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

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Abstract

Background

The aim of this study was to examine the feasibility of a cohort study on health risks due to radio frequency/microwave exposure. Ideally the exposure should be similar in frequency range and level to the exposure to mobile phones, because these conditions would allow an extrapolation of results to the exposure to mobile phones.

Methods

A criteria catalogue was developed to evaluate the feasibility of a cohort study on health risks caused by exposure to radio frequency electromagnetic fields (RF-EMF). The criteria aimed at conditions of exposure, possibility to set up a cohort and the feasibility of a follow-up study.

Results

21 occupational settings with potentially exposed workers were considered. Three of them were selected as promising for further evaluation based on expert ratings, literature reviews, and according to our criteria catalogue: workers on dielectric heat sealers, amateur radio operators, and personnel of medium/short wave transmitting plants. The cohort of workers on dielectric heat sealers showed the most disadvantages (small number of exposed workers, exposure depends on the respective working process, mixture of exposures, e.g. plastic vapors, probably unreadiness of firms to cooperate) although exposure is highest in this group. The strength of the cohort of amateur radio operators was the large number of persons, whereas the strength of the cohort of personnel working at transmitting plants was the quality of retrospective exposure assessment.

Conclusions

In all, the vast majority of occupational groups that we had considered from literature reviews and discussed with experts had to be excluded from further consideration due to small numbers of exposed subjects or exposure levels only marginally higher than for the general public. We did not find a suitable occupational cohort with an exposure to RF-EMF, similar in frequency and quantity to mobile phones; therefore it was concluded to evaluate the feasibility of a cohort study of users of mobile phones.

Background

Due to the widespread use of cordless and cellular phones the portion of the population exposed to radio frequency electromagnetic field (RF-EMF) has increased rapidly.

Although the portion of occupationally exposed persons appears to be small, an increased number of exposed people can be anticipated, in particular outside of the industrial production facilities (use of cellular phones, wireless local area networks and/or Bluetooth technologies). There is a need to study the health risks of electromagnetic fields because of the ever-increasing sources of radio frequency radiation and because of the increasing public concern on potential health effects.

So far, only few epidemiological cohort studies investigating the effects of radio frequency electromagnetic fields (RF-EMF) on the health status in occupational settings or in leisure time (amateur radio operators) have been conducted [1-10]. 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 [11]. In most occupational studies it is exceedingly difficult or too expensive to determine the individual exposure in more than a few hundred persons. However, a large number of subjects is needed to achieve a sufficient statistically power of the

study to detect presumable small health risks, if any. In addition, the higher the exposure, the more likely it might be that there is an effect, thus, studying groups of highly exposed workers appear to be more promising. Besides, studies are complicated by the fact that exposure often is a mixture of radio frequencies, extremely low frequencies and even other exposures, like chemical agents.

The aim of this study was to examine the feasibility of a cohort study on health risks due to radio frequency exposure. In addition a possible extrapolation from expected results to the exposure to mobile phones should be examined.

Methods

First of all occupational groups should be considered as potential cohorts, which are higher exposed from RF-EMF than the total population, e.g. vocations in the field of technical manufacturing of plastics. Information about possibly exposed occupational groups was obtained by different professional associations, visits of industry sites, contacts with committees, and administrative bodies. Contemporaneously a literature review including technical reports was realized. Thus, after identification of potential cohorts the ascertainability of exposure is an important criterion to decide whether with the potential cohort a study is feasible.

Criteria for assessment:

One of the most important criteria for the feasibility of a cohort study is the measurement of exposure. A quantitative assessment is the only way to determine a dose-response-relationship. This again is a condition for the quantification of possible health risks in occupational cohorts. To conduct a cohort study, the following requirements have to be fulfilled:

Criteria for assessment of RF-EMF exposure: Subjects in an occupational cohort have to be exposed regularly as well as over a longer time period (a portion should be

exposed for a ten year period or longer), and the exposure should be on a higher level compared to the total population, otherwise possible health effects can not be detected. Exposure estimates should be possible on an individual base. A retrospective estimate of exposure should be possible, e.g. by using a job-exposure-matrix.

Ideally the exposure of the cohort is similar in frequencies and quantity to mobile phones as a condition for the extrapolation of results.

Criteria for assessment of the cohort: It must be possible to set up the cohort. A well defined group of persons needs to be available. 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. It must be possible to choose an unselected cohort from files held by the employers, public authorities or companies. Demographic variables must be available from documents of the employers, and should retrospectively be available for about 5 to 10 ten years (minimum). Cohorts in big companies or public authorities are of special interest under logistic aspects, because of the existing infra structure. Lines of communication (e.g. intranet) in a company can be used for the distribution and collection of questionnaires. More over this approach is very cost-effective. Representatives of employees and the management of the firm must be willing to endorse the study. Important parameters to obtain the number of cases are the size of the cohort and the time of follow-up.

Criteria to carry out a follow-up: A follow-up has to be possible. If a cohort study with mortality as outcome will be performed, it is sufficient, to obtain addresses not too old. In this case the follow-up can be done by registration offices and public health authorities. If a morbidity study will be performed, ideally cohort members are

contacted for interviews and medical examinations. The above stated conditions apply when data from registries is not available in a country as e.g. in Germany.

Definition of outcomes:

Possible outcomes of the cohort study were identified by the review of 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 outcome, because then a retrospective part of the cohort study is possible. Thus, mortality on cancer, cardiovascular diseases, and neurodegenerative diseases were determined as possible outcomes for the cohort study.

Calculation of expected cases:

To find possible health effects of the exposure to RF-EMF, assumptions have to be making about the size of the cohort and the expected odds ratio, under consideration of the statistical criteria alpha and power. The calculation of expected cases was done for a classical cohort study on mortality. The following parameters were used: latency period = 5 years, loss to follow-up = 5 %; age of study population 20 to 60 years with a uniform age distribution. Bold marked figures in table 1 show the expected number of deaths, fulfilling the given criteria of an alpha of 0.05 and a power of 80 %. Doubling the cohort size goes along with a doubling of expected cases, doubling the observation time goes by with multiple increase of expected cases (table 1). 5000 subjects and a 30-year follow-up are needed to reject a relative risk of 1.0 (number of cases >=30), if the relative risk is greater or equal 1.5 and the above stated assumptions are correct. This situation is given analyzing breast cancer. Of 10,000 subjects and a 30-year follow-up are needed to reject a relative risk of 1.0 (number of

cases >=9), if the relative risk is greater or equal 2.0, which is given analyzing brain cancer.

The long terms of follow-ups in mortality studies (see table 1) illustrate that results can not be expected within a few years. For this reason retrospective approaches were discussed, because these approaches allow to achieve results over 3 or 4 years.

Results

21 occupational settings were considered as at least potentially exposed (table 2). Comments and conclusion for exclusion are presented in the annex, table 4. Three of them were selected for further evaluation basing on the results of discussions with experts and according to the criteria stated above. The other occupational groups were excluded from further analysis due to:

1. Condition of exposure not fulfilled or low exposure levels. E.g. for captain in inland water transportation and working in a sluice the exposure to RF emitted by radio communication regarding to experts does not play a role. An exposure to microwave emitted by radar is technically questionable due to the position of radar equipment on the roof of the ships.
2. Small number of exposed subjects. Typically there is one high exposed work station to handle a gluing press in a small firm. Thus a cohort can not be build.
3. Automated and shielded working processes. E. g. blister packaging is an automated and shielded process. Maintenance of the devices takes only place when the machine is switched off (see table 2).

After the selection process basing on the above mentioned criteria, three cohorts remained: Personnel of medium/short wave transmitting plants, amateur radio operators, and workers on dielectric heat sealers.

Personnel of medium/short wave transmitting plants: At transmitting plants about 200 to 250 employees (engineers and technicians) are potentially exposed to radio frequencies (medium or short wave). Personnel are employed only on plants with a transmitting power of ≥ 100 KW. In Germany 20 of 29 transmitting plants operate at this power level. As the personnel in the workplaces is continuously exposed, the duration of the exposure corresponds to the daily working time. It is possible to obtain a rough estimation and/or an exact determination of the exposure. Such data can be determined by measurement or computationally. In addition, former exposures can be computationally derived on the basis of current exposure. This is important because the transmitting plants were previously operated partly with a higher transmitting power and other modulation procedures. The operating condition (transmitting power and field-strength) of the amplitude modulated AM transmitters 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. Recruiting an internal control group is likely to be unproblematic as for example switch room technicians could be recruited for this purpose.

The limitations of the study design include the rather small exposure (mechanical workshop, Mühlacker transmitting station, electrical field: 1.5 V/m, magnetic field: 0.2 A/m), the small cohort size (N max. = 250 potentially exposed persons) and the fact that such a cohort consists exclusively of persons of 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 are active. A reporting obligation exists, but only for instruments with a transmitting power of > 10W and thus so-called class 3 operators are not under obligation to report. The permissible frequencies for amateur radios lie between 2 MHz and about 300 GHz. In reality however, less than 5% of amateur radio operators can transmit in the frequency range used by mobile phones, 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. Probably the exposure duration 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. An intensity of exposure, as it might arise around the ear during the use of mobile phones, does not result from normal amateur radio transmission. The whole body exposure, amongst others from antennas installed within the house, can however be considerably more than that, acquired by the use of mobile phones.

Advantages: A cohort is easily accessible, and due to the structure of the organization of amateur radio operators also retrospectively available for a long time. Demographic data of the members are present and also backdated. Long time exposure is common and varies widely between the individual members. The fluctuation of the membership is probably 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 and varies extremely. Also this cohort comprises quite a specific study population (technicians

and handicapped persons) which can not easily be compared with a general population.

Workers on dielectric heat sealers: High frequency dielectric heat sealers are mainly used for welding of plastic property, are operating 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 screening level of the electrodes, exposure to different levels of RF-EMF can occur.

Measurements done at the request of the Lower Saxony Social Department and the Regional Office for Ecology already showed in 1996 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 make up an occupational cohort highly exposed to RF-EMF.

Information on the number of exposed workers per company, gender and age structure were very different. Interviewed experts of different professional associations and the Lower Saxony Regional Office for Ecology were in general in agreement that this concerns employees who had been working in the field for a long time, who are older than 30 years of age, who only in rare cases were provided with protective clothing/measures and who are employed in small and medium enterprises. In principle objective data are available, but due to the unknown willingness to cooperate of those small companies that come into question, no concluding assessment can be drawn.

Disadvantages of a possible cohort are the intensive work to be invested in recruiting persons due to the generally small number of exposed workers per company and the

different working processes at the dielectric heat sealers which depend on the production process during which differently mixed exposures (plastic vapors, low frequency fields, and noise) can arise. Moreover the experts could not make a precise estimation of the number of all exposed employees since an incomplete view of the company structures is still present. Besides, the frequency of dielectric heat sealers differs from frequencies of mobile networks, which makes an extrapolation difficult. 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, a fact which is to be seen as advantageous. The fact that workers are continually 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 3 summarizes the advantages and disadvantages of the three selected potential cohorts regarding our criteria catalogue (see methods). The cohort of workers on dielectric heat sealers shows the most disadvantages although exposure is highest in this group. The other cohorts have all about the same amount of advantages and disadvantages. The strength of the cohort of amateur radio operators is the large number of persons, whereas the strength of the cohort of technicians is the quality of retrospective exposure assessment.

Discussion

In all, the vast majority of occupational groups that we had considered from literature reviews and discussed with experts had to be excluded from further consideration due to small numbers of exposed subjects or exposure levels only marginally higher than for the general public. Furthermore we did not find an occupational cohort with an exposure to RF-EMF, similar in frequency and quantity to mobile phones. With

regard to the three remaining occupations a cohort study revealed manifold disadvantages. The cohort of workers on dielectric heat sealers show the most disadvantages, when comparing the three selected potential cohorts, which are the intensive amount of work for recruitment because of the small number of employees per firm, the spread of firms all over Germany, the mixture of exposures (e.g. vapors, low frequency fields) and the different operational procedures, depending on the current manufacturing process (table 3). Due to the implementation of digital broadcasting and the switch-off of all analogue broadcasting frequencies until 2010 in Germany a cohort study with technicians and engineers of medium and short wave transmitting plants seems to be obsolete. Amateur radio operators are not exposed on a daily basis and the average weekly exposure is rather low. An exposure assessment seems to be possibly, but only by a questionnaire which is sent to the participants.

Conclusions

In conclusion, the aim of our study was to detect an occupational cohort exposed to RF-EMF and to test the feasibility of a cohort study with this occupational cohort. Additionally a possible extrapolation from expected exposure of the potential cohorts to the exposure to mobile phones was researched. We did not identify an occupational cohort, in which the determination of the RF-EMF-associated morbidity or mortality risk is possible without serious problems. In addition, we did not find an occupational cohort with an exposure to RF-EMF, similar in frequency and quantity to mobile phones. Therefore the present potential cohort studies did not replace a cohort study of users of mobile phones.

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 had the initial idea for this paper and J Breckenkamp wrote the initial draft, 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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