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## INTERFERENCE WITH CARDIAC PACEMAKERS BY CELLULAR TELEPHONES

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### ABSTRACT

**Background** A growing body of evidence suggests that electromagnetic interference may occur between cardiac pacemakers and wireless hand-held (cellular) telephones, posing a potential public health problem. Electromagnetic interference may occur when the pacemaker is exposed to an electromagnetic field generated by the cellular telephone.

**Methods** In this multicenter, prospective, crossover study, we tested 980 patients with cardiac pacemakers with five types of telephones (one analogue and four digital) to assess the potential for interference. Telephones were tested in a test mode and were programmed to transmit at the maximal power, simulating the worst-case scenario; in addition, one telephone was tested during actual transmission to simulate actual use. Patients were electrocardiographically monitored while the telephones were tested at the ipsilateral ear and in a series of maneuvers directly over the pacemaker. Interference was classified according to the type and clinical significance of the effect.

**Results** The incidence of any type of interference was 20 percent in the 5533 tests, and the incidence of symptoms was 7.2 percent. The incidence of clinically significant interference was 6.6 percent. There was no clinically significant interference when the telephone was placed in the normal position over the ear. Interference that was definitely clinically significant occurred in only 1.7 percent of tests, and only when the telephone was held over the pacemaker. Interference was more frequent with dual-chamber pacemakers (25.3 percent) than with single-chamber pacemakers (6.8 percent,  $P < 0.001$ ) and more frequent with pacemakers without feed-through filters (28.9 to 55.8 percent) than with those with such filters (0.4 to 0.8 percent,  $P = 0.01$ ).

**Conclusions** Cellular telephones can interfere with the function of implanted cardiac pacemakers. However, when telephones are placed over the ear, the normal position, this interference does not pose a health risk. (N Engl J Med 1997;336:1473-9.)

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**R**EPORTS of interference between European cellular telephones and cardiac pacemakers in 1994<sup>1-3</sup> prompted the U.S. government and researchers to examine the potential for wireless (cellular) telephones to interfere with implanted pacemakers. Since that time, further European in vitro studies and small in vivo studies have also shown that hand-held wireless telephones interfere with the function of pacemakers.<sup>4-7</sup> (Household cordless telephones are not considered wireless.) Furthermore, in vitro studies in the United States have demonstrated the potential for interference between American wireless telephones and pacemakers.<sup>8-12</sup> This interference may prevent the pacemaker from functioning properly, resulting in possible adverse health effects. At least one case report has documented pacemaker malfunction due to interference from a communication device.<sup>13</sup> The purpose of this multicenter study was to assess the prevalence of interference and the potential for a serious clinical risk resulting from the exposure of permanently implanted pacemakers to cellular telephones.

### METHODS

#### Patients and Procedures

Clinical testing sites for this prospective, crossover, double-blind study included the Mayo Clinic, New England Medical Center, and the University of Oklahoma Health Sciences Center. The study followed Good Clinical Practices guidelines, including the use of standard operating procedures and monitoring by a quality-assurance unit.<sup>14</sup>

A total of 980 patients with permanent pacemakers were selected for participation in the study and were required to give in-

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formed consent. The protocol and informed-consent form were approved by each institution's internal review board.

Five types of hand-held cellular telephones were tested on each patient in random order: one analogue telephone and four digital telephones (North American Digital Cellular [NADC]; Time Division Multiple Access-11 [TDMA-11]; Personal Communication System-1900 [PCS-1900]; and Code Division Multiple Access [CDMA]). If there was more than one manufacturer of a type of telephone available for testing, the manufacturer was also selected randomly. Telephones were operated in a test mode and programmed to transmit at the maximal power in order to simulate the worst-case scenario. The NADC telephone was also tested while in an actual transmission mode, which includes ringing and dialing, to simulate real use (this was considered a sixth telephone).

Patients were tested while sitting at an angle of 60 to 90 degrees, with pacemakers programmed to their usual settings and with constant monitoring by a three-channel electrocardiographic recorder. One technician selected and activated the telephones and directed the procedures. Another technician monitored the electrocardiogram for interference but was unaware of the type of telephone being tested. When the testing was completed, all electrocardiographic tracings were reviewed for evidence of interference.

Two sets of tests were conducted with each telephone. The first consisted of placing the telephone at the patient's ipsilateral ear. The second consisted of positioning the point on the antenna at which the electromagnetic emissions were highest 1 to 2 cm over the pacemaker in a series of defined movements and positions. Each test was followed by a recovery period and then repeated. Between tests the programmed settings of the pacemaker were checked. The patient was also asked to report any symptoms during testing.

The types of interference identified on the electrocardiogram included undersensing, tracking, cross-talk or safety pacing, rate-adaptive sensor-driven pacing, switching to a noise-reversion mode, inhibition, asynchronous pacing, and mode switching. Interference was further defined by its duration. Transient interference was defined as a change in the electrocardiographic pattern that occurred while the pacemaker was exposed to the telephone. Transient interference was further categorized as intermittent if it lasted less than 50 percent of the period of exposure and as constant if it lasted for at least 50 percent of the period of exposure. Persistent interference was defined as any continued interference after the telephone was removed from the testing position.

Interference was also classified according to a previously designed classification of clinically significant interference. The objective of this classification scheme was to categorize interference in terms of primary responses to electromagnetic interference as well as electrocardiographic presentations of the pacemaker's response to electromagnetic interference. There were three classes of clinically significant interference: class I, clinical responses that were definitely clinically significant; class II, clinical responses that were probably clinically significant; and class III, clinical responses that were probably not clinically significant. The types of clinical responses are shown in Table 1. This system of classification was adapted to facilitate measurement of the outcomes of the clinical study.

#### Data Collection and Statistical Analysis

Standardized data-collection forms were used to collect information on demographics, the date and details of pacemaker implantation, pacemaker programming, base-line values, and test results. A random sample of 10 percent of the data-collection forms was read weekly by a cardiologist to ensure the accuracy of information.

We used SUDAAN statistical software to adjust variability estimates in logistic-regression models for the primary binary outcomes (e.g., any interference vs. no interference). This system uses a linear approximation for the hypothesized statistic and then

**TABLE 1.** DEFINITION OF THE THREE CLASSES OF CLINICALLY SIGNIFICANT INTERFERENCE WITH PACEMAKER FUNCTION.\*

#### Class I

Interference associated with the following symptoms: presyncope, syncope, dizziness, shortness of breath  
Transient ventricular inhibition for 3 seconds or more  
Transient atrial inhibition for 3 seconds or more in a patient with a pacing mode of AAI or AAIR  
Persistent ventricular inhibition  
Persistent atrial inhibition in a patient with a pacing mode of AAI or AAIR  
Any change in programmed settings  
Secondary events of supraventricular or ventricular arrhythmias

#### Class II†

Transient (intermittent) ventricular inhibition for more than 2 seconds but less than 3 seconds  
Transient (intermittent) atrial inhibition for more than 2 seconds but less than 3 seconds in a patient with a pacing mode of AAI or AAIR  
Transient (constant) ventricular inhibition  
Transient (constant) atrial inhibition in a patient with a pacing mode of AAI or AAIR  
Any type of interference and the presence of palpitations  
Persistent interference of the following types: undersensing, tracking, cross-talk or safety pacing, rate-adaptive sensor-driven pacing, atrial noise-reversion mode, ventricular noise-reversion mode, atrial inhibition, asynchronous pacing, mode switching  
Any of the following secondary events: pacemaker-mediated tachycardia, rate-drop response, rate-adaptive pacing

#### Class III

Any other type of interference  
Any other secondary events

\*AAI denotes atrial pacing, atrial sensing, inhibition response; and AAIR atrial pacing, atrial sensing, inhibition response, rate-adaptive.

†Intermittent transient interference lasted less than 50 percent of the duration of exposure to the telephone, and constant transient interference lasted for at least 50 percent of the period of exposure.

applies robust estimators of the variance between clusters. This provides estimates of statistical variability, resulting in estimates of risk identical to those obtained with the usual method of logistic regression adjusted for clustering. Standard logistic regression was used to model interference with any telephone or location and to test for differences in outcomes between telephones of the same type.

We analyzed potential crossover effects by looking at specific sequences of telephone allocation, including interactions between period and telephone in the above models, and modeling on only first-period data. Results were checked for consistency across sites by including either site interactions in the models or modeling data from each site separately.

## RESULTS

### Base-Line Characteristics

A total of 980 patients were tested (Table 2). Because 725 patients were tested with six telephones and 255 were tested with five telephones, there were a total of 5625 tests. Ninety-two tests were eliminated because of incomplete data. Thus, statistical analyses were based on 5533 tests.

No interference was observed in any pacemaker at base line. Abnormalities of pacing were observed at base line in 23 of 976 patients (2.4 percent). During testing, evidence of these abnormalities was not considered to be due to interference.

**TABLE 2.** CHARACTERISTICS OF THE 980 STUDY PATIENTS.

CHARACTERISTIC	VALUE*
Sex — no. (%)	
Male	638 (65.1)
Female	342 (34.9)
Age — yr	
Mean	67.4
Range	14–94
Height — cm	
Mean	170.9
Range	124–200
Weight — kg	
Mean	80.0
Range	38–184
Indications for pacing — no. (%)†	
Sinus-node dysfunction	382 (39.0)
Atrial-ventricular-node dysfunction	503 (51.3)
Neurocardiogenic syncope	134 (13.7)
Hemodynamic need	16 (1.6)
Other	36 (3.7)
Pacemaker pacing mode — no. (%)‡	
VVI or VVIR	282 (28.9)
AAI or AAIR	20 (2.1)
DDD or DDDR	640 (65.6)
DDI or DDIR	19 (1.9)
DVI	14 (1.5)
VDD	1 (0.1)
Pacemaker sensing polarity — no. (%)§	
Atrial	
Unipolar	114 (11.7)
Bipolar	571 (58.3)
Not applicable	294 (30.0)
Ventricular	
Unipolar	193 (19.7)
Bipolar	761 (77.8)
Not applicable	24 (2.5)

\*Because of rounding, not all percentages total 100.

†There may have been more than one indication for pacing.

‡VVI denotes ventricular pacing, ventricular sensing, inhibition response; VVIR ventricular pacing, ventricular sensing, inhibition response, rate-adaptive; AAI atrial pacing, atrial sensing, inhibition response; AAIR atrial pacing, atrial sensing, inhibition response, rate-adaptive; DDD atrial and ventricular pacing, atrial and ventricular sensing, inhibition and tracking response; DDDR atrial and ventricular pacing, atrial and ventricular sensing, inhibition and tracking response, rate-adaptive; DDI atrial and ventricular pacing, atrial and ventricular sensing, inhibition response; DDIR atrial and ventricular pacing, atrial and ventricular sensing, inhibition response, rate-adaptive; DVI atrial and ventricular pacing, ventricular sensing, inhibition response; and VDD ventricular pacing, atrial and ventricular sensing, inhibition and tracking response. Data were available for 976 patients.

§Data were available for 978 patients.

### Incidence of Interference

There were no changes in the programmed settings of the pacemakers during testing. The overall incidence of interference was 20.0 percent. Tracking interference sensed on the atrial channel, noise reversion or asynchronous pacing, and ventricular inhibition were the most common types of interference, with incidences of 14.2 percent, 7.3 percent, and 6.3 percent, respectively. Atrial inhibition, ven-

tricular safety pacing, undersensing, and rate-adaptive sensor-driven pacing were less common, with incidences of 2.3 percent, 1.8 percent, 0.9 percent, and 0.3 percent, respectively.

There was a marked difference between the various telephones in the incidence of interference ( $P=0.01$ ) (Table 3). The PCS-1900 and analogue telephones had the lowest incidences of interference, and the TDMA-11 had the highest incidence. There was a significant difference in the incidence of interference between analogue and digital telephones (2.5 percent vs. 23.7 percent,  $P=0.01$ ). With the NADC telephone, the incidence of interference was higher during actual transmission than during the test mode, and this effect was noted for all manufacturers of pacemakers (Fig. 1).

The incidence of interference was higher when the telephone was positioned near or over the pacemaker (12.9 percent; range, 11.4 to 13.8 percent) than when it was placed at the ear (0.2 percent,  $P=0.01$ ).

There was no significant difference in the incidence of interference according to the ventricular sensing polarity of the pacemakers (Table 4). When analyzed according to the type of lead, there also was no difference in the incidence of interference in either chamber. However, in the case of atrial sensing polarity the incidence of interference was greater for a unipolar than a bipolar configuration (Table 4). This difference may reflect differences in design and filtering in unipolar and bipolar configurations.

There was a difference in the incidence of interference according to the number of chambers that were paced (Table 4). Pacemakers programmed to a dual-chamber mode had a higher incidence of interference than those programmed to a single-chamber mode ( $P<0.001$ ).

The incidence of interference was higher among patients who were completely or intermittently dependent on pacing (20.9 percent and 21.5 percent, respectively) than among those who were not dependent on pacing (15.2 percent).

There was considerable variation in the incidence of interference according to the manufacturer of the pacemaker (Table 3). For each manufacturer, however, there was a marked variation in the incidence among individual models. This difference was most apparent between models with and those without features to minimize the effects of interference. Pacesetter models without a feed-through filter had a higher incidence of interference (28.9 percent) than those with a feed-through filter (0.4 percent,  $P=0.01$ ). Similarly, Medtronic models 7940 to 7950, which do not have a feature that minimizes interference, had a higher incidence of interference (55.8 percent) than model 7960 (0.8 percent,  $P=0.01$ ), which is functionally similar but has a feature that minimizes interference. Therefore, the incidence of

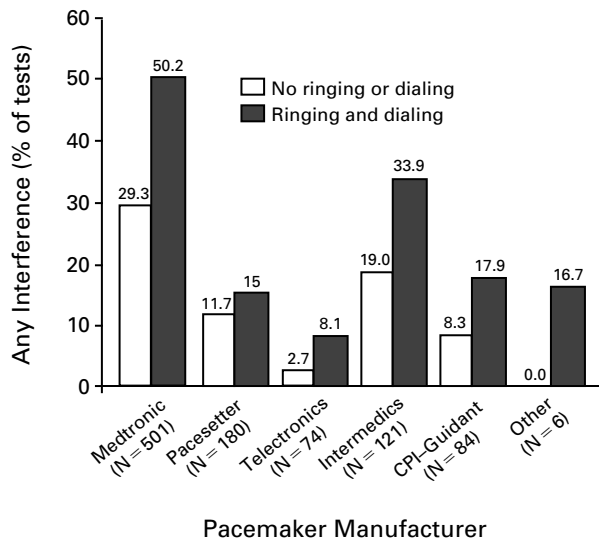
**TABLE 3.** INCIDENCE OF INTERFERENCE AND SYMPTOMS DURING TESTING.\*

CHARACTERISTIC	No. OF TESTS	% of tests (95% CI)	
		INTERFERENCE	SYMPTOMS
Telephone model			
Analogue	973	2.5 (1.5–3.4)	2.1 (1.2–2.9)
NADC — test mode	972	21.8 (19.2–24.4)	6.0 (4.5–7.5)
TDMA-11	969	52.6 (49.5–55.8)	20.8 (18.3–23.4)
PCS-1900	694	1.2 (0.4–1.9)	2.0 (1.0–3.1)
CDMA	959	15.7 (13.4–18.0)	6.6 (5.0–8.1)
NADC — actual transmission†	966	20.8 (18.2–23.4)	5.0 (3.6–6.3)
Pacemaker manufacturer			
Medtronic	2952	27.0 (25.5–28.4)	9.4 (8.4–10.3)
Pacesetter	989	7.4 (6.1–8.7)	5.2 (4.1–6.3)
Telectronics	415	7.2 (4.8–9.6)	4.8 (2.8–6.8)
Intermedics	686	24.9 (21.8–28.0)	7.4 (5.6–9.2)
CPI-Guidant	457	7.2 (5.1–9.3)	1.1 (0.1–2.1)
Other‡	34	8.8	2.9
Classification of interference			
Any interference	5533	20.0 (19.0–20.9)	NA
Class I	5533	1.7 (1.3–2.0)	NA
Class II	5533	4.9 (4.4–5.5)	NA
Class III	5533	13.4 (12.5–14.2)	NA

\*CI denotes confidence interval, and NA not applicable.

†Ringing and dialing were not included in this analysis of actual transmission.

‡This category comprised pacemakers made by several manufacturers that were present in small numbers; thus, the sample was too small for statistical testing.



**Figure 1.** Incidence of Any Interference during Exposure to an NADC Telephone, According to the Pacemaker Manufacturer. The telephone was evaluated in a test mode (no ringing or dialing) and during actual transmission (ringing and dialing).

interference according to pacemaker manufacturer largely reflected the relative distribution of pacemaker models rather than a difference in the manufacturers.

**Incidence of Symptoms**

Symptoms were noted during a weighted average of 7.2 percent of tests; however, in no case were symptoms reported when the telephone was placed at the ear. The incidence of palpitations, the most commonly reported symptom, was 4.5 percent. Lightheadedness or dizziness was reported in 1.2 percent of tests. Presyncope occurred in 0.2 percent. Syncope was never reported. However, the incidence of presyncope and syncope may have been underestimated, since the telephone could be removed at the discretion of the technician when prolonged inhibition occurred.

Symptoms also varied according to the pacemaker manufacturer and type of telephone (Table 3). Although the overall incidence of symptoms was not related to the degree of dependency on the pacemaker, the incidence of presyncope was 0.4 percent among patients who were completely dependent on their pacemakers, 0.1 percent among those who were intermittently dependent, and 0.0 percent among those who were not dependent. The incidence of presyncope was dependent on the duration of inhibition and increased as the duration of inhibition increased.

**TABLE 4.** INCIDENCE OF INTERFERENCE ACCORDING TO THE PROGRAMMED SETTINGS OF THE PACEMAKERS.

PROGRAMMED SETTING	NO. OF TESTS	INTERFERENCE		TWO-TAILED P VALUE
		% of tests (95% CI)*		
Atrial sensing polarity	3849			0.02
Unipolar	654	29.5	(24.8–34.3)	
Bipolar	3195	25.0	(23.0–26.9)	
Ventricular sensing polarity	4410			0.85
Unipolar	112	20.4	(18.3–22.5)	
Bipolar	4298	19.5	(18.5–20.6)	
Chambers paced	5415			<0.001
Single-chamber†	1631	6.8	(5.6–8.0)	
Dual-chamber	3784	25.3	(24.0–26.5)	

\*CI denotes confidence interval.

†The single-chamber pacemakers were limited to ventricular devices in our analysis, because of the small number of pacemakers with atrial single-chamber systems (20 patients, or 118 tests).

**Incidence of Clinically Significant Interference**

The incidence of clinically significant interference was low (Table 3). No class I or II interference occurred when the telephone was positioned at the ear. The incidence of class I and of class I and II interference varied according to the pacemaker manufacturer and type of telephone (P=0.01).

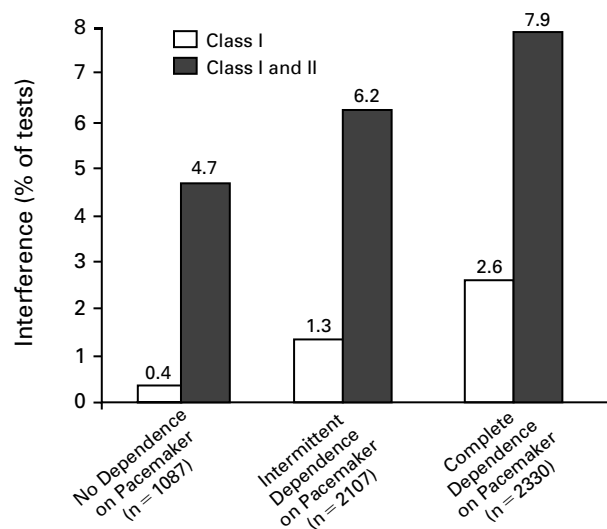
The incidence of class I and of class I and II interference was associated with the degree of dependence on the pacemaker (Fig. 2). Patients who were completely dependent on the pacemaker had the highest incidence of class I and of class I and II interference. This difference may have been due to the fact that interference is more apparent in these patients; the incidence of true interference may not be determined by the degree of pacemaker dependency. With respect to the overall incidence of interference, the incidence of class I and of class I and II interference was higher among pacemakers programmed to a dual-chamber mode than those programmed to a single-chamber mode. The incidence of class I interference was 2.0 percent among dual-chamber pacemakers, as compared with 0.9 percent among single-chamber pacemakers (P=0.01). The incidence of class I and II interference was 8.3 percent among dual-chamber pacemakers, as compared with 2.7 percent among single-chamber pacemakers (P=0.01). (The single-chamber pacemakers were limited to ventricular single-chamber devices in our analysis, because of the small number of pacemakers with atrial single-chamber systems.)

**DISCUSSION**

Many forms of electromagnetic energy could potentially interfere with the function of implanted cardiac pacemakers. In hospitals, magnetic resonance imaging scanners, lithotripsy devices, and other med-

ical equipment can result in interference. In other settings, there are relatively few electromagnetic sources that would interfere with the function of pacemakers — examples include high-amperage welding equipment and degaussing equipment. The potential for cellular telephones to interfere with pacemakers has only been recognized since 1994. Beginning with in vitro studies, several investigators have demonstrated various forms of interference resulting from cellular telephones.<sup>1-4</sup> Several small studies have demonstrated that interference may occur with various digital telephones, whereas analogue telephones appear to cause no interference.<sup>5-8</sup>

The cohort tested in this multicenter study was representative of the typical U.S. population with pacemakers in terms of demographics and the brand of implanted pacemakers (Tables 2 and 5). There was a wide range in the incidence of interference. The overall incidence of interference — 20 percent — was high. However, to use this single percentage out of context would be clinically misleading. The incidence of interference when the telephone was positioned at the ear, which is considered the normal position, was very low, and none of the episodes of interference were clinically significant, which is evidence of the safety of normal use. The incidence of interference and of clinically significant interference, in particular, was also highly variable according to the combination of the type of telephone being tested, the pacemaker manufacturer, and the pacemaker model. If the results for the TDMA-11 telephone, which is not being commercially produced, are eliminated from the analysis, the incidences of interference and clinically significant interference drop to 13.1 percent and 2.8 percent, respectively. The inci-



**Figure 2.** Incidence of Class I and of Class I and II Interference According to the Degree of Dependence on the Pacemaker.

**TABLE 5.** PREVALENCE OF THE VARIOUS PACEMAKERS AMONG THE 980 STUDY PATIENTS AND U.S. MARKET SHARE.

MANUFACTURER	PREVALENCE AMONG STUDY PATIENTS	U.S. MARKET SHARE
	percent	
Medtronic	52.1	50.0
Pacesetter	18.6	28.0
Intermedics	12.5	11.0
CPI-Guidant	8.6	6.0
Telectronics	7.5	2.0
Other	0.7	3.0

dence of interference continued to be highly variable according to the manufacturer of the pacemaker. Even for a given manufacturer, the incidence varied depending on the model of the pacemaker, reflecting the effect of the pacemaker's design on its susceptibility to interference.

We examined a number of variables as predictors of interference. Perhaps because the atrial channel of a dual-chamber pacemaker is more sensitive, there is a greater likelihood of tracking and noise reversion in response to electromagnetic interference. Consequently, there was a higher incidence of interference in dual-chamber pacemakers. Although it is well known that pacemakers with a unipolar sensing configuration are more susceptible to many forms of electromagnetic energy than pacemakers with a bipolar sensing configuration, we found a similar incidence of interference among pacemakers with unipolar and those with bipolar sensing configurations. However, because we did not change the polarity during our study it is not possible to determine the exact role of polarity. Data have shown that interference from cellular telephones occurs at the header of the pacemaker and does not appear to depend on the distance between the cathode and anode of the sensing circuit, making sensing polarity a less important factor.<sup>15</sup>

The highest incidence of interference occurred when the telephone was directly over the pacemaker. Although this positioning might occur if the activated telephone was carried in a pocket directly over the pacemaker, it is certainly not a normal position and could be consciously avoided. As stated earlier, there was minimal interference when the telephone was positioned at the ear. This finding is in agreement with other studies examining the effect of distance on the incidence of interference. Many studies have confirmed that to cause interference the cellular telephone must be no farther than 8 to 10 cm from the pacemaker.<sup>5,9,10</sup>

Tracking of telephone-induced interference by the atrial sensing circuitry was the most common type of

interference. Although tracking results in paced rates that are physiologically inappropriate in the absence of exertion, the rate of tracking was always limited by the programmed upper rate limit of the pacemaker, which had been set by the patient's physician.

Ventricular inhibition was the next most common type of interference. Clinically, ventricular inhibition is potentially one of the most deleterious forms of interference, and a pause of more than three seconds is frequently considered to be clinically significant. In addition, the frequency of symptoms such as presyncope increased with the duration of ventricular inhibition.

Although symptoms were present during 7.2 percent of tests, the majority were due to palpitations. The incidence of presyncope was highest among patients classified as being completely dependent on the pacemaker. Therefore, the greatest potential risk of presyncope was among patients who were at least intermittently dependent on the pacemaker. When episodes associated with TDMA-11 telephones were eliminated, the incidence of presyncope was lower.

Specific changes in the design of pacemakers, such as the inclusion of feed-through filters, may limit electromagnetic interference, as was seen with certain models of Medtronic and Pacesetter pacemakers. However, although design changes in pacemakers have significantly reduced the rates of interference, changes in the design of cellular telephones could result in the potential for pacemaker interference, thus requiring further testing.

One limitation of this study was that every potential variable was not specifically examined. The only distances tested were the distance from the telephone held at the ear to the pacemaker and the distance from the telephone held directly over the pacemaker to the pacemaker. Programmed settings of pacemakers such as those involving sensitivity, polarity, and mode were not varied; instead, the usual settings were used.

There were also limitations regarding the incidence of symptoms. Because patients were seated at an angle of 60 to 90 degrees, we could not rule out the possibility that the incidence of symptoms might increase among patients who stand while using the telephone. In addition, the technician was permitted to remove the telephone if there was a prolonged pause due to interference. Therefore, the incidence of symptoms and the duration of interference may be underestimated.

Although the distribution of the brands of pacemakers in our patients approximated the U.S. market share, many models were underrepresented. Specifically, VDD (ventricular pacing, dual-chamber sensing, with capability of tracking and inhibition as the response mode) single-pass lead systems were not studied and might have different incidences of interference.

The analogue telephone was associated with the lowest incidence of clinically significant interference and therefore appears to be the safest. Although the PCS-1900 telephone was also associated with a low incidence of interference, further testing should be done with the telephone in the discontinuous-transmission mode, which was not tested in this study, before the use of this telephone can be recommended for patients with pacemakers.

The degree of dependence on the pacemaker must be considered, and for patients who have ever been classified as dependent, analogue telephones appear to be the safest. For patients who have always been classified as not dependent on the pacemaker, the use of any of the telephones that were tested in this study in the normal position is likely to result in a very low incidence of clinically significant interference.

Use of telephones in the normal position — at the ear — was associated with the lowest incidence of interference of any position tested and did not result in any clinically significant interference. Placement of the telephone over the pacemaker should be avoided. While the telephone is on, it should not be carried in a pocket over or close to the pacemaker.

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