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ORIGINAL ARTICLE

Does Radiofrequency Exposure Affect Hearing of Children?

Faruk Meric, Suleyman Dasdag, M. Mutlu Dasdag

ENT Department of Dicle University Medical School, Diyarbakir 21280, Turkey (FM)
Biophysics Department of Dicle University Medical School, Diyarbakir 21280, Turkey (SD)
Biostatistics Department of Dicle University Medical School, Diyarbakir 21280, Turkey (MD)

Objective: The effects of radio frequency (RF) and microwave radiation on humans have been the subjects of continuous investigation. Since one of the major group of children exposed to RF/microwave radiation includes those living in the employee residential houses of radio broadcasting station, this study investigates whether RF affects auditory systems of children living in the houses close to a 1,062 kHz medium wave radio broadcasting station.

Materials and Methods: The study is carried out on twenty-five volunteer children (Boys: 13, Girls: 12) living in employee residential houses close to a broadcasting stations. All subjects in the control group were similar in age, socioeconomic status, but they were not exposed to radiofrequencies. Brainstem Evoked Response Audiometer (BERA) and Pure Tone Audiometry (PTA) were used to measure the effects of RF under investigation on hearing thresholds of the subjects. I-III, III-V and I-V inter peak intervals were measured in BERA. Hearing thresholds at 250 Hz, 500 Hz, 1,000 Hz, 2,000 Hz, 4,000 Hz and 8,000 Hz were measured in pure tone audiometric measurement.

Results: Statistically insignificant sensory neural hearing loss was observed in six children living in residence of broadcasting station at 4,000 and 8,000 Hz frequencies ($p > 0.05$). However, no difference was observed between the children in the residence of broadcasting station and control ($p>0.05$). BERA results also indicated no significant differences ($p> 0.05$).

Conclusion: Our results showed no actual hearing loss in the RF exposed children living in employee residential houses. However, we suggest monitoring of hearing function.

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Research activities on radiofrequency exposure have generally focused on brain tumors and cancer. However, the research should also be focused on hearing functions of persons working or living in RF/microwave fields such as radio broadcasting, TV transmitting stations, and radar. Some people may perceive individual pulses of RF as audible clicks, chirping, or buzzing sounds, depending on the pulsing regime and intensity of the frequency and this may play a role on hearing functions. Frey was the first scientist to investigate this phenomenon [10, 21]. However, there have been numerous studies on the auditory responses of volunteers today. Other radiation parameters (peak power density, energy density per pulse, and pulse width) are also important to determine human threshold. Most experimental results indicate that the auditory perception of RF pulses is due to the induction of thermo elastic waves in the head rather than direct brain stimulation by the RF [22]. At high power levels, RF/microwave energy can rapidly heat biological tissue and cause damage, such as burns [20]. However, the RF/microwave health issue has generally focused on whether there are any adverse biological effects from long term or frequent exposure to low-levels radio frequency emissions that are not caused by heating (non-thermal effects). While most workers in the field of communication and radar are exposed only to low strength fields, in a few situations workers can potentially be exposed to high levels of RF radiation. Power density is usually very low (1 microwatt/cm2) in radio transmitter rooms, near the bases, and surrounding areas [12, 14, 15, 18, 19].

Corresponding address:
Suleyman Dasdag
Biophysics Department, Medical Faculty of Dicle University, Diyarbakir 21280, TURKEY
Phone : +90 412 248 80 89; Fax: +90 412 248 84 40; E.mail: dasdag@dicle.edu.tr

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Employees who have been both working at and living in the surrounding areas of broadcasting stations constitute one of the major groups occupationally exposed to RF and microwave. The children living in the employee residential houses of radio broadcasting stations expose to RF/microwave radiation chronically, because they spare their daily life in this area. Therefore, another important exposure group is children living in employee residential houses close to the antenna of broadcasting stations because of their parents' job.

Clinical investigations on occupational RF and/or microwave exposure on humans have been still the subject of continuous investigation [1-5, 12, 17]. Consequently, since the RF auditory phenomenon has been widely recognized as one of the most interesting biological effects of RF, this study presents an analysis of the effects of radiation emitted from antenna of the radio broadcasting stations on hearing functions in children residing near these stations.

Materials and Methods

Twenty-five children living in the employee residential houses near broadcasting stations and 20 age-matched children-a total of 45-were selected for this study. All subjects in the control group were matched in terms of age (7-14 years old), socioeconomic status, and lack of experience with RF sources. Ten of the children in the study group have been born in the houses provided for employer. Duration of stay in these houses for the rest of 15 children was between 2 - 11 years. After obtaining the subjects' consents an otolaryngologist examined their ears and excluded the cases that had ear diseases such as otitis media, otosclerosis, a history of any ear and/or neurologic diseases, and noise-induced hearing loss, which may affect neurotologic pathway. All children in one radio broadcasting station volunteered to participate in the study.

BERA and PTA were used to measure the effects of RF under investigation on hearing functions of the subjects. In BERA measurements, I-III, III-V and I-V interpeak intervals were defined. In pure tone audiometric measurements, hearing thresholds at 250 Hz, 500 Hz, 1,000 Hz, 2,000 Hz, 4,000 Hz and 8,000 Hz were measured in subjects of the study and control groups. Interpeak latencies and bone conduction hearing thresholds of subjects in the study group were compared with those of the control group.

Bone conduction hearing threshold was recorded by means of pure tone audiometry (OB-822, Madsen electronics, Copenhagen, Denmark).

BERA was performed by Sapphire 2A EP System (Medelec, Old Woking, UK) device after children lay supine on a bed in a sound-isolated and electrically shielded room.

Recording of BERA

Three silver chloride disk electrodes were placed, respectively, at the forehead in the midline (ground), at the mastoid ipsilateral to the acoustic stimuli (negative), at the vertex (positive). Inter-electrode resistance was maintained at 4kΩ or less; 100-μsec duration of rarefaction clicks were used as acoustic stimuli. Brainstem responses to 2,048 clicks were recorded for each run. The recording signals were band pass-filtered between 100 and 2,000 Hz and processed by an averaging computer. Automatic artifact rejection was used to reduce inclusion of high-amplitude muscular activity in the averaged responses. Measurement was discontinued whenever there were excessive muscle artifacts on the monitoring oscilloscope. In repeating records, sound waves with stable duration and shape were recorded at 90 dB sound pressure level (SPL) delivered monaurally through TDH 39 earphones used for comparisons. The contra lateral ear was masked with white noise 40 dB below the ipsilateral click stimuli. All subjects were tested at a click rate of 10/sec.

Measurement of Electrical-Field and Power Density

Power density and Electrical (E) field of radio frequency inside and around the employee residential houses and playing area of the children as well as other nearby locations were measured by using electrical field probe of EMR 300 (NARDA, Pfullingen, Germany).

Statistical Analysis

Statistical analysis of Mann-Whitney U non-parametric test was performed for pure tone

audiometry results in all frequencies and BERA values of 90 dB SPL.

Results

The distance of the antennas to the employee residential houses was between 300 and 350 meters. Electrical field and power density inside the employee residential houses of radio broadcasting station were between 0.48 V/m and 2.86 V/m and 0.0001 mW/cm2 and 0.0023 mW/, respectively, depending on the distance from the antenna. However, average E field and power density in children's playgrounds were measured as 12.75 V/m and 0.0436 mW/cm2. Average E field and power density outside the playgrounds and employee residential houses were measured as 18.64 V/m and 0.097 mW/cm2. E field and power density inside and around these houses where the subjects in the control group normally reside were measured between 0.34 V/m and 2.00 V/m, and 0.0000 mW/cm2 and 0.0011 mW/cm2, respectively.

Pure tone audiometry results showed no statistically significant differences in 250, 500, 1,000, 2,000, 4,000, 8,000 Hz frequencies between the exposed and unexposed groups ($p > 0.05$). However, statistically insignificant and minimal sensory neural hearing loss was observed in six of the children in exposed group especially for 4,000 and 8,000 Hz frequencies ($p>0.05$). This insignificant hearing losses usually observed on right ears of these six children except one.

Additionally, hearing of children born in these residential houses were compared with control children and no differences was observed ($p>0.05$). Statistical analyses of subjects's BERA findings also indicated no difference in the I-III, III-V, or I-V interpeaks intervals ($p >0.05$). On the basis of Mann - Whitney U test results, the findings of interpeak intervals are illustrated in Table 1. However, mean values of the PTA frequencies in two groups were shown in Table 2.

Table 1. Results (mean (SD) of BERA interpeak intervals for the children

	Interpeak intervals; 90 dB, 10 pps					
Subjects	**I-III* (msec)**	**I-V* (msec)**	**III-V* (msec)**	**I-III* (msec)**	**I-V* (msec)**	**III-V* (msec)**
Control children						
Right Ear	2,20 ± 0,23	3,97 ± 0,26	1.77 ± 0.12	2.28 ± 0.14	4.18 ± 0.13	1.90 ± 0.03
Left Ear	2.18 ± 0.19	3.96 ± 0.40	1.78 ± 0.22	2.24 ± 0.18	4.22 ± 0.23	1.98 ± 0.07
Study children ±n=7)						
Right Ear	2,04 ± 0,15	3.76 ± 0.31	1.71 ± 0.28	2.23 ± 0.08	4.18 ± 0.14	2.04 ± 0.17
Left Ear	2.16 ± 0.05	3.98 ± 0.40	1.82 ± 0.26	2.24 ± 0.13	4.23 ± 0.20	4.02 ± 0.13

*There is no difference between the two groups ($p>0.05$).

Table 2. Bone conduction hearing thresholds (mean (SD) of the children for six frequencies

	Frequencies(Hz)					
Subjects	**250***	**500***	**1,000***	**2,000***	**4,000***	**8,000***
Control Children						
Right	16.5 ± 3.37	13 ± 2.58	9 ± 5.67	10.5±12.79	18 ± 15.3	16 ± 9.06
Left	15 ± 3.33	12 ± 4.21	6.5 ± 5.29	6 ± 5.67	12 ± 4.21	11 ± 5.67
Study children						
Right	16 ± 5.67	10.5 ± 4.97	5 ± 5.27	7.5 ± 5.40	12 ± 4.83	16.5 ± 5.79
Left	15 ± 4.08	12.4 ± 4.69	7.5 ± 3.53	8 ± 4.83	12 ± 6.32	17 ± 6.75
Control (for the children born in the residential houses)						
Right	16 ± 5.67	10.5 ±4.97	5 ± 5.27	7.5 ± 5.4	12 ± 4.83	16.5 ±5.79
Left	15 ± 4.08	12.4 ± 4.69	7.5 ± 3.53	7 ± 6.32	12 ± 6.32	17 ± 6.75
Children born in the employee residential houses						
Right	16.5 ± 3.37	13 ± 2.58	9 ± 5.67	10.5 ± 12.8	18 ± 15.3	16 ± 9.06
Left	15 ± 3.33	12 ± 4.21	6.5 ± 5.29	6 ± 5.67	12 ± 4.21	11 ± 5.67

*There is no difference between the two groups ($p>0.05$).

Discussion

Microwave auditory phenomenon has been widely recognized as one of the biological effects of RF [7]. Some animal studies have shown that exposure to electromagnetic field may alter the endocrine and nervous system [8, 11].There is only one data in the existing literature for the long-term effects of electromagnetic field to the hearing of those working at radio broadcasting stations using BERA and PTA together [16]. It has been shown that radiation induced pressure changes result from the absorption of RF pulses could produce significant acoustic energy in water and potassium chloride solution [6]. It is well documented that when the human head is in a pulsed RF field, an audible sound described as a click, buzz, chirp, or a knocking sensation is perceived by some individuals [6, 9]. Audible sound is produced by rapid thermo elastic expansion, resulting from a rise of 5 x 10-6 oC in a short period of time (10 _sec) [6, 13]. However, Lin stated that when human subjects are exposed to rectangular pulses of microwave radiation, an audible sound occurs which appears to originate from within or behind the head [9, 10]. Lin also stated that thermo elastic theory is adequate for describing microwave induced sound frequency, threshold of sensation, the influence of pulse width and frequency of the impinging microwave radiation [9, 10].

Hearing a transient buzzing sound on exposure to the intermittent rotating beam was reported in subjects who were in RF field. The apparent location of the sound was described as a short distance behind the head and was independent of orientation [13]. Available data support the conclusion that the RF auditory effect is evoked by a possibly different mechanism from the conventional acoustic stimuli; however, the primary site of interaction seems to be the same as the cochlea. However, in order to sound exposure to result in hearing damage, the intensity of sound has to be high. Because RF exposure from the radio station does not cause vibrations that give rise to sound perception, a damaging mechanism similar to the one causing damage by acoustic exposure is not possible [6]. Therefore, the results/ideas mentioned here have been supporting the results of our study. Because our results also showed that radiofrequencies emitted from broadcasting radio station do not affect the hearing of the children who living residence of the station statistically ($p>0.05$). By the way, sensory neural hearing loss was observed in six of twenty-five children in the exposed group especially in 4000 and 8000 Hz frequencies. However, this hearing loss was at minimal level and statistically insignificant. On the other hand hearing of children who born in the residential houses of media broadcasting station were not different from that of the control children ($p>0.05$).

Auditory brainstem response techniques are of value in evaluation of hearing and identification of site of lesion from cochlear nucleus to inferior colliculus in auditory pathway. Comparison of interpeak intervals after stimulation of each ear separately is of value in distinguishing cochlear pathology from retro cochlear pathology. Oktay et al. find no difference in the I-III, III-V, or I-V interpeak intervals between the subjects working at the broadcasting stations and control subjects [16]. Their results obviously showed that chronic exposure of the electromagnetic field did not cause any damage in the brainstem, which was detectable by BERA. The BERA results of Oktay et al. also support the results of our study. Because we also did not find any statistical differences between exposed and control groups ($p>0.05$). These results showed that chronic exposure of the electromagnetic field did not cause any damage in the brainstem, which was detectable by BERA.

In conclusion, our results showed no actual hearing loss in the RF exposed children living in employee residential houses. However, we suggest continuous monitoring hearing function once a year because of the hearing loss observed in six children at minimal level, which was found statistically insignificant.

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