Emanuel Kanal, MD • Joseph Gillen, BS • Josephine A. Evans, MD, MPH
David A. Savitz, PhD • Frank G. Shellock, PhD

Survey of Reproductive Health among Female MR Workers[1]

Epidemiologic data were obtained to evaluate potential risks from exposure to the static and time-varying magnetic fields used in magnetic resonance (MR) imaging. A questionnaire sent to women workers in more than 90% of clinical MR facilities in the United States addressed menstrual-reproductive experiences, work activities, and potential confounders (eg, age, smoking, alcohol use). In 1,915 completed questionnaires, 1,421 pregnancies were reported: 280 occurred in an MR worker (technologist or nurse), 894 in an employee in another job, 54 in a student, and 193 in homemakers. Comparing MR-worker pregnancies with those occurring in employees at other jobs, a relative risk ratio of 1.27 (95% confidence interval [CI], 0.92–1.77) was found for spontaneous abortions; for conception taking more than 12 months, 0.90 (CI, 0.54–1.51); for delivery before 39 weeks, 1.19 (CI, 0.76–1.88); for birth weight below 5.5 lb (2.5 kg), 1.01 (CI, 0.50–2.04); and for male gender of the offspring, 0.99 (CI, 0.80–1.22). Adjustment for maternal age, smoking, and alcohol use also failed to markedly change any of the associations. These results suggest that there is not a substantial increase in these common adverse reproductive outcomes.

Index term: Magnetic resonance (MR), biological effects

Radiology 1993; 187:395–399

THERE has recently been a renewed interest in safety considerations of magnetic resonance (MR) imaging. Multiple areas of potential concern exist in and around clinical and research MR imaging systems, including the biological and mechanical effect(s) of the static magnetic field; power deposition and/or heating effects of the radio-frequency oscillating magnetic fields; potential biological effects of the extremely-low-frequency modulation of the radio-frequency oscillating magnetic fields; electrical inductive and auditory effects of the time-varying magnetic-field gradients; and nonmagnetic-field-related safety considerations, such as those related to psychologic issues, MR contrast agent administration, and use of cryogens. Of all potential areas of concern, the most volatile and emotional involve the possible interactions between the MR imaging environment and the pregnant patient or health care practitioner. In 1988, we found that 36% of sites surveyed simply did not perform MR examinations in pregnant patients (1). In that same survey, we found that there were markedly varied policies regarding pregnancy among health care practitioners, ranging from no pregnancy policy through exclusion from the magnet room to unrestricted activities. Some policies, when present at all, depended on the stage of gestation.

To address the issue of possible effects on pregnancy of working in the MR environment, a questionnaire that focused on these issues was distributed to a large proportion of clinical and research MR sites in the United States in an attempt to elicit epidemiologic data regarding these questions.

MATERIALS AND METHODS

In the 3rd and 4th quarters of 1990, we sent a survey to all the MR sites in the United States for which we were able to obtain addresses. The site list was generated and compiled from data obtained from multiple sources, including MR imager manufacturers, MR pharmaceutical firms, previous survey data bases, and other assorted MR data bases gleaned from various national MR user groups. Two thousand twenty sites were included in this master list. Besides the typical demographic data requested, the eight-page questionnaire focused on issues related to work history, infertility, pregnancy history, and menstrual history. The administrator or chief technologist of each MR site, to whom three copies of the survey were sent, was asked to distribute the questionnaire to each female MR technologist and nurse at the site; to collect the completed questionnaires; and to return them to us in the postage-paid, self-addressed mailer provided. To increase dissemination of the survey, it was also published in its entirety in the July 23, 1990, issue of *Advance for Radiologic Technologists*, a national technologist newsweekly with a circulation of approximately 110,000 readers. As a further incentive to completion and return of the questionnaires, a drawing was held to select a questionnaire randomly; the person who completed that questionnaire received an expense-paid trip to an MR conference held in Bermuda.

All responses were entered into a central data base and were reviewed for completeness and accuracy of response. We ensured, by matching of names and addresses, that there was no duplication between those responding to the questionnaire printed in the newsweekly and those responding to the mailed survey. All responses that were out of range (eg, an answer of 5 for a choice of only 1–4) were ignored and treated as missing. Several

[1] From the Division of Magnetic Resonance, Department of Radiology, University of Pittsburgh, the Pittsburgh NMR Institute, 3260 Fifth Ave, Pittsburgh, PA 15213 (E.K., J.G.); the School of Public Health, Department of Epidemiology, the University of North Carolina at Chapel Hill, Chapel Hill (J.A.E., D.A.S.); and Tower Imaging and the UCLA School of Medicine, Los Angeles, Calif (F.G.S.). From the 1991 RSNA scientific assembly. Received August 14, 1992; revision requested September 22; revision received October 15; accepted November 2. Supported in part by a grant from Berlex Laboratories, Wayne, NJ. **Address reprint requests to** E.K.

Abbreviation: CI = 95% confidence interval.

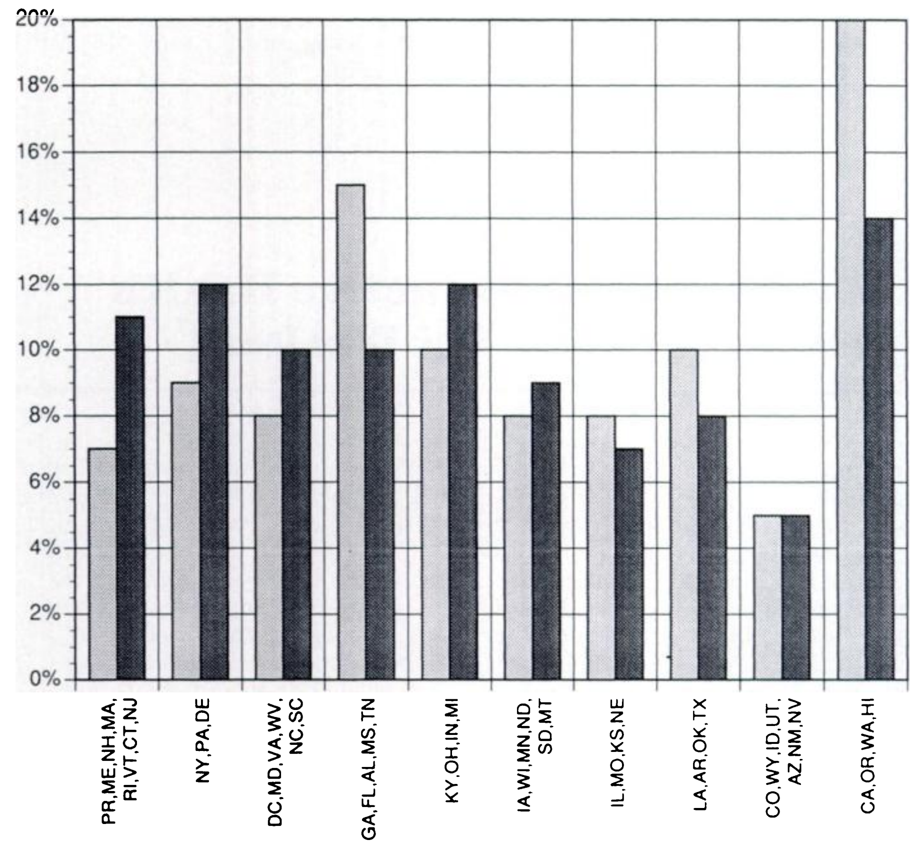
questions in the survey were identified as key to the analysis; missing responses to these questions resulted in elimination of the respondent or the pregnancy from the analysis. These questions were the respondent's date of birth, a date of birth or termination for a pregnancy, work history at time of pregnancy, and outcome of the pregnancy.

The number of responses from nonwhite technologists and nurses were too few for a meaningful statistical analysis by race. Nonwhite groups were therefore excluded from the analysis to provide a more homogeneous body of data.

The responses to five questions in the survey are addressed in this article. These questions concern pregnancy outcome, fertility, length of gestational period, gender of the offspring, and birth weight. Gender differences were evaluated to address the possibility of differential survival of male and female embryos. Pregnancy outcome end points used for statistical analysis were live births (survey responses of "single live birth" or "twins or multiple births") versus miscarriages (defined in the survey as "miscarriage [less than 20 weeks])." The infertility end point was chosen as more than 11 months of attempting unsuccessfully to conceive, which is slightly more stringent than the accepted definition of infertility as being more than 12 months of attempting unsuccessfully to conceive. Respondents indicated on the survey if the pregnancy was unplanned; such pregnancies were not included in the statistical analysis of the infertility section.

The other questions relate only to pregnancies with live birth outcomes. Delivery was considered preterm if the actual delivery date was 15 or more days earlier than expected (ie, pregnancy term of less than 39 weeks). We used the accepted value of under 5.5 lb (< 2.5 kg) as the definition of low birth weight.

The data for each of these questions were separated into four categories based on employment at the time of pregnancy: pregnancies occurring in women working as MR technologists or nurses ("MR Worker"), those in the women when they were in any other employment but not as an MR worker ("Other Worker"), those in women not employed outside of the home ("Home"), or those in women when they were students ("Student"). Too few responses were received in the Student category to enable reliable statistical analysis of this group. Statistical analyses were performed of the other groups to characterize the association between the five study categories and employment history. The relative risk (risk ratio), χ^2 value, 95% confidence interval (CI), and *P* value were calculated for the MR Worker group compared with the Other Worker group for each of the end points: miscarriage, infertility, preterm delivery, gender, and low birth weight. These same statistics were calculated comparing the MR Worker group with the Home group and the Other Worker group with the Home group. The data were also evaluated separately for three identified and well-known potential confounders: smoking and/or alcohol use during pregnancy and maternal age over 30 years at the time of delivery. A Mantel-Haenszel adjusted odds ratio (2) was computed with χ^2, CI, and *P* value for each confounder and end-point combination.



Percentage of MR sites sent questionnaires and percentage of respondents to questionnaire by geographic area (x axis labeled with state zip code abbreviations). Light gray columns = percentage of questionnaires distributed to these states (n = 2,020), dark gray columns = percentage of questionnaires received from these states (n = 1,915).

Table 1
Race and Pregnancies of MR Worker Group

Race	No. Pregnancies (n = 1,065)	One or More Pregnancies (n = 823)	Total (n = 1,888)
White	1,017 (95)	770 (94)	1,787 (95)
Black	11 (1)	26 (3)	37 (2)
Hispanic	16 (2)	14 (2)	30 (2)
Asian	12 (1)	4 (0)	16 (1)
Other	9 (1)	9 (1)	18 (1)

Note.—Numbers in parentheses are percentages (percentages may not add up to 100% because of rounding).

RESULTS

A total of 1,915 responses were received, of which 178 were from the newsweekly and 1,737 were from survey mailings. Nine percent of the respondents were MR nurses, while 91% were MR technologists.

Responses were received from sites in which the following MR units were used: CGR 0.35 T (Milwaukee, Wis); Diasonics 0.35 T (Milpitas, Calif); Elscint 0.5 T (Hackensack, NJ); Fonar 0.3 T (Melville, NY); GE 0.5 T, 1.5 T, and 4.7 T (GE Medical Systems, Milwaukee, Wis); Hitachi 0.2 T (Tarrytown, NY); Oxford 1.9 T (Clearwater, Fla); Philips 0.5 T and 1.5 T (Shelton, Conn); Picker 0.5 T (Mayfield Village, Ohio); Resonex 0.4 T (Sunnyvale, Calif); Siemens 1.0 T and 1.5 T (Iselin, NJ); Technicare 0.15 T and 0.6 T (GE Medical Systems); Thompson 0.5 T (Minneapolis, Minn); and Toshiba 0.35 and 0.5 T (Tustin, Calif). Unclear or unidentifiable systems were not included.

The Figure shows the geographic distribution of the sites to which question-

Table 2
Pregnancies by Race and Group during Pregnancy

Race	Home (n = 212)	MR (n = 291)	Other Work (n = 963)	Student (n = 59)	All (n = 1,525)
	Group				
White	193 (91)	280 (96)	894 (93)	54 (92)	1,421 (93)
Black	11 (5)	5 (2)	26 (3)	4 (7)	46 (3)
Hispanic	6 (3)	4 (1)	20 (2)	1 (2)	31 (2)
Asian	0 (0)	1 (0)	9 (1)	0 (0)	10 (1)
Other	2 (1)	1 (0)	14 (1)	0 (0)	17 (1)
	Work during Pregnancy as Percentage of All Responses in Category				
White	193 (14)	280 (20)	894 (63)	54 (4)	1,421 (100)
Black	11 (24)	5 (11)	26 (57)	4 (9)	46 (100)
Hispanic	6 (19)	4 (13)	20 (65)	1 (3)	31 (100)
Asian	0 (0)	1 (10)	9 (90)	0 (0)	10 (100)
Other	27 (12)	1 (6)	14 (82)	0 (0)	17 (100)

Note.—Numbers in parentheses are percentages (percentages may not add up to 100% because of rounding).

Table 3
Pregnancy Outcomes

Pregnancy Outcome	Home (n = 193)	MR (n = 280)	Other Work (n = 894)	Student (n = 54)	All (n = 1,421)
	Group				
Single	177 (92)	216 (77)	718 (80)	32 (59)	1,143 (80)
Multiple	2 (1)	2 (1)	10 (1)	0 (0)	14 (1)
Miscarriage	11 (6)	50 (18)	125 (14)	6 (11)	192 (14)
Stillbirth	1 (1)	0 (0)	6 (1)	2 (4)	9 (1)
Abortion	1 (1)	8 (3)	23 (3)	12 (22)	44 (3)
Ectopic	1 (1)	4 (1)	12 (1)	2 (4)	19 (1)

Note.—Numbers in parentheses are percentages (percentages may not add up to 100% because of rounding).

Table 4
Months to Conception

Months	Home (n = 193)	MR (n = 280)	Other Work (n = 894)	Student (n = 54)	All (n = 1,421)
	Group				
Pregnancy not planned	93 (48)	95 (34)	357 (40)	33 (61)	578 (41)
No response	13 (7)	16 (6)	76 (9)	9 (17)	114 (8)
1–11	80 (41)	150 (54)	400 (45)	10 (19)	640 (45)
>11	7 (4)	19 (7)	61 (7)	2 (4)	89 (6)

Note.—Numbers in parentheses are percentages (percentages may not add up to 100% because of rounding).

naires were distributed as a percentage of the total number of questionnaires distributed, as well as the geographic distribution of the respondents as a percentage of the total number of respondents. As demonstrated, a broad representation of imager manufacturers, magnet field strengths, and geographic distributions was included among the mailings and the respondents. MR imaging systems from all major MR system manufacturers were represented, as were the majority of the commonly used imaging field strengths.

A total of 27 of 1,915 respondents (1.4%) were eliminated from analysis owing to missing data. Table 1 presents the pregnancy status and racial breakdown of the remaining 1,888 respondents, of whom 823 had at least one pregnancy and of whom 770 (94%) were white. Reported pregnancies totaled 1,580, of which 55 (3.5%) were eliminated due to incomplete data. Table 2 presents the data about the remaining 1,525 pregnancies according to work history at the time of pregnancy and race. The white population of technologists or nurses totaled 1,421 (93%). All following results are reported on this group of 1,421 pregnancies in 770 women (Tables 3–9).

We found that there was no large or statistically significant difference in the pregnancies between those that occurred in the MR Worker group versus the Other Worker group regarding the prevalence of pregnancy outcome, infertility, premature delivery, gender of the offspring, or low birth weight. Although we observed a slightly increased spontaneous abortion rate for the MR Worker group (19%) compared with the Other Worker group (15%), the rate was not demonstrated to be statistically significant.

We found that there was, surprisingly, a substantially increased rate of spontaneous abortions for the MR Worker group (50 of 280 [18%]) compared with the Home group (11 of 193 [6%]). This remains the case even when corrected for smoking, alcohol use, and age. However, there was a similarly increased rate for the Other Worker group (125 of 894 [14%]) compared with the Home group. Furthermore, there was no statistically significant correlation between the MR Worker group relative to the Other Worker and Home groups combined with regard to miscarriage rates. This suggests that those in the Home group have lower prevalence of spontaneous abortions than women employed outside of the home. Additionally, it seems that the Home group had an aberrantly low rate of apparent spontaneous abortion (11 of 193 [6%]) compared with the 10%–25% of pregnancies recognized in the general population, as reported by Warburton and Fraser (5), the 14% reported by Miller et al (6), or the 16%–19% reported by Mattox (7).

The prevalence of prematurity has been reported to be roughly 7.1% (7). This is not significantly different from the 10% and 11% values reported for the Other Worker and MR Worker groups, respectively; nor are these two groups significantly different from each other in this regard. The prevalence of low birth weight among the offspring in study groups also did not vary in a statistically significant manner, remaining at less than 5% for all groups studied. This was similar to the reported national data for whites of a low birth weight rate of 5.7% (8). There was no statistically significant difference in the prevalence of infertility reported among the study groups; nor did employment status significantly affect the rates of male versus female births. The percentage male births of 52% (93 of 179) for the Home group, 50% (110 of 218) for the MR Worker group, and 52% (375 of 728) for the Other Worker group were similar to the national reported data of

51.3% for 1985, 51.2% for 1986, and 51.2% for 1987 (8).

We also examined the issue of menstrual regularity, cyclicity, and related questions (Table 9). This is a very difficult area to examine objectively, as it depends on both subjective data and the memory of the respondent for a topic on which subjective memory is notoriously inadequate. Nevertheless, the data suggest no definite correlation between the MR Worker group and any specific modification of the menstrual cycle. We found no strong trend toward any particular direction of menstrual pattern modification. Indeed, approximately two-thirds of those responding to this question believed that there was no subjective change at all in their menstrual cyclicity noted in relation to starting work as an MR worker. Individual and combinations of answers were examined and appear relatively evenly distributed. The only exception was a small preference toward heavier bleeding response from those who chose either "heavier" or "lighter" as a possible response. While roughly three-fourths of the respondents did not think that there was any change in this particular category since they became employed as an MR worker, the significance of this observation is uncertain.

Table 5
Length of Gestational Period

Length	Group				
	Home (n = 179)	MR (n = 218)	Other Work (n = 728)	Student (n = 32)	All (n = 1,157)
No response	92 (51)	107 (49)	354 (49)	17 (53)	570 (49)
<39 wk	12 (7)	25 (11)	70 (10)	1 (3)	108 (9)
On time	75 (42)	86 (39)	304 (42)	14 (44)	479 (41)

Note.—Numbers in parentheses are percentages (percentages may not add up to 100% because of rounding).

Table 6
Gender of Offspring

Gender	Group				
	Home (n = 179)	MR (n = 218)	Other Work (n = 728)	Student (n = 32)	All (n = 1,157)
No response	3 (2)	3 (1)	3 (0)	1 (3)	10 (1)
Male	93 (52)	110 (50)	375 (52)	16 (50)	594 (51)
Female	83 (46)	105 (48)	350 (48)	15 (47)	553 (48)

Note.—Numbers in parentheses are percentages (percentages may not add up to 100% because of rounding).

Table 7
Birth Weight

Birth Weight	Group				
	Home (n = 179)	MR (n = 218)	Other Work (n = 728)	Student (n = 32)	All (n = 1,157)
No response	21 (12)	10 (5)	38 (5)	2 (6)	71 (6)
<5.5 lb (2.5 kg)	5 (3)	10 (5)	33 (5)	1 (3)	49 (4)
≥5.5 lb (2.5 kg)	153 (85)	198 (91)	657 (90)	29 (91)	1,037 (90)

Note.—Numbers in parentheses are percentages (percentages may not add up to 100% because of rounding).

DISCUSSION

There has been much interest yet relatively few available data, to our knowledge, regarding the potential effects of the multiple factors involved in the MR imaging process and pregnancy (3). In fact, the U.S. Food and Drug Administration has stated, regarding the risk of MR imaging of fetuses and infants, that "data establishing the safety of the device are lacking" (4). This lack has likely contributed in part to some uncertainty about how to deal with pregnancies in patients for whom MR examinations are clinically requested. The question also arises, however, about how to advise pregnant health care practitioners appropriately regarding exposures related to the MR imaging environment. To our knowledge, there are few data for mammalian systems specifically addressing the questions associated with the types of exposures experienced by MR technologists and nurses. This subpopulation is exposed on a routine basis to the static magnetic fields associated with MR imaging devices when they enter the imaging room to position the patient; inject contrast agents; administer sedation and/or other medication during imaging; occasionally personally monitor or, rarely, perform ventilation on the patient during the examination; and escort the patient out of the imaging room after the examination is completed. Exposure to the time-varying magnetic field gradients and/or the radio-frequency magnetic fields for this population is likely to be less common. Even if the health care practitioners are in the room with the patient during actual imaging when these processes are active, the exposure levels outside of the bore of the imaging system itself are negligible. We thus must presume that the data obtained from this group relate essentially exclusively to exposures to the static—but not time-varying—magnetic fields associated with the MR imaging environment.

This study inherently addresses those who perform the routine duties associated with MR nurses and technologists, such as patient positioning, imaging, archiving, filming, and administration of contrast material. Such duties typically expose the MR worker to the static—but neither the radio-frequency nor the gradient-induced time-varying—magnetic fields of the study. Nurse anesthetists, however, and others actually performing ventilation on the (eg, pediatric) patient may spend much of the examination literally within the magnet and would, thus, be directly exposed to the time-varying components of such an MR examination. Such exposures are not directly addressed in this study.

Additionally, as there is no compilation of MR health care practitioners (nurses and/or technologists), to our knowledge, there is no way to assess the percentage response rate. This limitation may be somewhat ameliorated by approximating the number of health care workers per existent system in this country at the time of the survey. Assuming, for the sake of approximation, that there were two to five female MR workers per installed MR system, and knowing that there were approximately 2,000 installed sites at the time of the survey, this would yield a rough estimation of response rate of 50% or 20%, respectively.

Another limiting aspect of the study is the self-reporting of the data con-

Table 8
Relative Risks

End Point	Relative Risk in Groups: MR Worker to Other Worker	MR Worker to Home	Other Worker to Home
Miscarriage	1.27	3.22*	2.53†
Infertility	0.90	1.47	1.62
Delivery <39 wk	1.19	1.71	1.43
Male gender	0.99	0.97	0.98
Low birth weight	1.01	1.52	1.51

Note.—CI of all but relative risks indicated below include 1.0 in their range, $P > .05$.
* CI = 1.74–5.97, $P < .05$.
† CI = 1.40–4.59, $P < .05$.

Table 9
Menstrual Cyclicity Responses

Cyclicity	No.
No change	1,209
Longer time between periods	152
Shorter time between periods	156
Heavier bleeding during periods	238
Lighter bleeding during periods	148
Longer duration of bleeding	132
Shorter duration of bleeding	157
No response	105

Note.—Multiple answers were permitted. Total number of respondents was 1,915; total number of responses was 2,297.

tained herein. While this is a very common and accepted technique for gathering such data (especially as a first attempt in the field to investigate whether an obvious trend can be revealed), it remains a limitation nevertheless. Furthermore, the potential for preferential reporting by MR workers who believe that there may be health-related concerns or interactions between MR environments and pregnancy would likely, if anything, increase the positive response rate, thus tending toward false elevation of any reported association. As no strong association was demonstrated in this study, this criticism is not likely to be a significant concern. Additionally, all respondents are presumably now members of the MR Worker group. Thus, the MR Worker group data reported by the respondents are, by design, more recent than the data for either the Home or Other Worker group.

There is also the inherent difficulty of attempting to identify a control population that is comparable in age and work history. By comparing experiences among the present MR workers, socioeconomic backgrounds are the same and many other possibly confounding variables are removed when the control group is from the same population as a whole but before they were employed as MR workers. Age at time of pregnancy would differ; therefore, we analyzed the data with regard to age as a possible confounder, but no strong association was found.

This survey does not include a sufficient number of women with pregnancies that occurred both before and after employment in an MR environment to provide information regarding the outcome of each pregnancy in that one individual. To our knowledge, there is no information yet available regarding the strength of the magnetic field versus exposure during a specific pregnancy and its outcome. We did, however, reexamine the data after excluding those MR Worker pregnancies that occurred in respondents who reported that the MR sites in which they worked had a policy that did not allow pregnant health care workers into the vicinity of the magnet, and no differences in the results were found.

It is also important to stress that the data reported herein refer only to the white subpopulation of MR workers. As demonstrated in Tables 1 and 2, the responses for the nonwhite groups of MR workers were too few for meaningful statistical analysis. These responses were excluded from all analyses to provide a more homogeneous population. We have no data to suggest whether extrapolation to other groups is scientifically sound. On the other hand, there does not appear to be any obvious reason to suggest that other subpopulations might respond to exposure to a static magnetic field in a different way from that of the white subgroup.

Finally, the data are, in our opinion, representative of the behavior patterns of the average technologist or nurse (ie, intermittent exposure to the static magnetic fields associated with the MR imaging systems). There is nothing to suggest that any of this might be safely extrapolated to the time-varying magnetic fields that exist when the magnet is operational (ie, actively imaging). Thus, the results of this study should not be extended to the case of exposure to the imaging system during imaging but rather to the more common interactions of the technologists and/or nurses with only the static fields of the imaging system(s).

The data do not demonstrate a strong correlation between the status of an MR worker (technologist or nurse) versus employment in other capacities for miscarriage rates, premature delivery, infertility, low birth weight, or offspring gender. While a positive association may exist between miscarriage rates for the MR Worker group versus that for the Home group, there also seems to be a similarly positive correlation between being in either Worker group versus being in the Home group in terms of miscarriages. Although any explanation is purely conjectural at this point, nonspecific stresses associated with the MR or other workplaces may be related to this rate. This latter point might warrant further investigation in an attempt to confirm and clarify this unexpected correlation. Further, there also does not seem to be a clear-cut association between working as an MR nurse or technologist and any type of irregularity in the menstrual cycle.

While findings in this study are not in and of themselves sufficient to prove safety (which is an intrinsically impossible task), the data do not demonstrate a correlation between working in the MR environment and offspring gender or changes in the prevalence of premature delivery, infertility, low birth weight, or spontaneous abortion. To our knowledge, unlike in many other work environments, no clear-cut policy exists regarding pregnant MR workers. The data reported herein suggest no major increase in risk for any of the adverse outcomes discussed above. ■

References

1. Kanal E, Shellock F, Sonnenblick D. MRI clinical site safety survey: phase I results and preliminary data (abstr). Magn Reson Imaging 1988; 7(suppl 1):106.
2. Rothman KJ. Modern epidemiology. Boston, Mass: Little, Brown, 1986; 177–236.
3. Murakami J, Yoshikuni T, Masuda K. Fetal development of mice following intrauterine exposure to a static magnetic field of 6.3 T. Magn Reson Imaging 1992; 10:433–437.
4. Guidance for content and review of a magnetic resonance diagnostic device 510(k) application. Washington, DC: U.S. Food and Drug Administration; August 2, 1988.
5. Warburton D, Fraser F. Spontaneous abortion risks in man. Am J Hum Genet 1964; 16:1–15.
6. Miller J, Williamson E, Glue J, Gordon Y, Grudzinkas J, Sykes A. Fetal loss after implantation: a prospective study. Lancet 1980; 2:554–556.
7. Mattox J. Female infertility. J Family Pract 1982; 15:533–539.
8. Statistical abstract of the U.S. Washington, DC: U.S. Department of Commerce, Bureau of the Census, 1990.