Environmental Toxicology and Pharmacology 40 (2015) 600–605

Contents lists available at ScienceDirect

Environmental Toxicology and Pharmacology

journal homepage: www.elsevier.com/locate/etap

Review

Effects of acute exposure to WIFI signals (2.45 GHz) on heart variability and blood pressure in Albinos rabbit

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ARTICLE INFO

Article history:
Received 25 March 2015
Received in revised form 8 August 2015
Accepted 13 August 2015
Available online 17 August 2015

Keywords:
Heart rate (HR)
Arterial pressure (PA)
Electrocardiogram (ECG)
Efficacy of catecholamines
Dopamine
Epinephrine

ABSTRACT

Electrocardiogram and arterial pressure measurements were studied under acute exposures to WIFI (2.45 GHz) during one hour in adult male rabbits. Antennas of WIFI were placed at 25 cm at the right side near the heart. Acute exposure of rabbits to WIFI increased heart frequency (+22%) and arterial blood pressure (+14%). Moreover, analysis of ECG revealed that WIFI induced a combined increase of PR and QT intervals. By contrast, the same exposure failed to alter maximum amplitude and P waves. After intravenously injection of dopamine (0.50 ml/kg) and epinephrine (0.50 ml/kg) under acute exposure to RF we found that, WIFI alter catecholamines (dopamine, epinephrine) action on heart variability and blood pressure compared to control. These results suggest for the first time, as far as we know, that exposure to WIFI affect heart rhythm, blood pressure, and catecholamines efficacy on cardiovascular system; indicating that radiofrequency can act directly and/or indirectly on cardiovascular system.
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Contents

1. Introduction

Due to the constant evolution of new technologies more and more people are exposed at home or at work to different frequencies of electromagnetic fields (Feychting et al., 2005). In fact, there is an increase in the use of WIFI (wireless fidelity) devices 2.40 GHz by local networks (Brunel, 2004). Increasing evidence suggests that electromagnetic field (EMF) in the environment have many bioeffects (Lahbib et al., 2014; Ghodbane et al., 2015) that could affect cardiovascular system (Gmitrov, 2007) and induce oxidative stress (Salah et al., 2013). Besides that, Abdelmelek et al. (2006) showed an increase in norepinephrine in skeletal muscle after static magnetic field (SMF) exposure, indicating sympathetic hyperactivity. Interestingly, Heart rate variability was usually used for

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http://dx.doi.org/10.1016/j.etap.2015.08.015
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quantifying the autonomic nervous system activities (Acharya et al., 2002). Previous studies on animals and humans, demonstrated that EMF induced changes in heart activities. Pawlak et al. (2013) show that the exposure of animals to EMF increased heart rate, in chick embryos especially from 17 days of incubation (Gaffey and Tenforde, 1981), in rats, (Togawa et al., 1967) in rabbits, (Gaffey et al., 1980) in baboons, (Tenforde et al., 1983) in monkeys, and (Jehensen et al., 1988) in humans. Moreover, Thomas and Tenforde (2005) demonstrated the rise of blood flow under magnetic field environment. Interestingly, magnetic exposure induced electrocardiogram (ECG) abnormalities (Bortkiewicz et al., 1997). Creasey and Goldberg (1993) showed increase in heart rate and arrhythmia in people working around electrical trains (26 kV/m). In addition, Braune et al. (1998) reported that exposure to GSM signals for 35 min increased (+10%) blood pressure in volunteers. Vangelova et al. (2005) found that the radiofrequency may enhance hypertension and dyslipidemia. Cai et al. (2006) reported that radar exposure increased the rate of ECG changes in soldiers. Interestingly, Israel and Tomov (2000) showed high rates of hypertension in broadcast and TV station operators. The chronotropic effects, classically observed under radiofrequencies RF could be related to heart's excitability characteristic and rhythm or contraction (Elmas et al., 2012).

The present study aimed to evaluate (i) firstly the effects of WIFI on heart rate variability and blood pressure, (ii) secondly the physiological effects of catecholamines (dopamine and epinephrine) on heart rate under WIFI in rabbit.

2. Materiel and methods

2.1. Animals

In the present investigation we used adult male rabbit weighing 2.00 ± 0.50 kg (Central Pharmacy, Tunis, Tunisia). Animals were housed in groups of six in cages at +25 °C, under a 12:12 h light/dark cycle, with free access to water and commercial mash. Animals were cared for, under the Tunisian code of practice for the care and use of animals for scientific purposes. The experimental protocols were approved by the Faculty Ethics Committee (Faculté des Sciences de Bizerte, Tunisia).

2.2. Exposure system

The animals were exposed to an access point (AP) from WIFI device (D-Link DWL-3200 AP with 802.11 g mode and WPA2 network protection) as previously described in Salah et al. (2013). WIFI integrated two omnidirectional antennas that were setup for internet broadcast via wireless at 2.45 GHz. The sham control rabbits were placed under the same condition without applying RF (0 Hz). Antennas of WIFI were placed at 25 cm at the right side near the heart (animal in dorsal decubitus).

2.3. Experimental design

The rabbits were divided into six groups and for each group six rabbits and treated by intravenous injection as follows:

Group 1. Normal healthy control.
Group 2. Normal healthy: rabbits were exposed to WIFI one hour (between 9 h and 13 h).
Group 3. Rabbits were intravenously injected once with epinephrine (0.50 ml/kg).
Group 4. Rabbits were exposed to WIFI one hour (between 9 h and 13 h) following once intravenous injection of epinephrine (0.50 ml/kg).
Group 5. Rabbits were intravenously injected once with dopamine (0.50 ml/kg).
Group 6. Rabbits were exposed to WIFI one hour (between 9 h and 13 h) following once intravenous injection (iv) of dopamine (0.50 ml/kg).

The variation of the frequency and the cardiac rhythm were measured with an electrocardiogram" ECG". The ECG was recorded using Biopac® (MP35/30). Changes in blood pressure were measured using a pressure transducer connected to a chart recorder.

2.4. Analytical procedures

Records of changes in heart rate were done using a device consists of a software Biopac Student Lab 3.7.1, Biopac acquisition unit (MP35/30) with the associated cables, transformer BIOPAC, BIOPAC of electrode cables (SS2L), a computer, three vinyl disposable electrodes subject (EL503). The electric phenomena hearts materialize on the ECG by a base line broken by a P wave, a complex QRS and a T-wave. We measured the intervals PR, QT, RR, and P wave, beats heart per minute (BPM) and maximum amplitude after each exposure to WIFI (2.45 GHz, 1 h) and before each injection of catecholamines (dopamine, epinephrine).

2.5. Statistical analysis

Statistical analysis of data was performed using analysis of variance (ANOVA) for comparison between groups. Values for (*) $P < 0.05$, (**) $P < 0.01$, (***) $P < 0.001$ were considered statistically significant. The data are shown as a mean ± standard error of the mean (SEM).

3. Results

Our investigation reported that acute exposure to WIFI device induced an important reduction of the RR interval duration compared to controls, indicating an increase of heart frequencies. Moreover, we observe an increase PR and QT intervals (Fig. 1A–C). WIFI may influence the activity of nodal tissues especially auriculo-ventricular nodes. By contrast, the same exposure failed to alter P wave (Fig. 1D).

The present data showed that WIFI radiation (2.45 GHz) induced an increase of heart beats of animals. However, amplitude of the electrocardiogram remained unchanged during WIFI exposure compared to controls (Fig. 2A and B). In addition, we observe that acute exposure of rabbits to WIFI (2.45 GHz) during one hour induced an important increase in blood pressure compared to controls as shown in Fig. 3.

Our investigation showed that the single injection of dopamine (0.50 ml/kg, iv) induced an increase of the RR, QT intervals duration and decreased the PR interval and P wave of electrocardiogram compared to controls. Moreover, injection of dopamine under acute exposure to RF (2.45 GHz, 1 h) induced an important decrease in the length of the RR and QT intervals and an important decrease in the duration of the interval PR compared with rabbits given only dopamine, whereas P wave remained unchanged (Fig. 4A–D).

The administration of dopamine under WIFI exposure (2.45 GHz, 1 h) induced an important increase of beats per minute and decreased the maximum amplitude, compared to the rabbits injected only dopamine as reported in Fig. 5.

The epinephrine injection induced a decrease of RR, PR, QT intervals duration and P wave of electrocardiogram compared to control. Contrary, combined treatment with epinephrine (0.50 ml/kg, iv) and WIFI induced an important increase in the length of RR and QT intervals. The same treatment provoke an important decrease of the duration of interval PR and P wave compared to control (Fig. 6A–D).

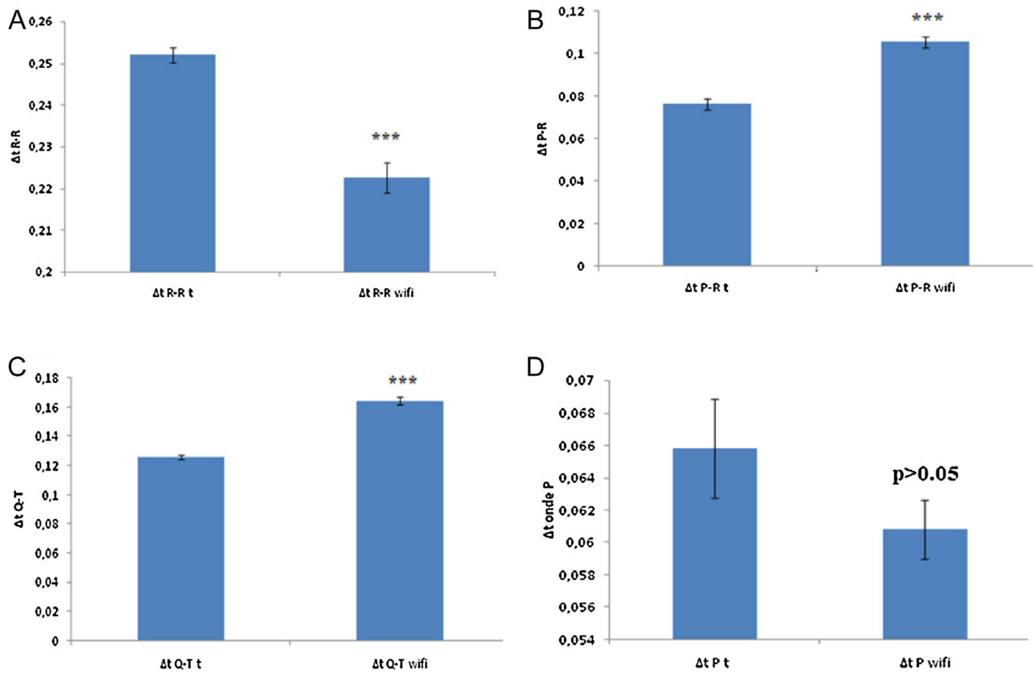

Fig. 1. The effects of acute exposure to WIFI (2.45 GHz, 1 h) on: (A) the RR intervals (Δt R-R) and (Δt R-R WIFI), (B) PR intervals (Δt P-R) and (Δt P-R WIFI), (C) QT intervals (Δt Q-T) and (Δt Q-T WIFI), (D) P wave of electrocardiogram in rabbits (Δt P) and (Δt P WIFI). Values are given as the mean ± SEM for groups of six animals. WIFI exposed rabbits were compared with control rabbits.

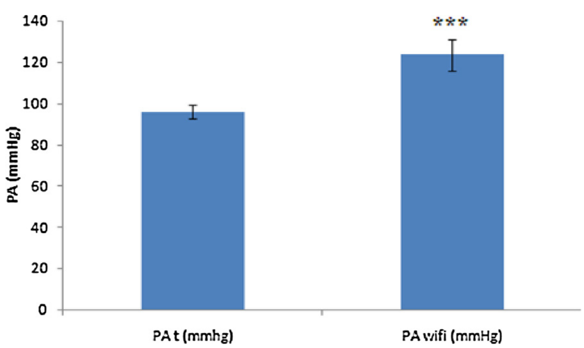

Fig. 2. The effect of acute exposure to WIFI (2.45 GHz, 1 h) on: (A) BPM control and BPM WIFI, (B) max control and max WIFI. Values are given as the mean ± SEM for groups of six animals.

The epinephrine injection induced an important increase in beats per minute and decreases the maximum amplitude compared to control. In case of rabbits treated with epinephrine (0.50 ml/kg, iv) under RF radiation (2.45 GHz), we observed an important decrease of beats per minute and the maximum amplitude compared to the rabbits injected only epinephrine (Fig. 7A and B).

Single injection of dopamine (0.50 ml/kg) decreased the arterial pressure compared to control. By contrast, single administration of epinephrine (0.50 ml/kg) increased the arterial pressure. In case of rabbits treated with dopamine and epinephrine under RF exposure the arterial pressure return to the normal state. WIFI (2.45 GHz, 1 h) exposure alters the classical responses observed following the administration of both catecholamines as showing in Fig. 8

4. Discussion

Our investigation point that acute exposure to WIFI induced an increase in heart rate and arterial blood pressure; showing a modulatory effects of RF on the cardiovascular system regulation. Interestingly, catecholamines (dopamine and epinephrine) bioeffects on cardiac rhythm and vasomotricity were altered by WIFI in rabbits.

Exposure to new wireless technologies will be inevitable in our domestic life. The development of new technologies such as WIFI, which allows data transfer through a microwave field (2.4 GHz) and

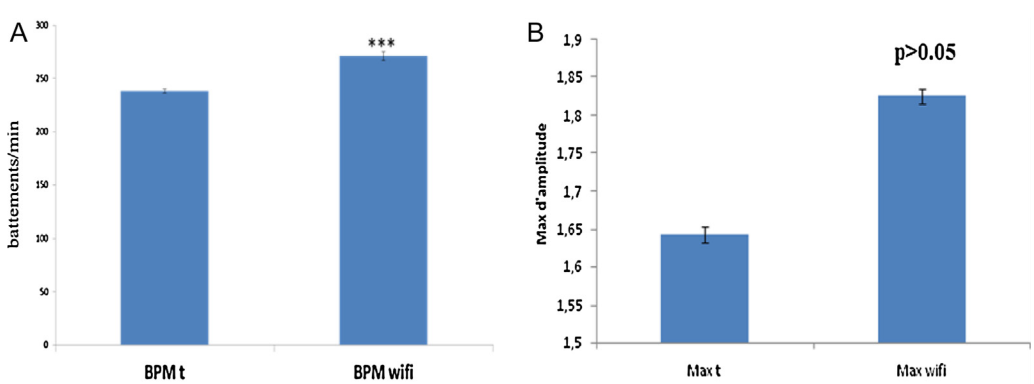

Fig. 3. Effects of acute exposure to WIFI on blood pressure of rabbits on: PAt control and PA WIFI. Values are given as the mean ± SEM for groups of six animals.

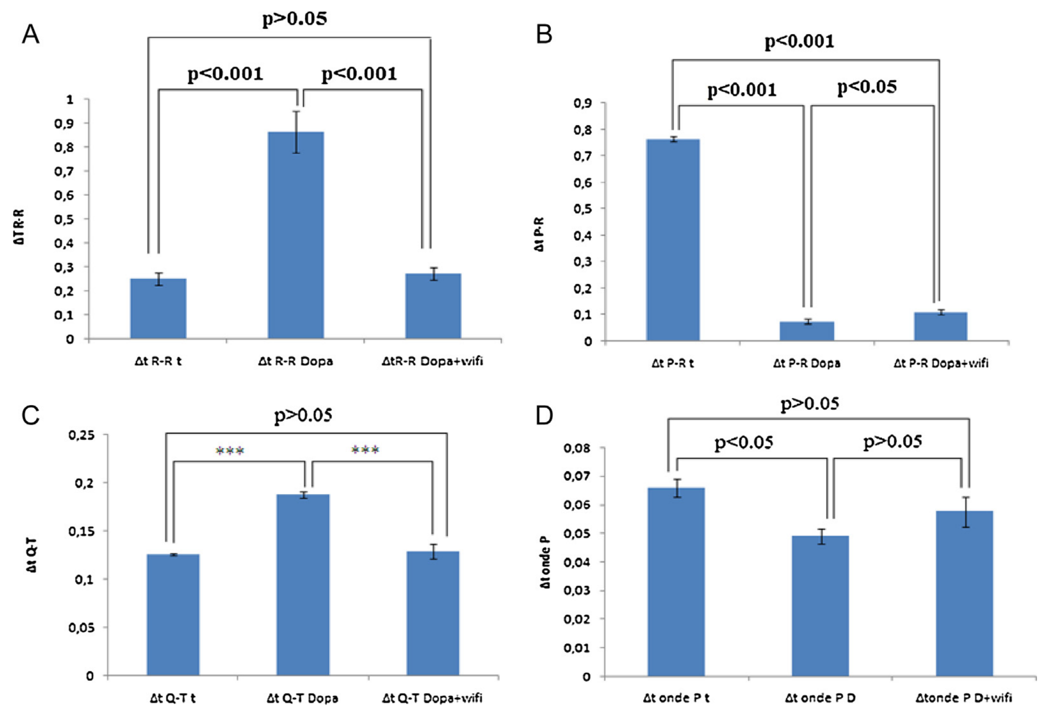

Fig. 4. Effects of single injection of dopamine on the component of electrocardiogram in rabbits under acute exposure to WIFI (2.45 GHz, 1 h). Values are given as the mean ± SEM for groups of six animals.

with a transmission rate from 1 to 50 Mbps (Valberg et al., 2007); can have serious consequences on public health and multiple bioeffects (Sage and Carpenter, 2009). Our results show clearly that WIFI increased heart rate and arterial blood pressure probably via direct and/or indirect pathways. The direct effects of RF could be related to their action on Ca^{++} and Zn^{++} homeostasis especially on divalent mineral flux modulated by EMF as shown previously by Amara et al. (2007). Interestingly, Pilla et al. (1999) demonstrated that static magnetic fields (SMFs) in the range of 0–200 mT accelerate Ca^{++}/calmodulin-dependent myosin light chain phosphorylation. In order to demonstrate the whole mechanism and the implication of K^{+} channel in the heart responses induced by RF, electrophysiological studies of RF will be programmed for future investigations.

The indirect pathway will deal with the modulatory effects of RF on autonomic nervous system, plasma catecholamines, and glucocorticoides.

In fact, Abdelmelek et al. (2006) showed an increase in norepinephrine in skeletal muscle following SMF (128 mT) exposure; indicating sympathetic hyperactivity. The sympathetic hyperactivity classically observed following EMF exposure explain in part our data reporting an increase of heart rate (HR) and arterial blood pressure under WIFI exposure. Similar investigation by Braune et al. (1998) pointed for the implication of sympathetic tone induced by EMF in hypertension. The present investigation reported that acute exposure to WIFI provoked a decrease in the RR interval, indicating a tachycardia explaining the hypertension. By contrast, Jehensen et al. (1988) showed an increase (+17%) of the length of the RR interval after ten minutes of SMF exposure in healthy volunteers. The PR interval reflects the time that electrical impulse takes to travel from the auriculo-ventricular node and enters to the ventricle. The increase in the PR interval supported that the conduction system of the heart was altered. It is in accordance with Blanchi et al. (1973) when mice were exposed to 100 kv/m (50 Hz); the QRS duration and the PR interval were each lengthened by 19.50%. While, the acute exposure to WIFI increased the QT interval; showing that the time for both ventricular depolarization and repolarisation was larger. Otherwise, the heart is a contractile organ that can generate its own rhythm (Elmas et al., 2012). Arber and Lin (1985) showed that continuous exposure of neurons to microwaves for 60 min inhibited spontaneous activity and prolong the refractory period following depolarization. An increase of K^{+} current could be implicated as a cause for prolongation of refractory period (Seaman and Wachtel, 1978; Arber and Lin, 1985) as reported in our investigation by the prolonged PR and QT intervals.

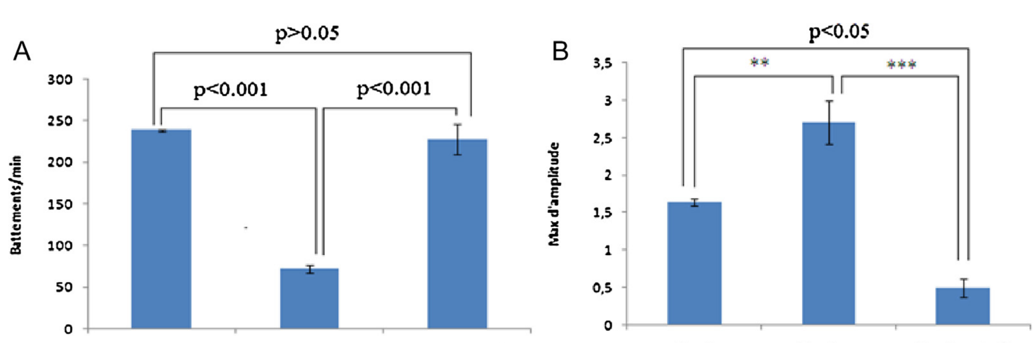

Fig. 5. Effects of single injection of dopamine on the beats per minute (BPM) and maximum amplitude (max) in rabbits under WIFI (2.45 GHz, 1 h).

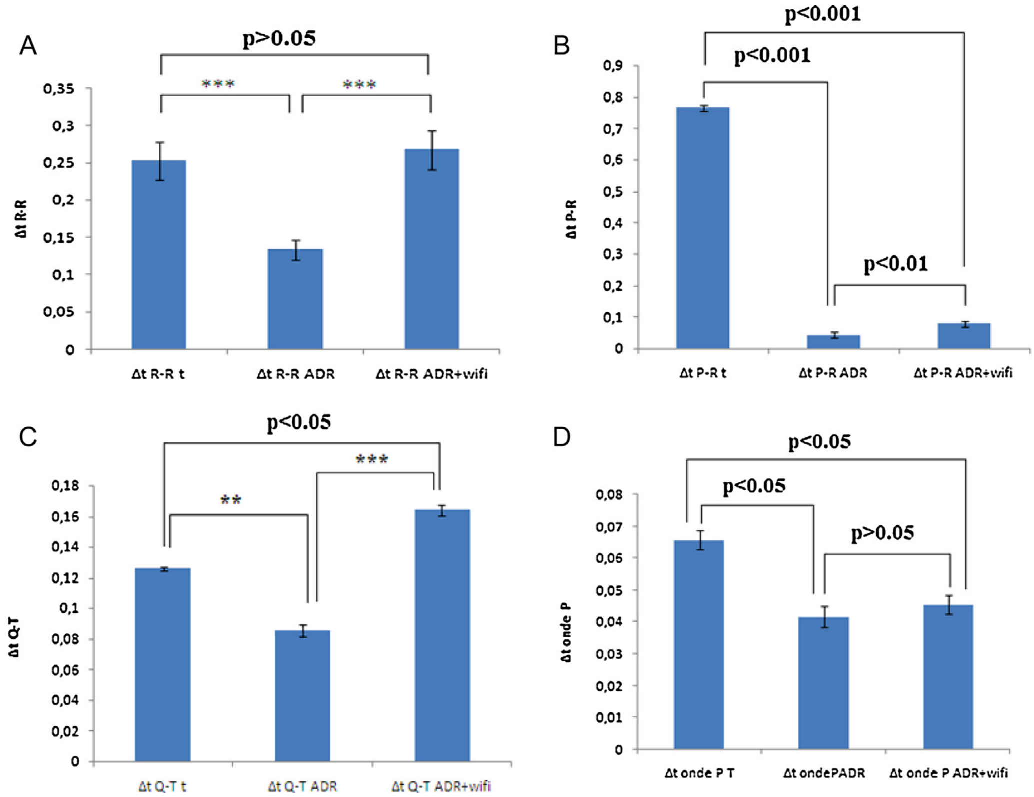

Fig. 6. Effects of single injection of epinephrine on the component of electrocardiogram under WIFI (2.45 GHz, 1 h). Values are given as the mean ± SEM for groups of six animals.

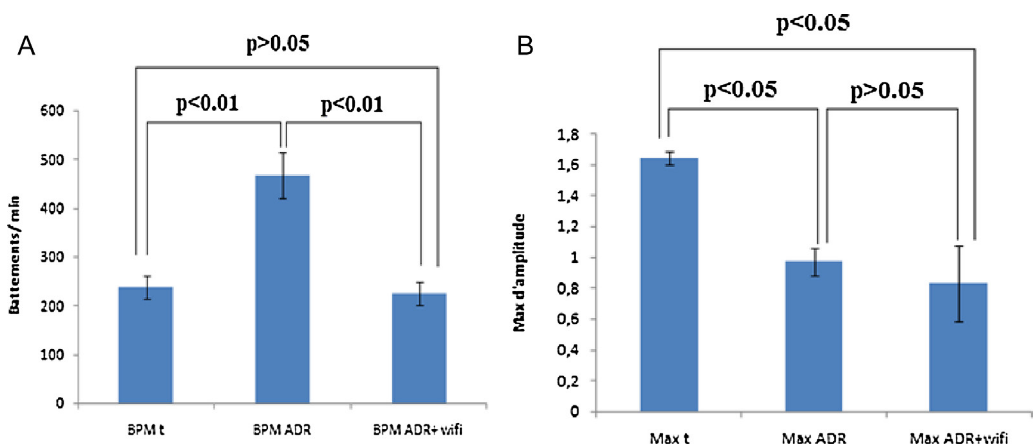

Fig. 7. Effects of single injection of epinephrine on the beats per minute (BMP) and maximum amplitude (max) in rabbits under acute exposure to WIFI (2.45 GHz, 1 h). Values are given as the mean ± SEM for groups of six animals.

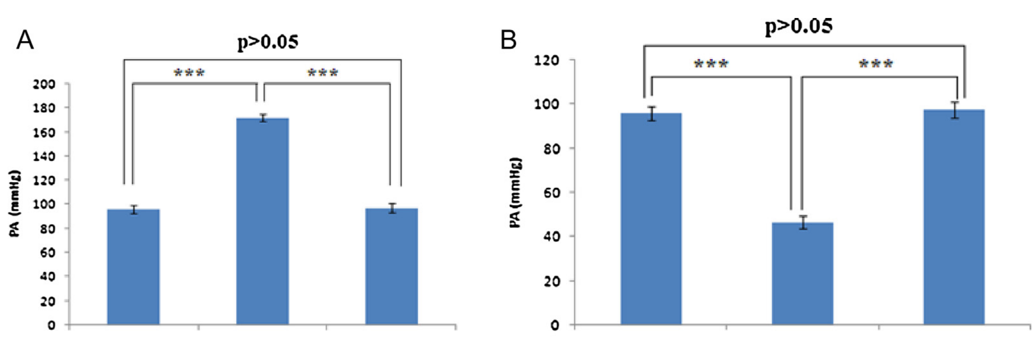

Fig. 8. Effects of epinephrine and dopamine injections on blood pressure under acute exposure to WIFI (2.45 GHz, 1 h). Values are given as the mean ± SEM for groups of six animals.

Our data demonstrate that single injection of epinephrine increase heart rate associated to a decrease in the RR, QT, PR intervals and even the P-wave. Moreover, single injection of dopamine decreased heart rate and increased RR, QT, PR intervals and even the P-wave. Acute exposure to WIFI (2.45 GHz during one hour) alters epinephrine and dopamine effects classically observed on heart rate, arterial blood pressure and the most studied intervals. This data report clearly that the action mechanism of epinephrine was abolished through RF. We can therefore say that RF emitted by WIFI act probably on the receptors, thereby altering the ligand–receptor binding. In fact, Chiabrera et al. (2000) showed that the probability of binding could be modified by the electric component of the RF. Previous study reported that exposure to 50-Hz magnetic field decreased the binding affinity of the 1B receptor subtype of serotonin (Masuda et al., 2010). Behari et al. (1998) shows that AM radio radiation alters Ca^{2+} binding in the membrane, $Na^{+}K^{+}$-ATPase activity.

Our studies point that WIFI is not completely safe at home near the animal or human body because it employ harmful radio waves. But it is safer compared to cellphone that it is close to our brain during communications. WIFI signals are everywhere. If you switched off your WiFi at night, you are still exposed to the WIFI signals coming in from neighbors but we have a significant reduction of the bioeffects of WIFI with distance from the router. Future investigations will focus on the long term bioeffects of WIFI placed at an important distance from the animal or the human.

5. Conclusion

These results suggested that exposure to WIFI (2.45 GHz) affect HR variability leading to tachycardia and hypertension. The WIFI alter the physiological action of catecholamines on cardiovascular system perhaps via the disruption of the interaction between ligand-receptors in rabbit.

Transparency document

The Transparency document associated with this article can be found in the online version.

Acknowledgment

We thank Bechir Azib for his excellent technical assistance.

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