[Environmental Health and Preventive Medicine 3, 55-58, April, 1998]

Original Article

Do Radiofrequency Radiation Affect the Auditory System of People with Occupational Exposure ?

Faruk MERIÇ *[1], Süleyman DAŞDAĞ ,*[2] and Kemal VERGILI *[1]

*[1] *Department of Ear, nose, and throat, Medical Faculty of Dicle University, Diyarbakir*
*[2] *Department of Biophysics, Medical Faculty of Dicle University, Diyarbakir*

Abstract

The present study intended to investigate whether radiofrequency (RF) affects auditory system of people who are occupationally exposed to RF in terms of noise-induced hearing loss (NIHL) or not. The study was carried out on 31 men from 26 to 53 years of age. All of them have been working in the Diyarbakir Radio Broadcasting Station. On the other hand, the control group was based on 30 unexposed voluntary and healthy men. The range of age for control group was the same as in the exposed group (experimental group). The results of the present study showed that the incidence of NIHL in the exposed group is more and more than that of the unexposed (control) group. The incidence of NIHL was approximately found 70 % for exposed group and 6% for unexposed group. The difference of the incidence of NIHL between exposed and unexposed groups were statistically found significant for right and left ears at "4 kHz notch" ($p < 0.001$). Hearing loss was not observed below 1 kHz. The percentage difference in the incidence of hearing loss (decibel) between control and experimental group was found insignificant for frequency below 1 kHz ($p > 0.05$). The experimental group was also divided to three subgroups of technicians, officers and men staying in the quarters of radio broadcasting station. Three subgroups were compared with one another statistically. The incidence of NIHL for the right ears of technicians was found higher than the officer ($p < 0.05$). The incidence of NIHL for the left ears of men staying in quarters was found higher than officers ($p < 0.05$). The other results of comparison were found insignificant ($p > 0.05$). In conclusion, the incidence of NIHL at "4 kHz Notch" in the experimental group was found more common than the control group.

Key words: Radiofrequency radiation, Noise-induced hearing loss

Introduction

The frequency ranges are defined as : 300 kHz-300 MHz for radiofrequency (RF) and 300 MHz-300 GHz for microwaves. These ranges represent one of several conventions used in defining this part of the electromagnetic spectrum. By another widely accepted convention, RF describes all frequencies below 300 GHz, with microwave being a part of the whole RF spectrum[10].

Biological effects of alternating electromagnetic fields have been studied since the turn of this century. In developed countries there has been a remarkable growth in number of processes and devices that utilize or emit RF and microwave. The using of these devices showed an increasing use in setting like industry, engineering, telecommunications, medicine, home. This situation remembered us a number of questions M.J.Suess asked [18]; How serious are problems linked with RF? What acute or chronic effects on human body are involved? Is there sufficient knowledge occupational risks and public health hazards? The effects of RF and microwave radiation on animal and human has been a subject of continuing investigations. Clinical investigation on occupational microwave and/or RF exposure in humans have been reported by investigators[2-19]. One of the major occupationally exposed groups is that who has been working in the communication systems. While most workers in the fields of communication and radar are exposed only to low strength fields, in a few situation workers can potentially be exposed to high levels of RF radiation[13,14,16,17]. Field strengths are usually very low (1 microwatt/cm^2) in radiotransmitter rooms, near the bases and surrounding areas.

Reprint requests to: Süleyman Daşdağ,
Department of Biophysics, Medical Faculty of Dicle University,
21280 Diyarbakir, TURKEY.
FAX: +90(412)248 84 40
e-mail: dasdag @dicle.edu.tr

High level exposures occur in the vicinity of antennas of high power transmitters. Workers climbing FM (frequency modulation) television towers may be exposed to high field strengths with a local electrical field of up to about 1000 V/m and a local magnetic field of about 5 A/m[14]. Potentially high exposure also exists when the interlocks of transmitter cabinet is defeated and the door is open. The equivalent power density can then be up to 2000 W/m^2. Owing to coupling from other transmitters through the antenna feeders, high power densities may even be found in the cabinet when the transmitter is switched off. Other sources of exposure to the general population and workers are portable and mobile radiotransmitters. Strengths of the electric and magnetic fields close to the antennas are quite high, even for low output powers[16,18].

Since the RF auditory phenomenon has been widely recognized as one of the most interesting biological effects of RF [4,5] the purpose of the present study is to investigate the effects of RF on people occupationally exposed to RF in terms of noise-induced hearing loss NIHL.

Material and Method

The study was carried out on 61 voluntary men between 26 to 53 years of age. Thirty-one of them have been working in Diyarbakir Radio Broadcasting Station [1062 kHz, Medium Wave (MW) and 98.4 MHz, 88.4 MHz, 95.5 MHz (FM)] and living in the broadcasting station's quarters. The characteristics of broadcasting station are given in Table 1. Ten of the subjects in this experimental group have been working as technicians in the broadcasting station, ten of them have been working as officers in the station while others are their family members living in quarters. The distance from the station to city was about 20 kilometers. The subjects in the experimental group have been working or living in the area mentioned above for at least three years. The technicians and officers have been working 8 hours per day in the station. The field strengths in the station and quarters are also given in Table 1.

On the other hand, 30 unexposed, voluntary and healthy men who have been working at Dicle University were accepted as a control group. The range of age in the control group was from 16 to 53 years of age. Distance from city to the university was about 15 kilometers. Special attention was paid in terms of age, sex, type of working (technicians, officers, etc.) and working period (8 h/day) in order to avoid selection bias. All these men in the control group were similar in age, work regime and socioeconomic status, and having never worked with RF sources.

People in this study were informed about the aim of the study before beginning the study. After giving information and taking consent from the subject, each subject's ears were examined by specialist of ENT (Ear, Nose, Throat). The ears of subjects were cleaned when it was necessary and then tested by using a pure-tone audiometer (Mercury, M.158 Audiometer). A pure-tone audiometer provides information about hearing ability, and site of disorder. As it is known, pure-tone thresholds indicate the degree of hearing loss. By comparing air condition and bone conduction results, the site of disorder in the peripheral auditory system can be determined[19]. Right and left bone and air conduction of each subject were tested and the audiograms were evaluated. The level of noise in the station was measured about 70 decibel (dB).

Statistical analysis : Student's-t test was used to compare hearing loss (below 1 kHz) for the right and left ears of the subjects in the exposed and unexposed groups. Since the incidence of NIHL at "4 kHz notch" was different in the two groups, Student's t-test was also used to compare NIHL in the right and left ears of the subjects in the exposed and unexposed groups. After the statistical analyses, the differences were observed between two groups. For instance, the rate of NIHL was 2/30 for the right ears of men in the unexposed group while the rate of NIHL was 23/31 for the right ears of men in exposed group. The exposed group was further divided into three subgroups : technicians (n = 10), officers (n = 10) and residents in the quarters (n = 11) to investigate if any difference exists between the subgroups of the experimental group in terms of NIHL or not. Student's t-test was also used to compare the incidence of NIHL among the three subgroups.

Definition of NIHL :

Traditionally, hearing loss caused by excessive noise has been separated into two distinct categories. One type called "acoustic trauma". It is caused by a single, short-lasting exposure to a very intense sound (for example, an explosive blast) and results in a sudden, usually painful, loss of hearing. The other type of hearing loss is commonly referred to as noise-induced hearing loss (NIHL) and resulted from chronic exposure to more moderate levels of sound. Moreover, noise-induced threshold hearing is usually symmetric for both ears, as seen in individuals who have been working in noisy industrial setting. The initial region of impairment in the audiogram of people with NIHL involves sensitive midfrequency range, between 3 and 6 kHz, and the corresponding impairment is classically described as the "4 kHz notch". This particular pattern of maximal hearing loss, with little or no loss below 1 kHz, typically exists regardless of the noise-exposure environment[13].

Results

No significant difference in the percentages of hearing loss (for the frequency below 1 kHz) between experimental and control groups ($p > 0.05$) was found (Table 2). The incidence of

Table 1 Characteristics of Diyarbakir Radiobroadcasting Station.

Type of wave	Medium wave (MW), Frequency modulation (FM)
Frequencies	1062 kHz, 98.4 MHz, 88.4 MHz, 95.5 MHz
Power output of antenna	300.0 kWatt
Field strength in the station	65 dB. μV
Field strength in the quarters	85 dB. μV

Table 2 Comparison of hearing loss measurements between control and experimental group (for frequency below 1 kHz).

	Control group (%dB)			Experimental group (%dB)				
Ear	n	x	SD	n	x	SD	t	p
Right	30	15.0	5.5	31	13.0	5.9	1.39	> 0.05, NS
Left	30	13.3	5.8	31	11.7	6.1	1.06	> 0.05, NS

x : Mean Value
SD : Standard Deviation
NS : Not Significant

Table 3 The incidence of NIHL at "4 kHz notch" for the control, experimental groups and the subgroup of experimental group such as technicians, officers and men in the quarters (%).

Groups		Control	Experimental group	Subgroups of experimental group		
				Technicians	Officers	Residents in quarters
		(n = 30)	(n = 31)	(n = 10)	(n = 10)	(n = 11)
Right ear	Frequency rate (%)	2/30 (6)	23/31 (74)	9/10 (90)	5/10 (50)	9/11 (81)
Left ear	Frequency rate (%)	2/30 (6)	21/31 (67)	8/10 (80)	4/10 (40)	9/11 (81)

n = 10 for technicians, n = 10 for officers, n = 11 for men in quarters.

NIHL for right and left ears of subjects in the experimental group and its subgroups (technicians, officers and residents in the quarters) are given in Table 3. The incidence of NIHL among subject in the experimental group was found higher than the control group ($p < 0.001$). Significant differences were also observed in NIHL between the right ears of the technicians and the officers and between left ears of the residents living in the quarters and the officers ($p < 0.05$). The comparison between the right and left ears of other subgroups showed no significant differences ($p > 0.05$). No connection was observed between NIHL and working years in the experimental group ($p > 0.01$). For instance, NIHL was observed in the men working both three years and ten years. On the other hand, four of the technicians, three of the officers and three of residents in the quarters suffered from buzz. Working years of subjects in this study was between 3 - 20 years. The statistical results of NIHL at "4 kHz notch" between control and experimental groups and subgroups of experimental group described in this study are shown in Table 4.

Table 4 The statistical results of NIHL at "4 kHz notch" between control and experimental groups and subgroups of experimental group described in this study.

Right ear	d	SD	t	p
Cont.- Exp.	0.680	0.089	7.563	< 0.001
Tech.- Officers	0.400	0.184	2.173	< 0.05
Tech.- Residents	0.009	0.596	0.596	> 0.05, NS
Officers-Residents	0.310	0.197	1.573	> 0.05, NS
Left ear				
Cont. - Exp.	0.610	0.094	6.472	< 0.001
Tech.- Officers	0.400	0.200	2.000	> 0.05, NS
Tech.- Residents	0.010	0.173	0.057	>0.05, NS
Officers-Residents	0.410	0.194	2.113	< 0.05

Tech.:Technicians, Cont.:Control group, Exp.:Experimental group, Residents:Residents living in the quarters.

SD : Standard deviation
NS : Not Significant

Discussion

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[3]. The available data support the conclusion that the RF auditory effect is evoked by a mechanism similar to that for conventional acoustic stimuli and that the primary site of interaction is peripheral to the cochlea. The most generally accepted mechanism responsible for the RF auditory sensation is thermoelastic expansion[3]. Thermoelastic expansion is elastic dimensional changes in materials as a function of temperature and time in various environments. It is also generally accepted that the response stems from thermoelastic expansion of tissue in the head which absorbs RF or microwave. When RF or microwave impinges on the head, the absorbed is converted into heat, which produces a small but rapid rise of temperature. This temperature rise, occurring in a very short time, generates rapid thermoelastic expansion of tissues in the head, which then launches an acoustic wave of pressure that is detected by hair cells in the cochlea[8]. The thermoelastic expansion mechanism explains how the pulse of RF energy can be transformed to an acoustic impulse in the head, although it is not known what structure in the head transduce the radiofrequency energy to acoustic energy. A very low average power density can cause an acoustic response in the head, and there is the potential of exposure of the public and workers to pulse that induce such effect[3,11,12].

The microwave auditory phenomenon has been widely recognised as one of the most interesting biological effects of RF or microwave radiation[4,5]. The earliest report on the auditory perception of pulsed microwaves appeared in 1956 as an advertisement of the Airborne Instruments Laboratory[3]. The advertisement described observation made in 1947 on the hearing of sounds that occurred at the repetition frequency of a radar while the listener stood close to an antenna. Such human auditory response to pulse-modulated radiation has been systematically studied. Hearing a transient buzzing sound on exposure to the intermittent rotating beam was reported in subjects who are in RF field. The apparent location of the sound was described as a short distance behind the head and was independent of orientation. It has been also shown both theoretically and experimentally that radiation-induced pressure changes are resulted from the absorption of RF pulses and could produce significant acoustic energy in solution. Audible sound are produced by rapid thermal expansion, resulting from a rise of only 5×10^{-6} ℃ in a short period of time (10 μ sec)[3,12].

As it is explained in the introduction of the present article, it is obvious that the subjects in the experimental group of this study should be evaluated in the second type of hearing loss[9]. The important results of this study is the observation of NIHL at "4 kHz notch" in the experimental group, indicated by the higher rate of NIHL in experimental group than in the control group. For example, the rate of NIHL was 2/30 for the right ears of subjects in the control group while the rate of NIHL was 23/31 for experimental group. This situtation was supported by the results of comparison of other groups or subgroups. The reason of NIHL in subjects under investigation can be explain with the thermoelastic expansion mechanism. The articles summarized above explain the reason of hearing loss in subjects discussed here[3,11,12].

Although the rate of NIHL in the technician group was approximately the same as that residents in the quarters, the rates of these two groups were found higher than the officers (as shown

in Table.3). Buzz observed in the experimental group was harmonious with the results of other researchers[3,11,12]. Consequently, it is obvious that the incidence of NIHL at "4 kHz notch" for the experimental (exposed) group is higher than the control (unexposed) group. Unfortunately, one unable compare the results of the present study with other articles because no previous study was performed at "4 kHz notch".

Conclusion

The results of the present study showed that the frequency of NIHL at "4 kHz notch" in people occupationally exposed to RF was more and more common than other unexposed individuals.

Acknowledgement : May valuable rewiev comments by Prof.Kanehisa MORIMOTO of Japanese Society for Hygiene and Prof.M.Salih Celik of Dicle University is gratefully acknowledged.

References

1) Cleary SF. Uncertainties in evaluation of biological effects of microwave and radiofrequency radiation. Health Physics 1973 ; 25:387-404.
2) Dasdag S, Balci K, Celik MS et al. Neurologic and biochemical findings and CD4/CD8 ratio in people occupationally exposed to RF and microwave. Biotechnology and BioE 1992 ; 4 : 37-9.
3) Elder JA, Czerski PA, Stuchly MA et al. Radiofrequency radiation. In: Nonionizing radiation protection. WHO Regional Publication European Series No.25, 1989 ; 4:143-4.
4) Frey AH, Messenger R. Human perception of illumination with pulsed UHF electromagnetic energy. Science 1973 ; 181: 356-8.
5) Guy AW, Chou CK, Lin JC, Christensen D. Microwave-induced acoustic effects on mammalian auditory systems and physical materials. Annals New York Academy of Science 1975 ; 247: 194-218.
6) Kalada TV, Fukolova PP, Gontsarova NN. Biologic effects of radiation in the 30-300 MHz range. in : Biologic effects and health hazards of microwave radiation. Polish Medical Publishers, Warsaw, 1974 : 52-7.
7) Klimkova-Deutschova E. Neurologic Findings in Persons Exposed to Microwaves, in : Biologic effects and health hazards of microwave radiation. Polish Medical Publishers, Warsaw, 1974 ; 268-80.
8) Lin JC, Su JL, Wang Y. Microwave-induced thermoelastic pressure wave propagation in cat brain. Bioelectromagnetics 1988 ; 9: 141-7.
9) Martin BL, Martin GK. Auditory Dysfunction from Excessive Sound Stimulation. In: Cummings CW, Fredrickson JM, Harker LA, Krause CJ, Schuller DE.Otolaryngology - Head and neck surgery (second edition), USA, Mosby Year Book, 1993; 2885-9.
10) Michaelson SM. Microwave and radiofrequency radiation. In: Nonionizing radiation protection, WHO Regional Publication European Series No.10, 1982 ; 98-9.
11) Michaelson SM. Microwave and radiofrequency radiation. In. Nonionizing radiation protection, WHO Regional Publication European Series No.10, 1982 ; 125-6.
12) Michaelson SM. Biological effects of radiofrequency radiation . Concept and criteri. Health Physics 1991 ; 61:3-14.
13) Mild KH. Occupational exposure to RF. Proceedings of IEEE. 1980 ; 68 : 12-7
14) Mild KH. Radiofrequency electromagnetic fields in Swedish radio stations and tall FM/TV towers. Bioelectromagnetics 1981 ; 2: 61-9.
15) Stuchly MA. Potentially hazardous microwave radiation sources-a review. Journal of Microwave Power 1977 ; 12: 370-81.
16) Stuchly MA, Stuchly SS. Industrial, scientific, medical and domestic applications of microwaves. Proceedings of the IEEE. 1983 ; 130: 467-503.
17) Stuchly SS et al. Energy deposition in a model of man in the near field. Bioelectromagnetics 1985 ; 6: 115-29.
18) Suess MJ. Introduction to first edition. In: Nonionizing radiation protection (second Edition). WHO Regional Publication European Series No.25, 1989 ; 7-12.
19) Yellin MS. Hearing Measurement in Adults. In: Paparella MM, Schumrick DA, Gluckman J, Meyerhoff WL. Otolaryngology (Third Edition). USA. W.B.Sounders Comp. 1991 ; 961-4.

(Received July29, 1996/Accepted Jan.19, 1998)