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BRIEF COMMUNICATION

Survey of Delivery Outcomes for Employees at MR Imaging Facilities in Japan Based on Information Recorded in the Maternal and Child Health Handbook

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The effect of maternal occupational non-ionizing radiation (NIR) exposure from MRI on premature birth and low birth weight delivery was analyzed based on questionnaire survey (263 employees, 443 births). Although the highest occurrence rates of both outcomes were observed in the group whose NIR exposure occurred only before pregnancy, no statistical significance was detected.

Keywords: *magnetic resonance imaging worker, pregnancy, static magnetic fields*

Introduction

MRI is a diagnostic imaging technique that uses multiple non-ionizing radiation (NIR) for image acquisition; especially, the use of strong static magnetic fields (SMFs) is one of the defining features of an MRI system. There have been no clear reports of NIR exposure from MRI equipment exerting a harmful effect on fetal development or growth;[1–3] however, views on pregnant employees performing MRI scan duties vary internationally.

This debate has emerged from a lack of epidemiological study updated as per the recent technological changes. The latest epidemiological study of female employees at MRI facilities was reported in 1993.[1] Results of the survey indicated that there was no significant increase in the common adverse reproductive outcomes among females working at MRI sites. However, an update report on this kind is currently required since the field intensity used in MRI systems has increased from 1.5T to 3T.

Our present study collected answers from female employees at MRI facilities in Japan via a mail survey. Respondents' Maternal and Child Health (MCH) Handbooks were also used for data collection. This study reports the results of the pregnancy outcomes (premature birth and low birth weight) classified by NIR exposure categories.

Methods

Study design and data screening

The questionnaires were sent to 2241 female employees at 806 institutes. The target of the questionnaire was all female workers who have access to MRI scanner room (radiologists, nurses, radiological technologists, researchers, etc.). Thus, respondents were not limited to employees in the radiology department. The answers were collected from 1193 employees (collection rate, 53.2%). After eliminating blank answers, responses from nulligravid women, and invalid answers (Supplementary Fig. 1), we performed a data analysis using 263 valid responses with 443 births from the collected answers.

Questionnaire

The questionnaire was composed of two parts. The first part was reported in the previous study.[4] The second part is a self-reported questionnaire asking the number of pregnancies, miscarriages, and employment period both at MRI facilities and non-MRI facilities. The number, sex, and ages of biological children were declared. The delivery reports were based on information in the MCH Handbook, which records pregnancy and delivery, child development, immunizations and illnesses, and health education.[4] The information of lifestyle, e.g. smoking habit, alcohol intake, past illnesses, etc., and work situations during pregnancies were also reported by the questionnaire.

Exposure categories

Respondents were divided into three exposure categories according to their exposure history: 1) NIR(–): unexposed;

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2) NIR(+): exposed to NIR only before pregnancy; and 3) NIR(++): exposed to NIR both before and during pregnancy. An exposure category was assigned based on the combination of answers to these two questions (Supplementary Table 1). Only NIR from the MRI system was considered as a source of exposure from NIR.

Outcome

To examine the effects of occupational NIR exposure, the study tracked two outcomes: premature birth and low birth weight. Occurrences of premature birth and low birth weight were all counted based on the delivery reports. Premature birth was defined as a baby born alive before 37 weeks of pregnancy, and low birth weight was set as a baby born weighing 2500 grams (5.5 pounds) or less.

Statistical analysis

In addition to occupational NIR exposure, this study considered other variables based on the questionnaire and the factors with known influence on pregnancy outcomes {pregnancy over 35 years old and body mass index (BMI; normal [ranges 18.5–24.99] or others)}. Chi-square test was performed to examine the relationship between occupational NIR exposure or other variables and the occurrence of premature birth and low birth weight. The IBM SPSS 25 Advanced statistics and regression modules (IBM Japan, Tokyo, Japan) were used for statistical analyses. Statistical significance was set at $P < 0.05$.

Ethics

This study was implemented under the approval of the ethical committee at the National Institute of Occupational Safety and Health, Japan (No. H2924). Written informed consents were requested at the beginning of the questionnaire. Submitting the blank answers was also permitted if respondents did not agree to the participation of this questionnaire.

Results

The characteristics of the respondents of this study are summarized in Table 1. The most common occupation of respondents was radiological technologist (83.3%). The proportion of each exposure category was NIR(–) (177 births, 40.0%), NIR(+) (66 births, 14.9%), and NIR(++) (200 births, 45.1%). The chi-square test indicated that there were significant differences between the "Exposure category vs Occupation" (degrees of freedom [df] = 4, $P < 0.001$), vs "Work condition 2 (work overtime)" (df = 2, $P = 0.002$), and vs "Work condition 4 (use of sources of ionizing radiation)" (df = 2, $P = 0.019$).

The reported health conditions at the pregnancy were as follows: "No clinical history" (385 births, 86.9%), "Hypertension" (5 births, 1.1%), "Diabetes" (2 births, 0.5%), "Other disease" (43 births, 9.7%), "Blank answer/ Not remember" (8 births, 1.8%), respectively.

The relationship between explanatory variables and pregnancy outcomes showed no statistically significant differences in all cases (Table 2). The occurrence rate of premature birth (31 births) was 7.9% (NIR[–], 14 births), 12.1% (NIR[+], 8 births), 4.5% (NIR[++], 9 births), and low birth weight (42 births) was 11.9% (NIR[–], 21 births), 12.1% (NIR[+], 8 births), 6.5% (NIR[++], 13 births), respectively. Among the exposure categories, the highest occurrence rates of both outcomes were observed in NIR(+). However, no statistical significance was detected ($P = 0.090$ for premature birth or $P = 0.151$ for low birth weight).

Discussion

This study analyzed the effect of maternal occupational NIR exposure from MRI scan duty on premature birth and low birth weight delivery and the highest occurrence rates of both outcomes were observed in NIR(+) although no statistical significance was detected. There were no statistically significant differences between explanatory variables and pregnancy outcomes.

So far, only one study is available that has surveyed the pregnancy outcomes among MRI technologists.[1] Possible adverse effects on reproductive systems by exposure to NIR from MRI system are one of the concerning issues for female employees at MRI facility. Although there are several animal studies whose results showed no adverse effects on fetal developing processes by SMF exposure[5–7] or a large-scale epidemiology study which aimed to clarify the influence of fetal MRI examination and showed no harmful effects,[8] these studies do not directly lead to the answers of our concerns. Our present study implemented a questionnaire survey among female employees who worked at MRI facilities and examined the influence of occupational NIR exposure from MRI systems on delivery outcomes to supplement the lack of updated epidemiological evidence.

The strength of our study is that the results reflected the pregnancy outcomes from female employees who are currently working (or previously engaged) in MRI scan duties. Also, the feature of this study is categorizing the exposure group into two types (NIR[+] and NIR[++]), which enabled comparisons not only between exposure groups and controls (NIR[–]) but also within exposure groups (Tables 1 and 2). Subanalysis among A3_1-4 showed no linear increase in the occurrences of both premature birth and low birth weight (Supplementary Table 2), suggesting that exposure duration has no influence on the occurrence rate.

The occurrence rates of outcomes in the previous study[1] were 3–10% premature births and 3–5% low birth weight. Our results (Table 2, category of variable: NIR) showed

Table 1 Characteristics of respondents in the present study.

Variable	All N = 443		Exposure category						*P value*
			NIR(–) n = 177		NIR(+) n = 66		NIR(++) n = 200		
	N	%	N	%	N	%	N	%	
Occupation									<0.001***
Radiology technologist	369	83.3%	130	73.4%	57	86.4%	182	91.0%	
Other medical professinals (e.g., doctors, nurses)	57	12.9%	30	16.9%	9	13.6%	18	9.0%	
Others (e.g., students)	17	3.8%	17	9.6%	0	0.0%	0	0.0%	
Smoking habit									0.270
No	438	98.9%	176	99.4%	66	100.0%	196	98.0%	
Yes	5	1.1%	1	0.6%	0	0.0%	4	2.0%	
Alcohol intake									0.097
No	420	94.8%	170	96.0%	59	89.4%	191	95.5%	
Yes	23	5.2%	7	4.0%	7	10.6%	9	4.5%	
Pregnancy over 35									0.236
No	411	92.8%	168	94.9%	62	93.9%	181	90.5%	
Yes	32	7.2%	9	5.1%	4	6.1%	19	9.5%	
BMI									0.459
Normal (18–25)	335	75.6%	139	78.5%	50	75.8%	146	73.0%	
Lower than 18 or Higher than 25	108	24.4%	38	21.5%	16	24.2%	54	27.0%	
Work condition 1									0.644
No	181	40.9%	76	42.9%	24	36.4%	81	40.5%	
Carrying heavy items	262	59.1%	101	57.1%	42	63.6%	119	59.5%	
Work condition 2									0.002**
No	248	56.0%	116	65.5%	37	56.1%	95	47.5%	
Working overtime	195	44.0%	61	34.5%	29	43.9%	105	52.5%	
Work condition 3									0.698
No	431	97.3%	171	96.6%	64	97.0%	196	98.0%	
Use of reproductive toxic substance	12	2.7%	6	3.4%	2	3.0%	4	2.0%	
Work condition 4									0.019*
No	162	36.6%	76	42.9%	27	40.9%	59	29.5%	
Use of sources of ionizing radiation	281	63.4%	101	57.1%	39	59.1%	141	70.5%	

Chi-square test was performed to clarify the relationship between each exposure category and variable. Number of responses were presented in the table. *$P < 0.05$, **$P < 0.01$, ***$P < 0.0001$. Others, students, not employed during pregnancy; BMI, body mass index; NIR, non-ionizing radiation.

similar rates (4.7%–13.8% for premature births) although the rate for low birth weight in our study showed a higher level (7.0%–13.8%) compared with the previous report.[1] However, the rates of both outcomes were the lowest in NIR (++) group (4.7% premature births and 7.0% low birth weight) among the three categories (Table 2). A possible reason is the job distribution among the exposure categories (Table 1). These results suggest that contribution from NIR exposure might be small although further analysis is required to clarify the cause.

The present study has several limitations. Firstly, the subjective measure of collecting exposure situations does not provide information about intensity and duration of exposure history. Secondly, the questionnaire of the present

Table 2 The relationship between explanatory variables and pregnancy outcomes.

Variable	Premature birth						Low birth weight					
	No, n = 412		Yes, n = 31				No, n = 401		Yes, n = 42			
	n	%	n	%	n	*P* value	n	%	n	%	n	*P* value
NIR						0.090						0.151
NIR(–)	163	92.1%	14	7.9%	177		156	88.1%	21	11.9%	177	
NIR(+)	58	87.9%	8	12.1%	66		58	87.9%	8	12.1%	66	
NIR(++)	191	95.5%	9	4.5%	200		187	93.5%	13	6.5%	200	
Occupation						0.604						0.103
Radiology technologist	345	93.5%	24	6.5%	369		336	91.1%	33	8.9%	369	
Other medical professionals (e.g., doctors, nurses)	52	91.2%	5	8.8%	57		48	84.2%	9	15.8%	57	
Others (e.g., students)	15	88.2%	2	11.8%	17		17	100.0%	0	0.0%	17	
Smoking						0.305						1.000
No	408	93.2%	30	6.8%	438		396	90.4%	42	9.6%	438	
Yes	4	80.0%	1	20.0%	5		5	100.0%	0	0.0%	5	
Alcohol intake						1.000						0.259
No	390	92.9%	30	7.1%	420		382	91.0%	38	9.0%	420	
Yes	22	95.7%	1	4.3%	23		19	82.6%	4	17.4%	23	
Pregnancy over 35						0.715						0.211
No	381	92.7%	30	7.3%	411		374	91.0%	37	9.0%	411	
Yes	31	96.9%	1	3.1%	32		27	84.4%	5	15.6%	32	
BMI						0.284						0.710
Normal (18–25)	314	93.7%	21	6.3%	335		302	90.1%	33	9.9%	335	
Lower than 18 or Higher than 25	98	90.7%	10	9.3%	108		99	91.7%	9	8.3%	108	
Work condition 1						0.852						0.069
No	169	93.4%	12	6.6%	181		158	87.3%	23	12.7%	181	
Carrying heavy items	243	92.7%	19	7.3%	262		243	92.7%	19	7.3%	262	
Work condition 2						0.853						0.145
No	230	92.7%	18	7.3%	248		229	92.3%	19	7.7%	248	
Working overtime	182	93.3%	13	6.7%	195		172	88.2%	23	11.8%	195	
Work condition 3						1.000						0.317
No	400	92.8%	31	7.2%	431		391	90.7%	40	9.3%	431	
Use of reproductive toxic substance	12	100.0%	0	0.0%	12		10	83.3%	2	16.7%	12	
Work condition 4												
No	147	90.7%	15	9.3%	162	0.119	146	90.1%	16	9.9%	162	0.867
Use of sources of ionizing radiation	265	94.3%	16	5.7%	281		255	90.7%	26	9.3%	281	

Chi-square test was performed to clarify the relationship between each pregnancy outcome and variable. BMI, body mass index; NIR, non-ionizing radiation.

study did not contain questions asking social status such as marital status or education. Finally, even though the number of respondents increased compared with the previous study,[1] sample size and the representativeness are other considering factors. The sample size in the present study was small because of the limited MRI facilities available to the study.

With regard to the representativeness, the lack of information for active MRI technologists, e.g., number of workers, sex ratio, etc., made it difficult to conduct an accurate evaluation of the results. Considering these limitations, it is difficult to infer a concrete conclusion from the results of this study. Further prospective data collection is required to confirm our results.

Conclusion

The highest occurrence rates of both outcomes were observed in NIR(+); however, no statistical significance was detected. Results of the present study showed no clear evidence that occupational NIR exposure during MRI scan duty cause adverse effects on the delivery outcomes of female employees. These results supplement the lack of existing knowledge in this research area, although careful consideration for the limitations need to be considered when generalizing our results.

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Conflicts of Interest

The authors have no conflicts of interest directly relevant to the content of this article.

Supplementary Information

Supplementary files below are available online.

Supplementary Fig. 1
The process of data screening.

Supplementary Table 1
Definition of exposure category. Exposure history was divided into three groups for analysis.

Supplementary Table 2
Subanalysis among A3_1-6 between occurrences of premature birth and low birth weight.

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