



Original Article

Effects of 5 G mobile phone network electromagnetic field exposure on testicular endoplasmic reticulum stress and the protective role of coenzyme Q10

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Aim

Nowadays, the electromagnetic field (EMF) has become an issue of *electromagnetic pollution*. This study aimed to determine the effect of 5 G Fr1 frequency band EMF waves on endoplasmic reticulum (ER) stress in testicular tissue and to demonstrate the efficacy of coenzyme Q10 (CoQ10) in suppressing the potential situation.

Materials and Methods

Three groups of eight male Sprague-Dawley rats were established. In group I (control) received only saline solution by oral gavage. In group II (EMF), saline solution was administered by oral gavage and the rats were exposed to 5.9 GHz EMF for 2 h/d (09:00–11:00). In group III (EMF+ CoQ10), the EMF exposure was created in the same way as in

group II and CoQ10 was given daily at 10 mg/kg (CoQ10), 2 mg/kg dissolved in corn oil and administered by oral gavage for the experimental period (30 days).

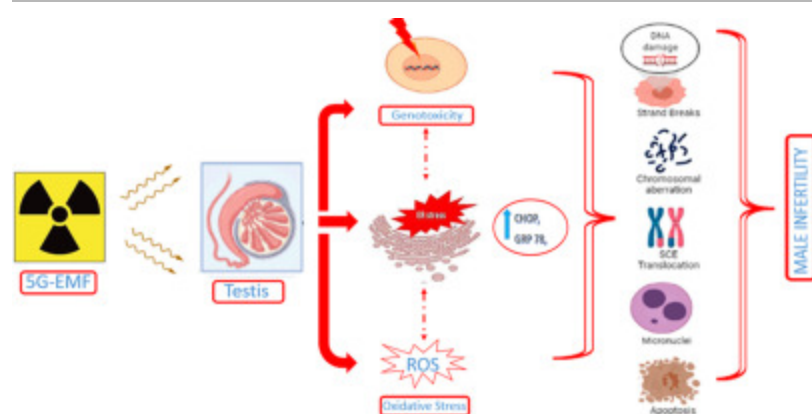
Results

Histopathological damage, including edematous regions, vascular congestion, and neutrophil inflammation accompanied by loss of spermatogenic cells, particularly spermatozoa, and spermatids, increased thiobarbituric acid (TBARS) and decreased total thiol (TT) levels were observed in the seminiferous tubules in the EMF group. Furthermore, germinal epithelial cells showing intense GRP-78 immunopositivity and spermatogenic cells indicating C/EBP homologous protein (CHOP) immunopositivity were increased in the seminiferous tubules. On the other hand, in the EMF+CoQ10 group, both histopathological and biochemical findings were observed in the opposite direction.

Conclusion

Due to its antioxidant properties and its ability to suppress oxidative stress and apoptosis, CoQ10 may be a promising candidate against 5 G EMF-induced testicular ER damage.

Graphical abstract



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Introduction

Despite its advantages, such as ultra-fast data transfer, low latency, and large network capacity, the revolutionary changes in 5 G (Internet of Things [IoT]) wireless communication technology infrastructure are causing concern. This is because its potential impact on

human health has been introduced without full disclosure. The lack of a standardized methodology for assessing EMF exposure from 5 G mobile phone networks and base stations exacerbates these concerns (1). In this context, the widespread use of 6 GHz $\leq$ EMF in the first frequency range (FR1) of 5 G, especially in the recent period, makes it necessary to investigate the potential adverse effects on human health (2), especially considering the growing body of evidence indicating that it may cause cytotoxic effects, oxidative stress, and DNA damage (3). Moreover, the use of 5 G will exponentially increase the number of base stations ($\times 10$ –100), making this need even more inevitable (4,5).

Coenzyme Q10 (CoQ10), a powerful antioxidant, has been reported to play an active role in the suppression of apoptosis which is closely related to endoplasmic reticulum (ER) stress, and in the prevention of cytotoxic damage caused by many stress factors including EMF (6,7). In the case of ER stress, the amount of the chaperone glucose-regulated protein (GRP78), which is one of the molecular markers, and C/EBP homologous protein (CHOP), which is a transcription factor, increases. This increases the stress stability, and the process evolves towards apoptosis. It has been reported that ER stress induces testicular and spermatogenic dysfunction processes by causing cellular apoptosis (8). It is known that ER stress can cause testicular dysfunction as a result of oxidative stress, apoptosis, and mitochondrial dysfunction (9). It has also been previously reported that ER stress may lead to varicocele formation, causing testicular dysfunction by increasing unfolded protein responses (UPR) in testicular tissue (10).

CoQ10 has been shown to have protective effects on sperm parameters, suggesting that it has the potential to mitigate spermatogenic cell death induced by various stress factors (11). Furthermore, different studies have reported that it is cytoprotective against reactive oxygen species (ROS)-induced mitochondrial dysfunction (12) and has neuroprotective and myocardial protective effects against ER stress (13,14). According to these studies and literature reviews conducted over the last decade, a broad spectrum of protective effects of CoQ10 against various types of stress and toxicity have been documented.

During our thorough review of the literature, no studies were found investigating the effect of 5 G mobile phone network on testicular ER stress levels and the protective role of CoQ10. In this context, the aim of our study was to investigate biochemically and histopathologically, the protective role of CoQ10 against potential ER stress (GRP78 and CHOP analysis) in testicular tissue. This is because EMF (mmWave [1–10 mm]) (5) propagation at the level of 6 GHz $\leq$, the first band range of 5 G networks, is absorbed in the superficial tissues and as a result of the increasing need for too many base stations.

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Animals and experimental design

The present study was approved by the Animal Experimentation Research Ethics Committee of the Recep Tayyip Erdoğan University (Rize, Turkey; approval number: 2022/25). Animals were handled in accordance with the National Institutes of Health Guidelines for the Care and Use of Laboratory Animals (IACUC). This study was carried out at the Animal Experiments Unit of the Recep Tayyip Erdoğan University using 24 male Sprague-Dawley rats (310 ± 30 g), aged 3–4 months. All rats were kept under optimal ...

Tissue homogenization

Testicular tissues from rats euthanized under anesthesia were washed with 0.9 % cold (+4 °C) NaCl, dried with blotting paper, and stored at -80 °C until the experiments were performed. Other testicle tissues were placed in 10 % formaldehyde solution for histopathological and immunochemical analyses.

An homogenization buffer was prepared with 20 mM 1 L sodium phosphate +140 mM potassium chloride (pH 7.4) (21). The tissues were homogenized by adding 1 mL of homogenization buffer to 100 mg of ...

Biochemical results

We measured TBARS level in testicular tissue to assess lipid peroxidation, and it was found to be significantly increased in the EMF group when compared to the control group (Table 4; $p=0.003$). In the EMF+CoQ10 group, there was a significant decrease in the levels when compared to the EMF group, but no significant difference was observed with the control group (Table 4; $p=0.002$).

The amount of TT, which was measured to determine antioxidant levels in testicular tissue, was found to be ...

CHOP/DDIT primary antibody

When the testicular tissue sections incubated with the IHC method and the CHOP primary antibody were observed under a light microscope, we observed that the testicular tissue sections of the control group were immune-negative for CHOP primary antibody (Fig. 4A, Table 7, CHOP positivity score: 0 [0–0]). In contrast, we observed an increase in the number of germinal epithelial cells with intense CHOP immunopositivity in the seminiferous tubules in the testicular tissue sections of the EMF ...

Discussion

Today, the potential impact of EMF on human health, which has reached the level of electromagnetic pollution, has been exacerbated by the recently deployed 5 G mobile phone network (1). In parallel, the need for an increasing number of base stations (10–100 times higher) in 5 G usage increases the magnitude of the concerns (4,5). Due to the high frequency (6 GHz <) and millimeter wavelength, the EM waves that will be used in 5 G are largely absorbed in superficial tissues. The testicular tissue ...

Conclusions and recommendations

Male infertility, which is a global health problem, can be attributed to homeostatic imbalances in the reproductive system that affect spermatogenesis. Under normal physiological conditions, the concentration of ROS plays a crucial role in the process of activating healthy sperm production. Nevertheless, excessive increase in ROS levels can lead to ER stress, which causes a state of oxidative stress. This condition can adversely affect sperm quality by disrupting the sperm's ability to ...

Availability of Data

The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request. ...

Ethical approval

All animals were cared for in accordance with the principles outlined in the National Institutes of Health Guidelines for the Care and Use of Laboratory Animals. The RTEU Local Animal Care Committee (Rize, Turkey) approved the study (Protocol No. 2022/25–30.06.2022). ...

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Conflicting Interests

The author(s) declared no potential conflicts of interest related to the research, authorship, and/or publication of this article. ...

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