

Cell Counter can be Interfered by Mobile Phone Radiofrequency Radiation: A Report and Short Review of the Recent Patents in Electromagnetic Interference

Golshan Mahmoudi¹, Ali Hosseinzadeh^{2,*}, Leila Hojaji-Najafabadi³ and Milad Baradaran-Ghahfarokhi^{4,5}

¹Medical Physics Department, School of Medicine, Sabzevar University of Medical Sciences, Sabzevar, Iran;

²Epidemiology and Biostatistics Department, School of Health, Sabzevar University of Medical Sciences, Sabzevar, Iran;

³Nanotechnology Department, Faculty of Advanced Sciences and Technologies, Isfahan University, Isfahan 81746-73441, Iran; ⁴Medical Physics and Medical Engineering Department, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran, and, Medical Students Research Center, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran; ⁵Medical Radiation Engineering Department, Faculty of Advanced Sciences and Technologies, Isfahan University, Isfahan 81746-73441, Iran

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Abstract: Electromagnetic interference (EMI) is a phenomenon that may occur when an electronic device is exposed to an electromagnetic (EM) field. The aim of this study was to investigate whether the CC could be interfered by exposure to the 900MHz cell phones in the laboratory. In addition, a review of the recent patents in electromagnetic interference is also presented. Human whole blood samples were collected from 20 healthy donors and each sample was divided to four aliquots and was placed into four batches for *in vitro* quantitative determination of human whole blood components. During CC reading of the first, second and third batches, the CC (Technicon H3 RTCTM, Bayer Diagnostics GmbH, München, Germany) was exposed to 1.90, 0.69 and 0.38 W/kg exposure of 900MHz radiation, respectively. For the fourth batch (control group), no radiation was applied. The final scores in the exposed batches I, II and III were statistically significant relative to the control batch ($P = 0.03$). The EMI caused profound changes on the CC reading of whole blood valid and macro cells in the exposed batches compared to the control batch ($P = 0.001$). This study showed that CC can be interfered by mobile phone RF radiation at a closed contact (less than 5cm distance). More accurate follow-up studies are needed for the evaluation of the electromagnetic interference due to radiofrequency radiation from external sources such as mobile phones in medical environments.

Keywords: Cell Counter, electromagnetic immunity, electromagnetic interference, electromagnetic shielding, mobile phone, radiofrequency radiation.

INTRODUCTION

Electromagnetic interference (EMI) due to radiofrequency (RF) radiation from external sources such as cellular telephone, radio communication, computer, radar, and antennas in medical environments is being widely studied by several authors [1-6]. EMI is a phenomenon that may occur when an electronic device is exposed to an electromagnetic (EM) field [1-6]. Any device that has electronic circuitry can be susceptible to EMI. With the ever-increasing use of the electromagnetic spectrum and the more complex and sophisticated electronic devices, issues of EMI are attracting attention [1-6].

Beside the beneficial characteristics of mobile phone devices, the user also has to pay attention to the different sources of EMI in medical environments and particularly the use of a mobile phone inside medical facilities as the most typical situation [7-9].

The Medicines and Healthcare Products Regulatory Agency (MHRA) in the U.K. carried out an EMI test on medical equipments using different mobile communication devices and showed that anesthesia machines, respirators, external pacemakers, ECG monitors, defibrillators, infusion pumps, and ventilators are sensitive to EMI [10-12]. Moreover, there are several reports published about EMI problems attributed to the use of a mobile phone near a medical device [13-16]. Hahn *et al.* reported the prompted malfunction of an epinephrine infusion pump due to a cellular phone received call [17]. Trigano *et al.* showed electrocardiogram recorded artifacts during 1800MHz mobile phone ringing that appeared 3 sec-

*Address correspondence to this author at the Epidemiology and Biostatistics Department, School of Health, Sabzevar University of Medical Sciences, Sabzevar, Iran, Tel: +98 9371058910; E-mail: a.hosseini20@yahoo.com

ond before the first ring tone and that persisted until end of ringing [10]. Tang *et al.* found that medical equipments such as ventilators, infusion pumps, defibrillators with an ECG monitor, and fetal monitors are quite susceptible to EMI [3]. They suggested that care should be taken when operating a mobile phone within 1m of these devices.

PATENT REVIEW

There are several patents on electromagnetic shielding and immunity due to EMI problems attributed to the use of a mobile phone near a medical device [13-15]. Ghosh *et al.* patented polymer composites that were suitable for use as electromagnetic interference mitigates [14]. Their patent included a lossy polymeric matrix, ceramic particles dispersed within the polymeric matrix, and conductive particles dispersed within the polymeric matrix. Hong disclosed an electromagnetic interference shielding assembly for use in electronic devices [13]. Yun-Hsing presented an electromagnetic interference shielding structure using a first metal layer, a second metal layer, a dielectric layer inter-disposed between the first metal layer and the second metal layer, an adhesive layer located on the second metal layer, and a release film located on the adhesive layer [18]. Chih-Hao invented an electromagnetic interference shield including a shell body and a magnetic material layer formed on the shell body [9]. Dolci *et al.* presented a shielding and plastic housing that may be used to house the shielding enclosure, printed circuit board, components mounted on the printed circuit board, and the metal plate [15].

As a consequence of these facts, many medical environments have prohibited the use of cellular phones in some areas. The factors affecting EMI can be broadly classified into properties of the emitting device (i.e. frequency, which is inversely proportional to wavelength and power of emissions); the physical relationship between the devices (i.e. distance); and susceptibility of the affected device (i.e. electromagnetic shielding) [19].

CELL COUNTERS

The Cell Counters (CCs) are widely used as a useful diagnostic tool in medical laboratories [20-23]. The mobile phone technology uses frequency range from 880 to 1800 Mega Hertz (MHz) [24, 25]. The magnetic field strength transmitted from the antenna of the majority of all cellular phones at about 7.5 - 10cm distance from the antenna is well over 0.002mT. While, at distances less than 2.5cm from the phone antenna, it emits electromagnetic fields (EMFs) of up to 0.01mT [26]. Of interest, mobile phone RF radiation might directly interfere with the CC diagnostic system and cause spurious results [27].

The aim of this study was to investigate whether the CC could be interfered by exposure to the 900MHz cell phones in the laboratory. In addition, a review of the recent patents in electromagnetic interference is also presented. At present, there is only evidence that the RF radiation does not affect the whole blood analytical equipment at a far distance (1.4

meter), [2, 7, 9, 13, 16, 28, 29] while, according to the best of our knowledge, there is no data for the closed contact with the methodology and analysis described here.

MATERIALS AND METHODS

The study was approved by the Pathology Research Board at the Sabzevar University of Medical Sciences, Sabzevar, Iran. All enrolled patients gave written, informed consent to the study.

Human whole blood samples were collected from 20 healthy donors (11 women and 9 men) and each sample was divided into four aliquots and was placed into four batches for *in vitro* quantitative determination of whole blood human whole blood components such as White Blood Cells (WBCs), micro and macro cells, hemoglobin, etc. The mean age \pm SD of the donors was 45.6 ± 17.6 years. During CC reading of the first, second and third batches, the CC (Technicon H3 RTCTM, Bayer Diagnostics GmbH, München, Germany) was exposed to 1.90, 0.69 and 0.38W/kg exposure of 900MHz radiation, respectively. Three cell phones with 0.38 (Sony Ericsson, Model T68i, Sweden), 0.69 (Nokia, Model 1100, Finland) and 1.09 (Nokia, Model 1202, India) Watt per kilogram (W/kg) of the tissue locally in the head Specific Absorption Rate (SAR), which produce 900 MHz RF radiation, were used to represent exposure of global systems for mobile communications (GSM). The distance between the phone antenna and each batch was kept at 5cm. For the fourth batch (control group) no radiation was applied.

It should be noted that, according to the International Commission for Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Commission (FCC), the reference level for RF exposure is peak power density [30-32]. It is a commonly used term for characterizing an RF electromagnetic field.

There were some irradiation sources in the laboratory (i.e. the wireless networks in the laboratory). Since, the study was performed, in a distinct place of the laboratory and background radiation was identical, power density of these sources was not monitored during the study [33].

All specimens (aliquots) were kept at room temperature to avoid the effect of temperature on the assay. All experiments were performed comparing CC read out results of the I, II and III batches with the control batch. To avoid the variability inherent to the assay used, all tests were performed for three independent experiments.

STATISTICAL ANALYSIS

Mean values and standard deviations (SD) were calculated and statistical significance of the differences between exposed and control batches was evaluated. A computer program (SPSS version 16.0, Chicago, IL, USA) was used for statistical analysis. Data were analyzed by Wilcoxon test (Nonparametric version of paired samples T-test). All hypotheses were tested using a criterion level of $P = 0.05$.

RESULTS

Figure 1 illustrates a comparison of average whole blood WBC with S.D. among control and the exposed batches I, II and III. The WBC concentrations were varied from 5.56 to $8.58 \times 10^3 / \mu\text{L}$ (mean: $7.55 \pm 0.14 \times 10^3 / \mu\text{L}$). The final scores of WBC in the exposed batches I, II and III were statistically significant relative to the control batch ($P = 0.03$). Figures 2 &

3 give a comparison of average whole blood valid and macro cells, respectively, with S.D. among control, and the exposed batches. The EMI caused profound changes on the CC reading of whole blood valid and macro cells in the exposed batches compared to the control batch ($P = 0.001$). Figure 4 shows a comparison of average whole blood micro cells with S.D. among control and the exposed batches. The final scores of

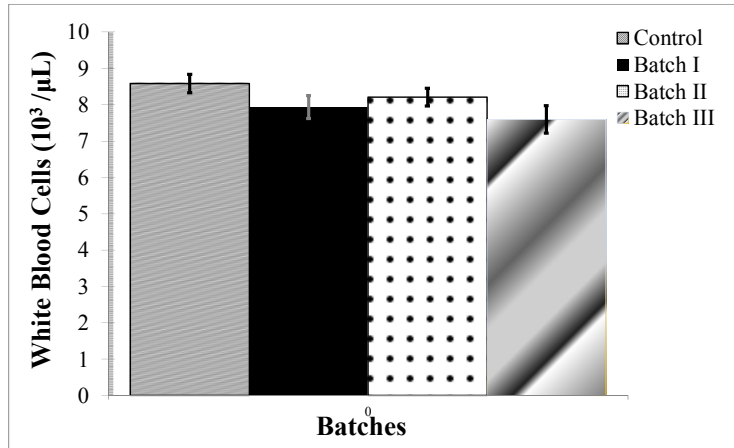


Fig. (1). A comparison of average whole blood WBC with S.D. among control, and the exposed batches I, II and III.

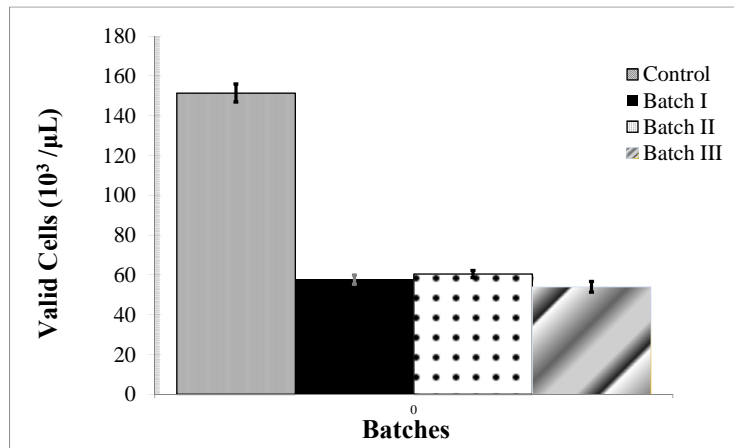


Fig. (2). A comparison of average whole blood valid cells with S.D. among control, and the exposed batches I, II and III.

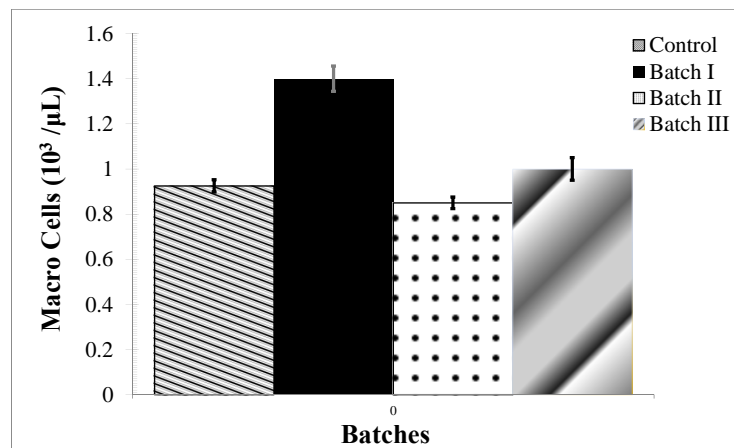


Fig. (3). A comparison of average whole blood macro cells with S.D. among control, and the exposed batches I, II and III.

micro cells in the exposed batches I, II and III were not statistically significant relative to the control batch ($P > 0.05$). The micro cells concentrations varied from 1.32 to $1.86 \times 10^3/\mu\text{L}$ (mean: $1.76 \pm 0.62 \times 10^3/\mu\text{L}$). Figures 5 & 6 demonstrate a comparison of average whole blood hemoglobin and CHCM with S.D. among control, and the exposed batches I, II and III. The EMI caused significant effects on the CC reading of whole blood hemoglobin in the exposed batches compared to the control batch ($P = 0.001$). A comparison of average whole blood hypo cells and system noise during CC reading is shown in Figs. (7 & 8), respectively. The final scores of hypo cells count and system noise during CC reading of the exposed batches I, II and III were statistically significant relative to the control ones ($P < 0.001$). In other words, the CC interfered by exposure to the 900MHz cell phones in the laboratory.

DISCUSSION

EMI has been responsible for many life-support and critical care medical device malfunctions, which raises concerns about the safety of patients who depend on these devices [25]. Recently, several reports have been published about EMI problems attributed to the use of a mobile phone near a medical device. Moreover, regarding the whole blood

analytical equipment, there was only evidence that the RF radiation does not affect these devices at a far distance (1.4 meter) [2]. In a medical laboratory, cell counters are widely used as a useful diagnostic tool for whole blood analysis. In this experiment, we aimed to investigate whether CC could be interfered by the closed contact (less than 5cm distance) exposure to the 900MHz cell phones in the laboratory.

Results of this study showed that, during whole blood colorimetric reading, CC reader does interfere by mobile phones exposure at a close contact Fig. (1 & 7).

There are some factors affecting the EMI in the medical laboratory such as properties of the emitting device, the distance between the devices, and electromagnetic shielding of the affected device [19]. The frequency of electromagnetic radiation plays an important role in relation to the length of various electric components in the susceptible device. Long wavelengths (low frequencies) transfer minimal energy to small electronic components, and very short wavelengths (extremely high frequencies) are easily shielded. Frequencies between 10kHz and 1GHz are generally the most problematic [19]. Although many factors affecting EMI are difficult to predict, the reduction in field strength with distance is generally predictable. Recently, Helhel *et al.* found that mo-

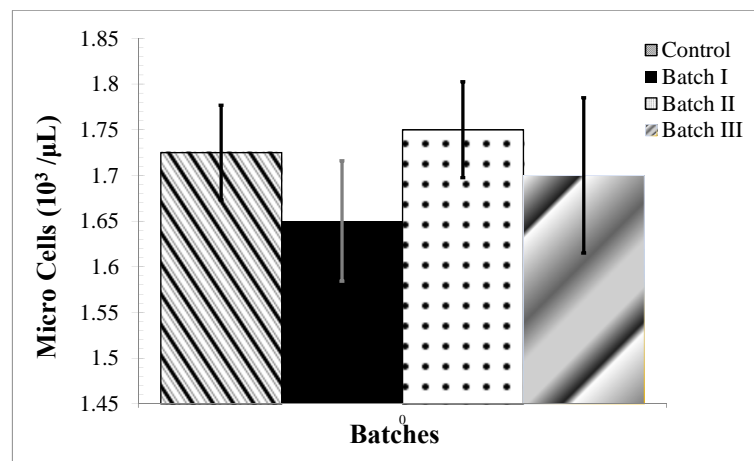


Fig. (4). A comparison of average whole blood micro cells with S.D. among control, and the exposed batches I, II and III.

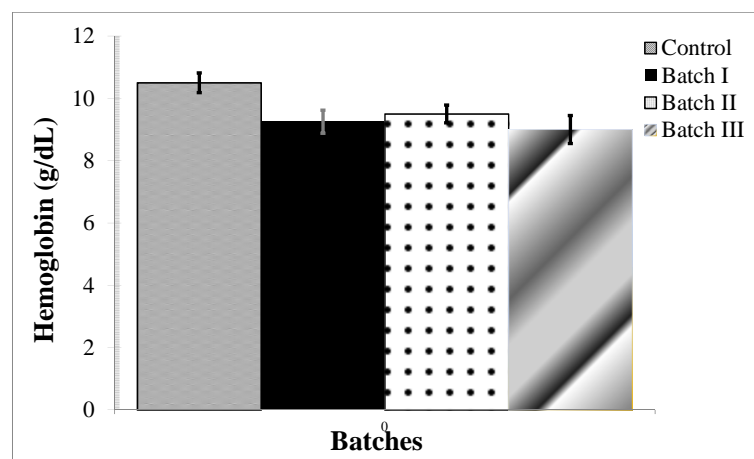


Fig. (5). A comparison of average whole blood hemoglobin with S.D. among control, and the exposed batches I, II and III.

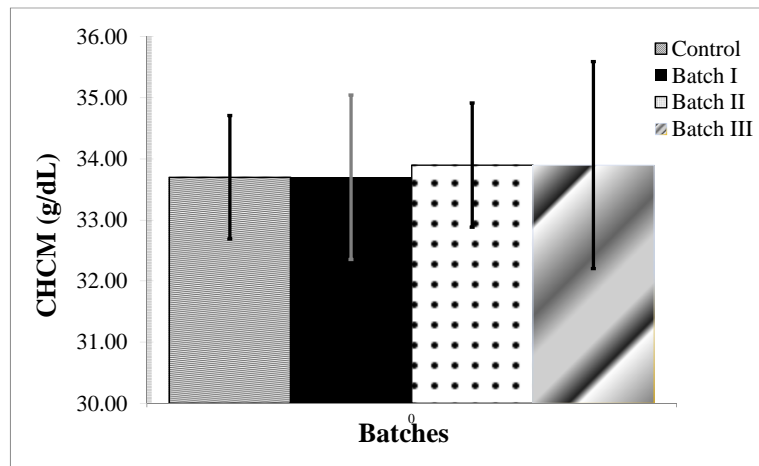


Fig. (6). A comparison of average whole blood CHCM with S.D. among control, and the exposed batches I, II and III.

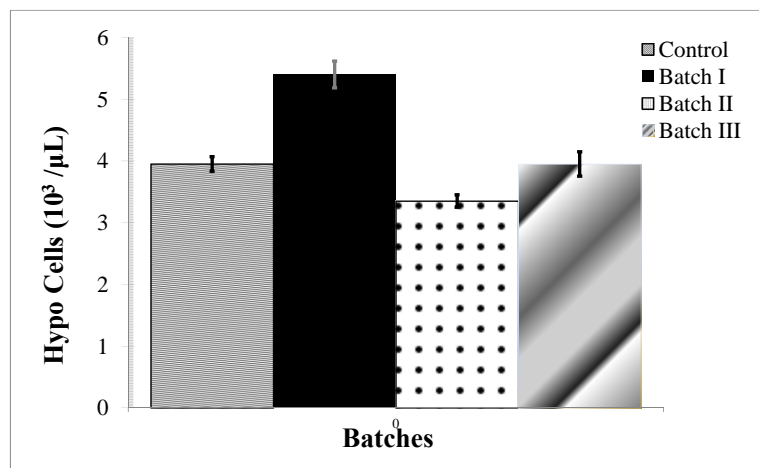


Fig. (7). A comparison of average whole blood hypo cells with S.D. among control, and the exposed batches I, II and III.

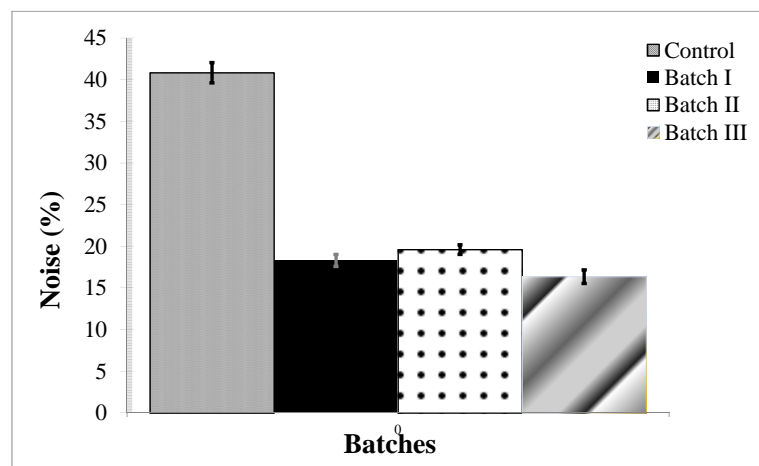


Fig. (8). A comparison of average noise with S.D. among control, and the exposed batches I, II and III.

mobile phone usage, 1.4m farther than the whole blood analytical equipments does not cause EMI [2]. However, some equipments such as electrocardiograms (ECGs) are susceptible to mobile phones EMI at a closer distance (less than 0.4m). The critical distance is not a concern itself, but also the location and orientation of both sources and medical

equipments are important as mentioned in ANSI C63.18 [34]. The electromagnetic shielding of the affected device affects the degree of malfunction that may occur. Newer devices are designed according to more stringent standards, with attention to shielding and electromagnetic immunity, and are less susceptible to EMI [2].

CONCLUSION

This study showed that cell counters can be interfered by mobile phone RF radiation at a closed contact (less than 5 cm distance). More accurate follow-up studies are needed for the evaluation of the EMI due to RF radiation from external sources such as mobile phones on cell counter devices. The results here should be confirmed in larger series, employing different machines, especially for greater powers (more than 2W powers).

CURRENT & FUTURE DEVELOPMENTS

Some institutions have followed the evidence presented earlier, that all significant interference problems occur at distances of 1m or less [12]. We found that there is a need for such distances from a CC during reading. The 1m rule can be established, in which the use of mobile technologies is permitted even in highly instrumented areas, such as the ICU, provided that they are deactivated within 1m of any functioning device [10-12].

More accurate follow-up studies are needed for the evaluation of the electromagnetic interference due to radio-frequency radiation from external sources such as mobile phones in medical environments.

Biomarker discovery and validation for whole blood analysis techniques have accelerated significantly as we have increased our understanding of human whole blood and its complex. One of the main issues responsible for driving this agenda has been the need for improved blood test outcome in clinical trials. There is an acute need for new biomarkers that are involved in early responses in human whole blood, biomarkers that will be clinically useful for detecting early stage blood problems [16, 23, 35, 36]. We also need to identify biomarkers that may be useful for characterizing the status, prognosis and measurement of treatment response in blood disease [22, 37-43].

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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