the device

on condition that monitoring and an external defibrillator are available.

### Radiotherapy

The complementary metal oxide semiconductor (CMOS) electronics currently used in all pacemakers and ICDs are responsible for the high sensitivity of these devices to ionising radiation. Nevertheless, no large recent studies have been performed which test the effect of radiotherapy on pacemakers and ICDs. In 1991 Rodriguez and colleagues<sup>29</sup> showed severe malfunctions of pacemakers and ICDs: of the 17 pacemakers exposed to photon radiation eight failed before 50 Gy, whereas four of the six pacemakers exposed to electron radiation failed before 70 Gy. For the ICDs detection and charging time increased with accumulated radiation dose, and charging time increased catastrophically at less than 50 total pulses delivered when compared with the charging time of six ICDs implanted at the same time. In 1995 Roethig and colleagues<sup>30</sup> showed similar results using 9 MV photon radiation. Our own experience with three ICD patients who underwent radiation therapy with a cumulative dose of < 5 Gy showed no damage of the device, oversensing or inhibition of pacing.

Therefore, direct radiation of pacemakers or ICDs at therapeutic levels should be strictly avoided. Furthermore, pacemaker and ICDs have to be controlled in short periods during and after radiation therapy, and pacemaker or ICDs should be exchanged after the radiotherapy when the accumulative dose on the pacemaker exceeds 5 Gy.

### Recommendations for patients implanted with pacemakers or ICDs

- **Common household equipment**—No special precautions for pacemaker and ICD patients in the use of microwaves or other common household equipment such as televisions, radios, toasters, and electric blankets.
- **Airport screening devices**—No special precautions for pacemaker and ICD patients. The metal cases may be detected by the screening devices. Patients should carry their device identification card for the purpose of obtaining security clearance.
- **Cellular phones**—It is inadvisable for the patient to place a cellular telephone that is switched on in a coat pocket overlying the pulse generator or ICD. The use of cellular phones does not appear to pose a significant health risk to patients with implanted permanent pacemakers or ICDs as long as the cellular telephone is kept at least 10 cm away from the pacemaker, preferably next to the contralateral ear.
- **Electronic article surveillance systems**—Avoid prolonged exposure to electronic article surveillance systems, lingering within the surveillance gates, and direct contact with the gates.
- **Magnetic resonance imaging**—For safety reasons, the presence of ICDs and pacemakers is an absolute contraindication to undergoing magnetic resonance imaging.
- **Electrocautery devices**—Before a surgical procedure, pacemaker dependent patients should be programmed into an asynchronous pacing mode. ICD patients should be programmed to detection-off or temporarily inactivated using a pacemaker magnet on condition that monitoring and an external defibrillator are available.

- **Radiotherapy**—Avoid cumulative dose on the device above 5 Gy. Because of the different manufacturing technologies and the scattering of the product parameters within a homogeneous set of pacemakers and ICDs we are not able to specify a guaranteed value for the radiation resistance.

MICHAEL NIEHAUS  
JÜRGEN TEBBENJOHANN

Department of Cardiology and Angiology,  
Hannover Medical School,  
Carl-Neuberg-Str. 1,  
30625 Hannover,  
Germany  
M.Niehaus@T-Online.de

- 1 Altamura G, Toscano S, Gentilucci G, *et al*. Influence of digital and analogue cellular telephones on implanted pacemakers. *Eur Heart J* 1997;18:1632–41.
- 2 Irnich W. Interference in pacemakers. *Pacing Clin Electrophysiol* 1984;7:1021–48.
- 3 Marco D, Eisinger G, Hayes DL. Testing of work environments for electromagnetic interference. *Pacing Clin Electrophysiol* 1992;15:2016–22.
- 4 Barbaro V, Bartolini P, Tarricono A. Evaluation of static magnetic field levels interfering with pacemakers. *Physica Medica* 1991;2:73–6.
- 5 Bonney CH, Rustan PL, Fond GE. Evaluation of effects of microwaves oven (915 and 23450 MHz) and radar (2810 and 3050 MHz) electromagnetic radiation on noncompetitive cardiac pacemakers. *IEEE Trans Biomed Eng* 1973;20:357–64.
- 6 Copperman Y, Zarfati D, Laniado S. The effect of metal detector gateways on implanted permanent pacemakers. *Pacing Clin Electrophysiol* 1988;11:1386–7.
- 7 Naegeli B, Deola M, Eicher B, *et al*. Pacemaker dysfunction caused by interference with Natel-D mobile phones [abstract]. *Pacing Clin Electrophysiol* 1995;18:842.
- 8 Irnich W, Batz L, Muller R, *et al*. Electromagnetic interferences of pacemaker by mobile phones. *Pacing Clin Electrophysiol* 1996;19:1431–46.
- 9 Naegeli B, Osswald S, Deola M, *et al*. Intermittent pacemaker dysfunction caused by digital mobile telephones. *J Am Coll Cardiol* 1996;27:1471–7.
- 10 Hofgartner F, Muller T, Sigel H. Could C- and D-network mobile phones endanger patients with pacemakers? *Dtsch Med Wochenschr* 1996;121:645.
- 11 Grimm W. Is the cardiac pacemaker patient at risk by using mobile telephone devices in D-net? *Internist* 1994;35:580.
- 12 Fahraeus T, Almquist LO. Cellular telephones may interfere with cardiac stimulators. Yuppie telephones and alarms are hazardous for patients with pacemakers. *Lakartidningen* 1995;92:4009–10.
- 13 Barbaro V, Bartolini P, Donato A, *et al*. Do European GSM mobile cellular phones pose a potential risk to pacemaker patients? *Pacing Clin Electrophysiol* 1995;18:1218–24.
- 14 Irnich W, Batz L, Müller R, *et al*. Störbeeinflussung von Herzschrittmachern. *Herzschrittmacher* 1995;15:5–20.
- 15 Barbaro V, Bartolini P, Donato A. GSM cellular phones interference with implantable pacemakers: in vitro observations. *Proceeding of the V International Symposium on Biomedical Engineering, Santiago de Compostela* 1994:275–6.
- 16 Cifford KJ, Joyner KH, Stroud DB, *et al*. Mobile telephones interfere with medical electric equipment. *Australas Phys Eng Sci Med* 1994;17:23–7.
- 17 Emergency Care Research Institute. Cellular telephones and radio transmitters interference with clinical equipment. *Health Devices* 1993;22:416–18.
- 18 Bassen HJ, Moore HJ, Ruggera PS. Cellular phone interference testing of implantable cardiac defibrillators in vitro. *Pacing Clin Electrophysiol* 1998;21:1709–15.
- 19 Hayes DL, Wang PJ, Reynolds DW, *et al*. Interference with cardiac pacemakers by cellular telephones. *N Engl J Med* 1997;336:1473–9.
- 20 Fetter JG, Ivans V, Benditt DG, *et al*. Digital cellular telephone interaction with implantable cardioverter-defibrillators. *J Am Coll Cardiol* 1998;31:623–8.
- 21 Hayes DL, Carillo RG, Findly GK, *et al*. State of the science: pacemaker and defibrillator interference from wireless communication devices. *Pacing Clin Electrophysiol* 1996;19:1419–30.
- 22 Niehaus M, Gille K, Cierpka R, *et al*. GSM-Handies can impare ICD-function during telemetry [abstract]. *J Am Coll Cardiol* 1997;29(suppl A):474.
- 23 Occhetta E, Plebani L, Bortnik M, *et al*. Implantable cardioverter defibrillators and cellular phones: is there any interference? *Pacing Clin Electrophysiol* 1999;22:983–9.
- 24 Barbaro V, Bartolini P, Caruso F, *et al*. Electromagnetic interference of digital and analog cellular telephones with implantable cardioverter defibrillators: In vitro and in vivo studies. *Pacing Clin Electrophysiol* 1999;22:626–34.
- 25 Jimenez A, Hernandez Madrid A, Pascual J, *et al*. Electromagnetic interference between automatic defibrillators and digital and analog cellular telephones. *Rev Esp Cardiol* 1998;51:375–82.
- 26 Groh W, Boschee SA, Engelstein ED, *et al*. Interaction between electronic surveillance systems and implantable cardioverter-defibrillators. *Circulation* 1999;100:387–92.
- 27 Lauck G, von Smekal A, Wolke S, *et al*. Effects of nuclear magnetic resonance imaging on cardiac pacemakers. *Pacing Clin Electrophysiol* 1995;18:1549–55.
- 28 Sommer T, Vahlhaus C, Lauck G, *et al*. MR imaging and cardiac pacemakers: in-vitro evaluation and in-vivo studies in 51 patients at 0.5 T. *Radiology* 2000;215:869–79.
- 29 Rodriguez F, Filimonov A, Henning A, *et al*. Radiation-induced effects in multiprogrammable pacemakers and implantable defibrillators. *Pacing Clin Electrophysiol* 1991;14:2143–53.
- 30 Roethig H, Herrmann T, Kopceck H. Experience in dealing with artificial pacemaker patients during therapy with ionizing radiation. *Strahlenther Onkol* 1995;171:398–402.