Effects of Mobile Telephones on the Function of Implantable Cardioverter Defibrillators

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Objective: We investigated whether mobile telephones affect the function of implantable cardioverter defibrillators (ICDs).

Background: It is well known that electromagnetic fields can affect medical devices.

Methods: The study included 43 patients with ventricular tachycardia and/or fibrillation treated with transvenous pectoral ICDs. Testing was done under continuous electrocardiograph monitoring under supervision of an ICD programmer. Initially, each patient was tested during spontaneous rhythm. Then the ICD was programmed to a pace rhythm higher than the patient's heart rate, and the tests were repeated at paced rhythm. In 7 patients, tests were performed during the implantation procedure as well. In 3 of the patients, only a single defibrillation zone was active. The other 40 patients had one or more active ventricular tachycardia zones. Two mobile phones (both GSM 900 MHz) were positioned 50 cm away from the implanted device in opposite directions and switched on. Communication was established between these phones, two investigators had a 20-second conversation, and then the phones were switched off. The same procedure was repeated at 30, 20, and 10 cm away from the implantation site, respectively. Finally, the procedure was performed with the antennae of both phones touching the device pocket. In the above-mentioned 7 cases where testing was done during implantation of the ICD, a call was made from one phone to the other, ringing occurred for 5 seconds, and then two investigators conversed while the device was implanted.

Results: There was no change in the function of the ICDs during any of the phone testing procedures. In 5 cases, artifacts were noted on the surface electrocardiographic (ECG) screen of the programmer during the tests, but no such changes were observed on the simultaneous intracardiac ECGs.

Conclusion: The results of the study suggest that mobile phones have no effects on ICD function.

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Mobile telephones transmit voice messages via radio waves of different frequencies, and they generate electromagnetic signals during switch-on, ringing, talking, and switch-off.[1] The magnetic fields produced by these phones are known to have unfavorable effects on certain medical devices.[2]

Implantable cardioverter defibrillators (ICDs) are very complex devices that are used to treat patients with malignant ventricular arrhythmias. Although these units reduce mortality, they also negatively affect quality of life in some cases.[3] Research has shown that electromagnetic fields can affect some of the functions of these devices,[4–8] and this can occur in several ways. Signals within the frequency range of the ICD can be recognized as arrhythmia, causing the device to generate an inappropriate shock.[7,9,10] The signals may also reduce the device's sensitivity to (cause "undersensing" of) ventricular arrhythmias.[11] In addition, electromagnetic effects may cause the ICD to switch to protection mode, or cause changes in programmed

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parameters.[11] As well, strong magnetic signals may even inhibit the device.[12]

The sensing circuits of ICDs are similar to those of pacemakers. Investigation has shown that electromagnetic fields produced by mobile phones can negatively affect the function of pacemakers;[13–16] however, it is not clear whether these phones have any impact on ICD function. The aim of this study was to evaluate whether Global System for Mobile Communication (GSM) mobile telephones affects the function of ICDs, and to investigate conditions in which these interactions might occur.

MATERIALS AND METHODS

The study included 43 patients who were on routine follow-up and had ICDs implanted between the years 2000 and 2002. The cardiac conditions in these individuals were spontaneous or inducible ventricular tachycardia/ventricular fibrillation accompanying coronary artery disease, hypertrophic cardiomyopathy, dilated cardiomyopathy, or long QT syndrome. All the patients were informed about the purpose of the study. Twenty-eight patients had different models of Guidant/CPI ICDs implanted (St. Paul, MN, USA [Ventak VR (n = 3), Ventak AV II DR (n = 1), Ventak Mini IV (n = 1), Ventak Prizm 2 VR (n = 13), Ventak Prizm DR (n = 9), H 135 Contak Renewall biventricular DDD-R (n = 1)]); 12 had different Medtronic models implanted (Medtronic Inc., Minneapolis, MN, USA [Micro Jewell II 7223 (n = 7), GEM III VR (n = 5)]), 1 had a St. Jude Medical ICD implanted (Sylmar, LA, USA [Photon Micro VR]), and 2 had ELA units implanted (Montregue, France, both Alto DR 614). All the devices were placed submuscularly in the left pectoral region. Five patients had the pacemaker function of their ICD turned on. The reasons for this were insufficient intrinsic heart rate in 3 cases (one Ventak AV II DR, one Ventak Mini IV, one Photon Micro VR); a related indication in 1 case (H 135 Contak Renewall biventricular DDD-R); and hypertrophic cardiomyopathy in 1 case (Alto DR 614). The programmer devices used for interrogation and programming of the devices were Zoom 2920 in the Guidant models, 9790 in the Medtronic models, PR 3500 in the St. Jude model, and Orchestra in the ELA models.

Mobile Telephones

The two types of telephones used in the tests were the Nokia 6150 (power output 2 W) and the Nokia 6110 (power output 2 W), both of which operate with the GSM 900 MHz digital system.

Study Protocol

All the testing was done in a room equipped with emergency medical equipment and under continuous electrocardiographic (ECG) monitoring. The programmer of the ICD was always ready to use.

Thirty-eight of the 43 (patient numbers 1, 2, 4–17, 19–27, 29–40, 43) patients were tested during spontaneous cardiac rhythm after their ICDs were in place and data were collected (details below). Then, in 28 of these subjects (patients 1, 2, 4–17, and 29–40), the minimum pacing rate was increased to 10 beats/min above the spontaneous rate and testing was repeated in VVI (R) mode. In the remaining 10 subjects (patients 19–27 and 43), the minimum pacing rate was increased 10 beats/min above the spontaneous rate and testing was repeated and in DDD-R mode. Besides that in 7 patients tests were performed in the cardiac catheterization laboratory during the implantation of the device and repeated later in routine controls. The pacemaker function of the ICD was active in 4 patients (number: 3, 18, 28, 41) whose tests were performed in the operating room during implantation and in 1 patient (number: 42) who had hypertrophic cardiomyopathy and ventricular tachycardia. In these patients, tests were done only during pacemaker rhythm, not in spontaneous cardiac rhythm.

In 40 patients, two or three tachycardia zones of the ICDs were active. In the other 3 patients, only one defibrillation zone was active.

The testing performed with the ICD in place was as follows: Two mobile phones were positioned 50 cm away in opposite directions from the device (in the patient's left pectoral region) and switched on. After communication was established, two investigators had a 20-second conversation and then the phones were switched off. The same procedure was repeated with the phones 30, 20, and 10 cm away from the implantation site, respectively. Finally, the procedure was performed with the mobile phone antennae both touching the device pocket. The testing performed during ICD implantation (7 patients) was as follows: At least two energy levels were tested to determine each patient's defibrillation threshold. The mobile phones were switched off during the first threshold test. In the second test, we dialed one of the mobile phones from the other phone, and let the phone

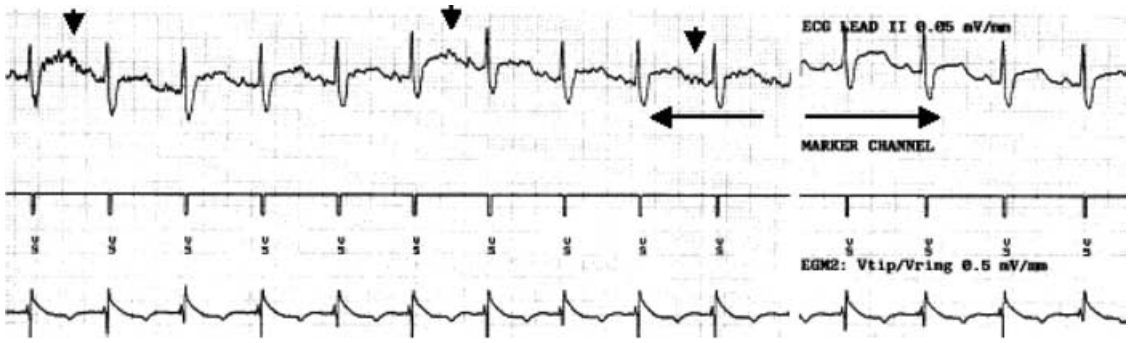

Figure 1. The programmer electrocardiogram (top trace) of one ICD recipient (Patient 40) showed artifacts (indicated by arrows) while the one mobile phone was ringing, and while the investigators were communicating over the two phones (→). The simultaneous intracardiac electrocardiogram revealed no artifacts. The artifacts disappeared when the mobile phones were switched off (→).

ring for 5 seconds. Then one investigator answered and carried on a conversation with an investigator on the other phone until the end of the defibrillation episode. Throughout this test, both mobile phones were located directly above the device pocket with their antennae touching the programmer head.

For each test, the presence/absence of the following parameters was recorded: (1) inappropriate antitachycardia pacing and/or antifibrillation shock due to an oversense problem in patients with spontaneous cardiac rhythm; (2) development of dysfunction in the pacemaker activity of the ICD (inhibition of the pacemaker, a change to the asynchronous mode, ventricular triggering in two- or three-chamber ICDs); (3) any effect of the mobile phones related to induction of ventricular fibrillation, appropriate recognition of the arrhythmias, or delivery of shock and postshock pacing. Intracardiac and surface ECGs were continuously monitored during all procedures.

For each patient, the mean time for the testing was 20 minutes. All subjects were tested in supine position, and were asked to keep as still as possible to avoid myopotential oversensing. Once the testing was completed, we rechecked the patient's ICD system with the programmer to assess for any change in battery status, lead impedance, and/or threshold results. As a final step, each ICD was reprogrammed with appropriate settings.

RESULTS

The indications for ICD implantation were spontaneous or induced ventricular tachycardia and/or ventricular fibrillation accompanying coronary artery disease, hypertrophic cardiomyopathy, dilated cardiomyopathy, or long QT syndrome.

In the 38 evaluations done with the ICDs already in place, none of the devices indicated false diagnoses and no inappropriate shock delivery occurred in any of the patients during the tests. Similarly, no changes in ICD function were detected during pacing, and none of the patients exhibited any symptoms. In the seven evaluations done during implantation, no changes were observed in device function. Also, there were no differences between the testing and nontesting periods with respect to the duration of ventricular tachycardia and/or ventricular fibrillation induction, the charging time of the ICD after induction, or the amount of energy used for shock delivery. As well, use of the mobile phones had no effect on the postshock pacemaker function of the device.

In 4 patients with Medtronic units (patients 31, 33, 38, and 40) and 1 patient with a Guidant unit (patient 8), there were intermittent artifacts on the surface ECG of the programmer while the mobile phones were ringing and during phone communication (Fig. 1). The size and frequency of these artifacts were correlated with the distance between the mobile phones and the programmer head, and was greatest when the phone antennae were in contact with the programmer head. The intracardiac ECGs recorded simultaneously showed no such artifacts.

DISCUSSION

Patients with ICD and their families are anxious and stressed, and tend to have social problems related to the need for and use of these devices. Some

patients with ICDs are reluctant to use mobile telephones out of fear that the signal will interfere with the function of the device. The results of the present study indicate that GSM 900 MHz mobile phones with 2-W power output do not alter the function of these devices.

Previous studies have shown that electromagnetic fields produced by different systems can have unfavorable effects on ICD function.[4–6,9,17] Bostrom[18] was the first to evaluate the effects of mobile phones on these devices in a study published in 1991. The results with 25 patients indicated no such interaction. Later work by Chiladakis et al.,[19] Fetter et al.,[20,21] and Occhetta et al.[22] also showed no adverse effects on these devices with different types of cellular phones. In line with these findings, our study indicates that mobile phones have no negative impact on ICD function.

In contrast to clinical investigations, in vitro studies have suggested that these phones do have important effects on the function of ICDs.[10] Barbaro et al.[11] reported that four of six ICDs they tested were altered by mobile phones used close by in the open air. No such interference was observed when the authors repeated the test with the ICD in a tank filled with salt water. Studies in which testing is done with ICDs submerged in special solutions or in open-air conditions may provide valuable information; however, they do not accurately simulate in vivo systems.[13]

As mentioned previously, studies have demonstrated that mobile phones can temporarily interrupt pacemaker function.[13–16] In a preliminary study, we found that 6% of pacemakers are affected when such phones are used nearby.[23] The sensing equipments in ICDs are similar to that in pacemakers.[1] However, unlike pacemakers, ICDs have different circuits and algorithms for detecting tachyarrhythmias.[1,24] It has been speculated that the electromagnetic field produced by a mobile phone might have an even greater effect on these different circuits in ICDs than on pacemaker sensors. On the other hand, ICDs are known to respond to interference more smoothly than pacemakers. Pacemakers sense the activity and interference at the end of the adjusted refractory period and, accordingly, respond rapidly to synchronize, inhibit, or stimulate. In contrast, ICDs respond to interference at the end of the programmed tachycardia zone, and a longer period of interference is needed to trigger a reaction. From this perspective on different sensing functions, it could be argued that ICDs are less likely to be affected by an electromagnetic field than pacemakers. Another factor in potential interference from an electromagnetic field is the intensity of the interference in the related area. ICDs are placed in a deeper location than pacemakers. They are usually inserted beneath the pectoralis muscle, and this might result in lower interference density from any electromagnetic source over them.[25]

Chiladakis et al.[19] observed artifacts on intracardiac ECGs of 19% of 36 patients with ICDs during testing with cellular phones, and concluded that the programming devices of Medtronic ICDs are more sensitive than those of other makes. Occhetta et al.[22] reported similar results. In our study, we observed artifacts on the programmer ECG during mobile phone use in 4 patients with Medtronic ICDs and 1 patient with a Guidant unit. The simultaneous intracardiac and external-monitor ECGs were normal in all 5 cases, and none of the patients exhibited cardiac symptoms during the time the artifacts appeared. These artifacts on the programmer screen reflected interference from the mobile phone affecting the head of the programmer specifically, not interference from the mobile phone affecting the ICD. These intermittent artifacts on the surface ECG might be caused by undulations in the power output of the mobile phones. The main limitation of our study was the size of the sample population. Only 43 ICD patients were investigated, and this is not sufficient to reflect the characteristics of the ICD patient population as a whole. We tested four different brands of ICDs, two different mobile phones (both with power output 2 W) and only the GSM 900 MHz telecommunication system. We did not test the GSM 1800 MHz and 1900 MHz systems.

CONCLUSION

This study indicates that mobile phones do not adversely affect the function of the four types of ICDs that were tested; however, it is not possible to conclude that use of this type of phone is safe for all patients with these devices. Based on this investigation and other research to date, we recommend that, in order to be safe, ICD recipients should keep any activated mobile phone at least 20 cm from the implantation site. As suggested for individuals with pacemakers, ICD patients should also avoid touching any activated phone to the device pocket site.

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