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The Effects of Mobile Phones on Pacemaker Functions

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MOBİL TELEFONLARIN KALP PİLİ FONKSİYONLARI ÜZERİNDEKİ ETKİLERİ

ÖZET

Çeşitli sistemler tarafından oluşturulan elektromanyetik alanın kalp pili fonksiyonları üzerindeki olumsuz etkileri bilinmektedir. Bu çalışmanın amacı mobil telefonların kalp pili fonksiyonları üzerindeki etkilerini değerlendirmektir. Bu amaçla 679 kalıcı kalp pilli hasta üzerinde çalışıldı. Çalışma iki basamak halinde uygulandı. Kalp pili lead polaritesi birinci basamakta unipolar, ikinci basamakta bipolar olarak ayarlandı. Her iki basamakta kalp pili sensitivitesi önce nominal değerlerde iken, daha sonrada o kalp pili için minimal değere indirilerek test yapıldı. Kalp pili cebine göre simetrik olarak yerleştirilen iki farklı mobil telefon (power output 2W, GSM 900 MHz) ile 50 cm, 30 cm, 20 cm, 10 cm ve mobil telefon antenleri kalp pili cebi ile temas ettirilerek, mobil telefonların açılma, standby, çaldırma, konuşulma ve telefonların kapatılması aşamasında test yapıldı. Otuzyedi kalp pilli hastada etkilenme saptandı (%5.5). Lead polaritesinin unipolar olması durumunda etkilenme bipolar olmasına göre daha fazlaydı (Sırayla %4.12, %1.40, $p<0.05$). Sensitivitenin artırılması kalp pili etkilenme oranı üzerinde tek başına etkili değildi ($p>0.05$). Etkilenme açısından iki ve tek boşluklu kalp pilleri arasında fark yoktu ($p>0.05$). Bir DDD-R kalp pilinde ventriküler tetiklenme, 33 VVI(R) kalp pilinde asenkron moda geçiş ve 3 VVI kalp pilinde inhibisyon saptandı. Kalp pili yaşı ilerledikçe mobil telefondan etkilenme oranı artıyordu ($p<0.05$). Etkilenmelerin hepsi reversibl idi.

Sonuç olarak mobil telefonlar belli şartlar altında kalp pili fonksiyonları üzerinde olumsuz etkilere neden olabilirler. Etkilenme durumu, kalp pili inhibisyonu hariç hastalarda önemli bir semptoma neden olmaz ve mobil telefonun uzaklaştırılmasıyla normale döner. ***Türk Kardiyol Dern Arş 2002; 30: 699-709***

Anahtar kelimeler: *Kalp pili, mobil telefon, elektromanyetik etkileşim*

The effect of electromagnetic field that is generated by different systems, on medical devices and pacemakers is very well known [1-3]. The fact that the use of mobile phones is increasing at a rapid pace, is creating public health problems due to the negative effects of the electromagnetic field that is generated [4-8]. One of such problems is the effect on permanent pacemakers by the electromagnetic field generated by mobile phones.

Mobile phones are devices which transfer voice messages by utilizing radio waves of different frequency and the perception of the signals that are generated during opening, stand-by, accepting a call, closing the mobile phone by the pacemaker perception circuit might result in oversensing and undersensing. This might create permanent or temporary changes in pacemaker functions.

In the studies conducted, it was demonstrated that the effects on the pacemakers can be influenced by the mode of the pacemaker, lead polarity and sensitivity, power output of the mobile phone, the size of its antenna and the distance between the mobile phone and the pacemaker [9-11]. The mobile phones that operate with the digital technology Global System for Mobile Communication (GSM) can have negative effects on pacemaker functions, although there are in vitro [10,12-14] and clinical studies [9,15-19] aimed at demonstrating such effects, the question of whether the use of mobile phones is safe for patients with pacemakers has not been clearly replied.

We have tested the effects of GSM 900 MHz mobile phones that operate with digital technology on pacemakers, we tried to identity if there was such an effect, under which circumstances this effect occurred and what type of measures could be taken for prevention.

METHODS

Patients and pacemakers: The study was performed during 1999-2001 on 679 patients who were implanted with

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transvenous pacemakers at different intervals and were coming to routine pacemaker control visits. The aim of the study was explained to all of the patients. The oldest pacemaker was implanted 16 years ago and the newest one only one day before the study. There were pacemakers from 8 different manufacturers. Of the 679 pacemakers; 535 were in VVI-R mode, 68 were VVI, 35 were in DDD-R, 8 were in DDD, 14 were in VDD, 1 was in AAI-R and 18 were in AAI mode. Except for the 7 VVI pacemakers which were unipolar, all the others were multi programmed and were using 6 different rate response sensors [of 571 pacemaker patients who had rate response sensors, 194 had minute ventilation, 212 had body activity sensors (piezoelectric sensor or accelerometer), 42 had QT interval sensors, 73 had minute ventilation - body activity sensors and 49 had minute ventilation -QT interval sensors].

Mobile Phones: Two mobile phones with external antenna were utilized in the study (Nokia 6150 power output 2 W, Nokia 6110 power output 2W); they were operating with GSM 900 MHz digital system.

Study Protocol: The study was performed under the emergency department conditions with continuous electrocardiography monitorization. In patients who had their own heart rhythms, the rate of the pacemaker was changed with a programmer to a value that was 10 beats/ minute above that of the patient and pacemaker rhythm was established (113 patients).

The study was done in two steps. In the first step, the lead polarity of all the pacemakers were converted to unipolar, the pacemaker sensitivity first had nominal values, then it was reduced to minimum value for that pacemaker (sensitivity was maximum) and tested. In the second step, pacemaker lead polarity was converted to bipolar and again, pacemaker sensitivity was first at nominal values and then reduced to minimum values for that pacemaker and tested. At both steps, two mobile phones were located on either side of the pacemaker being equidistant from the pocket. This distance was 50 cm in the beginning. One phone was used to call the other. After 20 seconds of ringing the other phone accepted the call. The call was terminated after talking for 20 seconds. Afterwards, the same procedure was repeated by placing both of the mobiles at 30 cm, 20cm, and 10cm and at direct contact with the pacemaker pocket.

For assessing the effect of mobile phones, several parameters such as pacemaker sensitivity and lead polarity, pacemaker mode, the presence of rate response sensor and its type, the age of the pacemaker, how the effect occurred, the distance between the mobile and the pacemaker pocket when the effect occurred and the symptoms that developed in the patients were evaluated (the evaluation related to the rate response sensor was done at only nominal values of the sensor).

If the pacemaker was affected at any stage of the study, the test was stopped due to ethical considerations and further steps were not performed.

When the lead polarity was unipolar and the pacemaker sensitivity was at minimal values, 19 patients (7 with VVI-R, 7 with DDD-R and 5 with VDD pacemaker) developed T wave oversensing, in these patients the test was performed when the lead polarity was unipolar with the sensitivity at nominal values and the test was not carried out at minimal sensitivity values. When lead polarity was bipolar and the sensitivity was at minimum values, 18 patients (7 with VVI-R, 6 with DDD-R, 5VDD) developed T wave oversensing, and this stage of the test could not be performed. (These patients were the same patients who developed T wave oversensing when the unipolar pacemaker sensitivity was at maximum values). In these patients, we did not find it ethical to reduce the sensitivity to levels at which T-wave oversensing did not develop and perform the test.

At the end of the study, we determined the age of the pacemaker according to the date of implantation and evaluated the effect of age on the results. The pacemakers that were implanted during the last year were accepted as 1 year-old.

The nominal value of the pacemaker sensitivity was 2.5±0.5mV for the ventricle and 1.5±1 mV for the atrium. When the sensitivity was reduced to minimum values, these were 1± 0.5 mV and 0.25± 0.15mV, respectively.

Average duration of test was 22 minutes for each patient during the study. In order to avoid the possibility of perceiving the myopotantials generated by the patient, care was given to have the patient in supine bed-rest position with the least movement possible. At the end of the study, the pacemaker lead polarity and sensitivity values were converted to their initial status in all of the patients. All nonadjusted pacing parameters were checked for electromagnetic interference induced reprogramming.

Statistical Analysis: The data was expressed as mean ±SD. For the comparison of clinical parameters student t test was used. Life table method was used to evaluate the rate of being affected at each step. For comparing the results, chi-square single sampling test was utilized. Linear and logistic regression analyses were used to evaluate the effect of pacemaker age on the results. P value of < 0.05 was accepted as statistically significant.

RESULTS

Six hundred seventy nine patients (188 females; 491 males, average age 68 ± 7 years) who had transvenous permanent pacemakers at different dates were included in the study. Patient characteristics are summarized on table 1.

Mobile phone-pacemaker interactions all occurred when the antennas of the mobile phones were in direct contact with the skin overlying the pacemaker pocket or at a distance of 10 cm. When the tests were performed with the antennas being at 20, 30, 50 cm. of distance, none of the pacemakers were affected. All of these effects occurred when the mobile phones were ringing and when the talk was continuing. During the opening and closing there was no effect.

Table 1. Clinical features of the study patients

Patients	679
Female/Male	188/491
Age (year)	68±7
ECG findings before the implantation	
Sick sinus syndrome	285 (42%)
AV block	312 (46%)
Other	82 (12%)
Pacemaker type	
VVI	68 (10%)
VVI-R	535 (79%)
DDD	8 (1.2%)
DDD-R	35 (5.2%)
VDD	14 (2%)
AAI	18 (2.6%)
AAI-R	1 (0.1%)

At the first step, the lead polarities of 679 pacemakers were converted to unipolar with the programmer. The test was performed when the sensitivity was at nominal values. When the mobiles were placed at 10 cm. of distance, 3 VVI pacemakers switched to asynchronous mode during the talk. When the antennas were in contact with the pacemaker pocket, 9 VVI-R and 4 VVI pacemakers switched to asynchronous mode when the mobile was ringing. At this stage of the test, when the lead polarity was unipolar and the sensitivity was at nominal values, 16 pacemakers (2.4%) were affected (Table 2).

When the lead polarity was unipolar and the sensitivity was at minimum values, 19 pacemakers (7 VVI-R, 7 DDD-R and 5 VDD) developed T wave oversensing and these patients were not included to this stage of the test. Sixteen other patients who were affected at the previous stage were not included to this stage either. At this stage of the test 644 patients with pacemakers (519 VVI-R, 61 VVI, 28 DDD-R, 8 DDD, 9 VDD, 1 AAI-R and 18 AAI) were tested. When mobiles were 10 cm away from the pacemaker pocket, 2 VVI-R pacemakers switched to asynchronous mode during ringing, 1 VVI-R and 6 VVI pacemakers switched to asynchronous mode during the talk. When the antennas of the mobile phones were in contact with the pacemaker pocket, 3 VVI pacemakers had inhibition during ringing (Fig. 1). At this stage of the test, when the lead polarity was unipolar and sensitivity was maximum 12 pacemakers (1.8%) were affected (Table 2).

At the second stage of the study, lead polarity was converted to bipolar in 644 patients with pacemakers (523 VVI-R, 45 VVI, 35 DDD-R, 8 DDD, 14 VDD, 1 AAI-R and 18AAI) and the test was performed. (28 patients who were affected at the first stage and 7 patients with VVI pacemakers whose lead polarity could not be converted to bipolar mode technically were not included to this stage). When the lead polarity was bipolar and pacemaker sensitivity was at nominal values, 2VVI-R pacemakers (0.3%) switched to asynchronous mode when the mobile phones were at a distance of 10 cm and the talk was continuing.

When the lead polarity was bipolar and the pacemaker sensitivity was at minimal values, 18 patients developed T wave oversensing (7 VVI-R, 6 DDD-R, and 5 VDD) and were not included to this stage of the study. This stage was performed with 624 patients (514 VVI-R, 45 VVI, 29 DDD-R, 8 DDD, 9 VDDD, 1 AAI-R and 18 AAI). 1 VVI and 3 VVI-R pacemakers switched to asynchronous mode during ringing from 10 cm of distance. At the time of contact with the pacemaker pocket, 2 VVI-R pacemakers switched to asynchronous mode and ventricular triggering developed in 1 DDD-R pacemaker (vent-

Table 2. Life table method

	Pacemakers patients	Out of study	The numbered of affected patients	The rate of being affected (%)*	The rate of not being affected**
Unipolar, nominal s.	679		16	2.4	97.6
Unipolar, max s.	663	19	12	1.8	95.8
Bipolar, nominal s.	644	7	2	0.3	95.6
Bipolar, max. s.	642	18	7	1.1	94.5

The rate of being affected and not being affected** from the start till the end of the study at each stage. s.: Sensitivity*

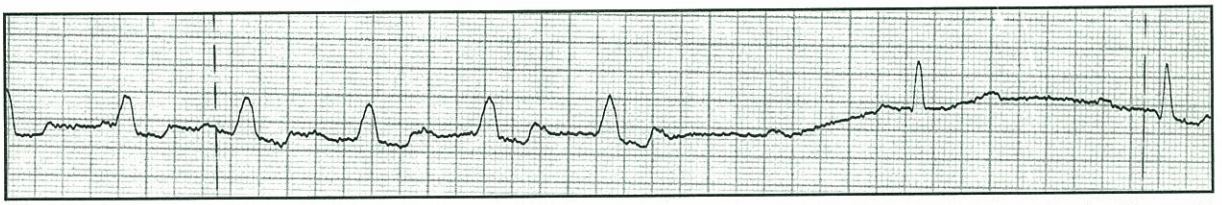

Figure 1. A patient with VVI pacemaker who developed pacemaker inhibition during the test. pacemaker inhibition developed at 14 seconds following the ringing of the phone, patient's own rhythm started 2.2 seconds later.

ricular rate reached the upper limit of the programmed rate). At this stage of the test, when the lead polarity was bipolar and the sensitivity was at maximum, 7 pacemakers (1.1%) were affected (Table 2).

The rate of being affected according pacemaker age calculated by the date of implantation is presented on table 3. The oldest pacemaker was 16 years old; the newest one was 1 year old. The risk of being affected increased as the age of the pacemaker got older.

One DDD-R patient who had ventricular triggering and 1 VVI-R patient who had asynchronous mode at the first step and 1 VVI-R and 2 VVI patients who had asynchronous mode at the second step complained of palpitation. Of the 3 VVI patients who had inhibition, one developed presyncope.

In this study, none of the patients had permanent changes in pacemaker programs or functions, the changes returned to normal after the removal of the mobile phone.

Interpretation of results:

1. Total rate of being affected: During the length of the study, when the lead polarity was bipolar and unipolar, when the sensitivity was at nominal values and was reduced to minimal values, out of 679 pacemaker patients, 37 patients were affected and total rate of being affected was calculated as 5.5%.

2. The effects of lead polarity and sensitivity on the results: The effects of pacemaker sensitivity and the lead polarity on the results are summarized on table 2. At the first step of the study, lead polarities of 679 pacemakers were converted to unipolar and 28 patients with pacemakers were affected (4.12%). When the lead polarity was converted to bipolar, 9 patients with pacemakers (1.40%) were affected. The rate of being affected was higher when the lead polarity was unipolar when compared with the bipolar state ($p< 0.01$) (Table 2).

When the test was conducted at nominal values of pacemaker sensitivity, after 1323 tests (trials) 18 pacemakers were affected (1.36%). When the sensitivity was increased to maximum, 19 pacemakers (1.50%) were affected after 1268 trails. The nominal and minimal values of sensitivity did not have any influence on the rate of being affected ($p>0.05$) (Table 2).

When the lead polarity was unipolar, the rate of being affected was 2.4% at nominal sensitivity values, and 1.8% at minimal sensitivity values. There was no difference between the two percentages ($p>0.05$). When the lead polarity was converted to bipolar, the rate of being affected was 0.3% at nominal values of sensitivity and 1.1% at minimal values, there was no any difference between the two values ($p>0.05$) (Fig. 2).

When the sensitivity was at nominal values, the rate of being affected was 2.4% when the lead polarity was unipolar and 0.3% when it was bipolar. Unipolarity increased the rate of being affected ($p<0.01$) to a significant degree. When the sensitivity value was minimal, the rate of being affected was 1.8% when the lead polarity was unipolar and 1.1% when it was bipolar. There was not any difference between the two values ($p>0.05$) (Fig. 2).

When the lead polarity was unipolar and the sensitivity was at nominal values, the rate of being affected was 2.4%. When the lead polarity was bipolar and sensitivity was at minimal values, it was 1.1%. The difference between the two was not significant ($p>0.05$). When the lead polarity was unipolar and sensitivity was minimal, the rate of being affected was 1.8%, when the lead polarity was bipolar and the sensitivity had nominal values, the rate of being affected was 0.3%. The rate of being affected was higher at the minimum sensitivity level of the unipolar pacemaker ($p<0.01$) (Fig. 2).

With these results, the negative effects of the electromagnetic field generated by the mobile phones on the

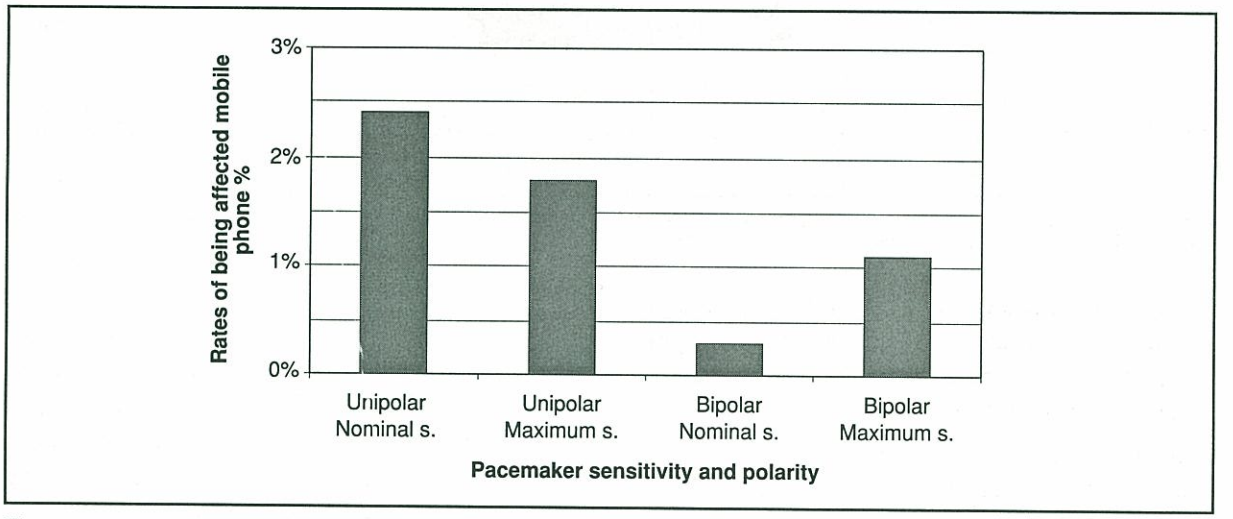

Figure 2. The rate of being affected by mobile phones according to pacemaker sensitivity and polarity. (S:Sensitivity)

pacemakers were seen most significantly when the lead polarity was unipolar and the sensitivity had nominal values (2.4%). The lowest risk was present when the lead polarity was bipolar and the sensitivity had nominal values (0.3%) (Table 2).

3. The mode of the pacemaker: Of the 679 pacemaker patients who were recruited in the study, 603 had VVI(R) and 43 had DDD(R) pacemakers. Of the 603 VVI (R) pacemakers, 36 (5.97%) were affected, of the 43 DDD (R) patients 1(2.32%) was affected. There was not any difference between the results in that sense ($p>0.05$). When single chamber and dual chamber pacemakers were compared, of 622 single chamber pacemakers [VVI, AAI (R)] 36 (5.78%) were affected, of 57 dual chamber pacemakers (DDD(R), VDD) only 1 (1.75%) was affected and there was no difference between the two groups ($p>0.05$). Of the single chamber pacemakers, only VVI and VVI-R pacemakers were affected; out of 68 VVI pacemakers, 17 (25%) were affected, of 535 VVI-R pacemakers 19 (3.55%) were affected. VVI pacemakers were more affected when compared to VVI-R ($p<0.001$).

4. The effect of the presence or the absence of the rate-response sensor on the results: Of the 37 patients who were affected, 36 were VVI(R) and 1 was DDD-R. The effect of the presence or absence of the rate-response sensor on the results was evaluated on patients with VVI-R pacemakers. Of the 36 VVI(R) patients who were affected, 19 were VVI-R and 17 were VVI pacemaker patients. 3.55% of the VVI-R pacemakers and 25% of VVI pacemakers were affected. The rate of being affected was significantly high in VVI pacemakers when compared to VVI-R ($p<0.001$).

The type of rate-response sensor: Of the 19 VVI-R patients who were affected, 11 had body activity sensors, 8 had minute ventilation type sensors. One DDD-R pacemaker had minute ventilation and body activity sensor. We do not find it correct to give a percentage with the figures we have in hand.

5. The type of the effect observed on the pacemaker: 36 VVI (R) and 1 DDD-R pacemaker patients were affected. The patient with the DDD-R pacemaker experienced ventricular triggering. Of the 36 VVI (R) pacemaker patients, 33 converted to asynchronous mode (91.7%) and 3 (8.3%) were inhibited. Switching to the asynchronous mode was more common than inhibition ($p<0.001$) (Table 4).

6. The role of telephone-pacemaker distance on the rate of being affected: Of the 37 pacemaker patients who were affected, 18 (48.6%) experienced the effect while the phone was at a distance of 10 cm; whereas 19 (51.4%) had it while the phone was in contact. Having the telephone at a distance of 10cm or having the antenna in contact with the pacemaker pocket did not alter the rate of being affected ($p>0.05$) (Tablo 4). When mobile phones were placed at 20, 30 and 50 cm of distance, none of the pacemakers were affected.

7. The effect of the phase of the mobile phone utili-

Table 3. The pacemaker age calculated by the date of implantation- the number of pacemakers that are affected at that age group

Pacemaker type	Pacemaker age (year)											
	1	**2**	**3**	**4**	**5**	6	7	8	10	12	13	16
VVI-R → 535/19	191/6	86/3	82/3	79/2	29/-	22/1	35/3	9/1	2/-	-/-	-/-	-/-
VVI → 68/17	3/-	5/1	1/-	5/2	3/-	8/1	14/4	17/5	5/1	5/2	1/1	1/-
AAI-R → 1/-	1/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
AAI → 18/-	3/-	7/-	1/-	2/-	1/-	-/-	2/-	2/-	-/-	-/-	-/-	-/-
DDD-R → 35/1	15/-	16/1	1/-	1/-	-/-	-/-	2/-	-/-	-/-	-/-	-/-	-/-
DDD → 8/-	1/-	-/-	5/-	1/-	-/-	2/-	-/-	-/-	-/-	-/-	-/-	-/-
VDD → 14/-	12/-	-/-	-/-	-/-	-/-	2/-	-/-	-/-	-/-	-/-	-/-	-/-
TOTAL → 679/37	224/6	115/5	90/3	88/4	33/-	34/2	53/7	28/6	7/1	5/2	1/1	1/-

Table 4. The mode of the pacemaker, the type of the effect, the stage and the distance at which the effect has occurred and the developing symptoms in 37 pacemaker patients who were affected by the mobile phone

	The type of effect			The stage of effect		The distance of effect		Symptoms	
	Asynchronous	Inhibition	Ventricular triggering	Ringing	a	10 cm	Contact	Palpitation	Presyncope
VVI-R	19			18	1	8	11	2	
VVI	14	3		8	9	10	7	2	1
DDD-R			1	1			1	1	
TOTAL	33	3	1	27	10	18	19	5	1

zation on the results: Of the 37 pacemaker patients who experienced an effect, 27 (73%) had this while the phone was ringing and 10 (27%) had it during the talk. The rate of being affected was higher at the ringing phase ($p<0.001$) (Table 4). None of the pacemakers were affected when the mobile phones were opened and closed.

8. The influence of pacemaker age on the results: For the 679 pacemaker patients who were included in the study, the pacemaker age that was calculated according to the date of implantation and for the pacemakers at that age group the rate of being affected by the mobile phone are being presented on table 3. The rate of being affected was 2.7% for the pacemakers that were one year old, 5.9% for the ones that were 6 years old and 40% for the ones that were 12 years old. As the pacemaker age increased, the rate of being affected increased linearly as well ($p<0.05$) (Fig. 3).

When the distribution of pacemakers were evaluated in terms of years, VVI pacemakers were older than VVI-R ($p<0.05$). In the linear regression analysis, it was shown that the higher rate of being affected that was observed in VVI pacemakers was due to the fact that they were older than VVI-R pacemakers ($p<0.05$) (Fig. 4).

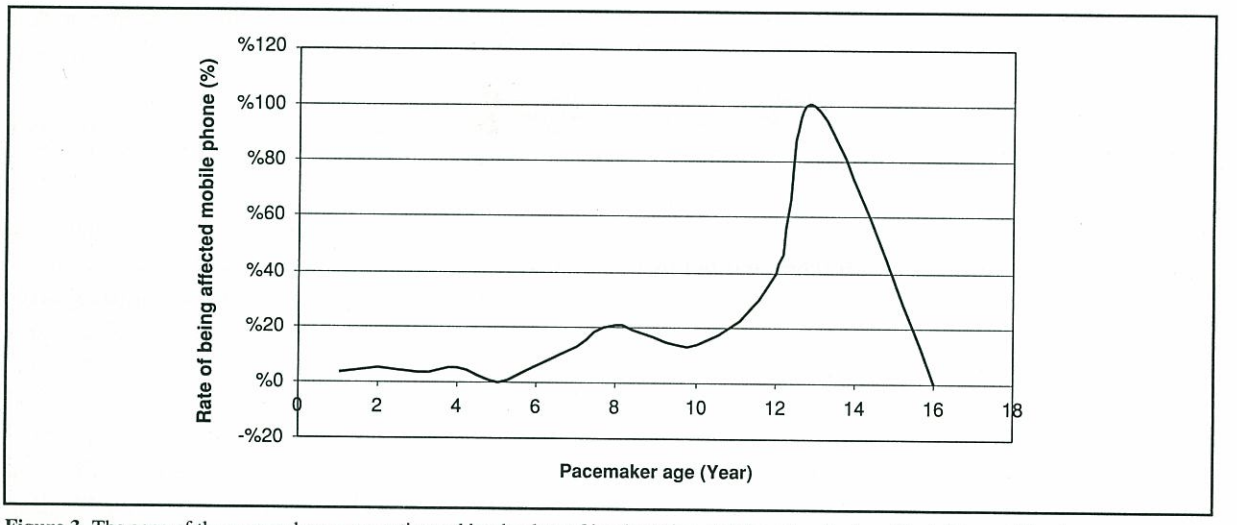

Figure 3. The ages of the pacemakers were estimated by the date of implantation and the rate of being affected by mobile phones

9. Symptoms that the patients experienced: 1 DDD-R patient who had ventricular triggering and 4 patients out of the 33 VVI (R) pacemaker patients who switched to asynchronous mode experienced palpitation. Of the 3 VVI pacemaker patients who had inhibition, two developed delayed spontaneous rhythm and no symptoms were observed. One patient who experienced presyncope returned to normal with the removal of the mobile phone. As a result 16.2% of the 37 pacemaker patients who were affected became symptomatic, 13.5% had palpitation while 2.7% developed presyncope (Table 4).

DISCUSSION

This is a clinical study trying to identify the effects of electromagnetic field generated by mobile phones that are currently used worldwide on transvenous permanent pacemaker function. In our study, we demonstrated the presence of such an effect without any doubt and found the affection rate as 5.5% in 679 pacemaker patients.

In 1994, in the annual scientific meeting of Bioelectromagnetic Association, 3 independent groups made presentations [8,20,21] about the possible negative effects of mobile phones on pacemakers for the first time, and first in vitro studies were initiated. Moberg et al [12], in their study on unipolar pacemakers, could not demonstrate any effect of GSM mobile phones. Irnich et al [10] identified the rate of being affected as 44.6%. Other in vitro studies yielded contradicting results [13,14,22,23]. The results of these in vitro studies are very valuable; however they cannot be totally identical with the in vivo systems [10]. These tests that are performed in special solutions can not reflect the natural environment of human body. In vitro studies cannot totally evaluate the behavior of a pacemaker that is in human body, in contact with a contracting heart, pacing and sensing continuously; in an electromagnetic field.

Barbaro et al [17] identified intermittent pacemaker inhibition in 10 (10%) of 101 pacemaker patients, ventricular triggering in 9 (20%) of 46 dual chamber pacemaker patients and asynchronous pacing in 4 (8%) of 52 pacemaker patients. Naegeli et al [9] identified an effect in 18% of the patients in their study of 39 pacemaker patients. The rate of being affected was 2.8 % for dual chamber pacemakers and

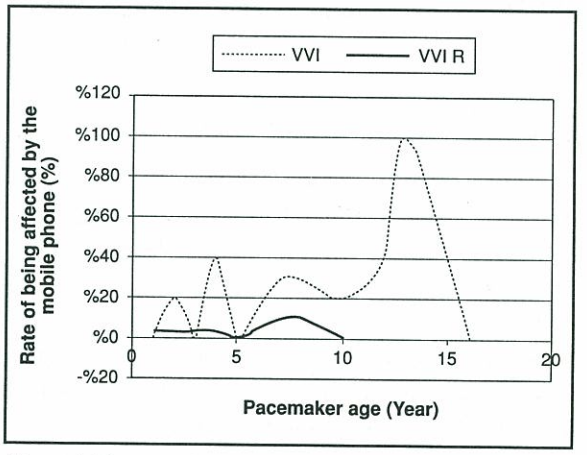

Figure 4. The ages of VVI and VVI-R pacemakers according to date of implantation and their rate of being affected by the mobile phone

5.6% for VVI pacemakers. Total rate of being affected was 3.1% in the study by Chen et al [18] and 20 % in the study by Hayes et al [24]. Naegeli et al [9] and Chen et al [18] reported that the effect was more significant in unipolar mode compared to bipolar mode. Wilke et al [25] did not report any effect on bipolar mode. Their findings were confirmed by Grimm et al [26]. Hayes et al [24] who reported that having a bipolar or unipolar sense polarity was not influential on the effects on the pacemaker. However, they added that, if the atrial sense polarity was unipolar, the rate of being affected was higher than that of bipolar. However, they did not perform any tests by changing pacemaker sense polarity in their study and they could not totally demonstrate the importance of pacemaker polarity on being affected. Irnich et al [10] identified similar rates for being affected in bipolar and unipolar modes in their study, however theirs was an in vitro study. The pacemakers might be affected similarly from lead unipolarity and bipolarity in vitro studies; however these results can not reflect the in vivo conditions of clinical studies. When a unipolar pacemaker is implanted into the human body, the body itself is responsible from part of the electrical flow route. In mobile phone pacemaker interaction, the electromagnetic field is effective on the part of the electrode that is not inside the thorax [9]. In unipolar mode, the surface of exposure for the electromagnetic field is increased in the pacemaker and the electrode. As the lead polarity was unipolar in our study, there was a high risk of being affected ($p<0.05$).

In most of the studies, when the pacemaker sensitivity was increased to maximum values, the risk of being affected is reported to be higher for mobile phones [9-11,15]. Under normal conditions, the signals generated by the mobile phones are externalized by the filter of the pacemaker. Because these signals are different than the cardiac depolarization signals that the pacemaker normally perceives. Continuous signals generated by the analog mobile phones and intermittent signals generated by the digital mobile phones, can be perceived by the pacemaker when they have a wide spectrum. In that sense, analog systems have been reported to be more dangerous than the digital systems [15,27]. Increase in the lead sensitivity means the perception of these signals at a wider spectrum [28]. We could not demonstrate a significant difference in the effects on the pacemaker when the sensitivity had nominal and minimum values. When the sensitivity was decreased to minimal values, having a unipolar or bipolar lead sensitivity did not change the rate of being affected ($p>0.05$). When the sensitivity was at nominal values, the rate of being affected was 0.3% with a bipolar lead polarity and 2.4% with a unipolar lead ($p<0.01$). Although there was a difference in the rate of being affected between unipolar and bipolar lead configurations at nominal values of sensitivity, such a difference did not exist when the sensitivity was maximal ($p>0.05$) (Fig.2). Utilizing a different study protocol than the previous studies might have an effect on this result that we have obtained [9-11,15]. We first performed the test at nominal sensitivity values with both unipolar and bipolar leads. The patients who were affected at this step were not included in the further stages. We thought that it would be unethical to repeat the test with minimal sensitivity values on these patients who were already affected at nominal values. It is highly probable that such patients would be affected at minimal sensitivity values as well, which means if the test had been repeated with minimal sensitivity values, the number of patients that would have been affected would be significantly high.

In our study, the rate of being affected was not different in single chamber and dual chamber pacemakers. Our results correlate with that of Naegeli et al [9] in that regard. Hayes et al [24] reported a higher rate of being affected for dual chamber pacemakers; due to atrial noise reversion (mode switch) when compared to single chamber ones. They explained this difference by the fact that the patients who were implanted with dual chamber pacemakers had severe atrioventricular block and frequently had low atrial sensitivity values. According to this line of thought, the risk of being affected by mobile phones should be higher in AAI (R) pacemakers, because the sensitivity filter is not different in single or dual chamber pacemakers. However, in both our study and the previous studies, the rate of being affected by the mobile phones was not high for AAI(R) pacemakers. According to our results, pacemaker sensitivity was not the single factor that was effective for defining the risk brought by mobile phones. Of the single chamber pacemakers that were affected in our study, 19

were VVI-R and 17 were VVI. The rate of being affected was 25% for VVIs, 3.55% for VVI-R pacemakers ($p<0.001$).

Irnich et al [10] demonstrated that older pacemakers had a higher rate of being affected by mobile phones when compared to newer ones. New generation of pacemakers are reported to be more protected against electromagnetic field due to the fact that they are equipped with more developed perception filters [9,28-31]. In the new model pacemakers by the same manufacturer, there are specific perception filters and the battery sizes of these newly manufactured pacemakers are smaller, which all result in a decrease in the risk of being affected by the magnetic field to a significant degree [16,33,33]. Medtronics reported that Kappa, Sigma and I series Thera model pacemakers that they produced were protected against this risk. Hayes et al [24] emphasized the fact that the risk of being affected was related to the model of the pacemaker rather than its brand. In our study we did not choose to compare pacemaker models and brands. When we made a comparison as to the age of the pacemaker, we showed that the rate of being affected increased by age ($p<0.05$). At this point, we explained the different rates of being affected in VVI and VVI-R pacemakers as follows; VVI pacemakers were much older ($p<0.05$) (Fig. 4). The lower rates that were observed in dual chamber and AAI(R) pacemakers can again be explained by the fact that these are new models.

Barbaro et al [17], Naegeli et al [9] and Altamura et al [11] reported that the effects that were observed were more like temporary or lengthened pacemaker inhibition rather than switching to the asynchronous mode. In our study, the rate of switching to the asynchronous mode was higher than the rate of inhibition ($p<0.001$) and ventricular triggering was only observed in one DDD-R pacemaker. The fact that our study protocol was different and that the patients, who were affected at a certain step were not included to the further steps of the study, might have an effect on these results. Because, the 3 VVI pacemakers that showed inhibition in our study were affected at the stage of contact.

Sparks et al [15] reported that the pacemakers with minute ventilation type rate-response sensors were not affected by mobile phones. On the other hand, Naegeli et al [9] and Chen et al [18] reported that pacemaker rate sensor would not have a role in that regard. We think that the presence or the absence of such a role cannot be demonstrated by the data we have in hand. Because, there is not any report showing that the pacemaker rate-response sensor was affected by the electromagnetic field under normal conditions.

The in vitro and clinical studies that have been performed up till now, revealed that effects of the mobile phones on the pacemakers were observed at a maximum distance of 10 cm and this effect was highest when the antenna of the mobile equipment was in close contact with the pacemaker [10,11,17,24,34]. Imich et al [10] reported that the maximum distance at which the effect was observed was inversely correlated with the sensitivity. In their in vitro studies, Ehlers et al [13] and Carrillo et al [14] demonstrated that the factor that was of essential importance in this interaction was the proximity of the pacemaker battery to the electromagnetic field and that pacemaker lead did not have that much of an importance. In our study all of the mobile phone effects were observed at a distance of 10 cm and at close contact. The effects that occurred at 10 cm and at close contact were not different that each other in proportion. However, according to our study protocol, if the patients have been affected at a distance of 10 cm we have not performed any further tests at close contact.

Seventy three percent of the effects on the pacemakers occurred when the mobile phone was ringing, 27% occurred during the call ($p<0.01$). The pacemakers were not affected while the mobiles were opened or closed. Altamura et al [11] demonstrated that the signals that were generated during the ringing phase and during the call were similar to each other, on the other hand, the signals that were generated while the call was initiated and terminated were similar as well. Meisel et al [35] reported that the effects were not only seen during the call but also present during the ringing phase as well. It is obvious that the signals that are generated by the mobile phones during ringing and talking will be more powerful. Another issue here is the signal exposure time. In our study all the stages lasted for 20 seconds and the effects on the pacemaker did not occur at the initial stages of the procedure but during the middle stage or towards the end.

Of the 37 patients who were affected during the study, only 6 patients (16.2%) became symptomatic. There was mild palpitation in 1 patient with DDD-R pacemaker who developed ventricular triggering and in 4 patients (13.5%) with VVI(R) pacemakers who switched to asynchronous mode. Of the 3 patients with VVI pacemakers who had pacemaker inhibition, one experienced presyncope (2.7%). In pacemaker patients, when the pacemaker switches to the security mode (VOO), the patients do not necessarily develop symptoms at all times and this is something that is frequently encountered during routine pacemaker controls. The important issue is the pacemaker inhibition that might develop in patients who are completely pacemaker dependent and who do not have a spontaneous rhythm, as this might result in dramatic consequences.

CONCLUSION

It is a very well known fact that mobile phones can create temporary dysfunctions on pacemaker functions under certain conditions. It is highly probable to see such an effect at a distance of 10 cm while the mobile is ringing or during the talk. Having a unipolar lead polarity increases the risk of being affected when compared to bipolar leads. Although sensitivity is not the determining factor for such an effect by itself, the increase in the sensitivity increases the risk of being affected especially in bipolar lead configuration. The risk of being affected is not different for single chamber and dual chamber pacemakers. Older generation of pacemakers are under greater risk when compared to newer generation ones. The effect demonstrates itself mostly as switching to asynchronous mode and less commonly as inhibition. However, there is no need to panic. Because, this effect is completely reversible, and is not life threatening except for the patients who are completely pacemaker dependent. The temporary changes in the functions of the pacemakers are observed as ventricular triggering in dual chamber pacemakers, and the entire dual chamber pacemakers that are manufactured today have the mode switch feature. Single chamber pacemakers usually switch to asynchronous mode (VOO). The important issue is that there is a possibility of total pacemaker inhibition in patients who are completely pacemaker dependent. To this end, when pacemakers are being implanted, the lead polarity should be bipolar if the patient does not have a rhythm of his own and they should be informed about how to use the mobile phones safely.

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Düzeltme

Dr. Hakan Tıkız ve ark. tarafından Türk Kardiyoloji Derneği Arşivi 2002;30:478-85 sayısında yayınlanan *"Wolff-Parkinson-White sendromlu hastalarda aksesuar yol yerleşimini belirlemede kullanılan yedi algoritma"* başlıklı makalenin 13 no'lu kaynağı dizi hatası nedeni ile yanlış basılmıştır. Kaynağın doğru şekli yazarların uyarısı doğrultusunda aşağıda sunulmuştur.

Sezer A, Adalet K, Mercanoğlu F, Yılmaz E, Büyüköztürk K, Ertem G: A new electrocardiographic algorithm to localize the accessory pathway in patients with Wolf-Parkinson-White syndrome and prospective study of three electrocardiographic algorithms proposed for the same purposes. Eur Heart J 1998;19:539. (Supplement)