Feasibility of a cohort study on health risks caused by radiofrequency electromagnetic fields

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Abstract

Background

The aim of this study was to examine the feasibility of performing a cohort study on health risks from exposure to radiofrequency electromagnetic fields (RF-EMF) in Germany.

Methods

A set of criteria was developed to evaluate the feasibility of a cohort study on health risks caused by exposure to RF-EMF. The criteria aimed at conditions of exposure and exposure assessment (level, duration, preferably on an individual base), the possibility to assemble a cohort and the feasibility of ascertaining various disease endpoints.

Results

Twenty occupational settings with workers potentially exposed to RF-EMF and a cohort of amateur radio operators were considered. Three of the cohorts were identified as promising for further evaluation based on expert ratings, literature reviews, and according to our set of predefined criteria: personnel of medium/short wave broadcasting stations, amateur radio operators, and workers on dielectric heat sealers. After further analyses, the cohort of workers on dielectric heat sealers seems not to be feasible due to the small number of exposed workers available and to the difficulty of assessing exposure (exposure depends heavily on the respective working process, mixture of exposures, e.g. plastic vapors), although exposure was highest in this occupational setting. The strength of the cohort of amateur radio operators was the large number of persons involved, while that of the cohort of personnel working at broadcasting stations was the quality of retrospective exposure assessment. However, in the cohort of amateur radio operators the exposure assessment was limited, and the

cohort of technicians was hampered by the small number of persons working in this profession.

Conclusions

The majority of occupational groups exposed to RF-EMF are not practicable for setting up an occupational cohort study due to the small numbers of exposed subjects or exposure levels only marginally higher than those of the general public.

Background

The widespread use of cordless and cellular phones lead to a rapid increase in the number of persons exposed to radiofrequency electromagnetic fields (RF-EMF), accompanied by concerns and fears concerning possible adverse health effects of RF-EMF exposure being widely raised. In total, 48 % of citizens of the Europe Union (25 member states) are very much or fairly concerned about potential health risks of electromagnetic fields [1]. The concern and fears in the population should be taken seriously and further research on potential health effects should be conducted. Although there are currently many studies available on the health risks of mobile phone use, the evidence is not yet convincing. This might be explained by the different and inconclusive results of reported studies which allow different interpretations [2-10]. A serious problem in studies on mobile phone use is the short latency period. Up to now, data from only two cohort studies are available [11, 12]. The exposure time as well as latency period were however short. The update of the Danish cohort study with an average follow-up time of 8.5 years revealed no increased cancer risk [13]. The interpretation of the results of the numerous case-control studies on mobile phone use and brain cancer published during the last years is hampered by the short exposure time as well as the short latency period.

Additionally, as in most case-control studies, recall bias and selection bias are a major concern.

It is of public health interest to get valid risk estimations of RF-EMF emitted from mobile phone handsets and masts as soon as possible. An alternative would be to investigate other RF-EMF exposures with longer exposure times, for example occupational RF-EMF exposure. So far, only a few epidemiological cohort studies have investigated the effects of RF-EMF on health in occupational settings or during leisure time (amateur radio operators) [14-23]. In these studies, total mortality, partially differentiated by important groups of diseases and/or cancer incidence or cancer mortality, especially brain tumour and leukaemia, were defined as outcomes. One common problem in all these studies is the assessment of exposure [24]. In most occupational cohort studies it is exceedingly difficult or too expensive to determine the individual exposure. On the other hand, a large number of subjects is needed to achieve a sufficient statistical power to detect presumable small health risks.

As case-control studies generally focus on less numbers of subjects, the assessment of occupational RF-EMF exposure seems to be more feasible. Hence the analysis of the association between RF-EMF exposure and health risks might be more appropriately done using case-control study designs. So far, three case-control studies on brain tumour and occupationally exposure of RF-EMF were conducted. In one of them, exposure classification was derived from the subject's work history, assigned as a three digit SIC (Standard Industrial Classification) code for industry [25]. In another setting, a nested case-control study was performed, where the complete occupational histories were obtained from personnel records for each study subject including job title and starting and ending dates [26]. And finally, in a third interview based study, a more specific, activity related RF-EMF exposure during work and leisure time was

estimated using an activity exposure matrix [27]. Even though positive associations have been reported in two of these occupational case-control studies, the overall picture is far from being clear.

Given the well known problems in occupational case-control studies, the aim of the present study was to examine the feasibility of a cohort study on health risks due to radiofrequency exposure except mobile phone use. This study design was chosen due to the advantage of a cohort study: prospective assessment of exposure and several diseases as outcome.

A major objective for the feasibility study was to investigate health effects in a group of persons in which a reasonable exposure assessment was feasible, and in which a potential for some high and long-lasting exposure was present.

Methods

Firstly, different occupational groups and amateur radio operators[1] were considered as potential cohorts with high and long-lasting exposure to RF-EMF. Information about possibly exposed occupational groups was obtained from different professional associations, visits of industry sites and contacts with committees and administrative bodies. We performed a literature review including published papers and technical reports. We searched for studies on the subject "health risk by exposure to radiofrequency electromagnetic fields". The search was performed using the literature data bases PubMed and CancerLit. Different search terms were used, among others: "electromagnetic fields", "radiation", "radiation/adverse effects", "cancer", "cohort study". In PubMed the filter "human" was set. In CancerLit, the filter "non Medline" was additionally used. Furthermore, a search with given medical subject headings (MeSH) was carried out in PubMed, i.e, "electromagnetic fields/adverse effects", "radiation non-ionizing/adverse effects". For this search the methodical filter "cohort study" was supplementary used. All searches were restricted to publications in English and German language. Further information is given in [24]. In addition, technical reports [28-33] were searched for on the Internet. Internal papers in the field of occupational medicine were also reviewed. The purpose of this was to identify jobs and occupational settings in which exposure to RF-EMF may play a major role.

Definition of outcomes:

[1] In the following text the term occupational groups / cohorts is used for both the occupational cohorts and the cohort of amateur radio operators

Possible outcomes of the cohort study were identified by reviewing the literature. In a first step, all diseases mentioned as outcomes in these papers were collected. Morbidity studies as well as mortality studies were considered. In a further step it was decided that mainly mortality should be considered as an outcome, because then a retrospective part of the cohort study would be possible. Thus, mortality from cancer, cardiovascular diseases, and neurodegenerative diseases were determined as possible outcomes for the cohort study.

Criteria for assessment:

After identifying potential cohorts, we checked whether each of them fulfilled our pre-defined set of criteria.

Four criteria were used:

Criteria for RF-EMF exposure: Subjects in an occupational cohort have to be exposed regularly as well as over a longer period of time (a certain part should be exposed for a ten year period and longer), and the exposure should be higher than that in the general population. In addition, the duration of employment as well as information about the affiliation to an occupational group must be available for at least 90 to 95 % of all members of the cohort.

Criteria for exposure assessment: Prospective exposure estimates should be possible on an individual level. A retrospective estimate of exposure should be possible at least on an aggregated level by using a job-exposure-matrix.

Criteria for assembling the cohort: A well defined group of persons needs to be available. It must be possible to choose an unselected cohort from personnel records of the employers, public authorities or companies. Demographic variables must be available from documents of the employers, and should retrospectively be available

for at least 5 or 10 years. Cohorts in large companies or public authorities are of special interest, as it would be difficult to include a large number of small factories or companies for the study. Representatives of employees and the management of the company must be willing to endorse the study. Important parameters were also the total numbers of persons employed in positions exposed to RF-EMF.

Criteria for the follow-up: A follow-up of preferably all members of the cohort is needed. As a cohort study with mortality as outcome was planned, follow-up can be easily carried out if the addresses (even former) of the cohort members are available. In this case the follow-up can be done through registration offices and public health authorities. Therefore cohorts could only be eligible if the addresses of cohort members were available.

Calculation of expected cases:

To calculate the power of a planned cohort, assumptions have to be made about the size of the cohort in terms of person years, the age distribution and the expected relative risk for exposed persons. The following assumptions were used for the power calculation: latency period = 5 years, loss to follow-up = 5 %, age of study population 20 to 59 years with a uniform age distribution. Table 1 shows the expected number of deaths, numbers in bold are needed if a significance level of 0.05 and a power of 80 % is required. It should be noted that doubling the cohort size means that the numbers of expected cases are doubled, while doubling the observation time may increase the number of expected cases (table 1) substantially as the cohort is aging. 5000 subjects and a 30-year follow-up are needed to reject the hypothesis of "no increased risk" (RR = 1) (number of cases >=30), if the true relative risk is greater or equal 1.5.

For example, if we are interested in female brain cancer, we need 10,000 subjects and a 30-year follow-up to reject a RR = 1.0 (number of cases >=9), if the true RR is greater or equal 2.0, which is given analyzing brain cancer in females (n=9) and males (n=12).

The numbers in Table 1 demonstrate that for a prospective cohort study, meaningful results can not be expected within a few years. For this reason, only a retrospective (historical) cohort study seems to be appropriate.

Results

Twenty occupational settings and amateur radio operators were considered as potentially exposed to RF-EMF (table 2). Exposure levels of all potential cohorts were rated by experts, e.g. occupational hygienists. Most of the experts' ratings were based on results of measurements, performed in different industries, mainly done in

the frame of preventive actions to avoid work-related health hazards. At least two experts were asked for each of the occupational settings.

Eighteen of the twenty one situations described in Table 2 were not further considered for a cohort study for one or more of the following reasons:

1. Exposure to RF-EMF rare or at very low level: e.g. for captains and boat personnel and persons working in a lock, exposure to RF emitted by radio communication does not play a major role. An exposure to microwave emitted by radar is probably very low if present at all, as the position of radar equipment is on the roof of the ship and rather far away from the working position.

2. Small number of exposed subjects: e.g. firms where gluing presses are used. Generally only very few persons are highly exposed in these firms. Assembling a cohort seems to be impracticable.

3. Automated and shielded working processes: e. g. blister packaging, is an automated and shielded process. Maintenance of the devices only takes place when the machine is switched off (see table 2).

Comments and conclusions for exclusion are presented in Table 3. Only three groups of persons were further considered after these considerations: (1) Personnel of medium/short wave broadcasting stations, (2) amateur radio operators, and (3) workers on dielectric heat sealers.

Personnel of medium/short wave broadcasting stations: At broadcasting stations about 200 to 250 employees (engineers and technicians) are potentially exposed to radiofrequencies from the antennas (medium wave: 526.5 kHz – 1,6065 MHz, bandwidth 9 kHz, or short wave: 3.4 MHz – 26.0 MHz, bandwidth 5 kHz). Personnel are employed only on stations with a transmitting power of ≥ 100 kW. In Germany 20 of 29 broadcasting stations operate at this power level. The employees in these

workplaces (e.g. mechanical workshop) are continuously exposed and the duration of the exposure corresponds to the total working time.

Exact determination of the current individual exposure can be obtained by measurements. In addition, it is possible to obtain an estimation of past exposure from computer simulations basing on current exposure. This is important because the antennas were previously operated partly with a higher transmitting power and other modulation procedures. The operating conditions (transmitting power and field-strength) of the amplitude modulated medium wave antennas can be traced back quite well over approximately the last 20 years.

The strengths of this cohort would be the readiness for co-operation and support of the project, the measurable and/or valid estimation of exposure, the almost daily exposure over a long time of the working life, the relatively high constancy of the cohort and the good accessibility. Furthermore personnel data are available and also backdated data for at least 10 years.

The limitations of the study design include the rather low levels of exposure (mechanical workshop, Mühlacker broadcasting station, electrical field: 1.5 V/m, magnetic field: 0.2 A/m), the small cohort size (max. 250 potentially exposed persons in Germany) and the fact that such a cohort consists exclusively of persons in technical occupations (highly selective group).

Amateur radio operators: Altogether, 80 000 amateur radio operators are registered in Germany. It is estimated that only two thirds of them are active.

Radio equipment with a transmitting power of > 10W is notifiable. The permissible frequencies for amateur radios lie between 2 MHz and about 300 GHz. However, less than 5% of amateur radio operators transmit in the frequency range 900 – 2.200 MHz

and above. This is because most amateur radio operators do not possess the necessary technical equipment to transmit within this frequency range.

The average exposure time of an amateur radio operator will rarely exceed the value of 10 h/week, with large individual variation. A high exposure to RF-EMF arises as a result of the adjustment of the antenna or other ‘work' on the radio transmitters and radio traffic with an antenna which is installed in the house. Measured exposure values are not available. The whole body exposure, amongst others from antennas installed within the house, can however be comparably high.

Advantages: A cohort with a large size can easily be ascertained and, due to the structure of the organization of amateur radio operators, is also retrospectively available for many years. Demographic data of the members are present, also for the past. Long time exposure is common and varies widely among the individual members. The fluctuation of the membership is small due to the high expenditure involved (examination, costs for radio equipment).

Disadvantages: Amateur radio operators are probably not exposed to RF-EMF on a daily basis. The average weekly exposure duration is rather small. An exposure assessment seems to be possible only by using a questionnaire for each individual and may therefore be rather unreliable. This cohort also comprises quite a specific study population (technicians and handicapped persons) which can not be easily compared with the general population.

Workers on dielectric heat sealers: High frequency dielectric heat sealers are mainly used for welding of plastic property, operate with the industrial frequency of 27.12 MHz and have been used in Germany since the 1960's. At dielectric heat sealers, the workers are mainly occupied with the introduction and removal of the product to be

welded. Depending upon the shielding of the electrodes, exposure to different levels of RF-EMF can occur.

Measurements done at the request of the Lower Saxony Ministry of Social Affairs (Niedersächsisches Sozialministerium) and the Regional Office for Ecology (Niedersächsisches Landesamt für Ökologie) in 1996 showed that the majority of plants exceeded the licit exposure range. Discussions held with the Lower Saxony Regional Office for Ecology and the Trade Association for Precision Mechanics and Electro-Technology also confirmed that workers on dielectric heat sealers are highly exposed to RF-EMF.

Information on the number of exposed workers per company was scarce. Interviewed experts of different professional associations and the Lower Saxony Regional Office for Ecology stated that in general these workers are employed for a long time. They also believed that protective clothing were rarely used. Workers are employed in small and medium sized companies.

The disadvantages of a cohort of this group of workers for epidemiologic research is the small number of exposed workers per company, as this would necessitate contacting a large number of companies. It was also unclear whether appropriate measurement of exposure could be obtained in all these firms. Additionally, several other occupational exposures (plastic vapors, low frequency fields, and noise) can arise. It was also not possible to obtain an estimation of the number of exposed employees due to an incomplete view of the company structures.

Measurements of the Lower Saxony Social Department and of the Trade Association of the Chemical Industry prove that workers on dielectric heat sealers are exposed to clearly higher levels of RF-EMF than the general population. The fact that workers are continuously employed at the same company for long periods of time and that

they work on a regular daily basis on these machines support the classification of the long exposure duration as suitable.

Table 4 summarizes the advantages and disadvantages of the three selected potential cohorts. The exposure of the cohort of workers on dielectric heat sealers is high, however ascertainment of the cohort is rather difficult. The strength of the cohort of amateur radio operators is the large number of persons, however, exposure assessment seems to be impossible. The strength of the cohort of technicians is the quality of retrospective exposure assessment but epidemiological research is hampered by the small number of persons working in this profession.

Discussion

Our aim was to investigate possible health effects of RF-EMF exposure in a large retrospective occupational cohort. We therefore considered different groups of persons potentially exposed to RF-EMF and explored whether it would be feasible to set up epidemiologic research in these groups. Most of the occupational groups that we had considered based on literature reviews and knowledge about potential exposure can not be realistically used for a cohort study as the numbers of exposed subjects are small, or exposure levels are only marginally higher than those of the general public. We identified three more promising groups: professionals in broadcasting stations, amateur radio operators and workers on dielectric heat sealers. However, further inspection of those groups revealed major obstacles. The implementation of digital broadcasting and the intention to switch-off all analogue broadcasting frequencies in Germany by 2010 makes a cohort study with technicians and engineers of medium and short wave broadcasting stations seem obsolete. A historical cohort has little power as the total number of persons working in this field is low. For amateur radio operators the average exposure is rather low. An exposure assessment seems to be possible only by using a questionnaire for each individual and may therefore be rather unreliable. Dielectric heat sealers work in many small firms, which are spread all over Germany. They have a mixture of exposures (e.g. vapours, low frequency fields) and different operational procedures, depending on the current manufacturing process (table 4). The result of our feasibility study was that we recommended not to perform a cohort study to investigate RF-EMF exposure at that time.

Admittedly our results are based on the situation in Germany and are only partly transferability to other countries. For example most German firms which use dielectric heat sealers have gone abroad (to countries with less labour protection) because they could not comply with the German labour protection regulations, which are stricter than the ICNIRP's (International Commission on Non-Ionizing Radiation Protection) reference exposure levels [34, 35]. Hence the number of workers at dielectric heat sealers might be substantially higher in other countries. Our concern to perform a cohort study among amateur radio operators may, however be true for other countries.

Conclusions

The aim of our study was to identify cohorts exposed to RF-EMF and to investigate the feasibility of conducting a cohort study based on these occupational cohorts. We identified three cohorts (technicians and engineers of medium and short wave broadcasting stations, amateur radio operators, workers on dielectric heat sealers), in which the investigation of RF-EMF-associated health risks is, in principle feasible. The conduction of a cohort study with persons exposed to RF-EMF poses a number of methodological problems that seem difficult to overcome. The expected effects are also considered to be low. In the meantime, prospective cohort studies of mobile phone users have become an option and have been started in some countries.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

M. Blettner, G. Berg-Beckhoff, B. Schlehofer, J. Wahrendorf and J. Schüz conceptualised the study and developed the study protocol. J. Breckenkamp and E. Münster were responsible for the conduction of the study. G Berg-Beckhoff and J Breckenkamp wrote the initial draft of the paper, which was subsequently modified in discussions with all authors. J Breckenkamp is the guarantor of the work. All authors read and approved the final manuscript.

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