Health Aspects of Wireless Communication: The Risk of Human Exposure to Cellular Mobile Communication Radiation

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Most of our knowledge concerning the biological effects of radio frequency (RF) radiation from wireless communication devices came out of investigations conducted using experimental animals, such as rats, mice, etc. When it comes to the impact of RF radiation on human health and safety, epidemiology can play a pivotal role, because it is a study of the distribution of disease and its determinants in human populations.

In recent years, there has been increasing interest on cancer induction and promotion from RF exposure. Prior to 1980, however, most epidemiological studies or medical surveillance in occupational settings did not take cancer induction into account.

To examine if exposure to wireless communication radiation is involved in cancer induction and promotion, it is necessary to collect data from people with similar background, other than RF exposure. For example, some factors that should be considered when collecting the data include age, sex, race, education, occupation, personal habits, and so on. Also, when reviewing the data, one has to be aware if there are any changes in diagnostic criteria, diagnostic technique, or improved reporting. This is not to suggest that RF exposure is adequately characterized in most studies. The fact is that it is far from it

The importance of confounding factors in observational data is illustrated by age in mortality rates in the United States. (A mortality rate is the number of deaths per population at risk per unit time. It is the reciprocal of population life expectancy.) The crude mortality rate of the United States, almost, stayed at the same level (1,000 per 100,000) from 1940 to 1990. A crude mortality rate does not take the effect of age into account. If age is taken into consideration - a procedure called age adjustment - the mortality rate goes dramatically down from 1940 to 1990 . Age adjustment makes the outcome of observations for which compositions of population age are different, comparable. The age-adjusted results indicate that the total number of deaths per year stayed the same. However, from 1940 to 1990, the longevity became greater, since fewer people died in the young and middle-aged groups. Therefore, when age adjustment is conducted, the mortality rate went down (to about 600).

Moreover, a false-positive relationship between exposure and disease can also exist, and it can be confusing. For instance, the association between cigarette smoking and lung cancer is well known. A positive relationship between alcohol consumption and lung cancer, which is false, can also be shown to exist. What actually happens is that smoking increases the risk of developing lung cancer. Since those who smoke tend to drink, a positive connection between alcohol consumption and lung cancer there exists. However, smoking is a significant confounding factor, in this case.

In epidemiologic studies, a relatively large sample size is required to detect a certain level in the difference of outcomes. If the study is conducted using a small sample size, true results cannot be drawn. In such a case, it is nothing more than a waste of time and money. One has to be careful about sample size when conducting studies. It is customary to assess how rare the outcome is, by calculating the p-value associated with an appropriate statistical test (Chi square, Fisher's exact, Student's T, etc.). In general, if the p-value is less than 0.05, the result of the study is usually considered to be statistically significant.

There were two early epidemiological papers reporting cohort studies of cancer and RF exposure. Between 1953 and 1976, U.S. personnel stationed at the Moscow Embassy were exposed to 0.015 mW/cm2 at 600-9600 MHz for 9-18 hr/day [1, 2]. The morbidity and mortality of the Moscow personnel were compared with those who had served at Eastern European embassies or consulates where only background levels were detectable during the same period. (Morbidity is the state of ill-health produced by a given disease.) There was no evidence of higher mortality or morbidity in the exposed group. Note that the small number of cancer cases makes interpretation of this study rather limited. Another study was conducted on U.S. Navy personnel, trained in the use and maintenance of radio and radar equipment. The study did not reveal any difference in the mortality rate or cancer incidence between the high-exposure (up to 10-100 mW/cm2) and low-exposure cohorts (¡1 mW/cm2) more than 20 years after exposure [3]. A major difficulty with these two studies is the uncertainty in assessing actual exposure to large numbers of people.

A cohort study is a prospective study, in which people who are free of the disease of interest at the time of entry into the study are classified according to their level of exposure to the putative risk factor: in this case, RF radiation. In a retrospective cohort study, a cohort is assembled by reviewing records to identify exposure in the past.

Several epidemiological studies on cancer and mortality have been published within the last few years. The mortality rate of male amateur-radio operators in the Western U.S. was compared to that of the U.S. general population [4]. Higher mortality ratios were shown for brain tumors (1.4), acute myeloid leukemia (1.8), and cancer in some lymphatic tissues (1.6). In other words, 1.4, 1.8, or 1.6 times as many people in the study group died because of brain tumors, leukemia, or lymphatic cancer as in the reference group. The potentially significant confounding factor of soldering fumes within this hobby group presents some uncertainty.

Some studies involving children and adults living in close proximity to radio towers used distance from the tower as a surrogate for exposure measure. In a cohort of 50,000, it was found that the relative risks (RR's) of children for brain tumor, leukemia, Hodgkin's disease, and non-Hodgkin's lymphoma were not elevated if they lived within 3.5 km of an RF tower in San Francisco [5]. (Relative risk is the ratio of risk of individuals exposed to a causal agent developing the disease to the risk of unexposed individuals developing the disease.) A small case-control study, based on a leukemia cluster around a broadcasting tower in Hawaii, gave an RR of 2.1 for children living within 4.2 km [6]. The risk of developing leukemia was 2.1 times as high for those living within 4.2 km of the broadcasting tower as for those in the control group. Also, the incidence of leukemia was found to be greater (1.58) among children living near TV towers in Sydney, Australia [7]. However, the rate for brain tumors was not increased, comparing those who live near and those who live further away (12 km).

A case-control study is a study in which the investigator selects persons with a given disease (the cases) and persons without the given disease (the controls), and measures and compares the extent of the exposure to the hypothesized causal agent between the cases and the controls.

A small area study of cancer incidences near the Sutton-Coldfield radio and TV towers in the U.K. indicated an increase in risk (1.83) of adult leukemia within 2 km. But there was a significant decline in risk with distance for leukemia, and for bladder and skin cancers [8]. A follow-up study of 20 other broadcast sites in U.K. found an excess risk no more than 15excess within 2 km [9].

In a case-control study of males serving in the U.S. Air Force between 1970-1989 [10], a small increase, in the RF, age, race, senior military rank-adjusted odds ratio (OR = 1.39) for brain tumors, was detected. (The odds ratio is the ratio between the chance of exposure to a causal agent for individuals with the disease to the chance for individuals without the disease.) This result is especially interesting, in view of the negative finding for a relatively well characterized carcinogen, ionizing radiation. Exposure of the men to ionizing radiation was reported to have an age, race, senior rank-adjusted OR of only 0.58.

Recently, a large-cohort mortality study among relatively young employees (a total of 195,775 during the 1976-1996 period) of Motorola - a manufacturer of wireless communication products - examined all major causes of mortality, with brain cancers, lymphomas, and leukemias as outcomes of interest [11]. The study classified workers into high, moderate, low, and background RF-exposure groups, using job titles. Using external comparisons, the standardized mortality ratios for RF-exposed workers were 0.53 and 0.54 for central nervous system/brain cancers and all lymphomas/leukemias. Rate ratios, calculated using internal comparisons, were about 1.0 for brain cancers and below 1.0 for all lymphomas and leukemias. The findings were consistent across cumulative, peak, and usual exposure classifications, and did not show higher risk with increased exposure duration or latency. Although this study is quite recent, it is limited by the use of a qualitative exposure metric.

To summarize the above epidemiological reports, the two older studies did not uncover a positive association. Among the more recent reports, there are nearly equal numbers of studies showing excess and no-excess cancer mortality. The studies that gave excess risk had reported relative risks that ranged from 1.4-2.1. Among the latter, the authors of the Sutton-Coldfield study suggested, after an enlarged study, that no more than a weak causal implication can be made. The finding by Grayson [10] was diluted by a small sample size. The highest risk ratio 2.1. was associated with a small cluster [6]. The study by Milham [4] had soldering fumes as a confounding factor within the group.

A survey of the mortality rates of portable cellular telephone users, who were active for three or more years including 1994, did not show any excess when compared to those using car-mounted mobile telephones [12]. Since the use of cellular telephones is a very recent event, and a large increase in mortality rates over the short term is a rare phenomenon, a difference is not expected from this preliminary study.

Nevertheless, there have been a few published case-control studies of cellular telephone users and the risk of brain tumors. A study from Sweden did not show any overall increase in brain tumors, as compared to nonusers of cellular or mobile telephones between 1994-1996 [13]. However, there appeared to be a tendency toward greater likelihood (statistically not significant) to develop brain tumors on the side of the head where the phone is held - laterality. The authors have stated that their results were based on small numbers of cases, and must be interpreted with caution. Their cases and controls were 209 and 425, respectively. The results would be more reliable if the numbers are circa 1500 in these studies. (The incidences of brain and central nervous system cancers are about 6 per year per 100,000 population in the U.S.).

Most recently, two case-control studies, conducted between 1994 and 1998 in the U.S. medical centers, have been reported [14, 15]. Neither showed an overall increase of risks of brain cancer compared by use of cellular telephones, in durations of use or in cumulative hours of use, except for the uncommon neuroepitheliomatous cancers had an OR of 2.1 [14]. It is noteworthy that cerebral tumors were reported to occurred more frequently, although not statistically significant, on the same side of the head where cellular telephones had been used. A total of 469 men and women aged with primary brain cancer and 422 matched controls without brain cancer were enrolled from five medical centers. Neuroepitheliomatous cancers are a rare type of neuronal cell tumors, for example, gangliogliomas. . The other study had enrolled 782 patients through several hospitals; 489 had histologically confirmed glioma, 197 had meningioma, and 96 had acoustic neuroma [15]. The 799 controls were patients admitted to the same hospitals as the patients with brain tumors for a variety of nonmalignant conditions. Results of this study suggest that there was a non-significant trend for cancers to be on the side of the head where the patients reported using their cellular telephones. It is interesting to note that the relative risks associated with using a cellular telephone were marginally depressed (RR = 0.7) for meningioma and slightly elevated (RR =1.4) for acoustic neuroma although not statistically significant. Acoustic neuromas are benign tumors attached to the auditory nerve and are often presented with tinnitus and hearing loss.

These results are encouraging in that they imply use of cellular telephones does not cause brain tumors in the short term. It may be possible to view these results as failing to indicate an excess of cancer mortality from RF exposure. However, it is important to recognize that the epidemiological understanding of effects of human exposure to RF radiation is still evolving, especially for cellular telephones and wireless personal communication devices. These investigations do not evaluate the risks in the long run or for cancers with longer latency periods of induction, especially for slow-growing tumors. They suggest that further studies are needed to account for acoustic neuromas and for the twofold increase in uncommon neuroepitheliomatous cancers among users.

Although not statistically significant, two of the three case-control studies showed a trend between reported laterality of the cancer with the self-reported laterality of use of the cellular telephone. Furthermore, it is fair to conclude from the above studies that they all can benefit from more quantitative measures of RF exposure and a longer observation period. These considerations present profound uncertainties in their use for risk analysis. It is noted that some efforts are being taken to expanded the current understanding of wireless telephone radiation and human health. In particular, a large-scale epidemiological study is underway in Europe, as part of a wide-ranging research effort on health effects of wireless telephone use.

References

[1] Silverman, C., 1980, Epidemiologic studies of microwave effects, Proceedings IEEE 68:78-84.

[2] Lilienfeld, A.M., J. Tonascia, S. Tonascia, C.H. Libauer, G.M. Canthen, J.A. Markowitz, and S. Weida, 1978. Foreign Service Health Status Study: Evaluation of health status of foreign service and other employees from selected Eastern European posts, Final Rept, NTIS PB 288, Dept of Epidemiology, Johns Hopkins Univ.

[3] Robinette, C.D., C. Silverman, and S. Jablon, 1980, Effects upon health of occupational exposure to microwave radiation (radar) 1950-1974, American Journal of Epidemiology. 112: 39-53.

[4] Milham, S. 1988, Increased mortality in amateur radio operators due to lymphatic and hematopoietic malignancies, American Journal of Epidemiology, 127:50-54.

[5] Selvin, S., J. Schulman, and D.W. Merrill, 1992, Distance and risk measures for the analysis of spatial data: A study of childhood cancers, Social Science in Medicine, 34:769-777.

[6] Maskarinec, G. and J. Cooper, 1993, Investigation of a childhood leukemia cluster near low frequency radio towers in Hawaii, American Journal of Epidemiology, 138:666

[7] Hocking, B., I.R. Gordon, H.L. Grain, and G.E. Hatfield, 1996, Cancer incidence and mortality and proximity to TV towers, Medical Journal of Australia; 165:601-605. Also 1997, 166:80.

[8] Dolk, H., G. Shaddick, P. Walls, C. Grundy, B. Thakrar, I. Kleinschmidt, & P. Elliott,1997, Cancer Incidence near radio and television transmitters in great britain. 1. Sutton Coldfield transmitters, American Journal of Epidemiology 145:1-9.

[9] Dolk, H., P. Elliott, G. Shaddick, P. Walls, & B. Thakrar, 1997, Cancer Incidence near radio and television transmitters in great britain .2. All high power transmitters, American Journal of Epidemiology 145:10-17

[10] Grayson, J.K., 1996, Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: A nested case-control study, Am. J. Epidemiol. 143:480-486.

[11] Morgan RW, M.A. Kelsh, K. Zhao, K.A. Exuzides, S. Heringer, W. Negrete, 2000, Radiofrequency exposure and mortality from cancer of the brain and lymphatic/hematopoietic systems. Epidemiology. 11:118-127.

[12] Rothman, K.J., J.E. Loughlin, D.P. Funch, and N.A. Dreyer, 1996, Overall mortality of cellular telephone customers. Epidemiology, 7:303-305.

[13] Hardell L., A. Nasman, A. Pahlson, A. Hallquist, and K. H. Mild., 1999, Use of Cellular telephones and the risk for brain tumours: A case-control study. International Journal of Oncology. 15:113-116.

[14] Muscat, J.E., M.G. Malkin, S. Thompson, R.E. Shore, S.D. Stellman, D. McRee,A.I. Neugut, and E.L. Wynder, 2000, Handheld cellular telephone use and risk of brain cancer. Journal of the American Medical Association. 284:3001-3007

[15] Inskip, P.D., R.E. Tarone, E.E. Hatch, T.C. Wilcosky, W.R. Shapiro, R.G. Selker, H.A. Fine, P.M. Black, J.S. Loeffler, M.S. Linet, 2001, Cellular-telephone use and brain tumors. New England Journal of Medicine. 344:79-86.