Quantification of exposure to electromagnetic fields (EMF) in a case-control study of brain tumor in adults in the U.S.

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Introduction

Some occupational case-control and cohort studies have reported increased risks of brain cancer and leukemia associated with employment in jobs linked with exposures to magnetic or electric fields. In early studies, these associations were based on only electrical-related jobs; however, various attempts have been made to quantify EMF exposure in recent epidemiological investigations (2). In this report, we present a new approach to quantify level of exposures to EMF in various ranges of frequencies, such as static magnetic fields (SMF: < 3 Hz), extremely low frequencies (ELF: 3-3,000 Hz), video display units (VDU: 15-30 KHz), and radio frequencies (RF: 30 KHz-300GHz).

Methods

A detailed questionnaire with lifetime work history information has been administrated to 782 cases and 799 controls (1). In addition, subject-specific information on EMF exposure was obtained using job-specific modules (i.e., integrated-questionnaires designed to obtain information on types of electrical equipment used, the distance from the electrical sources, and the frequency of exposure in a given time period) for potentially EMF-exposed subjects. Jobs in work histories were reviewed by an occupational hygienist shortly after the interview and further questions were asked to the subjects to clarify exposure information when needed. For ELF exposure assessment, we used type of electrical equipment and the proximity to the source in three categories (i.e., <3 feet; 3-6 feet; and >6 feet) to estimate the level of exposure intensity. We also used the frequency of exposure (i.e., hours per week) and the number of years worked at the exposed job. Two-way radios operated in offices, CB-radios in trucks and cars, and walkie/talkies were used as intensity variables for RF exposure assessment. Assessment of VDU exposure was based on use of computer or video monitor, while assessment of static magnetic field exposure was based on job titles associated with the use of electrical equipment operated with direct current, such as welding machine operators, forklift operators, or smelters.

From work histories of 1581 subjects, we had three types of exposure information for 8,750 unique jobs. First, we had general exposure information from work histories, such as job and industry titles, tasks or activities, and electrical tools or equipment used for every study subject. Secondly, for 61% of the jobs, we had job-specific module information on the use of electrical tools and equipment, and for 17% of the jobs, we had information from the follow-up interview to clarify the exposure conditions. From the module information, we developed quantitative estimates of ELF exposure using an algorithm with the following variables: (1) Intensity of

EMF produced by the electrical equipment or tools used; (2) distance from the equipment or tools; and (3) frequency of exposure. Thirdly, we developed several job exposure matrices (JEM) for EMF exposures for the various frequency categories using existing measurement data from the literature and our own experiences regarding to the jobs or industries. For ELF, we developed one semi-quantitative (JEM-1) and one quantitative (JEM-2) job exposure matrix. For jobs with information on work history only (n = 3,110), we used JEMs values and the descriptive data from job title, work place, activities, products, equipment and tools used, and calendar years of employment, plus literature data to develop quantitative exposure estimates. For the jobs with work history data and job-specific modules (n = 4,276), we used all the information listed in the work history data, plus algorithm results. For the jobs with information on work history, job modules, and responses to the follow-up interview (n=1,364), we used all the above data and the responses to the clarification questions. We also developed an exposure assessment software program to utilize all of the available information efficiently to reach the final quantitative estimate of exposure to EMF.

Results

We present examples for quantifying levels of exposure to ELF for three scenarios with different information sources:

Example 1:	Job with work history only
Job Title:	*Engineer*
Industry Title:	*Aircraft manufacturing*
Calendar Years:	*1950-1956*
Activities:	*Tested fuel control and electrical circuits*
Products Made:	*Carburetors and aircraft engine*
Chemicals Used:	*Stoddard fluid and JP4 Fuel*
Tools Used:	*Electrical test equipment*
JEM-1:	*Medium (3-4 mG)*
JEM-2:	*1.7 mG for Engineer*
FINAL ESTIMATE:	*3.0 mG*

Although the measurement-based JEM-2 suggested that the level of exposure to ELF should be 1.7 mG for engineers and 3.3 mG for electrical engineers, we assigned the final estimate to be closer to electrical engineers than unspecific engineers, because the subject used of an electrical test equipment for testing electrical circuits.

Example 2:	Job with work history and module information
Job title:	*Welder/grinder*
Industry title:	*Construction machine manufacturing*
Calendar Years:	*1973-1975*
Activities:	*Welding and grinding*
Products Made:	*Bulldozers, front end loaders*
Chemicals/Tool Used:	*Gasoline, hand grinder*
Electrical Equip. Used:	*40 hr/wk >3ft welding machine; 40 hr/wk >6ft generator*
JEM-1 :	*High (>5 mG)*
JEM-2 :	*20 mG*
Algorithm:	*5.0 mG without considering the grinding process*
FINAL ESTIMATE:	*13.7 mG*

JEM-2 suggested that the level of exposure should be 20.0 mG for welders. The algorithm was 5.0 mG. Because the subject did not report the use of grinder in the module, the estimated level of exposure calculated by the algorithm was lower than it should be, and we recalculated the algorithm result (i.e., 13.7 mG) with the information on grinder use.

Example 3:	Job with work history, module, and follow-up information
Job title:	*Production inspector*
Industry title:	*Boat Engine Manufacturing*
Calendar Years:	*1985-1990*
Activities:	*Examine engines and report results*
Products Made:	*Made 9-150 HP engines*
Chemical Tools Used:	*Solvents and Electrical test equipment*
Electrical Equip. Used:	*Hand-held test equipment 10 hr/wk*
Algorithm:	*1.4 mG*
Follow-up Que.:	*How much time did you spend in the engine area? Ans: 25 hr/wk*
JEM-1:	*Medium*
JEM-2:	*2.0 mG*
FINAL ESTIMATE:	*1.8 mG*

In the earlier review of responses, it was unclear how much time the subject spent in the production area, which he might be getting additional EMF exposure from other equipment in the production area. In the follow-up interview, the subject responded that he spent 25 hr/wk in the production area. JEM-2 suggested that the level should be 2.0 mG and the algorithm result was 1.4 mG. Since the actual time was longer than the one included in the algorithm, we increased the level to 1.8 mG to make it close to the JEM-2 value based on the response in the follow-up interview.

Discussion

We were unable to estimate subject-specific exposure levels using solely either semi-quantitative JEM-1 or measurement–based quantitative JEM-2, because they were developed as job-specific, and the assignment of exposure levels were generally averages of measured values for a limited number of samples. Subject-specific questionnaire information collected in this study suggested that the variability of exposure to EMF between different individuals with the same jobs could be substantial due to differences in work practices and frequency of exposure in a given period.

Conclusions

We found that descriptions of tasks or activities, responses to job-specific modules and follow-up interviews provided us with a significant amount of subject-specific exposure information to capture accurately the variability between workers holding the same job title.

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Preface

This book contains the extended abstracts to the X2001 Conference on Exposure Assessment in Epidemiology and Practice in Göteborg, Sweden, June 10-13, 2001. The excellent work performed by the contributing scientists has made this book a first-class, up-to-date, state of the art review on what is known about exposure assessment today.

The outstanding scientific quality of the extended abstracts was secured through the work of five international programme committees. The chairmen for the committees were: Chemical, Patricia Stewart; Ergonomic, Alex Burdorf; Physical, Ulf Bergqvist; Psychosocial, Annika Härenstam and Biological, Jean-Francois Caillard.

Financial support to the conference and thereby to the publishing of this book was made possible by contributions from The National Institute for Working Life, Stockholm, Sweden; The Swedish Council for Working Life and Social Research, Stockholm and Volvo. Without the excellent skills of the organizing committee - Ulrika Agby (administration and layout), Ann-Sofie Liljenskog Hill (administration) and Christina Lindström Svensson (administration) - the production of this book would not have been possible.

We want to express our gratitude to the contributing authors, session chairmen and to the participants who presented papers and contributed in the discussions, for making X2001 an outstanding meeting.

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