Original Article

Electromagnetic Energy Radiated from Mobile Phone Alters Electrocardiographic Records of Patients with Ischemic Heart Disease

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Abstract

Background: Electromagnetic energy radiated from mobile phones did not show significant effect on the blood pressure, heart rate, and electrocardiographic (ECG) parameters in animals and humans. **Aim:** This study aimed to investigate the effect of radiofrequency of mobile phone on the electrocardiographic parameters in patients with history of ischemic heart disease, taking into consideration the gender factor. **Subjects and Methods:** A total number of 356 participants (129 males and 227 females) were admitted in this study. They were grouped into: subjects without cardiac diseases (Group I), patients with ischemic heart disease (Group II), and patients with history of cardiac diseases not related to myocardial ischemia (Group III). Electrocardiogram was obtained from each patient when the mobile phone was placed at the belt level and over precordium in turn-off mode (baseline) and turn-on mode for 40 sec ringing. The records of ECG were electronically analyzed. **Results:** Prolongation of QTc interval was significantly observed in male gender of Groups I and III ($P < 0.001$). Male patients of Group II showed significant QTc interval prolongation ($P = 0.01$) and changes in the voltage criteria ($P = 0.001$). These changes were not observed in female patients with ischemic heart disease. The position of mobile at the belt level or over the precordium showed effects on the heart. **Conclusions:** The radiofrequency of cell phone prolongs the QT interval in human beings and it interferes with voltage criteria of ECG records in male patients with myocardial ischemia.

Keywords: Africa, electrocardiogram, ischemic heart disease, mobile phone

Introduction

World Health Organization (WHO) has classified mobile phone radiation on the International Agency for Research on Cancer (IARC) scale into Group 2B-possibly carcinogenic, i.e., there could be some risk of carcinogenicity.[1] The impact of microwave radiation on human health is mediated via thermal (dielectric heating) or nonthermal (biological responses) effects.[2,3] The metabolic changes in living cells under the exposure of microwaves from mobile communication systems include over expression of heat shock proteins, increased reactive oxygen species level, increased intracellular Ca^{2+}, DNA damage, inhibition of DNA reparation, and induction of apoptosis.[4] Self-reported symptoms associated with using mobile phones most commonly include headaches, earache, warmth sensations, perceived concentration difficulties, and fatigue.[5,6] Electromagnetic energy is a form of energy emitted and absorbed by charged particles, has two components, electric and magnetic fields, and travels through space as wave like. However, Electromagnetic field (EMF) exposure due to mobile phone use is not currently known to have any major health effects.[7] Previous studies found that the electromagnetic energy radiated from mobile phones did not show significant effects on the blood pressure, heart rate, and electrocardiographic (ECG) parameters in rats.[8] In humans, radiofrequency waves emitted by digital mobile phones did not show significant effect on cardiac autonomic modulation of the heart in healthy subjects, i.e., the heart rate variability did not show significant changes at turned off mode, at turned on

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mode, and at neither time calling mode over 5-min periods.[9] On the other hand, Andrzejak *et al.* found that the tone of the parasympathetic system, measured indirectly by analysis of heart rate variability, was increased, while sympathetic tone was lowered during 20-min call with the mobile phone in healthy subjects.[10] This study aimed to show the effect of radiofrequency of mobile phone on the ECG parameters in patients with history of ischemic heart disease, taking into consideration the gender factor.

Subjects and Methods

This study was conducted in Department of Medicine in cooperation with Department of Physiology-Medical Physics, College of Medicine, Diyala University, in Iraq. This study was approved by the scientific committee of the college and a verbal consent form was obtained from each patient prior to their admission in the study. Three groups of subjects were studied:

Group I (*n* = 142)

Subjects selected from general population (50 males and 92 females). None of them had history of cardiac diseases.

Group II (*n* = 104)

Patients presented with history of ischemic heart disease (36 males and 68 females).

Group III (*n* = 110)

Patients presented with cardiovascular diseases (e.g., high blood pressure, left ventricular hypertrophy, valvular heart disease) without evidence of myocardial ischemia (43 males and 67 females).

Patients with previous history of ischemic heart disease who attended the consultant clinic in the teaching hospital for follow-up were randomly (using simple randomization procedure) allocated to enroll in this study. The criteria of inclusion of ischemic heart diseases were based on the international classification of diseases (ICD-10) and the criteria of American Heart Association which included clinical signs and symptoms, biochemical markers of myocardial necrosis (obtained from patient's record), ECG findings, echocardiographic data, positive treadmill test, and cardiac catheterization.[11,12] Patients who fulfilled these criteria and had old myocardial infarction or angina pectoris, or acute coronary syndrome were admitted in the study.

At the time of entry in the study, the ECG records showed depression of ST segment and inversion of T waves in more than two leads.[13] Echocardiographic findings suggested myocardial ischemia included segmental wall motion abnormalities, systolic wall motion, systolic wall thickness, wall thickness, and low ejection fraction percent.[14]

All the patients were in sinus rhythm at the time of admission in the study and patients with history of hypertension or diabetes were included in the study. Patients with cardiac arrhythmias or implanted cardiac devices were excluded from the study. All patients on antiarrhythmic drugs or those that interfere with the impulse conduction velocity like antimalarials, antipsychotics, antidepressants, etc., were excluded from the study. Patients using antianginal agents, e.g., nitrites and nitrates, were included in this study. The sample size of patients was determined using the following formula:[15]

$$n = \{\mu\sqrt{([\pi(1-\pi)])} + v\sqrt{([\pi_0(1-\pi_0)])}\}^2/(\pi-\pi_0)^2,$$

where

n = required minimum sample size
π = proportion of interest which was proposed in this study (0.7)
π_0= null hypothesis proportion which is equal to 0.5
μ = one side percentage point of normal distribution corresponding to 100%, the significant power. In this study, the power 85% (100 − 85%) = 15% and μ = 1.036.
$\sqrt{}$ = percentage of the normal distribution corresponding to the required (two-sided) significance level. In this study, the significance level of 5% was considered, $\sqrt{}$ = 1.96.

Each patient was allowed to lie on the supine position and after a stabilizing period of 10 minutes, the ECG was done without application of cell phone and this ECG is considered as the baseline ECG. Then, the cell phone was placed on the left side of the lower abdomen at the belt level and allowed to ring once for 40 sec simultaneously recording ECG. This ECG is considered as ECG with cell phone ringing at belt level. After 5 min, the cell phone was placed in the left side chest pocket and allowed to ring once for 40 sec with simultaneous ECG recording. This ECG is considered as ECG with cell phone ringing over precordial region. The radiofrequency of cell phone is 900 MHz and the duration of each ring is 40 sec.

The following ECG variables (which are calculated electronically) were studied: Heart rate (beats/min), R-R interval (msec), P-R interval (msec), QRS period (msec), QTm (measured) interval (msec), and QTc (corrected) interval (msec). The amplitude of R wave in lead V5 (mV), the amplitude of S wave in lead V1 (mV), and the voltage summation of R wave in V5 and S wave in V1 (mV) were also studied.

Statistical analysis

The results were analyzed using SPSS version 10.0 (Chicago, IL). The results were presented as mean (SD). The data were analyzed using two-way analysis of variance (ANOVA) taking $P \leq 0.05$ as the lowest limit of significance.

Results

Table 1 shows the characteristics of the study. There were no

Table 1: Characteristics of the study

Parameters	Group I		Group II		Group III	
	Male (*n*=50) (14%)	Female (*n*=92) (25.9%)	Male (*n*=36) (10.1%)	Female (*n*=68) (19.1%)	Male (*n*=43) (12.1%)	Female (*n*=67) (18.8%)
Age (years)	40.5 (17.6)	45.7 (14)	60.7 (13)	57.9 (12)	50.7 (19.6)	48.1 (16.4)
Smoking (no.)	20	7	11	10	15	2
History						
Hypertension	9	22	9	33	7	22
Diabetes mellitus	5	4	4	4	2	2
Both	1	8	11	20	4	4

significant differences in age between males and females in each studied group ($P = 0.634$, $P = 0.723$, and $P = 0.887$ for Groups I, II, and III, respectively). Hypertension and diabetes mellitus were reported in each group and the number of hypertensives was observed to be higher in females compared to males in each group.

In healthy males, the radiofrequency of cell phone placed at belt level significantly interfered with the conduction velocity of the heart presented with shortening R-R interval ($P = 0.048$) and prolonged QTm ($P < 0.001$) and QTc ($P = 0.002$) periods [Table 2a]. Cell phone placed in chest pocket level significantly ($P < 0.001$) prolonged the QTc interval. In healthy females, nonsignificant prolonged QTm ($P = 0.823$) and QTc ($P = 0.720$) intervals were observed when the cell phone was placed at belt level or in chest pocket level [Table 2b]. Also, the heart rate was increased and reached a significant level ($P < 0.001$) when the cell phone was ringing at the belt level.

In male patients with ischemic heart disease, the duration of QRS wave was increased during cell phone ringing and reached a significant level ($P < 0.001$) when the cell phone was placed at belt level or in chest pocket [Table 3a]. Prolonged QTc interval and increased amplitude of R wave in V5 were observed where the cell phone was placed in chest pocket. The changes in the amplitude of R wave in V5 were not observed in female patients [Table 3b].

Male patients who presented with illness not related to cardiovascular diseases showed significant ($P < 0.001$) prolongation of QTm and QTc when the cell phone was placed at the belt level or in chest pocket [Table 4a]. In female patients, the prolongation of QTc did not reach a significant ($P > 0.05$) level [Table 4b]. It is interesting to mention that prolongation of QT period that exceeded the level (0.444 msec) was observed at baseline of female patients with ischemic heart disease. Tables 5a and 5b showed the summary of the effect of mobile radiofrequency in respect to its site whether at belt or in the chest pocket.

Table 2a: Effect of mobile radiofrequency on the electrocardiographs in subjects of Group I (males) without evidence of heart diseases

Parameters	Baseline values	Cell phone ringing at belt level	Cell phone ringing in the chest pocket
Heart rate (beats/min)	79.6 (14.67)	81.2 (13.97)	79.9 (13.63)
R-R interval (msec)	773.42 (137.28)	756.5 (130.72)*	768.3 (133.93)
P-R interval (msec)	148.3 (26.64)	151.7 (22.84)	151.8 (29.84)
QRS period (msec)	100.72 (9.54)	101.72 (12.24)	101.86 (8.38)
QTm interval (msec)	368.3 (26.28)	371.9 (25.0)†	371.1 (24.13)†
QTc interval (msec)	421.56 (22.15)	429.72 (19.36)‡	425.58 (22.90)†
R wave–V5 (mV)	1.445 (0.512)	1.457 (0.530)	1.457 (0.517)
S wave–V1 (mV)	0.906 (0.398)	0.889 (0.396)	0.893 (0.404)
R (V5)+S (V1)	2.351 (0.729)	2.358 (0.724)	2.351 (0.743)

The results are expressed as mean (SD) (*n*=50). *P=0.048, †P<0.001, ‡P=0.002, in comparison with baseline value

Table 2b: Effect of mobile radiofrequency on the electrocardiographs in subjects of Group I (females) without evidence of heart diseases

Parameters	Baseline values	Cell phone ringing at belt level	Cell phone ringing in the chest pocket
Heart rate (beats/min)	85.8 (15.7)	86.5 (15.43)*	86.2 (15.7)*
R-R interval (msec)	708.4 (139.4)	710.3 (124.5)	708.4 (134.1)
P-R interval (msec)	148.0 (16.74)	148.33 (17.04)	146.9 (16.91)
QRS period (msec)	96.92 (12.93)	97.13 (12.08)	96.6 (12.6)
QTm interval (msec)	374.5 (64.8)	372.12 (33.65)	372.3 (33.93)
QTc interval (msec)	437.0 (23.0)	445.49 (28.16)	443.1 (24.81)
R wave–V5 (mV)	1.243 (0.403)	1.236 (0.413)	1.238 (0.406)
S wave–V1 (mV)	0.798 (0.334)	0.804 (0.335)	0.808 (0.336)
R (V5)+S (V1)	2.052 (0.606)	2.039 (0.619)	2.046 (0.622)

The results are expressed as mean (SD) (*n*=92). *P<0.001 in comparison with baseline value

Discussion

This study explores the effect of cell phone radiofrequency on the heart at three levels: The place of cell phone, presence of ischemic heart disease, and the gender. The results reported in this study show that the radiofrequency of cell phone interferes with the cardiac conduction and the voltage criteria properties in human beings presented with prolongation of QT

Table 3a: Effect of mobile frequency on the electrocardiographs in patients (males) with ischemic heart disease

Parameters	Baseline values	Cell phone ringing at belt level	Cell phone ringing in the chest pocket
Heart rate (beats/min)	77.9 (16.1)	78.63 (17.30)	78.0 (16.6)
R-R interval (msec)	796.41 (153.15)	792.06 (164.85)	795.63 (160.23)
P-R interval (msec)	165.3 (46.33)	162.9 (36.07)	158.9 (27.0)
QRS period (msec)	107.52 (13.16)	109.39 (12.30)*	108.0 (12.32)*
QTm interval (msec)	381.75 (38.87)	383.41 (40.71)	375.3 (68.9)
QTc interval (msec)	429.91 (25.47)	433.22 (26.40)§	432.94 (26.67)§
R wave–V5 (mV)	1.39 (0.751)	1.402 (0.737)	1.444 (0.711)‡**
S wave–V1 (mV)	0.937 (0.373)	0.947 (0.372)	0.936 (0.375)
R (V5)+S (V1)	2.334 (0.894)	2.352 (0.889)‡	2.371 (0.876)†¡

The results are expressed as mean (SD) (*n*=36) **P*<0.001, †*P*=0.001, ‡*P*=0.004, §*P*=0.01 in comparison with baseline value; ¡*P*=0.001, ***P*=0.025 in comparison with cell phone ringing at belt level

Table 3b: Effect of mobile frequency on the electrocardiographs in patients (females) with ischemic heart disease

Parameters	Baseline values	Cell phone ringing at belt level	Cell phone ringing in the chest pocket
Heart rate (beats/min)	77.4 (15.44)	77.0 (17.2)	77.5 (15.4)
R-R interval (msec)	801.37 (162.6)	790.36 (162.8)	799.35 (158.7)
P-R interval (msec)	158.65 (22.2)	157.5 (26.9)	159.9 (24.7)†
QRS period (msec)	105.3 (21.95)	107.1 (23.6)	105.4 (21.3)
QTm interval (msec)	396.2 (48.3)	398.4 (46.2)	398.8 (46.93)
QTc interval (msec)	445.8 (34.76)	444.4 (44.2)*	448.1 (33.25)*†
R wave–V5 (mV)	1.245 (0.606)	1.205 (0.604)*	1.206 (0.59)*†
S wave–V1 (mV)	0.947 (0.558)	0.987 (0.725)	0.948 (0.57)
R (V5)+S (V1)	2.216 (0.944)	2.201 (0.991)	2.158 (0.918)

The results are expressed as mean (SD) (*n*=68). **P*<0.001 in comparison with baseline value, †*P*<0.001 in comparison with cell phone ringing at belt level

intervals (measured and corrected). Moreover, the effect of radiofrequency of cell phone on heart is independently related to the gender effect.

The results reported in this study are contrary to those reported by others who found that the cell phone on the precordium in a state of off, on, and ringing did not show significant effects on the blood pressure, heart rate, *P*-wave dispersion, QT dispersion, and QT-corrected dispersion parameters.[16] Further, it was reported in a study that the

Table 4a: Effect of mobile frequency on the electrocardiographs in patients (males) with non-ischemic heart disease

Parameters	Baseline values	Cell phone ringing at belt level	Cell phone ringing in the chest pocket
Heart rate (beats/min)	82.02 (18.56)	81.8 (17.78)	82.51 (17.27)
R-R interval (msec)	759.1 (151.6)	759.56 (149.28)	752.6 (140.5)
P-R interval (msec)	159.8 (34.5)	156.81 (52.02)	158.3 (55.59)
QRS period (msec)	105.46 (12.73)	106.58 (13.07)	105.93 (12.76)
QTm interval (msec)	374.37 (41.62)	375.19 (41.95)*	377.02 (41.86)*†
QTc interval (msec)	432.21 (31.34)	441.58 (78.42)*	438.72 (35.93)*
R wave – V5 (mV)	1.29 (0.517)	1.303 (0.537)	1.305 (0.536)
S wave – V1 (mV)	0.805 (0.458)	0.797 (0.454)	0.789 (0.443)
R (V5)+S (V1)	2.086 (0.792)	2.100 (0.774)	2.049 (0.781)

The results are expressed as mean (SD) (*n*=43). * *P*<0.001 in comparison with baseline value; †*P*<0.001 in comparison with cell phone ringing at belt level

Table 4b: Effect of mobile frequency on the electrocardiographs in patients (females) with non-ischemic heart disease

Parameters	Baseline values	Cell phone ringing at belt level	Cell phone ringing in the chest pocket
Heart rate (beats/min)	81.3 (17.7)	81.7 (18.3)	81.8 (17.9)
R-R interval (msec)	750.2 (171.7)	746.2 (167.7)	744.2 (176.2)
P-R interval (msec)	151.4 (24.2)	151.4 (26.7)	151.6 (26.3)
QRS period (msec)	99.0 (18.04)	99.4 (18.4)	98.9 (17.6)
QTm interval (msec)	380.9 (63)	380.9 (53.5)	380.6 (52.8)
QTc interval (msec)	436.8 (47.3)	444.9 (50.0)	440.4 (47.1)
R wave – V5 (mV)	1.264 (0.516)	1.236 (0.516)	1.239 (0.509)
S wave – V1 (mV)	0.878 (0.474)	0.885 (0.527)	0.876 (0.464)
R (V5)+S (V1)	2.153 (0.834)	2.119 (0.835)	2.114 (0.809)

The results are expressed as mean (SD) (*n*=67)

electromagnetic field emitted by mobile Global System for Mobile Communication (GSM) phone did not interfere with the time or frequency of heart rate variability domain in humans.[9]

The results of this study may be explained on the basis of the biological effects of electromagnetic energy radiated from mobile on human tissues. It is well known that the radiofrequency of mobile phone exerts three forms of effects on humans: Heating, interference with action potential of excitable tissue, and interference with electrophysiological machine record. The mobile phone radiates electromagnetic energy which is partly absorbed into the tissues. The slight heating, of maximum up to 0.3ºC, may cause some alterations in the expression of genes and proteins.[17] Exposure to radiofrequency electromagnetic field is associated with overproduction of reactive oxygen species in the brain of rat.[18] Barth *et al*. reported that the cognitive abilities neither

Table 5a: Summary of the significant effect of mobile radiofrequency on electrocardiogram trace mobile ringing at belt level

Parameters	Group I		Group II		Group III	
	M	F	M	F	M	F
Heart rate (beats/min)		↑				
R-R interval (msec)	↓					
P-R interval (msec)						
QRS period (msec)			↑			
QTm interval (msec)	↑				↑	
QTc interval (msec)	↑		↑	↓	↑	
R wave – V5 (mV)				↓		
S wave – V1 (mV)						
R (V5)+S (V1)			↑			

Table 5b: Summary of the significant effect of mobile radiofrequency on electrocardiogram trace mobile ringing in chest pocket

Parameters	Group I		Group II		Group III	
	M	F	M	F	M	F
Heart rate (beats/min)		↑				
R-R interval (msec)						
P-R interval (msec)						
QRS period (msec)			↑			
QTm interval (msec)	↑				↑	
QTc interval (msec)	↑		↑	↑	↑	
R wave – V5 (mV)			↑	↓		
S wave – V1 (mV)						
R (V5)+S (V1)			↑			

M: Male; F: Female

impaired nor facilitated electromagnetic fields emitted by GSM and Universal Mobile.[19] Neither heating nor overproduction of reactive oxygen species explain the cardiac effect of mobile in this study because the subjects were exposed to short duration of electromagnetic energy (40 sec). Yuasa *et al*. reported that the radiofrequency of mobile phone has no short-term (30 min) effects on the healthy human somatosensory evoked potential of sensory cortex.[20] In patients with ventricular tachycardia and/or fibrillation treated with transvenous pectoral implantable cardioverter defibrillators, the radiofrequency of mobile phones has no effects on the defibrillators' function.[21] On the other hand, it was reported that the mobile cells are a potential source of electromagnetic interference to ECG recording machine and are responsible for poor-quality ECG recordings.[22] Literature survey did not show the effect of mobile phones on the QT interval of the ECG records in patients with cardiac diseases. Furthermore, the results of this study indicated that men are more vulnerable than women to the effect of mobile cell on the ECG parameters. Previous studies showed that the 900 MHz exposure did not appear to affect the concentrations or the circadian rhythm of prolactin, thyroid stimulating hormone, adrenocorticotrophic hormone, and testosterone hormone in men.[23] One of the study limitations is the measurement of sex hormones in order to linkthe changes in their levels with the effect of mobile. Further studies are recommended to explore the effect of gender on the human susceptibility to the radiofrequency of mobile.

It can be concluded that the radiofrequency of cell phone prolonged the QT interval in human beings with or without ischemic heart disease and it interferes with voltage property of ECG records in patients with myocardial ischemia, of which female patients are immune from these effects.

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