Electromagnetic Interference of External Pacemakers by Walkie-Talkies and Digital Cellular Phones: Experimental Study

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TRIGANO, A.J., ET AL.: Electromagnetic Interference of External Pacemakers by Walkie-Talkies and Digital Cellular Phones: Experimental Study. *A number of experimental and clinical studies have documented the risk potential of interference with implanted pacemakers by various types of cellular phones. Radiofrequency susceptibility of external medical equipment has also been reported in experimental studies. The purpose of this experimental study was to evaluate electromagnetic interference of external pacemakers by walkie-talkies and digital cellular telephones. External bipolar pacing was monitored using a digital oscilloscope to record pacemaker pulses and electromagnetic interference separately. Tests with the walkie-talkie, Private Mobile Radio (PMR) (160 MHz, 2.5 W) were conducted during the calling phase. Tests with the cellular phones, global system for mobile communications (GSM) (900 MHz, 2 W) and Digital Cellular System (DCS) (1,800 MHz, 1 W) were conducted in the test mode. Nine widely used external pacemakers from four manufacturers were tested. Various disturbances including pacing inhibition and asynchronous pacing were observed in eight pacemakers by the PMR, in four by the GSM phone, and in two by the DCS phone. The maximum distance that interference persisted ranged from 10–200 cm. This experimental study shows a potential risk of interference of external pacemakers by walkie-talkies and cellular digital phones. Appropriate warnings should be issued against the potentially serious risks of using communication devices in the vicinity of acutely ill patients treated with temporary transvenous cardiac pacemakers. (PACE 1999; 22[Pt.I]:588–593)*

external endocardial cardiac pacing, electromagnetic interference, mobile telephones

Introduction

The potential for electromagnetic interference of implanted pacemakers by cellular telephones has been recognized since 1994. A number of clinical and experimental studies have been conducted to evaluate interference of pacemakers by various communications devices manufactured in Europe and the US. Experimental studies have also shown radiofrequency susceptibility in some external medical devices, but data on external cardiac pacing have not been published. External pacing is a temporary in-hospital treatment, used mainly in intensive care units and thus the risk of electromagnetic interference is limited to specific areas. Location of the pulse generator and part of the lead outside the thorax increases exposure of these devices to external interferences. Interference by walkie-talkies or cellular phones used by patients, visitors, and emergency and maintenance personnel can occur in intensive care units. Interference can also occur during patient transport between hospitals or from one area to another in the same hospital. This in vitro study was undertaken to evaluate interference of external pacemakers from various manufacturers by walkie-talkies and cellular telephones.

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Methods

To simulate endocardial temporary pacing, the external pacemaker was connected to a widely

used bipolar lead (USCI, 5F, 125 cm, Bard Ltd, Galway, Ireland) with its distal electrodes connected to a 470-Ohm resistance. A digital oscilloscope (Yokogawa, model DL 1100, 100 MHz, Electronic Corporation, Tokyo, Japan) was used to record electromagnetic interference and pacing pulses on separate channels (Figs. 1 and 2). Metallic shielding was applied to distal electrodes and to oscilloscope connections to prevent interference at these points. Nine widely used external pacemakers were tested including five single and four dual chamber models from four different manufacturers (Table I). Three successive generations from one manufacturer were tested. Pacemakers were set at maximum sensitivity. Single chamber pacemakers were tested in the SSI mode, during permanent pacing at 70 ppm and output amplitude of 10 mA, as well as during normal inhibition by an inhibiting signal. Except for the DVI model Medtronic 5330, (Medtronic Inc., Minneapolis, MN, USA) dual chamber pacemakers were set in the DDD mode, at the lowest minimal rate with the upper rate programmed at its maximum value. The ventricular channel was connected to the oscilloscope and the atrial channel in the DDD mode received a triggering signal at 70

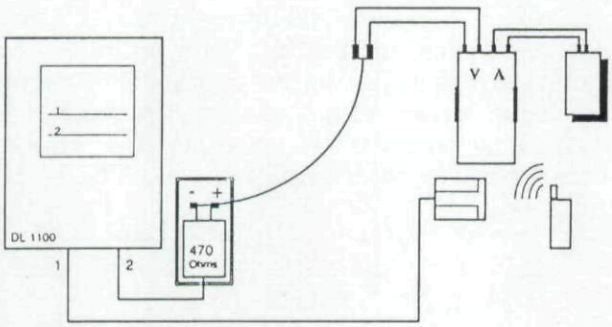

Figure 1. *This shows test set up for dual chamber pacing. The ventricular channel (V) of the external dual chamber pacemaker was connected to a bipolar endocardial lead. The atrial channel (A) received the triggering signal. Occurrence of electromagnetic interference was recorded on channel 1 of the digital oscilloscope. Pacing through a 470-Ohm resistance was monitored on channel 2. The distal dipole and its connection to the oscilloscope were shielded. The walkie-talkie or cellular phone was held with the antenna extended in close proximity to the pacemaker and its connection to the lead.*

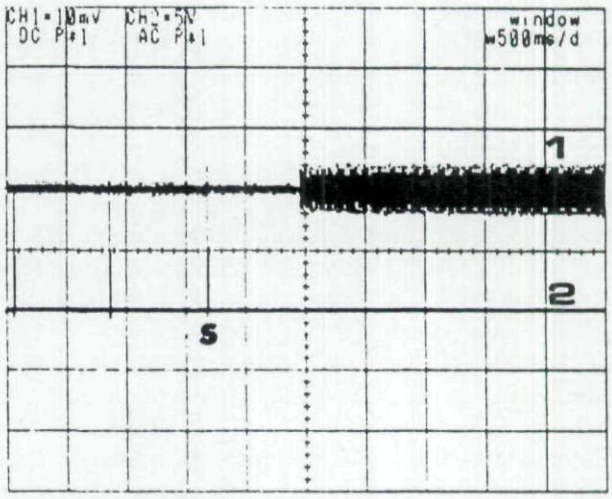

Figure 2. *This shows simultaneous recordings of electromagnetic interference and pacing pulses on separate channels. Pacing inhibition after the third stimulus (channel 2) caused by the electromagnetic field emitted by the walkie-talkie (channel 1). S-pacing stimulus.*

Table I.

Overall Results

	PMR 160 MHz 2.5 W	GSM 900 MHz 2 W	DCS 1800 MHz 1 W
APC			
4543	+	+	–
Biotronik			
EDP 20	+	–	–
EDP 30*	+	+	+
Medtronic			
5880	+	+	+
5330*	–	–	–
5346*	+	–	–
5348	+	–	–
Pacesetter			
3074	+	+	–
3076*	+	–	–

APC Medical Ltd, Welwyn Garden City, England; Biotronik GmbH, Berlin Germany; Medtronic Inc, Minneapolis, MN, USA; Pacesetter Inc, St. Jude Medical, Sylmar, CA, USA. *dual chamber pacemaker; + pacing dysfunction; – no effect. DCS = Digital Cellular System; GSM = Global System for Mobile; PMR = Private Mobile Radio.

ppm. The walkie-talkie tested was the two way Private Mobile Radio (PMR) transmitter (Alcatel Alsthom, France) that is widely used by emergency personnel, fire-fighters, and hospital workers. The output of this manually activated device is 2.5 W and its operating frequency is 160 MHz. Tests were conducted in the calling phase. The two European-made digital cellular phones tested were the Global System for Mobile communications (GSM) that operates at 900 MHz with a modulated pulse of 217 Hz, and the more recent Digital Cellular System (DCS) that operates at 1,800 MHz. The hand-held mobile phone models tested were the P 9026 for the GSM standard and the Flare B 300 for the DCS (Motorola International, USA). Emission is activated using a Subscriber Identity Module card inserted into the terminal. Tests were conducted in the test mode at a constant power of 2 W for the GSM and 1 W for the DCS. Devices were not tested in the actual transmission mode or DTX, discontinuous transmission mode. The source of interference was first held directly over the pacemaker and then moved at a steady rate of about 1 cm/s over the pacemaker and its connections. To avoid any triboelectric phenomena, care was taken not to touch the pacing equipment during testing. The exposure procedure was stopped by disactivating the communication device. Separate tests were performed to measure the distance at which any interference was produced. All tests were repeated after a recovery period to determine reproducibility.

Results

Electromagnetic interference was observed in eight pacemakers by the walkie-talkie, in four by the GSM, and in two by the DCS (Table I). The main disturbance was pacing inhibition associated or not with asynchronous pacing. Pacing inhibition was intermittent or permanent. Asynchronous pacing was defined as emission of pacing stimuli during normal inhibition by a single chamber pacemaker or minimal rate pacing by a dual chamber pacemaker during atrial triggering. During tests using the PMR as the source of interference, pacing inhibition was observed in all positive tests and asynchronous pacing in three cases. Inhibition lasted 2,500 ms by the APC model 4543 (APC Medical LTD., Welwyn Garden City, England), 1,500 ms by the Medtronic model 5348, and for the full duration of exposure to the source by the other models. The maximum distance at which interference persisted ranged from 10–150 cm (Table II). During tests using the GSM phone as the source of interference, inhibition lasted from 1,500 to 4,000 ms and was associated with asynchronous pacing. More prolonged or continuous pacing inhibition could be induced by waving the source of interference. The maximum distance at which interference persisted ranged from 10–200 cm (Table III). During tests using the

Table II.

Positive Results in Tests Using the PMR Walkie-Talkie Device

	I ms	A	D cm
APC			
4543	+ 2500	+	20
Biotronik			
EDP 20	+ c	+	30
EDP 30	+ c	+	150
Medtronic			
5880	+ c	–	100
5346	+ c	–	10
5348	+ 1500	–	10
Pacesetter			
3074	+ c	–	60
3076	+ p	–	10

A = asynchronous pacing; C = continuous pacing inhibition; D cm = maximum interference distance; I = pacing inhibition; ms = duration of the inhibition; p = inhibition persisted after removal of the source of interference.

Table III.

Positive Results in Tests Using the GSM Cellular Phone Device

	I ms	A	D cm
APC			
4543	+ 1500	+	10
Biotronik			
EDP 30*	+ 2500	+	200
Medtronic			
5880	+ 4000	+	200
Pacesetter			
3074	+ 2000	+	10

Table IV.
Positive Results in Tests Using the DCS Cellular Phone Device

	I ms	A	D cm
Biotronik EDP 30*	+ 2600	+	10
Medtronic 5880	+ 3800	+	80

DCS phone, inhibition lasted 2,600 and 3,800 ms and was also associated with asynchronous pacing. The maximum distances at which interference persisted were 10 and 80 cm (Table IV). Interference tracking resulting in transient rapid ventricular stimulation was observed during tests with the Biotronik EDP 30 dual chamber model (Biotronic, Lake Oswego, OR, USA) using the PMR and the DCS cellular phone. Normal operation returned after the source of interference was removed or turned off in all but one of the effected pacemakers. In the test in which the walkie-talkie was placed at 10 cm from the Pacesetter model 3076 (Siemens Pacesetter Inc., Sylmar, CA, USA), inhibition of pacing stimulus continued for 14 seconds after removal of the source of interference. This model is equipped with audio and visual warning signals, both of which went off during interference.

Discussion

Various forms of electromagnetic energy can interfere with cardiac pacemakers.[1] Electromagnetic signals with frequency higher than 9 Hz can cause asynchronous pacing. Signals between 2 and 9 Hz can inhibit or synchronize the pacing stimulus. Low-frequency components of digital phone signals (217, 8.3, and 2.2 Hz) can pass through protection filters. Numerous clinical and experimental studies have documented electromagnetic interference of implanted pacemakers by digital cellular phones.[2–7] The most common electrocardiographic changes are tracking interference sensed on the atrial channel, noise reversion, and ventricular inhibition. The maximum distance at which interference has been reported in these studies is less than 20 cm for handies and 40 cm for portable devices. Few clinical cases involving interference of external pacemakers by external electromagnetic fields have been reported.[8,9]

Incidence of Interference

As in several previous studies on implanted pacemakers, test conditions in this study were standardized to simulate a worst case scenario with the pacemaker programmed at highest sensitivity and the source of interference operating at maximal power in close proximity. The walkie-talkie used in this study was tested at normal power. In normal use, cellular phones operate automatically at the lowest possible power necessary to maintain communication. The standardized conditions used in this study are not unrealistic. Maximum atrial pacemaker sensitivity is frequently used in the clinical setting. Close proximity of communication devices is possible if mobile phones are used in the intensive care units, or if walkie-talkies and mobile phones are operated by emergency personnel during transport of the patient between departments in the same or different hospitals. Our findings showed that interference depended not only on emission characteristics, mainly frequency and output, but also on the pacemaker model. Continuous pacing inhibition was most frequent in tests using the walkie-talkie, which was the most powerful device. Evaluation of successive pacemaker models from the same manufacturer suggested that newer generation models are less susceptible to interference by cellular phones than older ones. Design changes in recent implantable pacemakers, such as inclusion of feed-through filters significantly reduce sensitivity to interference.[10] It should be emphasized that in our study the most severe disturbance (i.e., pacing inhibition that continued after removal of the source of interference) was observed in one of the most recent models tested.

Maximum Interference Distance

In experimental studies on interference of implanted pacemakers by cellular phones, trunk simulators have been used to mimic clinical conditions. The maximum interference distance in this configuration for a 2 W phone was 20 cm.[5] Since the chassis and lead connections of an external pacemaker are exposed, they can act as an

antenna for electromagnetic fields. In this study, the maximum interference distance in this configuration varied widely up to 2 m depending on the source and pacemaker model tested. In previous studies, cellular telephones have been reported to interfere with external monitoring devices at distances of one meter and walkie-talkies at distances up to 4 m.[11]

Study Limitations

Introduction of the distal part of the lead into a human trunk simulator, as done for implanted pacemaker testing, would have been a more realistic method of simulation. For testing of external pacemakers, this drawback can be considered limited. In the clinical setting, a long portion of the lead is outside the thorax and may act as an external antenna that probably picks up more interference than the short intrathoracic dipole. In our study, metallic shielding of the dipole and distal lead connections prevented direct interference at these points. Testing was not carried out in our anechoic chamber in order to simulate the normal clinical conditions of external cardiac pacing.

Clinical Implications

To our knowledge, no clinical study or case reports on interference of external pacing by walkie-talkies and cellular phones have been published. For clinical and ethical reasons, in vivo studies in acutely ill patients are difficult. However, the absence of evidence in the hospital setting or during transport does not reduce the clinical implications of in vitro interference with external pacing. Clinical studies have already confirmed the relevance of in vitro data on interference with implanted pacemakers.[3,4,6,7] Our study closely simulated the conditions under which external pacing is used in actual practice. The most common disturbance caused by interference in this study was pacing stimulus inhibition, which is easy to detect during permanent pacing. Asynchronous pacing due to noise reversion was also observed during normal inhibition or triggering. Ventricular inhibition can have serious clinical implications depending on its duration and the degree of dependency of the patient on the pacemaker. In a large clinical study of interference of implanted pacemakers by cellular phones, symptoms were noted in 7.2% of tests.[7,12] In patients with acute myocardial infarction or electrolytic disturbances, dependence on external cardiac pacing and induction of ventricular arrhythmias by asynchronous pacing are significant risks. The duration of pacing inhibition in most positive tests in our experimental study was long enough to cause significant clinical manifestations in pacemaker-dependent patients.

Conclusions

Our experimental study suggests that use of walkie-talkies and cellular phones may interfere with external cardiac pacing. In some countries, current safety recommendations call for a ban of mobile phones anywhere in the hospital. In other countries, the ban applies only to certain areas such as intensive care units. No recommendations have been made concerning transport. Shielding with a shirt woven with fine metallic threads may provide sufficient protection in this situation. Industry should be compelled to improve external pacing products with respect to electromagnetic compatibility. This could be done by retrofidding existing devices with appropriate shielding and building in protection on new devices. New standards for external pacemakers should take into account the potential risk of this type of electromagnetic interference. Inclusion of specific high frequency filters has proven effective in implanted pacemakers. Protection of connectors and warning alarms also could be useful.

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