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Influence of Electromagnetic Field Exposure Emitted from Mobile Phones on Kidney

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Abstract Exposure to electromagnetic fields (EMFs) released from mobile phones has been evident to affect individuals' health, indicating that almost all individuals in the globe will be affected in case health is influenced by mobile phones. Recently, using cellular phones has provoked several queries about their safety, since operators are exposed to ultra-high frequency EMFs. The effect on individuals' bodies is mainly dependent on the EMFs exposure's power and frequency. Besides, the potential health results of weak, high-frequency EMFs and biological effects have been increasingly interested in. Various system diseases have strong association with EMFs, including mobile phones, as reported by some studies conducted on the association of magnetic fields (MFs) with reproduction, cancer or neurobehavioral reactions. Since clinical and/or electrical appliances have been widely used, there is nowadays a growing increase in studies investigating the EMFs effect on the biological system. Some of which suggested EMFs exposure's adverse effects. Similar to technological advances, using EMFs is of a growing increase, resulting in higher levels of everyday EMFs exposure than those which naturally exist. The continuous increase in using cell phones with their effects produced by the exposure to EMFs has provoked another query of their potential side effect on the living organism and has raised various measures of concerns. The social life of humans has been dramatically changed after the discovery of electricity. A huge number of electronic devices has been generated due to the rapidly industrial and economic developments and improvements. Currently, exposure to EMFs from different electronic devices, including computers, phones, power lines, radios, etc. is inevitable in everyday lives. Nonetheless, the most individuals' awareness and knowledge of the harmful effect of EMFs on their health emitted by such devices are poor. In mobile-phone telecommunications, radio waves of 900-MHz as well as 1800-MHz are frequently used.

Keywords Magnetic field, electromagnetic field, mobile phones, kidney

Introduction

Radiation technologies such as mobile phone, microwave and radiofrequency have intensively used in the recent decades with the growing demand of electronic devices. X band radar frequency between 8-12 GHz is widely used in industrial and scientific devices and domestic, military, and medical applications. Irradiation emitted by radar system into the environment may pose a health risk to the workers in certain occupations. Since mobile phones and military radar devices are placed in close proximity to the genitals, the reproductive system is then absorbed high radiation rates when compared with other organs. Several studies have reported the detrimental EMFs effect on testis and seminal factors, such as morphology, motility, and concentration. Other studies investigated the cytotoxic effects of EMFs exposure on spermatogonia, spermatogenesis, induced apoptosis, decreased testicular biopsy score, degeneration of germ cells. Whereas, other studies suggested that EMFs do not impact the male reproductive system. Similar experiments were conducted to investigate the EMFs effects on the kidney structure. They were found that the exposure EMF scan cause pathological effects in kidney tissue including glomerular degeneration and cytoplasmic vacuolization. Though huge numbers of studies related to the adverse effects of EMFs, the histopathological and morphological effects of X band radar frequencies on testis and kidneys are still argumentative. So, this research was conducted to assess the EMFs adverse effects on mice testis and kidney in two different age groups [1,2].

In recent years, both at work and at home everyone is exposed to EMFs arising from telecommunications and broadcasting apparatus. Mobile phones and Wireless Fidelity (Wi-Fi) are two of the primary sources of exposure to radiofrequency EMFs for populations. The Wi-Fi devices allow the exchange of data through their waves. The devices that use Wi-Fi are such as wireless routers, tablet, personal computers, audio player, and cell phone. Emerging technology such as router devices operating at 2.45 GHz has recently seen broadly and become more needed in daily life [. The level of radiofrequency electromagnetic radiation in the world will rise quickly. Some hazards effects of EMFs exposure have been reported such as triggering oxidative stress in various tissues, and changing in levels of blood antioxidant markers significantly. The studies revealed that exposing to the radiation of Wi-Fi technologies has many health hazards on different body organs such as; Brain, liver, kidney, heart, pancreas, reproductive system, blood. This radiation carries also risk of cancer [3].

Possible health electromagnetic risks could be posed by exposing to EMFs of electronic devices, like cell phones despite their several advantages. Young individuals are mostly exposed to EMFs since they commonly use cell phones. The pathological effects of cell phones EMFs have been investigated by many previous studies; some of which found reversible and irreversible pathological influences of 900 MHz EMFs exposure at radiofrequency on different organs. Some others examined the possible causative roles of the EMFs natural or artificial source in health disorders. They depended on the exposure's dose and duration as well as on the morphological, biochemical, physiological influences of such EMFs on the living tissue. They found that a800-2,200 MHz radiofrequency is emitted from cell phones as per cell phone's use characteristics and models. Besides, a2100 MHz radiofrequency of EMFs is emitted from cell phones of third generation. However, no studies have been conducted to examine the influence of 2100 MHz EMFs exposure on kidney [4,5].

The healthy kidney has several vital roles, including anaemia prevention, excess water's removal, body homeostasis or bone health maintenance, chemical compounds' regulation in blood, blood pressure regulation, waste product elimination, and secretion of hormones such as prostaglandin renin, vitamin-D and erythropoietin. Although EMFs-induced histopathological alterations involve an unclear mechanism in tissues, changes in the level of malondialdehyde (MDA) and glutathione (GSH) are caused by the exposure to EMFs through the trigger of lipid peroxidation in relation to the free oxygen radical. Malondialdehydeis "a product of unsaturated fatty acid breakdown and a marker of lipid peroxidation in tissue". Cells are protected by antioxidants (i.e., superoxide dismutase, GSH peroxide, GSH peroxide or ceruloplasmin) which defend lipid peroxidation. It was indicated that exposure to EMFs decreased the level of GSH peroxide in rats and increased the level of MDA. Apoptosis is commonly illustrated to be caused by oxidative stresses and reactive oxygen species. It is also caused by low EMFs as reported by some studies. In terminal events before apoptosis, key roles are played by caspases, especially caspase-3 activation. The 900 MHz effects of cell phones' radiation on kidneys have been investigated by few studies which reported low radiation (in duration) that lasted for some minutes [1,3,4]. In fact, the cell phones' radiation exposure is far longer and lasts for hours. Moreover, a 2100 MHz radiofrequency is emitted from the 3G frequently wide use [6,7]. Consequently, this study was conducted to investigate the pathological changes, (i.e., oxidative stress and apoptosis) in rats' kidneys when exposing to a 2100 MHz radiofrequency from 6 to 12 hours per day.

2. Anatomy and Physiology of Kidneys

Within the posterior abdominal wall as well as the parietal peritoneum, human kidneys place in the spine's both sides, particularly in the retroperitoneal space. Muscles, ribs and fats form a collective structure that well protect the kidneys. Because of the slight displacement via the liver, the location of the right kidney is higher than that of the left kidney which is located at approximately the T12 to L3 vertebrae. To some extent, the 11^{th} and 12^{th} ribs protect the kidneys' upper portions. The weight of every kidney is approximately from 125 to 175 g in male individuals and from 115 to 155 g in female individuals. İts length is from 11 to 14 cm, and its width is about 6 cm, whereas its thickness is about 4 cm. Fibrous capsules consisting of irregular, dense connective tissues directly cover kidneys. Such tissues assist in protecting kidneys and holding their shapes. The capsules are encompassed by adipose tissues' shock-absorbing layers, namely renal fat pads. These pads are also covered by rough renal fascia which, with the overlying peritoneum, serves in rigidly anchoring the kidney to the abdominal walls posteriorly in retroperitoneal positions. Kidneys resemble the beans. Besides, the site from which the structures (i.e., ureters nerves, vessels and lymphatics) enter and exit to serve kidney is called the renal hilum. In the kidney’s convex indentation, the medial-facing hila are gotten. The kidney anterior part shows an internal (i.e., renal medullae) and external sites (i.e., renal cortexes). Every 5-8 renal pyramid is split up by the renal columns of connective tissues in the medullae. In addition, the urine is created by renal pyramids terminating into the renal papillae which drain to collecting pools, namely minor calyces. Different minorcalyces are connected to each other forming major calyces which are also connected to individual renal pelvises connecting to the ureters [8].

The kidneyis well vascularized receiving approximately a 25% cardiac outputs at its convenience. Through the renal arteries, the blood gets into the kidneys immediately forming from the aorta and every renal artery moves into the hila of kidneys. Segmental arteries are initially divided from every artery which are then branched forming interlobar arteries passing via the renal columns and reaching the cortexes. In turn, every arcuate artery and then the cortical radiate artery, followed by the afferent arteriole, are branched from the interlobar artery. Blood is delivered by the afferent arterioles into modified capillary beds called “the glomerulus” which is one of the kidney functional unit components called “the nephron”. Every kidney has 1.3 million nephrons functioning for blood filtering. After filtering, the blood is immediately returned to the lower vena cava through the renal vein. Portal systems are formed after the blood moves to from the glomerulus to the efferent arterioles. It passes via the second capillary beds, the peritubular capillaries (and vasa recta), and surrounds the Henle’s loop as well as the distal and proximal convoluted tubules. The second capillary beds recover most solutes and water. Therefore, this filtering process ends in collecting the filtrate through gathering every duct which drains into minor calyces, which are merged together forming majro calyces. Ultimately, this filtrate is moved to the renal pelvises and then terminated into the ureters [8].

In mammals, a distinct adaptation throughout the evolution process has been performed in kidneys and lower urinary tracts for maintaining the blood and homeostasis composition, including “water conservation, acid, base and electrolyte balance, red blood cells (RBCs) production, blood pressure regulation”. For achieving this, kidneys have sophisticated cellular architectures containing approximately a million nephrons in individuals who which consist of over 40 various cell types, thus including extensive tubular components. Such components exhibit constant epithelia moving from the glomerulus filtration outset, passing by the various nephron segments, to the ducts collection which eventually drain into ureters and bladders. The epithelial provides specialized, sophisticated, region-related roles which have heterogeneous and highly sophisticated niches containing – during this process and interact interstation – nerves, different vascular networks, lymphatics, resident immune cells, and extracellular matrices. In such processes, the defect may lead to critical health issues, consisting of end-stage renal diseases and chronic-kidney diseases which affect less than quarter of million Americans, incurring over 50 billion dollars in the healthcare cost and significantly causing mortality and morbidity [9].

Consequently, the full understanding of both the cellular compositions and the related functional attributes, underlying common and abnormal kidney functions is of greater interest for personalized medicines as well as for the effort to rebuild adult-human kidneys. Nevertheless, major impediments to solo-cell interrogations of kidneys, attributed by high-epithelial contents and extra-cellular matrices, remain – after their enzymatic dissociation – to be the activation of disproportionate cell-type recovery, gene expression artifact and poor viability. To solve such an issue, tissues are efficiently decreased to solo-nucleus isolates, providing a precise cell-type expression profile, during the dissociative artifact reduction. Here, a pipeline with robust-tissue process and solo-nucleus transcriptomic profile was developed for interrogating cell-type diversities and establishing molecular blueprints of individual kidney tissues. The study used an approach that illustrates the possibility of working with specific tissues on scales in accordance with clinical biopsies, yielding concurrent histological registrations of tissue contents. Besides, the study analysis demonistrates remarkably obvious molecular and cellular characteristics and insights for kidney organizations, functions and diseases. In addition, expressions of approximately 160 genes associated to diseases in the distinct types of kidney cells were identified to provide novel disease-related targets and unexplored ways for maladaptating or adaptating inconvenient physiologies, including hypertension [10].

3. Effects of Electromagnetic Fields on Kidney

Cells are also called geographic areas which are the sub-categories of mobile communication networks. All cells are individually preserved by base stations. Mobile phones are the users' links to networks. Systems are structured to guarantee the linkage of mobile phones with networks as the user moves from a cell to another. Radio signals are exchanged between mobile phones and base stations for communicating with each other. To ensure that the network has satisfactory performance, the signals' level should be carefully optimized. These signals are regulating in a close manner in order not to be interfered with any other radio systems, including radio broadcasters, televisions and emergency services. When mobile phones are switched on, they receive certain control signals from nearby base stations. Then they start connecting to the closest base station in the network to which they subscribe. Until calls are made or received, they become dormant, just updating with the network. In mobile phones, automatic power controls are used as tools of maintaining good call quality through decreasing the transmitted power to the minimum possible. For instance, whilst using phones, the mean power output range from 0.001 watt as a minimum level to < 1 watt as a maximum. The design of this feature is performed for prolonging the talk time as well as the battery life [11].

Hashem and El-Sharkawy [12] found that the exposure of mice to EMFs increases the levels of urea and serum creatinine. Similarly, Tsuji et al. [13] reported that the levels of creatinine and blood urea nitrogen are increased when exposing mice to EMFs [5 T] for 2 days. Moreover, they are also increased when exposing mice to static MFs. This could be attributed to the renal impairment of kidneys along with the contracted glomerular tufts of some glomeruli and focal leukocytic aggregation by pathologic examination. Besides, it was reported that exposing animals to EMFs of mobile phones' radiations induce oxidative stress which causes renal dysfunction and using antioxidants such as melatonin may protectively affect this dysfunction [14, 15, 16]. Contrarily, levels of serum creatinine and urea in rats are not influenced by the exposure to EMFs. Gholampour et al. [17] indicated that exposing a solenoid radiation of 50 Hz, 1 mT for 24 hours during 4.5 months to rats showed that the level of serum creatinine and urea nitrogen has significantly increased ($p<0.001$). Moreover, there were marked vascular congestions in the renal cortexes and a RBCs count decrease in the glomerular capillaries. However, no changes were shown in the total levels of the globulin, albumin and protein [17].

At homes and workplaces, the availability of power lines and electrical devices, such as washing machines, kettles, and refrigerators necessitate the existence of EMFs exposure [12], representing a hidden environmental pollutant factor that affects the health of human beings and animals. Therefore, EMFs become a part of our everyday live due to the unavoidably use of electrical devices either those with extremely high frequency EMFs, including power lines and microwaves or those with extremely low frequency EMFs, including cell phones. Electromagnetic sources can be classified into natural (e.g., human bodies, sun, few remote stars and atmospheric discharges such as thunders) and unnatural/human-made, including electrical devices (e.g., radio base stations, televisions, microwaves, phone equipment, mobile phones, computers and printers) [18], transformers, cables carrying electrical currents and home wiring airports. High electric current, mobile phones and their base stations are primary sources of EMFs with very high frequencies and they are increasingly used all over the world. EMFs are divided into three categories regarding their frequency fields: (1) EMFs with static fields;(2) EMFs with extremely low frequency fields;(3) EMFs with intermediate frequency fields; and (4) EMFs with radio-frequency fields. EMFs with low frequency fields are widely spread in human environments and are produced from various sources, including trains for public transportation, power lines, and devices used for generating, distributing or utilizing electric power. This category has been considerably paid attention among the scholarly scientific context [19,20].

During the last few decades, evaluating the EMFs effect on human health have been histologically and physiologically investigated. As a result, protecting human beings from such effect produced from EMFs sources at homes and workplaces has become a public health issue. These effects include chronic fatigue, headache, cataract, heart problem, stresses, nausea, chest pains, and forgetfulness, which may influence memories, cardiovascular systems, reproductive systems, central nerves systems, endocrine, or immune systems [20], and leads to alterations of electroencephalographic activities, modifications of biological functions, or sleep disturbances in both human beings and animals [21,22].

EMFs have been known to have negatively affected various facets of human health. It increases the risk of life-threatening diseases, including breast and lung tumors, and brain cancers and leukemia [20], infertility, Lou Gehrig's disease, genotoxicity and neurodegenerative diseases, increased risks of miscarriage, childhood morbidities, de novo mutation, amyotrophic lateral scleroses, depressions, birth defects [20], reproduction anomaly, suicides, and Alzheimer's diseases [23]. There is much debate and argument in the literature that exposing to EMFs may affect the reproductive, cellular, immune and endocrine vertebrate systems. The nocturnal production of hormone melatonin by pineal gland is reduced by exposing to very low-frequency EMFs; therefore, the susceptibility to the sex hormone-related cancer, including breast cancer, is increased. Besides, there may be an interference between EMFs and memory performance since some evidence suggest that the stress-induced corticosterone releases have impairing effects on object recognitions in rats, or risks of breast cancers and Alzheimer's diseases can be definitely increased. Exposing to EMFs arises some key events, including changes in cell membrane activities and different enzyme systems' effects [12]. The living organism is affected by EMFs which is one of the complicated phenomena. The literature shows that the nervous system activities, organs and the molecules, including the deoxyribonucleic acid (DNA), ionic channel and body protein, are adversely affected by EMFs [18].

Different theories were displayed regarding the EMFs effects on the living organism through the radical mechanism, resonance and induction, which affect the cell signal transmissions, structures of the biological membrane and ion transports, the process of replications and transcriptions of nucleic acid and protein syntheses, as well as the process of cell proliferation [24]. The biological effect develops after the physicochemical mechanism is naturally initiated. The EMFs' physicochemical actions consist of electrolytic polarization, electrons, ions, dipolars, and macrostructures. Different factors might also have additional roles, including altered dipole spins, radicals' generation, weakening of chemical bonds, molecular excitation, changes of hydration, altered relaxation times of atom vibrations, and biochemical activations. Serum biochemical parameters could be affected by such physicochemical alterations [24]. In various organs of experimental animals, tissue damages are induced by the very low frequency EMFs. It was also reported that several cellular functions are influenced by EMFs. Within all organs of the human body, EMFs are penetrated and act to alter the cell membrane potential and change the distribution of ions as well as dipoles. At the atomic levels, the chemical and physical process is the base of reaction among biomolecules in EMFs, since the chemical bonds can magnetically be affected by these EMFs among adjacent atoms with the free radicals' consequent production. The biochemical process in cells may be influenced by such changes, thereby altering the serums' enzyme activity and biochemical parameter [25].

4. Results and Discussion

Some assumptions exist regarding the 2.45 GHz wireless EMFs with their adversely possible effect on children and pregnants. Unexposing to wireless EMFs from technologies in daily lives are nearly impossible. Therefore, 2.45 GHz EMFs exposure implication was used to evaluate the pre- and post-natal kidney. The dose relevant to age and the risk adversely possible effect of wireless EMFs on their in-utero determination was evaluated. The tissues' electrical transmission and conductivity in adult rats were higher than those in the young [25]. Thinner skins and skulls as well as larger heads compared to the body in adults resulted in fewer certain absorption rate values after exposing to EMFs when compared to those in children. In the study of Conil et al. [26], a 60 MHz mean resonance frequency was reported in the adult model, whereas 80, 100 and 120 MHz in 12, 8 and 5 years old models, respectively. Adults are likely to have less sensitivity to EMFs exposure than children. Nevertheless, the EMFs side effect along with the protection principles has not been completely shown.

Studies evaluating EMFs effects on kidney tissues showed various results, which could be attributed to different factors, including the application method, duration, gender, and exposure cumulative concentrations. Responses to EMFs could vary from one living organism to another. In Sprague-Dawley male rats, the GSH and MDA peroxidase level in the tissues of kidneys was increase after exposing them to 50 Hz EMFs [27,28]. Besides, 60

Hz EMFs exposure resulted in decrease in the GSH peroxidase level in the rats' tissues of kidneys. After exposure to 900 MHz EMFs, levels of superoxide dismutase, catalase and GSH peroxidase decreased, and those of MDA peroxidase in kidney tissues and those of the urinary N-acetyl-beta-D glycosaminidases (NAGs) increased as reported by two previous studies [29]. After exposure to 2.45 GHz EMFs prenatally, some studies reported higher levels of total oxidant, superoxide dismutase, and MDA peroxidase as well as lower levels of total antioxidants. Despite the statistically unsignificant differences, post-natal exposure led to a higher level of total oxidants and a lower level of total antioxidants and superoxide dismutase in kidneys tissues. Furthermore, the evaluation of exposure to 900 MHz EMFs effect on the living organism was conducted in some studies which showed a decrease in the superoxide dismutase, catalases and enzymes of antioxidative defence systems, in the pre-natal exposure group. In the rats embryo development, oxidative stress was reported during the pre-natal exposure period; however, it was persistent after birth [26].

Another previous study evaluated the effect of 900 MHz EMFs on the living organism using a transmission electron microscopy and reported developed abnormalities in the tubule and glomerulus [30]. In the present study, a high level of daily urinary NAGs in rats were caused by the 2.45 GHz EMFs exposure pre-natally and post-natally. Moreover, by examining the sections stained with eosin and hematoxylin, it was shown that tubular damages were caused by pre-natal EMFs exposure. Significant concerns and adversely possible effects in the intrauterine lives were received by exposing pregnant women to EMFs. Few investigations have been conducted in literature regarding the EMFs effect on fetuses, which could be attributed to the difficulty in planning and conducting fetal studies. Damaging effects on developing embryos in the pre-implantation stage were caused by the exposure to 50 Hz EMFs as a very low frequency for 14 days, wherein the blastocysts number was decreased and the deoxyribonucleic acid (DNA) fragmentations were increased [31].

As implicated in cell death, DNA mutation and aging, macromolecules' oxidation could be caused by a higher level of oxidative stresses in cells. Mitochondria associated with oxygen radical productions have essential roles in releasing the pro-apoptotic protein, that triggers caspase apoptosis and activations. Oxidative stresses have close relationships with apoptosis. For embryologically developing the kidney disease, urinary system and malignancy, tight balances between apoptotic and anti-apoptotic factors are extremely essential. Acute and chronic damages in kidneys have predisposing factors, including the low level of inflammatory reaction, imbalance between natural oxidant and anti-oxidant molecules. In addition, kidney damages have principal responsible molecules, including interleukin 6 proteins, reactive proteins, adhesion molecules and tumors necrosis factor alpha [32].

Tubular cells have the most sensitivity to oxidative stress in kidneys. The DNA fragmentations and the acute kidney damage period may rapidly increase the apoptotic cells' number. Apoptosis is stimulated by depleting guanosine triphosphate through p53 molecules which are moved from cytosol to mitochondria. Some proapoptotic and antiapoptotic proteins are induced by p53 molecules. Bax is "the main molecule that damages mitochondrial membrane and is induced by Bid, Bim and p53 molecules (protein)". Besides, the permeability of membranes is increased and the caspases with cytochrome c are activated. Apoptosis is also caused by excess calcium transitions into the cell. So, tubular necroses develop. In the ischemic renal damages, necroses and apoptosis coexist. Apoptosis is activated by tumors necrosis factor via the outer pathway through the activating nuclear factor-B, enhancing leukocyte migration's and expressing adhesion molecules and cytokines. "Tumors necrosis factor alpha is the common member of both external and internal apoptotic pathways, which activates Bid and triggers caspase-dependent apoptosis" [33].

The effects on human health emitted by cell phone and base station EMFs are of much debate and discussion. Therefore, different studies are using various methods aiming at investigating the EMFs' possible effects. Consequently, stereology has been rapidly grown in the last few decades, and it refers to "a scientific methodology which involves the estimation of the three-dimensional (3D) properties of histological structures based on two-dimensional (2D) images". It works with a low error level and obtains highly reliable outcomes within short periods because of some properties as it has high objectivity and can avoid systematic deviations from real values. So, stereology has a vital role and is a very important part in the morphometric studies. In such contexts, stereological outcomes of the EMFs group revealed a significant increase ($p < 0.01$) in the mean volume of cortex, medulla, distal, and proximal tubules. The increase could be resulted from oedema due to the infiltrations of mononuclear cells within tubules [34].

It is obviously known that the kidney volume can be increased due to any dilatation. When compared to the control group, the glomeruli number had a significant increase ($p < 0.01$) in the EMFs group. Apoptosis is "a major mechanism for controlling the glomerular population's size and is responsible for the progressive cell loss emerging in the glomerular sclerosis' pathogenesis". It was indicated by Hattori et al. that apoptosis is associated with the decrease in numbers of glomerular cells, which also leads to reduced renal functions. Histopathologically, the current study found that a common mammal renal histology in the control group was shown in the rats' kidneys. An increase in the degeneration (i.e, glomerulosclerosis, tubular defect, and tubule cells' hydrophiid degeneration) was shown on the EMFs groups' images. These EMFs' degenerative effects were reduced again by the folic acid administration. In the tubular cells, such histopathological alterations could be caused due to reduced glomerular blood flow as well as filtrated and constricted peritubular capillary walls in the interstitial linked tissues led through kidneys' oxygen radicals by the bioactive lipids' release. Deficient oxygenation and nutrition of both proximal and distal tubules as well as degeneration may be resulted from such constriction [35].

The frequent exposure to EMFs in smooth endoplasmic reticulum causes a reduction in toxicity which leads to vacuolization that initiates with the organelle's increased density. This organelle "plays a role in cell detoxification, the regression thereof and its manifestation in the form of vacuolization" [35]. Furthermore, massing of polymorphonuclear and mononuclear cells occured with chemotaxis may be related to mononuclear infiltration. In fact, EMFs are emitted from standard cell phones emit resulting in increased oxidative stresses and apoptosis in various body tissues. The oxidative process occurs more intensely in kidneys, that's why kidneys particularly have sensitivity to oxidative damages. The antioxidants' primary effects on the health of human beings occur through antioxidants' radical scavenging mechanisms. Therefore, EMFs' adverse effects as well as the antioxidants usage are highlighted by many studies so as to minimize them [36].

In the current study, exposing rats prenatally to EMFs of 900MHz decreased the glomeruli entire number and raised the kidneys' total volume. In another study, levels of renal superoxide dismutase, catalase and GSH peroxidase activities decreased after 900 MHz EMFs exposure of cellular phones [4]. Infiltrated leucocytes, vacuolation and degeneration of renal tubules with renal epithelium's necrosis, congested blood vessels, and Bowman capsules' dilatation with atrophied glomeruli are caused by the 900 MHz EMFs exposure [25]. In another study, it was concluded that the EMFs exposure also causes tissue damages; therefore, EMFs are considered to be a stress factor. Besides, significant positive effects ($p < 0.05$) were shown on the mean volume of medulla, kidneys and cortexes as well as on the glomeruli entire number. Folic acids in the current study act as free radical scavengers which can eliminate the EMFs' adversely possible effects. Consequently, this study the first study in which folic acids are used against renal damages caused by the EMFs exposure using stereological techniques [34].

Along with the technological advancement, it is obviously known that there are increasing amounts of EMFs emanated from power lines and electrical devices; of which cellular phones are essential because they are intensively used by human beings, which cause the body various harmful effects. These devices lead not only to enhanced waves in surrounding environments but also to stereology as "a multidisciplinary science field, which supplies practical techniques for obtaining quantitative information about 3D data from 2D sections for any type of structure". So far, few studies have been stereologically examined EMFs effects on the organs' prenatal development, particularly the kidneys using precise design-based stereological techniques. In the literature, studies estimated the EMFs' effects on the body focusing on brains, livers, kidneys or others. However, EMFs' harmful effects co-treated with melatonin and omega-3 for protection were stereologically evaluated [37,38].

Mobile phones' 900 MHz EMFs can cause oxidative damages by producing the free radical. Melatonin protects the kidney by acting as a powerful free radical scavenger. For rats exposed to 20 kHz triangular EMFs for 3 months, studies show no substantial toxicity or histological changes. Besides, the EMFs effect on the tissue tested are highly dependent on types and amplitudes of the EMFs as well as the duration of exposure. Furthermore, data from pregnant rats exposed to a sub-acute static MF found no evidence of DNA damages in livers and kidneys. EMFs radiated by mobile phones were also found to cause metabolic abnormalities and oxidative stress in renal tissues in another investigation [38]. The current findings suggest that the 1800 MHz EMFs exposure in case of experimental conditions can change gene expression in rat neurons [38,39].

These findings also showed that redox mediatory signals were involved in the cell growth control caused by 50-Hz very low frequencies. These investigations were conducted to lessen the detrimental effects of EMFs by employing compounds, such as MEL and -3, due to the EMFs negative influence on bodily organs. Moreover, the activity of these antioxidant enzymes was significantly increased by EMFs. Similarly, under intermittent hypobaric hypoxic situations, melatonin can protect the kidney, heart and lung and from oxidative stresses (lipid peroxidation). Also, it can protect against oxidative stresses in the kidneys and detoxes hydroxyl radicals produced by prolonged exposure to light. Arginine-induced nephrotoxicity and oxidative damages can be reduced by consuming omega-3 polyunsaturated fatty acids. Consequently, omega-3 has been labeled a free radical scavenger [38,40].

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